Chapter

1

Floods: Basic Concepts and Literature Review

1.1 Flood and natural disasters

A flood is an overflow of an expanse of water that submerges land. The EU Floods directive defines," a flood as a temporary covering by water of land not normally covered by water in the sense of flowing water", the word may also be applied to the inflow of the tide. Flooding may result from the volume of water within a body of water, such as a river or lake, which overflows or breaks levees, with the result that some of the water escapes its usual boundaries. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, it is not a significant flood unless the water covers land used by man like a village, city or other inhabited area, roads, expanses of farmland, etc. Floods are common and costly natural disasters. Floods usually are local, short-lived events that can happen suddenly, sometimes with little or no warning. They usually are caused by intense storms that produce more runoff than an area can store or a stream can carry within its normal channel. Rivers can also flood when dams fail, when ice jams or landslides temporarily block a channel, or when snow melts rapidly. In a broader sense, normally dry lands can be flooded by high lake levels, by high tides, or by waves driven ashore by strong winds. Small streams are subject to floods (very rapid increases in runoff), which may last from a few minutes to a few hours. On larger streams, floods usually last from several hours to a few days. A series of storms might keep a river above flood stage (the water level at which a river overflows its banks) for several weeks.

1.2 Weather patterns and floods

Floods can occur at any time, but weather patterns have a strong influence on when and where floods happen. Cyclones, or storms that bring moisture inland from the ocean, can cause floods. Thunderstorms are relatively small but intense storms that can cause floods in smaller streams. Frontal storms form at the front of large, moist air masses moving across the country and can cause floods. Hurricanes are intense tropical storms that can cause floods.

1.3 Very large scale floods

The size, or magnitude, of a flood is described by a term called recurrence interval. By studying a long period of flow records for a stream, it is possible to estimate the size of a flood that would, for example, have a 5-year recurrence interval (called a 5-year flood). A 5-year flood is one that would occur, on the average, once every 5 years. Although a 100-year flood is expected to happen only once in a century, there is a one per cent chance that a flood of that size could happen during any year. The magnitude of floods can be altered if changes are made in a drainage basin. Harvesting timber or changing land use from farmland to housing developments can cause the runoff to increase and cause an increase in the magnitude of flooding. Building dams that store water can reduce the magnitude of floods.

1.4 Flood plains

Flood plains are lands bordering rivers and streams that normally are dry but are covered with water during floods. Buildings or other structures placed in flood plains can be damaged by floods. They also can change the pattern of water flow and increase flooding and flood damage on adjacent property by blocking the flow of water and increasing the width, depth, or velocity of flood waters.

1.5 Zoning restrictions limit flood damage

Flood-plain zoning, which places restrictions on the use of land on flood plains, can reduce the cost of flood damage. Local governments may pass laws that prevent uncontrolled building or development on flood plains to limit flood risks and to protect nearby property. Landowners in areas that adopt local ordinances or laws to limit development on flood plains can purchase flood insurance to help cover the cost of damage from floods.

1.6 Dams and levees reduce the risk of floods

Flood-control dams have been built on many streams and rivers to store storm runoff and reduce flooding downstream. Although the same volume of water must eventually move down the river, the peak flow (the largest rate of stream flow during a flood) can be reduced by temporarily storing water and releasing it when river levels have fallen. Levees are artificial river banks built to control the spread of flood waters and to limit the amount of land covered by floods. Levees provide protection from some floods but can be over-topped or eroded away by large floods.

1.7 Flood Disaster: Definition and Basic Concepts

The term “flood” is a general or temporary condition of partial or complete inundation of normally dry land areas from overflow of inland or tidal waters or from the unusual and rapid accumulation or runoff of surface waters from any source.

" A Flood is too much of water in the wrong place, whether it be an inundated city or a single street or a field flooded due to a blocked drain, flooding is generally defined as any abnormally high stream flow that overtops the natural or artificial banks of a stream".

1.7.1 Causes of Floods

Flooded areas of land usually start off as very dry land. Floods are caused by heavy rains that pour too much water into rivers and other waterways. Making these natural channels unable to carry all the water rising water flows over or breaks the banks to the waterways causing the surrounding land to be flooded. Different causes of floods can come from masses of snow melting of tidal waves. Floods are causes not only by rain but also by human changes to the surface of the earth. Forming deforestation, and urbanization increase the runoff from rains thus storms that previously would have caused no flooding today inundate vast areas. The reckless building in vulnerable areas, poor watershed management, and failure to control the flooding also help create the disaster condition.

1.7.2 Flood impact

Floods have the greatest damage potential of all natural disasters worldwide and affect the greatest number of people. On a global basis, there is evidence that the number of people affected and economic damages resulting from flooding are on the rise at an alarming rate. Society must move from the current paradigm of post-disaster response. Plans and efforts must be undertaken to break the current event-disaster cycle. More than ever, there is the need for decision makers to adopt holistic approaches for flood disaster management.

Extreme flooding events are not relegated to the least developed nations, but can also devastate and ravage the most economically advanced and industrialized nations. In the last decade there has been catastrophic flooding in Bangladesh, China, India, Germany, Mozambique, Poland, the United States and elsewhere. When floods occur in less developed nations, they can effectively wipe out decades of investments in infrastructure, seriously cripple economic prosperity, and result in thousands of deaths and epidemics. The majority of the deaths associated with such disasters can be found within the most vulnerable members of society, namely women and children. The greatest tragedy is that most of these deaths, associated post traumatic stresses, and social and economic hardships can be either avoided or dramatically reduced through pre-, during, and post-disaster investments in preparedness activities and associated infrastructure, flood plain policy development, effective watershed land use planning, flood forecasting and warning systems, and response mechanisms.

> ***Disaster: "Any incident that causes a severe disruption to the organization's ability to function or to provide service to internal or external customers"***

1.7.3 Flood Hazard Assessment: Basic concepts

Timely assessments *are valuable over detailed reports. A rapid assessment takes minimum time in compiling, presenting and sharing the collected information on 'impact' and 'needs.' of the situation.*

Representative coverage of both urban and rural areas*: This is important as both vulnerabilities and capacities are different in these two areas. This data is essential to realistically ascertain both needs of the affected and the capacities of different agencies to intervene.*

Special focus on vulnerable geographical areas: *These include isolated patches in villages and slums in cities and small towns. If not covered in the initial assessment, identify the need to cover these in later assessment and response.*

Vulnerability and capacity assessment of local resources: *In addition to assessing the damage it is also important to assess the available local (government, voluntary sector and community) resources for relief and recovery.*

Amixed focus on assessment with planning *for relief and recovery. This prevents the time lapse between assessments and planning; contributes to realistic assessment and planning and helps makes affected communities views of response an integral part of assessment.*

Design indicators of flood intervention impact with affected populations' *perspective of relief and recovery needs. These indicators will reflect the recovery priority of communities (demand) as different from the recovery priority of agencies (supply), which is often based on the agencies area of specialization. These indicators will be later used to evaluate the appropriateness of agency intervention in floods.*

1.7.3.1 Flood control and its difficulties

Because rivers are important sources of water, power, and transportation, and because floodplains are so fertile, humans have a tendency to occupy the land immediately adjacent to rivers in floodplains. Unfortunately, as with beaches and barrier islands, these lands are inherently unstable - in this case prone to flooding. Because we do not want the destruction and loss of life the results from flooding, efforts to control flooding are as old as civilization itself.

1.7.3.2 Flood: A Natural Hazard

Floods are physical events and natural hazards. Floods can be slow or fast rising depending upon the amount of rains and snow melt, generally developing over a period of days. A number of definitions related to floods have been proposed by various organizations and many scientists. Some of these definitions are summarized below. Flood is defined as "any relatively high water flow that overtops the natural or artificial banks in any portion of a river or stream." When a bank overflows; the water spreads over the flood plain and generally becomes a hazard to society. Floods are caused by excessive rainfall, snowmelt or dam failure. The rivers generally originate from mountains. Excessive rainfall or snowmelt in mountainous regions results in flooded rivers.

Mountainous regions become more vulnerable to landslides, hyper concentrated flows, debris flow, etc. (Scofield and Morgottini, 1999). Smith and Word (1998) have pointed out that the terms 'floods', 'flooding' and 'flood hazard' cover a very wide range of phenomena, not all of which are treated with equal emphasis. The main focus in this project is on river floods, with low-lying deltas and estuaries of many of the world's major rivers exposed to the hazards of flooding from the sea by storm surges and tsunami, as is all low-lying coastal land. For present purposes, a meaningful definition of a flood should not only incorporate the notions of inundation and damage, but also move beyond the restrictive definitions of river floods given. A flood is an overflowing of water from rivers onto land. Floods also occur when water levels of lakes, ponds, aquifers and estuaries exceed some critical value and inundate the adjacent land, or when the sea surges on coastal lands much above the average sea level. Nevertheless, floods are a natural phenomenon important to the life cycle of many biotas', not the least of which is mankind. Floods became a problem as humans began establishing farms and cities in the bottomlands of streams and rivers. In doing so, they not only expose their lives and properties to the ravages of floods, but also exacerbate floods by paving the soil and constructing stream channels. Over time, continued urbanization of natural floodplains has caused great annual losses of both wealth and human life. In this way, in many countries and regions of the world, floods are the most deadly hazards in terms of both loss of human lives and material damage (Fattorelli et al., 1999).

1.7.3.3 Flooding as a natural hazard

Most of the natural hazards result from the potential for extreme geophysical events, such as floods, to create an unexpected threat to human life and property (Smith, 1996). When severe floods occur in areas occupied by humans, they can create natural disasters that involve the loss of human life and property plus serious disruption to the ongoing activities of large urban and rural communities. Although the terms 'natural hazards' and 'natural disasters' emphasize the role of the geographical processes involved, these extreme events are increasingly recognized primarily as the 'triggers' of disaster, which often have more complex origins including many social and economic factors. A flood in a remote, unpopulated region is an extreme physical event of interest only to hydrologists. Entirely natural floodplains can be drastically changed but not damaged by the events that create them. Indeed, most floodplain ecosystems are geared to periodic inundation. Terms such as flood risk and flood losses are, therefore, essentially human interpretations of the negative economic and social consequences of natural events. As with other human value judgments, different groups of people have been found to differ markedly in their selection and definition of the risks from flooding Technical report of project (Green et al., 1991). In addition, the flood risk in any given locality may be increased by human activity, such as unwise land-use practices related to flood control structures or by ineffective emergency planning. The real risk from floods stems from the likelihood that a major hazardous event will occur unexpectedly and that it will impact negatively on people and their welfare. Flood hazards result from a combination of physical exposure and human vulnerability reflected by key social-economic factors such as the number of people at risk in the floodplain or low-lying coastal zone, the extent of flood, and the ability of the population to anticipate and cope with hazard. It is the balance between these two elements, rather than the physical event itself, which defines natural hazard and determines the outcome of a natural disaster. As long as the river flows close to the average or expected level, there is no hazard and the discharge is perceived as a resource because it supplies water for useful purposes, such as irrigation or water transport. However, when the river flow exceeds some predetermined threshold of local significance and extends outside the band of tolerance, it will cease to be beneficial and becomes hazardous. Thus, very low or very high flows will be considered to create a drought or a flood hazard, respectively. The relationship between physical exposure and human vulnerability is highly dynamic and can change through time. Various possibilities giving rise to increased flood risk. Another important attribute of flood risk is the relative unpredictability of the event. The difficulty of issuing precise warnings of flood locations and their timing is a major cause of flood disaster, especially with flash floods. On the other hand, many rivers exhibit regular floods that, especially in large drainage basins, will rise slowly and predictably in seasonal ‘flood pulse’, thereby offering an opportunity for an efficient loss reducing response.

1.7.3.4 Global patterns and trends

Flooding along low-lying plains adjacent to rivers and coasts is commonly regarded as the most frequent and widespread natural hazard in the world. Floods regularly account for about one-third of all global disasters arising from geophysical hazards and adversely affect more people than any other natural hazard, apart from drought. This dominance is usually explained by the fact that the overtopping of natural or artificial boundaries of a watercourse, together with the submergence of coastal zones, is a frequent occurrence compared with the incidence of other hazards such as damaging earthquakes or major volcanic eruptions. In addition, the density of much floodplain and coastal settlement places large numbers of people at risk. Any estimate of a flood hazard is plagued by the problem of defining basic terms (e.g. 'flood disaster' or 'flood-prone') and the related inadequacy of recorded data on flood events and losses. In the absence of any agreed international database of flood disasters, it is difficult to authenticate claims about flood losses worldwide and any related trends. Because of differing definitions and more general reporting difficulties, all the resulting figures should be treated with caution. According to Gleckman et al. (1992), floods are responsible for 31Per cent of the natural disasters that claimed 25 or more lives worldwide between 1945 and 1986. These data also show that, between 1945 and 1986, the average annual numbers of floods causing 25 or more deaths have more than tripled, a trend that is confirmed by the OFDA series from 1964 to 1996. The OFDA figures indicate that, since 1964, 835 floods that occurred outside the USA have killed over 130,000 people rendered about 70 million homeless and adversely affected well over one billion humans. The direct economic cost of such flood disasters is estimated at over US $91 billion. The burden of flood disasters is most heavily borne by the impoverished countries of Asia

1.7.3.5 Effects of flooding

In 1993, the northern Mississippi River and Missouri River basin experienced over a month of fairly continuous rain due to a southerly bend in the jet stream. This saturating rainfall produced the most extensive flooding in North America in recorded history. Particularly hard-hit were Illinois, Nebraska, Missouri, and Iowa. This flood was an economic and personal disaster for millions of people and provides abundant examples of the problems associated with flooding.

1.7.3.6 Regional disruption

Flooding caused bridges to close and prevented the flow of goods and traffic across large portions of the Mississippi. Barge traffic on the Mississippi was stalled for months as dams and locks on the river became choked by debris. Bridge failures resulted in disruption of rail traffic across the river. Damage to water treatment plants caused loss of fresh water supply to many cities and towns, including those far from rising flood waters. The 200,000 people living in Des Moines were without water for a week and many businesses were forced to close. Hundreds of other businesses were destroyed by floodwaters in river communities, Crop losses totaled in the billions.

1.7.3.7 Health problems

Flooded sewage treatment plants released untreated sewage into the floodwaters, spreading potentially dangerous fecal bacteria. Fuel oil and pesticides were also dumped and carried by the flood waters. Standing water provided abundant breeding areas for mosquitoes.

1.7.3.8 Beneficial effects

Flooding washed fish and nutrients into formerly isolated lakes and ponds. Temporary wetlands attracted waterfowl and the exploding fish populations attracted eagles and hawks. Flood sediments rich in nutrients blanketed farmlands, increasing future harvests (although current year crops were lost).

1.7.4 Flood control and mitigation

1.7.4.1 Floodways

The most sensible way to mitigate flooding is to work with the river and allow it to flood along undeveloped regions of the channel called floodways. Creating floodways requires relocation of existing homes and businesses or the conversion of farmland back into natural habitat. Communities that take this approach to flood control often design the floodways as riverside parks with shallow depressions that can serve as temporary reservoirs for flood waters.

1.7.4.2 Floodwalls

Urban areas built adjacent to rivers (St. Louis, New Orleans) cannot easily be relocated. These areas are often protected by a large, reinforced concrete wall parallel to the banks of the river. The floodwall along the Mississippi in downtown St. Louis is 52 feet high. On August 1, 1993 the river level climbed to a peak of 50 feet above normal just 2 feet below the top of the wall. This illustrates the main problem with floodwalls they can be overtopped. Had the St. Louis floodwall been compromised, downtown St. Louis would have been severely damaged. At one point during the 1993 flood in suburban St. Louis a leak in the wall developed that flowed at a rate of 40,000 gallons per minute. Fortunately, engineers were able to plug the leak with thousands of sandbags and 6 tons of stone. Another problem with floodwalls is that, if flooding occurs, they prevent the floodwaters from returning to the channel when the river level subsides. Floodwaters become trapped and persist for much longer than they normally would.

1.7.4.3 Artificial levee

This is an extension of the natural levee built along a river to prevent high water from leaving the channel. This works well for small flooding events, but like floodwalls, levees are always in danger of being overtopped by unexpectedly large floods. Also, levees can fail if floods persist for too long and the levee becomes highly saturated and weakened. During the flood of 1993 many large, expensive levees failed and were unceremoniously washed away. Another drawback of both floodwalls and levees is that they do not let the floodplain function as a natural reservoir to contain flood waters. This causes the excess discharge of the flooding river to move downstream until it finds a place not protected by artificial levees. In a way, these structures only move the flooding problem farther downstream. During the floods of 1993 the lower Mississippi did not experience flooding. This is due in part to the failure of many of the upper Mississippi flood control structures, but also to the fact the other main tributary of the Mississippi - the Ohio River - was flowing at below normal level in 1993 (the Ohio valley did not get the rains that the Missouri valley did). Because of this the lower Mississippi was able to accommodate the excess water from the upper Mississippi without flooding.

1.7.4.4 Dams

The natural reservoir function of floodplains can be taken up by artificial reservoirs created behind dams. In fact, the majority of dams and reservoirs built in the world are built primarily for flood control. The reservoir allows you to store water during times of high discharge and release it during times of low discharge. In effect, you store the floodwaters and let them out slowly in a controlled manner later on. An added feature of dams is that you can use the controlled discharge to generate electricity, and you can use the stored water for irrigation during dry seasons.

Dams have some big problems. First, like levees, they can be overwhelmed by large floods. This can be very dangerous if the dam fails. For example, 2200 people died in 1889 in Johnstown Pennsylvania when a dam on the river failed and a 36foot high wall of water swept down a populated valley. Dams also have the problem of their reservoirs being non-permanent. As the stream empties into the reservoir it dumps its load of sediment. The water leaving the reservoir through the sluice gates is mostly sediment free. So, all reservoirs in the world are slowly filling up with sand and mud. Most have projected useful lives of only Dams have other major problems besides these. The mixed blessing of dams is perhaps best illustrated by the High Aswan Dam built along the Nile River in Egypt. The High Aswan Dam was completed in 1970. It greatly increased the supply of irrigation water and electrical power to Egypt, and it stopped the seasonal flooding of the Nile River. But it created unforeseen new problems as well that possibly outweigh its benefits...

1.8 Spatial Information Technology: Basic concepts

1.8.1 Remote Sensing

Remote sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with it. This device can be a camera or a bank of sensors operated from an airplane or a satellite.

1.8.2 Geographical Information System

A GIS is "an organized collection of computer hardware, software, geographical data, and personnel designed to efficiently capture, store, update, manipulate, and display all forms of geographically referenced information."

1.8.3 Global Positioning System

GPS is a satellite-based system that uses a constellation of 24 satellites to give a user an accurate position. It is important at this point to define 'accurate'. Investing in sustainable livelihoods increases the speed of recovery and reduces vulnerability of the poor to disasters.

1.8.4 Flood and Economy

People's livelihoods are as important as physical defenses. Plugging the spending leaks by maximizing local procurement ensures that post-disaster resources re-circulate within the local economy, rather than leaking out of it, and helps boost longer-term recovery. Diversified local economies are best that maximize employment and respect economic, social and environmental priorities, and are more disaster resilient than agricultural or industrial monocultures. The impacts of globalization, in terms of trade and financial flows, as well as climate change, are draining the resources needed to deal with disasters from the least developed countries. A lot can be learnt from the experience of places highly vulnerable to climate driven disasters such as low-lying, small, island states. Understanding of how to reduce the impact of disasters is particularly advanced in the South Pacific region. Research identified several factors as enhancing community ability to recover from 'natural' disasters.

They include strong, extended family structures, strong local government, and building on traditional approaches to housing and farming. Economic diversity and financial mechanisms to spread losses were also vital (for example, insurance, disaster funds, community trust funds). A dynamic civil society is important along with good transport, communications, sanitation, good education and health services, coupled with disaster preparedness and emergency services. Conversely the loss of such social and economic fabric hampers post-disaster recovery. A narrow economic base, over exploitation of natural resources, and loss of diversity provide the weakest foundations for recovery. In Africa, particular risk-reduction measures would include participatory vulnerability assessment, rainwater harvesting, grain banks, designing and improving evacuation routes and sites, famine and flood early warning systems, protecting community buildings in flood-prone areas, and community disaster preparedness training. Such measures prove highly effective in saving lives and livelihoods in vulnerable regions around the world. Importantly, many risk-reduction measures are low cost and are relatively simple to implement.

1.8.5 Post disaster and floods

Plugging the leaks ensuring that post-disaster resources re-circulate within the local economy, rather than leaking out of it 'Leaks' from the local economy Aid staff use foreign-owned hotels and services Payments to foreign consultants and contractors Purchase of foreign reconstruction materials and agricultural/medical inputs Crop and business losses Profiteering and corruption Economic markets lost to competitors during economic recovery Long-term development aid redirected to disaster response Long-term commodity-price decline Higher risk-related returns expected on investment Post-disaster flight of capital Costs of flying aid in rather than procuring locally Local initiative and ownership of recovery undermined by donor-driven aid 'Plugs' to stop the leaks Ensure staff localize spending on services Support local NGOs and businesses localize purchase of recovery materials and inputs Introduce disaster insurance against crop and business losses Work with governments, NGOs and communities to stop corruption Provide small enterprises with flexible credit during recovery period Ensure fresh funds for disaster recovery Commodity-price support for primary commodity-dependent regions Ensure 'investment measures' are not undermined Introduce controls in high-risk areas to prevent destabilizing capital flight Establish targets for local procurement Rebuild social economy through community-designed reconstruction. As the UK's Department for International Development (DFID) observes: "Effective integration of disaster risk reduction into development will help transform 'vicious spirals' of failed development, risk accumulation and disaster losses into 'virtuous spirals' of development, risk reduction and effective disaster response. Gains include a wide range of positive impacts on progress towards MDG." Yet despite the clear rationale, donor organizations tend to approach disaster risk reduction on an ad-hoc basis, normally as a reaction to a major disaster, rather than systematically integrating it into their development planning and programming.

This was the conclusion of extensive research on donor policy towards risk reduction. Much progress needs to be made in donor organizations in terms of understanding, owning and prioritizing risk reduction as an integral component of all activities within Africa. The finding was confirmed by DFID in its recently commissioned study on the links between risk reduction, poverty and development. "Disaster risk reduction has not so far received serious attention as a facet of development, despite the increasing seriousness of disaster impact." A core recommendation of DFID's study is that donors should ", establish and implement time-bound strategies for incorporating the reduction of risk from disasters as a central concern of development policy and programming as well as of humanitarian work, and for promoting and supporting a risk reduction agenda amongst their various development partners globally". Thousands of lives could be saved each year and economic losses prevented in Africa if more emphasis was placed on this issue. For example, in Mozambique a well co-ordinated community-based early warning system was put in place after the devastating floods in 2000.

When another flood occurred a year later, the impact was significantly reduced. Disaster risk reduction can also be highly cost effective. It has been estimated that for every $1 spent on preparing for disaster, a further $7 is saved in the cost of recovering from it. There is a now a clear political mandate to invest in disaster risk reduction in Africa. At the World Summit on Sustainable Development (WSSD) in 2002, all governments agreed to “Provide financial and technical assistance to strengthen the capacities of African countries… including at the local level, for effective disaster management, including observation and early warning systems, assessments, prevention, preparedness, response and recovery.”82 It is not necessary to wait years for more research on climate change before investing in disaster risk reduction. Governments have agreed on the need for action, and tools and methods for protecting communities from disasters are well developed. Now they need to be employed immediately in African countries and communities on a much greater scale.

1.8.6 Low-cost ways to reduce vulnerability: Disaster-resistant housing

Floods are a normal part of life in much of Bangladesh, and typhoons in the Philippines. Various traditional housing techniques have been formulated to cope with this situation. ITDG worked with communities regularly affected by monsoon floods to develop a design for a flood-resistant house. It used available low-cost materials and local skills, and built on local skills and knowledge. The approach could readily be applied in other countries affected by floods and storms, like Mozambique. Success depends on collaboration between local masons and carpenters and any outside experts. In Bangladesh, an improved attic to be used as living and storage space during times of floods resulted from contributions from the community on how to improve the housing design. Poorer people cannot afford more water-resistant materials like corrugated metal, and have to suffice with thatched roofs, walls of woven grass or palm and bamboo. But, innovative methods can be applied, building on local traditional methods. Weaving, and joining bamboo and timber to form joists, results in a building that can withstand typhoon-force winds through its very flexibility, better than a rigid building of modern materials. Where the floodwater level is not normally too far above normal water level, houses can be built on raised earthen platforms. Planting water-resistant plants and trees such as bamboo and banana next to homesteads helps to protect the houses from erosion. Food, household items and crops are stored on a platform in the main living room. An added benefit is that the structure using woven walls can be designed to be dismantled in the event of a severe flood forecast, and moved for re-election on a new site or restoration after floodwaters subside.

High death toll directly related to coastal 'development' for fisheries and tourism Damage to Africa from the waves from the tsunami of 26 December 2004 was minimal compared to Asia, but there was a serious local impact in Puntland State, Somalia where the village of Hafun was devastated, many other villages damaged, over 1,000 homes destroyed and 2,400 fishing boats smashed, plus freshwater wells and reservoirs made unusable. Also, the tsunami was the result of an earthquake, not global warming, but the lessons about managing disaster apply to a warming world. Analysis of the places worst hit in Asia show that in many cases they had been developed for fish farming and tourism. In both cases, development required the destruction of the natural vegetation, and often resulted in the destruction of inshore coral reefs through over fishing or intensive use of motorized fishing vessels. Tropical mangroves are amongst the world's most important ecosystems, providing a variety of goods and services to coastal communities and protecting inland areas from violent storms and tidal waves. They stabilize sediments, reduce shoreline and riverbank erosion, regulate flooding, and recycle nutrients. Mangroves provide a nursery area for three quarters of the commercial fish species that spend part of their life cycle in the mangrove swamps. Each acre of mangrove forest destroyed results in an estimated 300kg loss in marine harvest. Despite these multiple benefits, shrimp farming in Southeast Asia that displaces the mangroves has been encouraged, aided by World Bank loans, for the sake of earning foreign currency. The industry is eating away more than half of the world's mangroves. In Indonesia, at the time the tsunami struck, logging companies were busy axing mangroves in the Aceh province for exports to Malaysia and Singapore.

The tourism boom in the Asia-Pacific region coincided with the growth in shrimp cultivation. What is being projected as an indicator of spectacular economic growth hides the enormous environmental, and ultimately human and economic costs that these countries have suffered. Mangroves and coral reefs protect against storms and tsunamis Myanmar and the Maldives suffered very much less from the impact of the tsunami because the tourism industry had so far not spread to the virgin mangroves and coral reefs surrounding the coastline. The large coral reef surrounding the islands of Maldives absorbed much of the tidal fury thereby restricting the human loss to a little over 100 dead. Mangroves help to protect offshore coral reefs by filtering out the silt flowing seawards from the land. The epicenter of the tsunami was close to Simeulue Island, in Indonesia. The death toll on this particular island was significantly low simply because the inhabitants had the traditional knowledge that a tsunami invariably happened after an earthquake and fled to higher ground in time. They also attribute minimal damage of their island and minimal loss of life to the protective belt of mangroves that surrounds their island and has not yet been destroyed. Mangrove and coral reef restoration: cost-effective disaster prevention the challenge, therefore, for developing countries is to learn from the time-tested approaches that have been perfected by the local communities.

Fisher folk have the expertise to be the primary managers of the health of the coastline and rehabilitate fisheries. When given the opportunity, they manage the shoreline, mangroves and coastal fishing zones the source of most of the aquatic diversity and health of the oceans. The massive tsunami aid effort must work with such fisher folk and support their organizations and use their expertise to ensure the restoration of their livelihoods, re-equipping them for sustainable artisanal fishing, and, in the long-term, rehabilitating the coastline and marine fisheries to protect them from future storms and floods likely to occur as a result of climate change. The government of Kerala state, observing that the tsunami left less destruction in Indian regions protected by mangroves than barren and exposed beaches, has already started a project for insulating coasts with mangroves.

1.9 Type of floods

Among the many classifications of floods, Smith and Ward (1998) classified floods as river floods and coastal floods.

1.9.1 River floods

Floods in river valleys occur mostly on floodplains or wash lands as a result of flow exceeding the capacity of the stream channels and over spilling the natural banks or artificial embankments. Sometimes inundation of the floodplain, or of other flat areas, occurs in wet conditions when an already shallow water table rises above the level of the ground surface. This type of water table flooding is often an immediate precursor of overspill flooding from the stream channels. In very dry conditions the ground surface is baked hard or becomes crusted, extensive flat areas may be flooded by heavy rainfall pounding on the surface. This rainwater flooding is typical of arid and semi-arid environments. Sheet wash flooding occurs by the unimpeded lateral spread of water moving down a previously dry or nearly dry valley bottom or alluvial fan. This is typical of arid and semi-arid areas where no clearly defined channels exist. In urban areas, flooding often results from over spilling or surface pounding, as described above, but may also occur when urban storm water drains become supercharged and overflow (Smith and Ward, 1998).

1.9.2 Coastal floods

Floods in low-lying coastal areas, including estuaries and deltas, involve the inundation of land by brackish or saline water. Brackish-water floods result when 22 river water overspills embankments in coastal reaches as normal flow into the sea is impeded by storm-surge conditions, or when large freshwater flood flows are moving down an estuary. Direct inundation by saline water floods may occur when exceptionally large wind-generated waves are driven into semi-enclosed bays during severe storm or storm-surge conditions, or when so-called 'tidal waves', generated by tectonic activity, move into shallow coastal waters.

1.9.3 Other flood types from a different perspective

1.9.3.1 Flash floods

These floods are frequently associated with violent, convection storms of a short duration. Flash flooding can occur in almost any area, but is most common in mountain districts subject to frequent severe thunderstorms. Flash floods are often the result of heavy rains of short duration falling over a small area. This particular type of flooding has been known to wash away roads and bridges, damage houses and drown livestock.

1.9.3.2 Riverine floods

A riverine flood occurs in the valley of a large river with many tributaries. Usually flooding develops from rainfall lasting for hours, sometimes days, and covering a wide area of the watershed.

1.9.3.3 Single event floods

This is the most common type of flooding in which widespread heavy rains of 2 to 3 days' duration over a drainage basin results in severe floods. Such heavy rains are associated with cyclonic disturbances, such as storms, slow moving depressions etc., during the summer monsoon season when air moisture content is very high. In India most floods belong to this category.

1.9.3.4 Multiple event floods

Sometimes heavy rainfall occurs when successive weather disturbances follow each other closely. Floods in the Indo-Gangetic plains and central Indian regions often are caused by the passage of a series of upper air cyclonic circulations, low-pressure areas or depressions from the Bay of Bengal, more or less along the same track.

1.9.3.5 Seasonal floods

These are floods that occur during different seasons. The summer monsoon season experiences a large number of floods, since major storm activity occurs during this season. The southern half of the Indian peninsula experiences floods mostly during the winter monsoon season. These floods are caused by heavy rainfall over a drainage basin. However, floods can also occur due to unusually high water levels of lakes fed by a river. Sometimes flood events are caused by events other than rainfall e.g. coastal floods, floods caused by dam failures and estuarine floods.

1.9.3.6 Coastal floods (or) tidal flooding

Storm surges, tidal waves or earthquakes occurring in the ocean generally cause these floods. The surge is the outcome of piling of seawater against the coast due to strong winds generated by a cyclonic storm. The surface waters are driven towards the coast, where due to shallow water the return flow is retarded by the frictional force of the seabed. If the surge takes place near the mouth of a river falling into the sea, the river flow is held up due to the surge that results in severe flooding over and near the coastal areas. Such coastal floods often occur along the east coast of India during summer and winter monsoon months due to the activity of tropical cyclones/depressions in the Bay of Bengal.

1.9.3.7 Estuarine flood

Estuaries are the only portions of the coastline where the normal tide meets a concentrated seaward flow of fresh water in a river. The interaction between the seaward flow of fresh water in the river and landward flow of saline water from the sea during high tides may result in opposing land water flows, causing a wall of water. Sometimes the funnel shape characteristic of many estuaries causes an increase in high water levels in the upper narrow reaches of the river. These types of floods are mostly experienced in deltaic areas of rivers along the coasts and are not considered serious floods. Apart from the above factors, occasionally Himalayan Rivers experience minor to medium floods due to a sudden rise in temperature which causes quick melting of snow and glacier ice in the upper reaches of rivers. Floods also occur due to heavy rains over snowfields having thick snow cover. Such floods occur during the summer months in the plains area adjoining the Himalayas. Floods of this type are rather uncommon and occur mostly in the Himalayan valleys and do not cause large-scale destruction or damage on the plain.

1.9.3.8 Floods caused by dam failure

A dam failure or collapse obstructs the flow of water in a river by glacial tongues moving down the mountain slopes. Landslides across rivers flowing through hills cause serious floods in the downstream areas due to pressure of accumulated water upstream of the failure. In 1979, the collapse of the Machhu Dam in Gujarat State of India caused the loss of about 10,000 human lives.

1.10 Causes of floods

1.10.1 General causes of floods

Most river floods result directly or indirectly from climatological events such as excessively heavy and/or excessively prolonged rainfall. In cold winter areas, where snowfall accumulates, substantial flooding usually occurs during the period of snowmelt and ice melt in spring and early summer, particularly when melt rates are high. Flooding may also result from the effects of rain falling on an already decaying and melting snow pack. An additional cause of flooding in cold winter areas is the sudden collapse of ice jams, formed during the break-up of river ice. Major landslides may cause flooding in two ways. First, pounding occurs behind the debris dam across the valley causing upstream flooding; then, as the debris dam is overtopped, its erosion or collapse delivers massive flows downstream. Estuarine and coastal floods are usually caused by a combination of high tides and elevated sea levels, plus large waves associated with storm surges that result from severe cyclonic weather systems. In estuarine and coastal areas protected by walls or embankments, inundation may result from either overflow, when the water level exceeds the level of the crest of the defense, or from overtopping, when the combined effect from waves and water level results in waves running up and breaking over the defense, or from structural failure of the defense (Burgess and Reeve, 1994). When a storm surge coincides in an estuary with large inflows of river water, flood conditions in the estuary result (as shown by the broken line). Estuary and coastal flooding may also be caused by tsunamis which result from the increase in amplitude of seismically generated long ocean waves when these enter shallow coastal waters.

1.10.2 Causes of floods: Flood-intensifying factors

Bangladesh and UNDP, 1989; It is not known, however, if the heavy precipitation is actually an effect of other processes such as the greenhouse effect or destruction of forests in the upstream region.

1.10.3 Synchronization of flood peaks

The synchronization of flood peaks for major rivers may take place within the same period, which may cause a sudden increase in the water level in virtually all areas of the Bangladesh. While the synchronization of flood peaks can explain the cause of the 1988 flood, it fails to explain the reason for an overall increased propensity for low frequency floods in recent years (such as those which occurred in 1974, 1984, 1987, and 1991). The answer might lie in other long-term processes that reduce the water-carrying capacity of the drainage system and decrease land elevation with respect to the base level of the rivers in Bangladesh.

1.10.4 Long-term causes: Local relative sea level rise

The ultimate destination of most rivers is the ocean. Land elevation is measured with respect to sea level in an area. Therefore, any change in sea level causes land elevation to change. At the present time, sea level is rising globally (Pilkey et al., 1989). If sea level rises in an area at a rate faster than the rate of land aggradations due to sedimentation, then land elevation decreases. Any decrease in land elevation can cause increased inundation by rivers overflowing at bank full stage. The rate of local relative sea level rise is 7 mm/year around the coastal areas of Bangladesh (Emery and Aubrey, 1990). An increase in sea level raises the base level of rivers, which in turn reduces the gradient of river flow. As a result, the discharge of rivers decreases as the water flow becomes sluggish, creating a backwater effect further inland. The backwater effect caused by sea level rise can result in more flooding of land from "piled up" river water inland (Warner, 1987). This certainly seems to be one of the reasons for the increase in flood intensity in recent years in Bangladesh. Inadequate sediment accumulation the only way for land to counter the effects of a rising sea is for sediment to accumulate at a rate that is sufficient to keep pace with the rate of sea level rise.

Limited data show that the average sediment accumulation rate for the last few hundred years in the coastal areas of Bangladesh is 5-6 mm/year, not enough to keep pace with the rising sea level. As a result, net land elevations must have decreased over time, resulting in more flood inundations. Subsidence and compaction of sediments on a delta plain are rich in decomposed organic matter, and are subject to compaction due to dewatering and the weight of the overburden. Most deltas subside due to the weight of the thick sediment layer. Subsidence along with compaction reduces land elevation with respect to the rising sea level (Pilkey et al., 1989). Even though the rate of subsidence and compaction are not yet well documented, based upon knowledge Technical report of project about processes active in other deltas, it can be assumed that Bangladesh's delta is also undergoing subsidence and compaction.

1.10.5 Riverbed aggradations

Due to relatively higher settling velocity, large-grained sediments are deposited near the source area on the riverbeds, forming sand bars. The river gradient decreases rapidly if sedimentation continues on riverbeds. Because of low gradients and high sediment loads, riverbeds of most rivers in Bangladesh aggraded very quickly. Riverbed aggradations are most pronounced for the Ganges and its tributaries. From the border with India to the point where the Ganges meets the Brahmaputra, the riverbed has aggraded as much as 5-7 meters in recent years (Alexander, 1989). Riverbed aggradations are so pronounced in Bangladesh that changes in riverbed level can be observed during one's lifetime. For example, the Old Brahmaputra was navigable for steamers until 30 years ago, but is presently an abandoned channel. This situation is true for many other distributaries of the Ganges and Meghna such as the Madhumati, the Bhairab, the Chitra, the Ghorautra, etc. Riverbed aggradations reduce the water carrying capacity of rivers, causing them to overflow their banks. This recent increase in riverbed levels has contributed to the increased flooding propensity in Bangladesh.

1.10.6 Deforestation in the upstream region

A rapid increase in population on the Indian sub-continent this century has resulted in an acceleration of deforestation in the hills of Nepal to meet the increasing demand for food and fuel wood. Deforestation of steep slopes is assumed to lead to accelerated soil erosion and landslides during monsoon precipitations. This in turn is believed to contribute to devastating floods in the downstream regions such as in Bangladesh (Hamilton, 1987; The New York Times, 1988; Alexander, 1989). However, Hofer 1998, after 12 years of research in Himalayas, concluded that it has not been possible to find significant correlation between human activities in the mountains (e.g. forest removals) and catastrophes in the plains.

1.10.7 Damming of rivers

Damming a river reduces the velocity of water flow downstream from the dam. As a result of reduced velocity, the sediments carried by the river start to settle down faster on the riverbed, causing riverbed aggradations and in turn reducing the water carrying capacity of the river (Shalash, 1982).

1.10.8 Soil Erosion due to tilling

Plowing makes the land surface more susceptible to soil erosion. Surface run-off can easily wash away the topsoil from cultivated land. This surface erosion reduces land elevation, which in turn increases flood intensity in an area. The land elevations in Bangladesh must have been reduced over time due to cultivation. Aside from this, the Technical report of project tilling on the mountain slopes of the Himalayas is thought to be responsible for massive soil erosion in Nepal (Dregne, 1987; Thapa and Weber, 1991; Sharma, 1991) that eventually caused rapid riverbed aggradations in Bangladesh (Alexander, 1989). Excessive development Rapid population growth creates extra pressure on the land in already overcrowded areas. Agricultural lands give way to housing developments and roads. This rapid development and urbanization has aggravated the flooding problem in many countries. Prior to urbanization there is a greater lag time between intense rainfall and peak stream flow. After urbanization the lag time is shortened, peak flow is greatly increased, and total runoff is compressed into a shorter time interval – favorable conditions for intense flooding. For example, in a city that is totally served by storm drains and where 60 per cent of the land surface is covered by roads and buildings, floods are almost six times as likely to occur as before urbanization (Pipkin and Cunnings, 1983).

1.10.9 Seismic (Earthquake) and Geotectonic activities

Earthquakes cause movement of the land, and this can change the topography of the region and alter river courses. A sudden change in a river course can cause substantial flooding. For example, the Old Brahmaputra changed its course to its present location following an earthquake in the mid eighteenth century (Er-Rashid, 1978). The northern regions of Bangladesh are earthquake-prone (Morgan and McIntyre, 1958). Geotectonic activities (recent movements in the Earth's crust) are affecting river courses in the area. The Madhupur tract and the Barind tract are undergoing such geotectonic activities (Morgan and McIntyre, 1958). Most recent floods have occurred approximately simultaneously with earthquake activities. For example, the 1950 earthquake in Assam caused "swallowing" of the Brahmaputra, by causing it to breach its banks and flood the region (The Times of India, 1988). The floods of 1988 and 1991 coincide with earthquake activities in northern parts of Bangladesh (The Times of India, 1988; The New York Times, 1991). A powerful earthquake occurred on October 20, 1991 in northern India, which was preceded by a flood in Bangladesh and was followed by another flood in the Ganges valley in India (The Philadelphia Inquirer, 1991). Floods can be both a cause and an effect of an earthquake. Floodwater places an extra hydrostatic pressure on unstable and mobile crustal blocks. If this extra pressure reaches the threshold strain limit along a fault zone or plate boundary within the Earth's crust, it can cause an earthquake to occur due to a sudden release of the strain energy accumulated over time. Similarly, an earthquake can change the surface drainage pattern and consequently the course of a river, causing sudden flooding in an area. Even though the cause and effect relationship between floods and earthquakes is not very clear, historic records suggest a relationship between these two phenomena.

1.10.10 Greenhouse effect

The world is about to enter a period of rapid warming. Should the greenhouse effect become a reality, the low-lying coastal areas will be affected by a rising of sea level of even greater magnitude (Milliman et al. 1989; Gable and Aubery, 1990). Bangladesh will be severely impacted by such an increase in sea level. Besides many other adverse environmental, economic, and climatic consequences, the base level of all rivers will change following any change in the sea level. The effect on flooding of a higher base level resulting from a rising sea level has already been discussed earlier in this section. The greenhouse effect will also increase the amount of rainfall and storminess, which will further aggravate the flood problem.

1.10.11 Meteorological Causes of Floods in Asia

Heavy rainfall is the main cause of floods in India for any river basin. In India, heavy rainfall is normally associated with the summer and winter monsoons. During these monsoon periods, certain meteorological systems interact with the monsoon circulations, causing heavy to very heavy rainfall. Meteorological situations responsible for causing floods in the Indian rivers have been studied by Parthasarthy (1955), Bose (1958). Ramaswamy (1987) pointed out following synoptic systems for the cause of severe floods:

a. Tropical disturbances such as monsoon depressions and cyclonic storms moving through the country from the neighboring seas of the Bay of Bengal and the Arabian ocean.

b. Passage of low-pressure system or monsoon lows.

c. Break monsoon situations generally prevailing during July and August.

d. Active monsoon conditions prevailing over a region for a number of days and offshore vortices along the west coast.

e. Mid-latitude westerly systems moving from west to east.

f. Mid-tropospheric cyclonic circulations over western region of the country.

Apart from the above meteorological situations there are man-made factors, which are responsible for causing serious floods in different parts of the country.

1.10.12 Monsoon and cyclonic depressions

From June to September, river flooding is caused by the movement of monsoon depressions and cyclonic storms throughout India. These disturbances mostly originate from the Bay of Bengal and very rarely from the Arabian Ocean. As they move, these disturbances cause heavy to very heavy rainfalls along and near their tracks. Predicting the movement of these disturbances, therefore, is essential in the flood forecasting and warning system. These cyclonic disturbances during the monsoon months mostly form at the head of the Bay of Bengal and travel in a northwest to west direction through the Indo-Gangetic plains and its neighborhood after crossing the coast. Sometime after moving far into the interior of the country, these disturbances re curve and move towards the north or northeast and break over the foothills of the Himalayas under the influence of westerly troughs or western disturbances moving from west to east at higher latitudes. Associated with these disturbances, both the Arabian Ocean and the Bay of Bengal branches of the summer monsoon currents strengthen considerably and cause heavy to very heavy rainfall over the region. However, it has been observed that in the summer monsoon, heavy rainfall generally occurs in the southwestern sector of these disturbances. According to Rao (1976), heavy rainfall (7.5 cm and above) occurs over a belt of 400 km wide to the left of the track for a length of 500 km from the center of the disturbances. As a result of heavy rainfall, severe floods occur in the rivers of the region. These are generally known as single event floods. The floods on northern and central Indian rivers occur mostly due to heavy rainfall caused by the slow movement of these disturbances.

The deltaic areas of Orissa, Andhra Pradesh and also Tamil Nadu (during winter monsoons) suffer frequently from the floods caused by these bay cyclonic disturbances at the time of their landfall. Passage of low-pressure areas and upper air cyclonic circulations Passage of low pressure areas both of ocean or land origin or movement of upper circulations during summer monsoon months often cause heavy rains and consequent floods. Low pressure areas are less intense than monsoon depressions but they form frequently during the monsoon months and their contribution to the rainfall in India is quite substantial. Unlike cyclonic storms/depressions, there is no regular account of the number of 'lows,' which occurred during summer monsoon months. However, Srinivasan et al. (1972) found that 87 lows, both of ocean and land origin, occurred during the 20-year period from 1950-1969. Recently, Nandargi (1995) found that 93 lows occurred over India during the summer monsoon period during the 10 years from 1984 to 1993, causing 557 low days. In general, lows have an average life span of about 4 to 6 days. In any certain year, the lows travel one after another in quick succession through north India, causing continuous heavy rainfall for a number of days. Such multiple events are responsible for causing serious floods in the rivers of north and central India such as the Narmada, the Tapati and the northern tributaries of the Godavari.

1.10.13 Break situations during monsoon periods

A 'break' monsoon situation occurs when the axis of the seasonal monsoon trough, which normally passes through Delhi, Kanpur, Patna and then to Kolkatta shifts northwards from its normal position and lies close to the foothills of the Himalayas both on surface and 850 mb synoptic weather charts. This particular situation results in heavy rainfall over the northeastern and central Himalayas and their adjoining plain areas (Dhar et al., 1984), while the rest of the country is under drought conditions with little rain. During break situations, due to heavy rainfall over Himalayan arid sub-Himalayan regions, floods occur in the rivers of northeast and central Himalayas i.e. Brahamaputra and its tributaries, Testa, Kosi, Gandak, Ghagra, Kamla Balan, Bagmati, and Rapti. During break monsoon days, areas under the Sikkim and eastern Nepal Himalayas and their neighborhood receive heavy rainfall, which is 50 to 300 percent or more of the daily rainfall over these areas, while the areas south as well as to the north receives less rainfall. A southward shift of the axis of the seasonal monsoon trough its normal position results in a well-distributed rainfall over the central parts of the India and adjoining northern parts of the Indian peninsula. During a break situation, a paradox often arises in which flooded rivers from the Himalayas inundate areas in the Ganga plains, which are under drought conditions. Break situations very rarely last for more than a week at a time and generally occur in July and August of the summer monsoon season. During the break in July and August 1954, there were widespread floods in the Himalayan Rivers from Gandak on the western side to the Brahamaputra on the eastern side. According to Partasarthy (1955), the plains of Bihar, Bengal, Orissa and southern districts of Uttar Pradesh suffered from partial droughts while north Bihar, Bengal and Assam experienced the fury of floods. The floods and heat condition of underlying surface in the Tibetan Plateau the East Asia monsoon is greatly affected by the Tibetan Plateau. In addition, snowmelt in the Plateau has a direct effect on Yangtze River floods. Heat conditions on the underlying surface on the Tibetan Plateau are one of the most important meteorological predictive factors. Mean temperatures of the Tibetan climate stations have been selected to represent the plateau's surface temperature. A correlation index between the mean monthly temperature in Tibet and the total amount of precipitation during flooding season in the Yangtze River basin was calculated. The temperature in March, August, and December in any given year has a significant correlation with the precipitation during the flooding season of the following year. The closest correlation is between August temperatures in the Tibetan Plateau with Yangtze River precipitation during the flood season the following year with the degrees confidence that reaches 0.99 (Lu and Ding, 1997).

1.10.14 Floods due to glacial lake outburst

Glaciers result from an accumulation of ice, air, water and rock debris or sediment. A glacier is a large enough quantity of ice to flow with gravity due to its own mass. Glaciers flow very slowly, from tens of meters to thousands of meters per year. The ice can be as large as a continent, such as the ice sheet covering Antarctica; or it can fill a small valley between two mountains. Accumulation of snowflakes stimulates glacier formation. Snowflakes fall to the ground and over time, lose their edges and slowly become tiny grains separated by air. Additional snowfall compresses underlying layers of snow grains that become loosely compacted with randomly oriented ice crystals and connected air spaces. Ice in this form that has survived a season is termed firm. Continuous compression removes air bubbles from firm and forms true glacial ice with a blue tone; it takes about 1,000 years for snow to form glacial ice.

1.10.15 Himalayan glaciers

The Himalayan glaciers receive annual accumulation mainly in the summer. The monsoon precipitation from June to September contributes about 80per cent of annual precipitation. Ageta and Higuchi (1984) called these glaciers summer accumulation types. These glaciers are different from the winter accumulation type, which are common in Europe and America. In summer accumulation type glaciers, which are common in Himalayan region, accumulation and ablation occur simultaneously. Under such conditions, summer snowfall sometimes changes to rain under warm air temperature conditions. New snow cover melts away quickly. Summer air temperature in the Himalayan region is an important factor, which controls ablation through albedo variation at the glacier surface. Ageta (1983) has estimated relations between summers mean air and accumulation, ablation and balancing during summer.

1.10.16 Cloudburst floods

Cloudburst is very common in the Himalayan region. In 1963, a cloudburst struck the meadow of a tourist resort near Srinagar (J & K), which killed several people and caused a flash flood in the Lidar River. In September 1995, heavy incessant rain in the upper reaches of the Bias River and a cloudburst on the southern slope of Rohtang in the higher Himalayas formed a small dam debris flow north of Manali. The bursting of the dam generated a flash flood.

1.10.17 Flood with special events: Floods and sunspots

Recent research shows that solar activity has some effect on regional long-term global precipitation. (Wu and Gough, 2001). It is indicated that extreme flood years are usually when the 11-year periodical variation of sunspot relative number is either at its peak or its lowest values, especially at the lowest values.

1.10.18 El Niño and Floods

As the most remarkable connective signal between the global climate and sea, El Niño profoundly affects the world climate. There have been many studies on El Niño and its relationship to regional climates. Statistical analysis proves that most of Yangtze River floods occur in the years following El Niño. Taking the 1998 flood as an example, the 1997 El Niño was the most active in the last 100 years, which greatly affected the precipitation in the basins of Yangtze River. The precipitation during the winter of 1997 and spring of 1998 was 2 to 5 times greater than that during the same period in the past, with the main rain belt in the southern areas of Yangtze River. The rain belt then began to move to the upper and middle reaches with the central rain belt located at the middle reaches in June. The precipitation in this month reached 800 mm, twice the historical norm. In July, the central rain belt was in the Wuhan region where the mean monthly precipitation was 4 times normal. The precipitation on July 21-22, 1997 in Wuhan reached 221.5 mm and 175.2 mm respectively, both of which broke the historical record. In August, the rain belt arrived in the upper basins. Daily rainfalls of over 100 mm occurred in Three Gorges Reservoir, which caused several flooding peaks in the upper. The above time and space distribution of precipitation raised the flood's level in the middle and lower reaches at the beginning, which when combined with the following heavy rains in the middle and upper reaches, resulted in extreme floods in entire reaches of the Yangtze River (Wu and Gough, 2001).

1.11 South Asia Floods

Every year the monsoon season brings about major flooding in parts of South Asia Heavy rainfall and a rise in temperatures causing melting of snow in the Himalayas result in the rapid and massive rise of water levels in large rivers like the Indus, Ganges and Brahmaputra, and their tributaries. As a result, the planes of Bangladesh and Nepal, north-eastern states of India, as well as parts of Pakistan get flooded almost every year between July and September. Global climate change has potentially serious consequences for this situation and it is suspected that over the coming years the combination of increased glacial melt and increased monsoon intensity will add to the devastation caused by floods during the monsoon season. Flooding has numerous adverse effects, including loss of life through drowning, increased prevalence of disease and destruction of property, crops and resources to sustain livelihoods. The year 2005 saw flooding across the region, affecting over 22 million people, leaving more than 3,400 people dead, 1,100 people injured and another 450,000 people displaced. The South Asian national societies provided assistance to hundreds of thousands of affected people. The International Federation launched emergency appeals seeking over CHF 2.2 million and used another CHF 300,000 out of its disaster relief emergency fund (DREF). This year, the monsoon that touched the southern coast of India one week early, on 26 May, has triggered moderate rainfall across the country and heavy to very heavy rainfall at a few places leading to floods.

Eight states are facing flood-like situations that have resulted in the death of 140 people so far. The states of Assam, Arunachal Pradesh, Mahrashtra and Kerala have been severely affected. Floods triggered by heavy rains in Assam have displaced 25,000 people and snapped road and rail communications. In Nepal too, early monsoon is expected this year and rains have already started.

The meteorological department has forecasted the possibility of more rain and there is a likelihood of big disasters such as floods and landslides. Warming trends have already had significant impact in the Nepal Himalayas, most significantly in terms of glacier retreat and significant increases in the size and volume of glacial lakes, making them more prone to glacial lake outburst flooding. Late April this year saw the northern region of Afghanistan affected by floods caused by the melting of snow. In Pakistan, however, the meteorological department forecasts that this season's monsoon will be 'normal' based on the indication that most of the month of May remained dry and that the temperature level this year has been significantly higher than normal. In Bangladesh, by 1 June the Flood Forecast Warning Centre has so far not issued any flood warning messages. All the rivers in the basins are at present flowing below their respective danger levels, except for three rivers in the Meghna basin, which are all registering rising trends. Similarly, rainfall data of the Sri Lankan meteorological department suggests that severe floods should not be expected in the country this year. With the recent climatic changes in the region and atmospheric changes world over, it is hard to forecast the extent of monsoon rainfall and flooding with hundred per cent accuracy.

1.11.1 Afghanistan

Unlike last year, the Afghanistan delegation has not yet needed to launch an emergency appeal or plan a full-scale operation to help with floods caused by melting snows in the northern region of the country. During the year, the ARCS and the Federation have been able to cope with small-scale emergencies, like floods, with the national society distributing non-food items for up to 10,000 families from their regional warehouses around the country. As part of the Movement contingency plan, Afghan Red Crescent Society (ARCS), International Committee of the Red Cross (ICRC) and the Federation hold regular coordination meetings, as well as with other agencies like the Department of Disaster Preparedness, the Ministry of Rural Rehabilitation and Development, UN agencies and other stakeholders, to discuss ways in which to prepare for a possible emergency. The Movement partners recently coordinated a floods-assessment evaluation in Baghlan, Faryab, Samangan and Sar-i-Pul provinces. The ARCS, with technical support from the Federation, have conducted training programmes for their national disaster response team (NDRT), disaster response unit and community-based disaster preparedness (CBDP) teams across the country. The national society has over 2,000 CBDP trained volunteers whose task is to recruit more volunteers in the coming months to ensure the ARCS will have enough manpower to cope with the possible flooding. The ARCS trainers at headquarter level hold regular meetings with the volunteers to ensure they are well trained and prepared.

1.11.2 Bangladesh

The Bangladesh Red Crescent Society (BDRCS) and the Federation have developed a preliminary plan of action. The Federation is updating this plan on a regular basis and maintaining contact with various donors in the country. The BDRCS and the Federation regularly attend meetings of the disaster emergency response group, a disaster management coordination group. BDRCS is also organizing a meeting with all concerned unit level officers in the flood-prone districts, before the onset of the monsoon. The BDRCS and the Federation are renting warehouses in strategic locations in the country and assessing any need for maintenance of existing warehouses located in Dhaka and Chittagong. The Federation is processing the procurement of buffer stocks consisting of various relief materials (i.e. family kits, clothing items, buckets etc.) and disaster response materials that would be required in the event of a major disaster.

1.11.3 India

The Indian Red Cross Society (IRCS) is already working to assist with flooding in the state of Assam (see separate information bulletin). The society is also working on a contingency plan for flood response and is coordinating with concerned agencies in the Indian government towards this end. IRCS has instructed the programme states to prepare their monsoon preparedness plans as well. The IRCS has kept emergency response units specialised in water and sanitation, communication, health ready for immediate deployment. Warehouses have been renovated and warehouse equipment, machinery and vehicles have been repaired. Non-food relief items (disaster preparedness stock) have been stored in the six regional warehouses of IRCS and can cater to at least 50,000 families at any point of time anywhere in the county. The IRCS has formed a multi-sectoral national disaster response team (NDRT) and state level disaster response teams (SDRTs) in four states, namely Gujarat, Maharashtra, Bihar and Orissa, which can be mobilized immediately. A disaster management centre has been started at the IRCS national headquarters and has been in constant touch with affected state branches of the national society to collect data for generating daily situation reports, which are shared widely. The existing disaster response database of emergency response persons, trained volunteers, and health team and disaster preparedness stock has been updated.

1.11.4 Nepal

The Nepal Red Cross Society (NRCS) has relief materials (30,000 family packages) and basic rescue kits prepositioned at various strategic locations. Rescue kits are being pre-positioned at NRCS disaster management centers. A disaster management centre is being established at national headquarters in Kathmandu. Emergency response teams have been alerted at different levels that can be mobilized immediately. The NRCS national headquarters has informed all district chapters to start necessary preparedness actions District level.

1.11.5 Pakistan

The Pakistan Red Crescent Society (PRCS) has identified 53 districts as ‘flood-prone’ and is developing disaster management cells in these districts. Six of these cells are already in place, with priority being given to areas that have historically been hardest hit. The districts where cells have been established are Jhang and Narowal in the Punjab, Badin and Khairpur in Sindh, Swat in North West Frontier Province and Sibi in Balochistan. Stockpiles of emergency shelter (20,000 tents) are in place at the Federation/PRCS logistics compound in Mansehra. The national and provincial headquarters will act as the main hubs for relief stocks. The amassing of stocks in the national headquarters has been completed, with stocks for up to 2,000 families, while it is almost complete at the provincial level, with each provincial branch holding stocks for 400 families. The disaster management cells hold stocks sufficient for 200 families. Contingency plans for the needs of communities already made vulnerable by the October 2005 earthquake are in place. Under these plans, a significant scaling up of the PRCS's disaster management capacity is planned for 2006- 2008, which will include the establishment of national and branch disaster response teams as well as local disaster preparedness teams.

1.11.6 Sri Lanka

The Sri Lanka Red Cross Society (SLRCS), in collaboration with government agencies and other local and international stakeholders, have identified a few vulnerable districts that are prone to floods (Colombo, Kalutara, Gampaha, Galle, Matara, Hambantota, Kegalle and Ratnapura). Disaster preparedness stocks have been earmarked, with financial assistance from the Federation, to face any emergency situations that might arise. A network of relevant agencies in the districts has been formed so that, in the event of a disaster, the required resources can be mobilized. The SLRCS and the Federation have developed contingency plans, which are in place and branch offices in the districts have been informed about these plans. SLRCS is in constant touch with relevant government departments, such as the meteorological department, in order to obtain up-to-date facts and figures regarding impending floods in the country and region. Relevant information received is immediately passed down to the branches/district points for quick action. The branch offices also maintain links with the local police and concerned government authorities for disaster response.

1.11.7 Coordination

The South Asian regional delegation held a floods preparedness with representatives from the country delegations of India, Bangladesh and from Nepal Red Cross to build on the regional disaster management team and to discuss practical issues about flood preparedness and contingency plans. A draft of internal standard operational procedures for disaster response was also circulated. In addition, coordination between the disaster management teams of the Federation's regional and country delegations and the headquarters of the national societies has also been strengthened through regular meetings and information exchange. As in the past, in all countries close coordination is maintained with government authorities, both at national and provincial level, and other partners assisting the preparedness activities in communities. Contacts with donors have been established and/or strengthened. The South Asia regional and country delegations and Red Cross and Red Crescent national societies will continue to work together closely to monitor the progress of the monsoon and keep all partners up to date with preparedness and response activities in the region.

1.12 Recent Literature Review

Arya et. al (1996) has used Satellite remote sensing technology to solve the problem of mapping, monitoring and management of flood prone areas. The study was carried out to map the extent of floods in Rohtak district, Haryana using remote sensing technology and to suggest management practices for mitigating flood. The data used are IRS IB. LISS II Diapositive of September 16 and 18, 1995 and LANDSAT TM diapostive bulk scene of September 24, 1995 of the area, Survey of India topographical maps on 1:50,000 scales and other ancillary data. Two categories of flood-affected areas were identified as standing water and receded water/wet areas. The study demonstrates the capability of satellite data for mapping and management of flood inundated areas. Till now structural methods have been adopted for planning of flood affected area but with the advent of satellite based information system, including all weather satellites, priority may be given to non-structural methods such as disaster preparedness, relief and rehabilitation.

Lal Samarakoonet. al (1996) has carried out a research on Siwalik area where the sediment transport is very high depositing enormous amount in the Terai Plain. Sub-streams comparatively short in length with higher gradient, and very flat riverbed is typical to the rivers originate in the Siwalik Hills. The conventional topographical and vegetation map were digitized and incorporated into the GIS database. Some form of different gradation was observed in the old deposits and newly deposited areas. Spectral response pattern of the selected sample are depicted graphically satellite datasets were classified into sediment deposited and non-deposited areas. In the present study, radiometric correction or rectification was not considered. The spectral response patterns of sediments and riverbeds are significantly different from those of surrounding permitting easy classification. The difference of the 16-year period 1977 to 1993 was noticed. The present trend of the channel formation, spatial distribution of sedimentation observed by satellite data has inferred the current sedimentation activities and future channel developments.

Sarma.P (1999) has studied the Flood water from the river Dikrong generally inundates Flood plains in the Lakhimpur district of Assam. The data used by them were survey of India toposheets on 1:50,000. IRS 1B data (LISS

II) of 14 Feb. 1995, Land use map of Lakhimpur district, Assam prepared by Assam Remote Sensing Application Centre, Hydrologic data from Brahmaputra Board, Ministry of Water Resources, Government of India, Literature and Maps on various themes of the area from Brahmaputra Board. Frequency Analysis has been adopted in this study. The analyses for various returns period flood were analyzed. The basic idea of flood risk mapping as undertaken in this study is to regulate land use by flood plain zoning in order to restrict the damages.

According to Rao (2000) India is the worst flood-affected country in the world after Bangladesh and accounts for one-fifth of the global death count due to floods. About 40 million hectares or nearly 1/8th of India's geographical area is flood-prone. An estimated 8 million hectares of land are affected annually. The cropped area affected annually ranges from 3.5 million hectares during normal floods to 10 million hectares during worst floods. Information on inundation and damage due to floods is furnished to the concerned departments so as to enable them to organize necessary relief measures and to make a reliable assessment of flood damage. Owing to large swath and high receptivity, WIFS data from IRS-1C and -1D hold great promise in flood monitoring. The poor performance is attributed to the high spatial variability of rainfall not captured by ground measurements and lack of spatial information on the catchments characteristics of the basin such as current hydrological land use / land cover, spatial variability of soils, etc. Incorporation of remote sensing inputs such as satellite-derived rainfall estimates, current hydrological land use / land cover, soil information, etc. in rainfall-runoff model subsequently improves the flood forecast. A comprehensive database including Digital Elevation Model (DEM) generated using Differential Global Positioning System (DGPS), hydraulic/hydrologic modeling capabilities and a Decision Support System (DSS) for appropriate relief response has been addressed in collaboration with the concerned departments of the Andhra Pradesh Government. Initial results have been quite encouraging. The deviation in the flood forecast from actual river flood has been within 15 per cent.

Srivastava, Y.K et al. (2000) has used High Resolution Remote Sensing Data and GIS Techniques in updating of Infrastructure Details for Flood Damage Assessment in flood mitigation/ protection work in North - Eastern part of India and especially the Assam State is most prone to flood due to its delicate geographic location in the Brahmaputra valley. Infrastructure, GIS, Remote Sensing, Flood Damage, Brahmaputra River, Disaster, IRS -1C /1D, LISS -III, PAN had been used. Merged products of PAN+LISS- III are generated and used for extraction of infrastructure details in GIS environment, that is settlements, metal and unmetal roads/ cart tracks, rails, embankments/ dykes and causeway. Apart from infrastructure details, natural features were also digitized, that is drainage, ox-bow lakes, streams, river, river islands, tanks and reserve forests boundaries. WIFS data is used for extraction of flood layer and the resultant flood layers were used along with all infrastructure layers to intersect the inundated area and assess the damage. Classified land use/ land cover (level III) map generated from LISS - III data is used to assess the damage to agricultural crops. They also identified 30 - 35 years changes taken place in this district either in form of change in river course or infrastructure.

Mohapatra.S. et al (2001) has identified the Orissa super cyclone impact on east coast of India on October 29, 1999 damaging agricultural crops and vegetation throughout the coastal districts. In the present paper IRS P4

OCEANSAT data analysis and GIS modeling have been developed. The detailed analysis show damaged areas and kind of damage in various districts of Orissa. The NDVI images were generated from the red and near infrared channels of the atmospherically corrected OCM images. The two NDVI images have been subtracted and the resulted image has been classified into following four classes such as unaffected Vegetation, Mildly affected Vegetation, Highly affected Vegetation and severely affected Vegetation. The OCEANSAT data before and after the cyclone shows that the coastal districts have been severely suffered.

Venkatachary.K.V (2001) has developed a space-based disaster management system for floods Brahmaputra during 1998 floods. Amongst the largest river in the world, total length of Brahmaputra from its origin in a glacier east of Manasarovar to its outfall at Bay of Bengal is 2880 km, out of which 918 km is in India. In Assam, the length is 640 km and its average width is just 80 km. Although two-third of its length and more than half of the catchments are in Tibet, about two-third contribution of its flow is from the drainage area in India. The available data show clearly that the average area affected by floods during 1990s was higher than in 1980s. Drainage order, density, etc., various themes such as Hydrology, topography, Socio-economic population, Manmade features, Land use/land cover, Soil map, Drainage Order, density, and so on, were prepared. The 3-day revisit of combined IRS-1D and IRS-1C WiFS data results in good temporal coverage in addition to IRS-P3 which revisits at every five days over any specific area during the flood months. Whereas, LISS III with a spatial resolution of 36.5 m and PAN with a spatial resolution of 5.6 m provide more detailed information on the ground conditions. The maps relating to inundation modeling, modeling for crop damage assessment for the problem. In the present study on damage assessment due to floods, the core elements of DMS have been synthesized.

Falak Nawaz, and Mohammad Shafique (2003) has selected Muzaffarabad city, which is one of the flood-affected area in northern Pakistan, which is at the confluence of River Neelum and Jhelum. High-class residential area and commercial activities are situated along riverbanks, which are severally vulnerable to flooding. Due to rugged topography and lack of further land for extension, the people are imposed to construct either double-storey buildings or multi-storey buildings. For a number of reasons the most frequent choice should be protection from the flooding by means of physical control of the river, but there is also need for a broader and comprehensive program for managing flood hazard in the study area. The coordinates of the map were not known but taking control point with the help of Global Positioning System (GPS) on the ground, the required maps were georeferenced. GPS data were collected with respect to Land use, age of the buildings, material used for these buildings, vulnerability and number of storey of the houses. Land Use Map, Classified Hazard Map produced after slicing with different domain also thematic layers created by them. For reduction of vulnerability in the study area to flood hazard there is urgent need to adopt long-term strategies by skillfully combining the engineering devices with proper planning.

Chiradeep Adhikari (2003) has studied the compatible rainfall surface runoff model for regional level planning using GIS and Remote Sensing Techniques. The requirements for the application of the proposed model to catchments are an elevation contour map of the area, corresponding land use and soil maps preferably in a digital format, and a guideline for estimating the design storm. The elevation map, if available in a digital form, is processed by GIS software to create a Triangulated Irregular Network (TIN) form of digital elevation model (DEM). Graphical links between ARC/INFO, Microsoft visual basic VER. 6.0 and the catchments, Channel network of model catchments through TIN model, Model utility for practical applications, Bridges, Culverts, and Aqueducts, Spillways for small dams, Levees for flood protection, Predicting erosion potential due to land use change, Site planning for micro hydels were prepared. A physically based rainfall-runoff model is presented for estimation of flood hydrographs. The model, based on the triangulated irregular network (TIN) digital terrain model is adaptable to GIS (like soil type, etc.) and RS (like land use / land cover etc.) data. The model is simple to run, though some experience is needed during its setting up and calibration stages. It is oriented towards the use of regional level managers for taking a decision on local water resources related projects and some applications of the model have been demonstrated with examples.

Amit Kumar (2005) has applied GIS techniques in Flood Hazard Management in North Indian Plain. The Ganga System creates the flood plain. This system constitutes of the Ganga, and its largest tributary the Yamuna, other Himalayan rivers- Ramganga, Gomati, Ghaghara, Gandak, Rapti, Gandak and Kosi, and some peninsular rivers, like Chambal, Son and Punpun. Focus the study of various possibilities for the alternative methods for flood management and their applicability in North Indian plain. It is also examines the potential of GIS to meet the purpose. The alternative plan requires a proper integration of physical, socio-cultural, economic and demographic data. As data management and map representations tools of GIS helps in exploring new portions its integration with Remote Sensing, enhance the ability for preparing flood hazard map and forecasting. Besides its constraints like technological knowledge requirements, hardware and software requirements, thus GIS can be very useful to minimize flood hazard

Ramalingam.M and M.Vadivukarasi (2005) has used SAR data for flood inundation studies. Two hours of rain in November 2002 was enough to create total chaos in several parts of the city and its outskirts. The study area comprises of Velachery and its surrounding. They used data such as RADARSAT SAR - November 2002, IRS LISS III and PAN merged imagery-2002, Maps of Adyar and miscellaneous watersheds using Survey of India Toposheets, Rainfall level data - November 2002. The SAR data was displayed using the ENVI 4.0 image processing software. Base Map is prepared using survey of India Toposheet. Since the reflectant characteristics of the flood inundated areas are not known, only unsupervised classification has been done initially. After detailed studies the training sites have been given and supervised classification has been made. The best one was identified as the Wavelet Transformation Classification to classify. This information is assigned as the component of the feature vector of a pixel. The classification using this method was successfully applied to Merged SAR image. Results indicate high classification accuracy for all classes. This class is contained with texture information that does not provide a unique feature. It is also seen that the information at the higher level can improve the classification accuracy. Venkata Bapalu.G and Rajiv Sinha (2005) have tried to identify areas of risk and prioritize their mitigation/ response efforts in the flood-hazard areas in the Kosi River Basin, North Bihar, India in a GIS environment. The primary data used for this study were obtained from three sources. The first set of data includes topographic maps, district level maps, and census data of 1991 for the regional divisions of Bihar are obtained from the Survey of India, National Atlas and Thematic Mapping Organization (NATMO), and District Statistical Office, Saharsa respectively. The second set of data includes the digital elevation data (GTOPO30), a global digital elevation model (DEM) from U.S. Geological Survey's EROS Data Center in Sioux Falls, South Dakota and the DEM derived from the toposheets of the study area. The third set of data is the digital remote sensing images for the study area in IRS-1D, LISS III. The primary decision factors considered in this study are geomorphic features, elevation, vegetation, land cover, distance to active channels, and population density. They have prepared flood Hazard Index. This study formulates an efficient methodology to accurately delineate the flood hazard areas in the lower Kosi River basin, North Bihar, India. This study represents some exploratory steps towards developing a new methodology for inexpensive, easily read, rapidly accessible charts and maps of flood hazard based on morphological, topographical, demographical related data.

Vinu Chandran.R (2006) has used the Airborne Synthetic Aperture Radar (ASAR) images in mapping the flood inundation and causative factors of flood in the lower reaches of Baghmati river basin for the period July– October 2004. Integration of the flood inundation layer and land cover layer derived from LISS III data indicate that 62 per cent of the agricultural area was inundated. Floodwater drained faster in the left bank, whereas it was slow in the right bank. The Digital Elevation Model of the area shows that the flood-prone right bank of the Baghmati River is a topographic low sandwiched between Kosi and Burhi Gandak highs (mega fans). Area under flood inundation for various land cover classes has been shown comparative bar graph. Spatial maps such as fluvial geomorphology of the study area, drainage configuration of Baghmati river during pre-flood, flood and post-flood, Transverse spatial profiles across Kosi–Ganga transect, Bhirkhi–Ranka transect and Bharath–Bachhauta transect and, Longitudinal spatial profiles along (*a*) Chanha nadi and (*b*) under fit channel of Baghmati, and difference image (pre-post) showing flooding from tributaries and embankment failure has been prepared by them. In this study, they observed that the right bank of the Baghmati river undergoes frequent flooding due to topography, channel morphometry and discharge characters. The embankment constructed along the course (Baghmati and Burhi Gantak) is found to impede the recession of floodwater.

Joy Sanyal and Xi Xi Lu (2005) have designed a Flood Hazard Mapping, which has vital component for appropriate land use planning in flood-prone areas. It creates easily read, rapidly accessible charts and maps, which facilitates the administrators and planners to identify areas of risk and prioritize their mitigation/ response efforts. An efficient methodology is used to accurately delineate the flood-hazard areas in the Kosi River Basin, North Bihar, India in a GIS environment. They have used one of the multi-criteria decision-making techniques, Analytical Hierarchical Process (AHP) which provides a systematic approach for assessing and integrating the impact of various factors, involving several levels of dependent and independent, qualitative and quantitative information. They presented a novel methodology for computing a composite index of flood hazard derived from topographical, land cover, geomorphic and population related data. All data are finally integrated in a GIS environment to prepare a final Flood Hazard map.

1.13 Problem Statement

According to the reports from the district administration during monsoon season the river Kollidam carried a maximum of 337,000 cusecs of water during monsoon seasons which lead to a major breach at Karuppur in Papanasam taluk to a length of 50 meters and river water entered adjacent villages in Thanjavur district. Farmers in the delta districts were the most affected persons due to this flood every monsoon season. Due to severe continuous drought during the past three years, cultivation of paddy crops in these districts had been severely affected. Since water has been released from Mettur dam this year, Kuruvai and Samba were cultivated in the Kaveri Delta areas. Due to unexpected heavy rain in these areas, paddy crops, which were in good condition got submerged due to undesirable rainfall thereby resulting in heavy damage to paddy crops besides causing untold misery to the farmers. The Collectors of the affected districts were requested to send reports to ascertain the area of the extent of lands affected so as to give relief to the affected persons. As per the reports of the Collectors, 176,864 hectares of land was damaged more than 50 per cent and above during every season. Breaches were also noticed in a lake at Kalimedu near Thanjavur, inundating paddy crops of hundreds of acres of land. Thanjavur District out of the total cultivated area of 141,000 hectares, crop on 71,000 hectares was submerged.

The flood at Peivari, a jungle river near Sengipatti washed away a temporary road across Thanjavur and Tiruchirapalli and snapped the connection. Another 50 meters of breach, along the river Kaveri was noticed in the northern bank at Vengore near the Grand Anaicut water flowed into the nearby Grand Anaicut canal, broke its two banks and entered the Vennar breaking its right bank. Floodwaters from the breach inundated a vast stretch of paddy fields, flooded the Thiruverumbur-Grand Anaicut Road and marooned a few villages, Thohur, Arasankudi, Kiliyur and Nadarajapuram. Based on the background of the flood situation in the Kaveri delta region, the problem to be addressed will be: to study the conceptual development of floods in delta region and to assess the damages caused to people living in rural and urban environment, being Thanjavur Town, the extent of damages to the physical conditions of the river features and tanks which lead to the discharge of water to surrounding villages and the low lying urban areas, and develop a GIS Model to reduce the flood disaster in the future.

1.14 Objectives

a. **To assess the damages caused in general and agricultural lands in particular due to several breaches along the rivers and streams in the district during the past decade,**

b. **To demarcate the river breaches that lead to free flow of water into the rural as well as urban areas and damages caused to men and materials during the selected flood seasons,**

c. **To present a comprehensive picture about the Thanjavur Town, two aspects, spatial distribution and growth, and physical infrastructural services has been taken into account using High-resolution satellite imagery IRS P6 LISS III satellite imagery,**

d. **To identify and delineate the slums in Thanjavur to detect the changes that has taken place in terms of new slum development and to map condition of slum environment and related parameters,**

e. **To design a vulnerability map using the Spatial Information Technology and suggest a flood control and disaster reduction model taking all the detrimental indicators for flood situation and can reduce the flood disasters in the study area.**

1.15 Research Methodology

To assess the flood disaster in Thanjavur District during the past decade Indian Remote Sensing Digital P6 LISS-III data was used to map the flood affected areas. A base map for Thanjavur District was initially prepared using 15 Survey of India topographical maps for the study area such as 58 M/8, 58 M/12, 58 J/13, 58 J/14, 58 N/1, 58 N/2, 58 N/3, 58 N/9, 58 N/5, 58 N/6, 58 N/7 and 58 N/8, 58 N/9, 58 N/10 and 58 N/11 in the scale of 1:50,000 and it is converted into digital data by scanning and on screen digitization method. Scanned topographical maps are then georeferenced using the software tool, ArcGIS 9.0. Spatial features needed for the study are digitized in the Georeferenced Topographical maps using ArcMap and it were converted into shape files. Digitized spatial layers such as major rivers, streams, tanks, settlements, transportation network, agricultural lands, etc are stored in shape files (*.shp) and the files are maintained in Arc Catalog. Flood related damages such as hut damages, agriculture loss and breaches are collected from the District Collectorate, Thanjavur and from Taluk Head Quarters of Kumbakonam, Orathanadu, Papanasam, Pattukottai, Peravurani, Thiruvaiyaru and Thiruvidaimarudur. Collected details about the damages of every taluk have been surveyed primarily using GPS (Global Positioning System) equipment GS 20. Sample points for breaches, damages and agricultural loss has been taken under GPS survey. GPS field survey has made the awareness about the present condition of the affected area and it also made the requirements to improve the affected area in the future. Secondary data of Digital Satellite image, Indian Remote Sensing IRS – P6 data dated December 8, 2005 for Thanjavur district has been collected from National Remote Sensing Agency (NRSA, Hyderabad).

Digital image is then cropped using the district boundary and digital image processing methods were adopted using ENVI image analysis software. Using the sample points collected from GPS survey, Classification methods were adopted for the agricultural losses, major breaches, and water stagnant area in ENVI image analysis software. Flood impact in Thanjavur District has been classified in the Digital satellite image of IRS P6 multispectral data and it is processed using ENVI image processing software. The classification adopted in the study area is major breaches, river and tank water, floodwater intrusion areas, water with scrub, water with mud, and unaffected area. Using the Benchmark sample points collected from GPS survey, using hand held GPS local slope map has been derived. Flood Vulnerability map of the district was performed by classifying the digital image of the flood affected area into five classes such as very high, high, medium, low, and very low. Agricultural losses have been performed by dividing into nine major classes such as paddy, banana, eucalyptus, barren land, sugarcane, coconut, teakwood, acacia, settlement with water, river and tank water using Digital IRS P6, LISS – III data. Located pie chart over the study area is done for loss in agricultural productivity due to floods for the crops such as paddy, sugarcane, banana, teakwood, and other crops. Vulnerability map is overlaid with the study area using overlay technique in ArcGIS 9.0. Global Positioning System (GPS) was used to track the breaches and breaches points and the affected tank are located.

The Slum environment during flood, base map such as Thanjavur Town map in the Town planning Office in the Scale of 1:50000 and wards maps obtained from Municipal Office and it is converted into digital data using Geographical information system (ArcView 9.1 software).

Spatial features needed for the study are digitized in the Georeferenced map using Arc view and it is converted into shape files. Digitized Spatial features such as Town boundary, Ward boundary, River, road network etc., are stored as shape files and maintained in Arc Catalog. Information regarding Slum environment are obtained from Thanjavur Municipal Office. Data such as Population data Ward wise, Slum area details, Number of houses, Crime data, slum area population, Sanitary facilities available in the slum areas are collected from the concerned authorities of the department. After collecting all the primary data, samples of the slum and breaches in the slum are obtained from direct field visit by using GPS (Global Positioning system) instrument – GS 20. GPS field survey has made awareness about the condition of the people in the slum environment. A Drainage map of the Town is overlaid in the base map and the sanitation facility of the slum environment is identified. On the basis of the sanitation facility and other social problems of the slum environment relocation is provided in suitable area.