Living with Floodplain Rivers – Indian Scenario

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Abstract
India is a topical country and its hydro-meteorological condition is dominated by monsoon confined to four months in a year. The intense rainfall during monsoon leads to flooding in various parts of the country in varying magnitude almost every year. Flood problems in India can be presented by four regions of flooding, viz. (a) Brahmaputra River region, (b) Ganga River region, (c) North-West Rivers region, and (d) Central India and Deccan Rivers region. On an average, floods have affected about 33 million persons between 1953-2000. The flood control can be planned either through structural engineering measures or non-structural measures. This paper briefly describes the flood problems of major floodplains of India, the magnitude of flood damages and outlines important flood management practices.

Keywords
Floods; floodplain Rivers; flood damage; Policies; Control measures

INTRODUCTION

Floods are recurrent phenomena in India from time immemorial. Every year some or the other parts of the country are affected by floods of varying magnitude. Different regions of the country have different climates and rainfall patterns and as such it is also experienced that when part of the country is experiencing devastating floods, there is another part of the country at the same time which is in grips of severe drought. Out of the total rainfall of India, about 75% of it is received during the four months (June to September) due to the South-West monsoon which is non-uniformly distributed in space as well. India is traversed by a large number of river systems. The rivers of North and Central India are prone to frequent floods during the South-West monsoon season, particularly in the month of July, August and September. In the Brahmaputra river basin, floods have often been experienced as early as in late May while in Southern rivers floods continue till November. However, the heavy and intense rainfall is not the only factor contributing to floods. The other causes of flood are inadequate capacity within riverbanks to contain high flows and silting of riverbeds, landslides leading to obstruction of flow and change in the river course, retardation of flow due to tidal and backwater effects, poor natural drainage, cyclones, snowmelt and glacial outbursts, and dam break flow. With the increase in population and developmental activity, there has been tendency to occupy the flood plains which has resulted in more serious nature of damage over the years. The National Flood commission (1980) has reported that out of 40 million ha flood prone area, about 15.8 million ha area have been provided with reasonable degree of protection so far. The area liable to floods in India is shown in Figure 1.

For minimizing the losses due to floods, various flood control measures are adopted. The flood control measures can be planned either through structural engineering measures or non-structural measures. Structural measures comprise multipurpose reservoirs and retarding structures which store flood waters, channel improvements which increase floods carrying capacity of the river, embankments and levees which keep the water away from floods prone areas, detention basins which retard and absorb some flood water, flood-ways which divert flood flows from one channels to another and over all improvement in the drainage system. However, it has been recognized that permanent protection of all flood prone areas for all magnitude of floods by structural means is neither possible nor feasible because of various factors such as financial constraints, cost-benefit criteria or topographic limitations of the region. There should be emphasis on non-structural works such as real time flood forecasting, flood plain zoning for management of the flood. Main objectives of this paper are to present (i) Flood problems in India (ii) Flood damages to human life and property and (iii) Flood management policies and control measures including structural and non-structural measures.

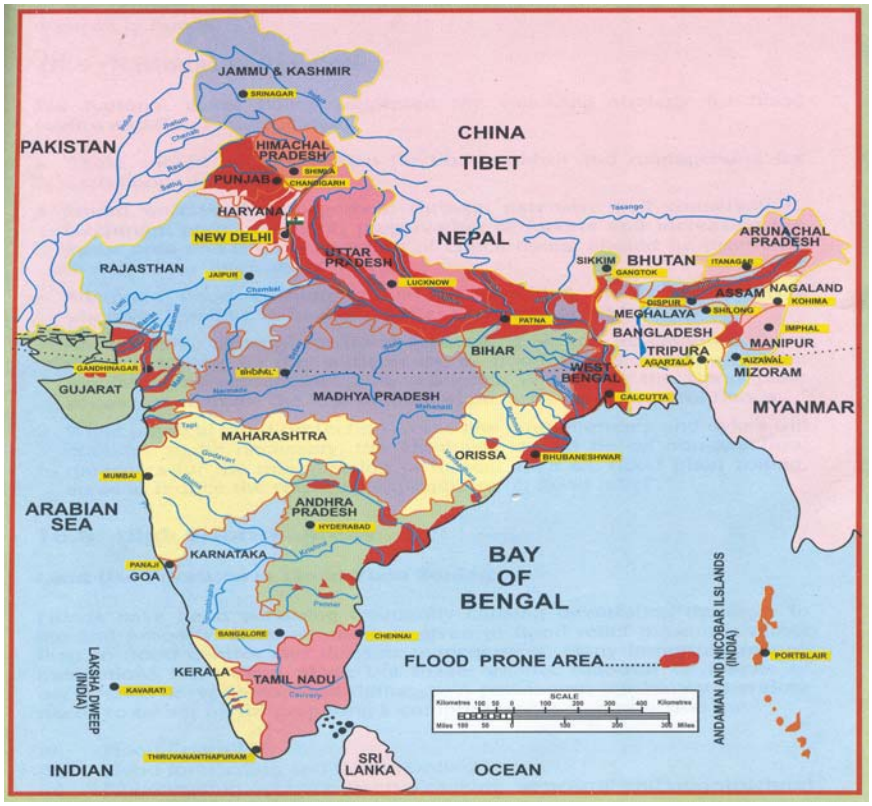


Fig. 1: Flood Prone Areas in India

FLOOD PROBLEMS IN INDIA

The rivers in India can be broadly divided into the following four regions for a study of flood problem: (a) Brahmaputra River region, (b) Ganga River region, (c) North-West Rivers region, and (d) Central India and Deccan Rivers region.

Brahmaputra River region

The first zone belongs to the basins of the rivers Brahmaputra and Barak with their tributaries. It covers the States of Assam, Arunachal Pradesh, Meghalaya, Mizoram, northern parts of West Bengal, Manipur, Sikkim, Tripura and Nagaland. The catchments of these rivers receive large amount of rainfall ranging from 110 cm to 635 cm a year which occurs mostly during the months of May/June to September. As a result of this, floods in this region take place very often and are severe by nature. The general tectonic wrapping up of North-East region has also significant effect on river Brahmaputra. Almost all Northern tributaries of Brahmaputra are affected by landslides in the upper catchment. Further, the rocks in the hills, where these rivers originate are fragile and susceptible to erosion and thereby cause exceptionally high silt charge in the rivers. In addition, the region is subject to severe and frequent earthquakes causing numerous landslides in the hills, which upset the regime of the rivers. Important problems in this region are flood inundation due to spilling of banks, drainage congestion due to natural as well as man-made structures and change of river flow. In recent years, the erosion along the banks of the Brahmaputra has assumed serious proportions.

Considering the individual states in the region, main problems of flooding in Assam are inundation caused by spilling of the rivers Brahmaputra and Barak as well as their tributaries. In addition, the erosion along the Brahmaputra is a serious problem. In Northern parts of West Bengal, the rivers Teesta, Torsa and Jaldakha are in floods every year and inundate large areas. During flooding, these rivers carry large amount of silt and have a tendency to change their courses. The rivers in Manipur spill over their banks frequently. The lakes in the territory are filled up during the monsoon and spread to large marginal areas. In Tripura, flood problems are the spilling and erosion by rivers.

Ganga River region

The Ganga and its many tributaries (the Yamuna, the Sone, the Ghaghra, the Gandak, the Kosi and the Mahananda) constitute this river region. It covers the states of Uttaranchal, Uttar Pradesh, Bihar, South and central parts of West Bengal, parts of Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and Delhi. The normal annual rainfall of this region varies from about 60 cm to 190 cm of which more than 80 per cent occurs during the South-West monsoon. The rainfall increases from West to East and from South to North.

The flood problem is mostly confined to the areas on the Northern bank of the Ganga River. The damage is caused by the northern tributaries of the Ganga by spilling over their banks and changing their courses. Even though the Ganga is a mighty river carrying huge discharges of 57,000 to 85,000 cumecs (2 to 3 million cusecs), the inundation and erosion problems are confined to some specific places only. In general, the flood problem increases from West to East and from South to North. In the North- Western parts of the region, there is the problem of drainage congestion. The drainage problem also exists in the Southern parts of West Bengal. The problem becomes acute when the main river, in which the water is to be drained, already has high water level. The flooding and erosion problem is serious in Uttar Pradesh, Bihar and West Bengal. In Rajasthan and Madhya Pradesh, the problem is not so serious. In Bihar, the floods are largely confined to the rivers of North Bihar and are an annual feature.

North-West River region

The main rivers in this region are the Sutlej, Ravi, Beas, Jhelum, Ghaggar and the tributaries of Indus, all flowing from the Himalayas. These carry quite substantial discharges during the monsoon and also large volumes of sediment. They change their courses frequently and leave behind vast tracts of sandy waste. The region covers the state of Jammu and Kashmir, Punjab and parts of Himachal Pradesh, Haryana and Rajasthan. In comparison to the two regions mentioned above, the flood problem in this region is relatively less. The major problem is that of inadequate surface drainage which causes inundation and water logging.

Central India and Deccan Rivers region

Important rivers in this region are the Narmada, the Tapi, the Mahanadi, the Godavari, the Krishna and the Cauvery. These rivers have mostly well defined stable courses. They have adequate capacity within the natural banks to carry the flood discharge except in their lower reaches and in the delta area, where the average bed slope is very flat. The lower reaches of the important rivers on the East Coast have been embanked.

This region covers all the Southern States namely Andhra Pradesh, Chhattisgarh, Karnataka, Tamil Nadu, Kerala, Orissa, Maharashtra, Gujarat and parts of Madhya Pradesh. The region does not have very serious problems except for some of the rivers of Orissa (the Brahmani, the Baitarni, and the Subarnarekha). The Delta areas of the Mahanadi, Godavari and the Krishna rivers on the east coast periodically face flood and drainage problems, in the wake of cyclonic storms.The Tapi and the Narmada are occasionally in high floods affecting areas in the lower reaches of Gujarat. In Orissa, damage due to floods is caused by the Mahanadi, the Brahmani and the Baitarani which have a common delta.

SPECIAL FLOOD PROBLEMS

In this section, some special flood problems in India are presented.

Problem of Tal areas

Natural depressions where water gets deposited during monsoon for longer period are known as Tal areas. Generally, they hamper normal activity affecting the Kharif crop. Mokama group of Tals in Bihar is known for its flood problem. Water gets accumulated in these areas during monsoon and remains stagnant up to September. Similar problems are also seen in Ghaggar

detention basin in Rajasthan, depressions available at Ottu, Bhindawas, Kotla lakes in Haryana. Flood problems in such areas are of special nature and needs to be treated separately.

River bank/bed erosion

A river erodes its banks due to various reasons causing considerable loss of land, deterioration of the river regime and sometimes account for huge losses during floods. Rivers in Brahmaputra-Barak and Ganga basins are prone to severe erosion. River erosion causes a loss to the land resources. The river behaviour causes new riverine landmass to be built up, but these become productive after many years and cannot compensate the land-loss due to erosion. Erosion in the Majuli island, the largest river-island in the world, is the most appropriate example to state the severity of the problem.

Sediment transport by rivers and river migration

One of the problems associated with the floods in India is the transport of sediments by rivers during floods. Himalayan rivers originating from Nepal bring a lot of sediment during floods to the alluvial plains in the valley. Transport of sediments has a major role on river behaviour and river morphology. The Kosi River in North Bihar, once called the "Sorrow of Bihar" is a burning example of this problem. Kosi has shifted its course from East to West to a distance of 210 miles during past few hundred years since 1731, (Gole and Chitale, 1966). Thus, this type of flood problem and its management measures depend a lot on sediment transport.

Dam break flows

Flooding due to dam break is a mega-disaster as it is associated with huge loss of life and property. An unusual high peak in a short duration and presence of a moving hydraulic shock/bore make it a different problem as compared to other natural floods. In India, historical events (e.g. failure of Machhu dam, Panshet dam, Nanak Saagar dam) for dam break floods are common (Palaniappan, 1997). Sometimes, blockage of water due to deposits caused by landslide takes place. When this natural blockage fails due to increased amount of water at the upstream, huge flooding occurs. The behaviour of this flood is similar to that of dam break floods.

Urban drainage

Flooding of cities in India is a common and annual event. Due to encroachment of the flood plain areas, presence of several structures and absence of proper regulations for maintenance, artificial flood is created. Therefore, proper drainage networking for a city has to be developed. Recent devastating flooding in Mumbai (26^{th} July, 2005), one of the largest metro city of India was also due to poor urban drainage system.

Flash floods

Flash floods are characterized by sudden rise and recession of flow of small volume and high discharge which causes damages because of suddenness. They generally take place in hilly region where the bed slope is very steep. Typical examples are flash flood of Arunachal Pradesh and flash flood of Sutlej in 2000. Large reservoir downstream of flood prone areas can absorb the flood wave. Flash floods are also experienced in arid and semi-arid regions due to the intense and short duration rainfall in the small catchments of the region.

Flood due to snowmelt

Snowmelt is a gradual process and does not produce floods. However, sometimes, glaciers hold large quantity of bounded water. When released suddenly, this causes severe flooding. The rivers originating from the Himalayas in the North are fed by snowmelt from glaciers. In 1929, the outburst of the Chong Khundam glacier (Karakoram) caused a massive flood at Attock.

Flood in Coastal Areas

Floods in Indian river basins are also caused by cyclones. Coastal areas of Andhra Pradesh, Orissa, Tamilnadu, and West Bengal experience heavy floods regularly. The flood due to the

super cyclone combined with heavy rainfall during October 1999 in the coastal region of Orissa is an example. During past 110 years (1891-2000), over 1,000 tropical cyclones and depressions, originating in the Bay of Bengal and Arabian Sea, moved across India. Passage of such storms over a river basin leads to severe floods.

IMPACT OF FLOOD ON HUMAN LIFE

More than the loss of life and damage to property, the devastating affect of flood, the sense of insecurity and fear in the minds of people living in the flood plains are more telling. The after effects of flood like agony of survivors, spread of epidemic, non availability of essential commodities and medicines, loss of the dwellings make floods more feared among the natural disasters being faced by human kind.

The systematic records of the flood occurrences, the damages associated and the measures taken to deal with them are available only from the year 1953 by which time the gravity of the problem passed by this natural phenomenon came to be realised by the government. As reported by the Central water Commission (CWC) under Ministry of Water Resources, the annual average area affected by floods is 7.563 million ha. This observation was based on data for the period 1953 to 2000, with variability ranging from 1.46 million ha in 1965 to 17.5 million ha in 1978. On an average, floods have affected about 33 million persons between 1953-2000. There is every possibility that this figure may increase due to population growth. The flood area affected, population affected, human lives lost and monetary damages due to floods during 1953 to 2000 (IWRS, 2001) are shown in figure 2 to 5 respectively in the form of histogram.

The minimum monetary damages due to floods during the year 1953 to 2000 was Rs 7 crore whereas, the maximum monetary damage has gone up to the maximum of Rs. 5846 crores. In general the monetary damages exhibit a rising trend. The major factors responsible for the increase in the monetary value of flood damages have been a rise in the price level, increasing human intervention into flood plains. While taking the development activities like expansion of rail and road network, establishment of irrigation systems, embankments, industrial estates and residential complexes etc. undertaken in the country since independence, adequate provisions of draining the flood water were not considered. Thus, these developmental activities have adversely affected the drainage of the surrounding areas leading to frequent problems of drainage congestion. Some parts of our country are experiencing the frequent flooding due to the drainage congestion which results in considerable damages of lives and properties.

Figure 2: Area affected (Thousnad Ha) due to floods during year 1953-2000

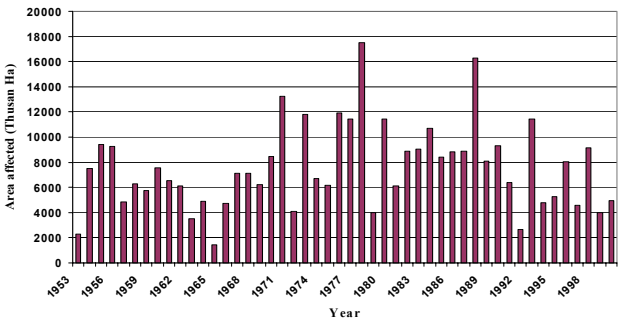


Figure 3: Population affected (thousand) due to floods during year 1953-2000

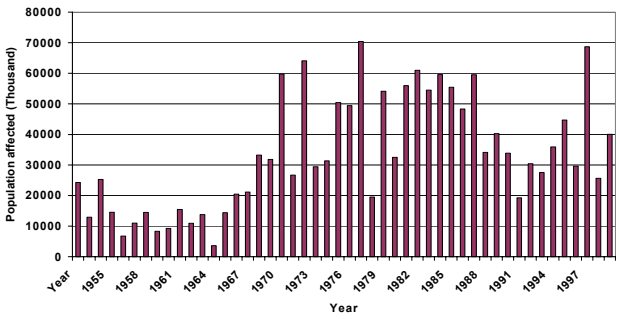


Figure 4 : Human lives lost due to floods during year 1953-2000

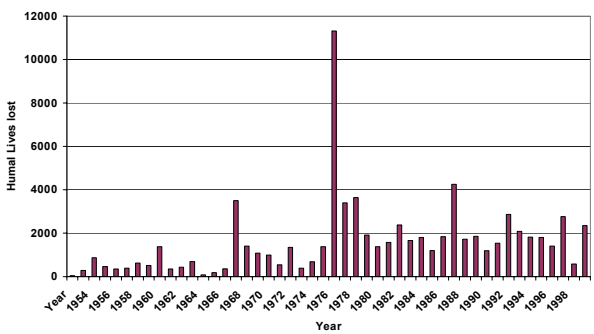
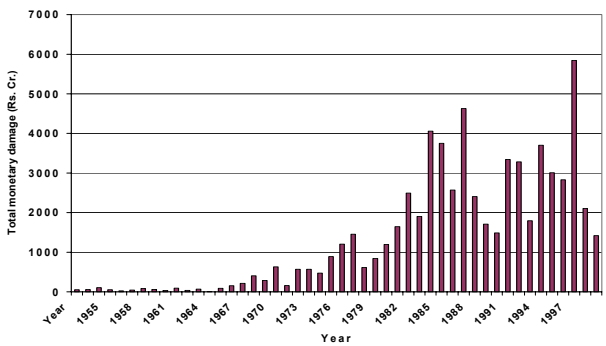


Figure 5:Total monetary damage (Rs. Cr.) due to floods during year 1953-2000



FLOOD MANAGEMENT POLICIES

After the unexpected heavy floods in 1954, the Government of India took several steps to constitute a number of committees to study flood problems in India. Some important ones are:

- Policy statement (1954).
- High level committee on flood (1957).
- Policy statement (1958).
- Ministerial committee on flood control (1964).
- Ministers committee on floods and flood relief (1972).
- Working groups on flood control for five year plans.
- Rashtriya Barh Ayog (1980).
- National water policy (1987).
- National commission for integrated water resource development plan (1996)
- Regional task forces (1996).
- National Water Policy (2002)

The above mentioned commissions on flood have given valuable recommendations on different aspects of flood management. Many of the recommendations are applied in the field in India. However, some of these are not accepted by various agencies. In addition, it is also observed that some of the recommendations are not effective in Indian context.

FLOOD MANAGEMENT MEASURES

The flood management and control are necessary not only because the floods impose curse on the society, but the optimal exploitation of the land and proper management and control of water resources is of vital importance for bringing prosperity in the predominantly agricultural based economy of this diversely populated country; and this can not become technically feasible without effective solution of flood problems. These measures are grouped as structural and non structural flood management measures.

Structural measures

Over the centuries a variety of structures have been evolved to mitigate the flood hazard. Their aim is to reduce flooded area, or depth of flood water, or flood discharge. The main thrust of the flood protection programme in India so far has been in the nature of structural measures like:

- The construction of dams and reservoirs for the temporary storage of flood waters.
- The construction of embankments (dikes or levees) and flood walls
- The improvement of river channels to enlarge their discharge carrying capacity.
- The construction of bypass and diversion channels to carry some of the excess flood water.

In India, between the period of 1954 to 2000, 33,630 km of new embankments and 37,904 km of drainage channels have been constructed. In addition, 2337 town protection works have been completed and 4705 villages have been raised above flood levels. Barring occasional breaches in embankments, these works have given reasonable protection to an area of about 15.8 million ha.

Non-structural measures

Non-structural measures strive to keep the people away from flood waters, bearing in mind the stark reality that the flood plains in fact, belong to the river and that the flood perceived only as a curse, could be turned into a blessing in disguise in some ways. It contemplates use of flood plains judiciously, simultaneously permitting vacating of the same for use of the river whenever the situation calls for. This technique allows the use of flood plains reducing the disaster dimension, while retaining its beneficial effects. Some of the popular non structural measures are discussed in brief here under:

Flood forecasting: Flood forecasting enables forewarning as to when the river is going to use its floodplain, to what extent and for how long. With reliable advance information/warning about impending floods, loss of human lives and moveable properties and human miseries can be reduced to a considerable extent. Flood forecasting and flood warning in India was commenced in a small way in the year 1958 with the establishment of a unit in the Central Water Commission (CWC), New Delhi, which is now responsible for issuing forecasts at 157 stations, of which 132 are for water level forecasting and 25 for inflow forecasting, used for optimum operation of certain major reservoirs. These 150 stations are located in 11 flood prone states and two union-territories. The total number of forecasts issued by CWC increased from 6964 in 1978 to 8566 in 1990. The percentage of accurate forecasts also increased from 82 in 1978 to 95 in 1989 (CWC, 1996). To improve the quality of forecasts further, the modernization of existing networks has been undertaken with international agencies and nations such as UNDP, USAID, World Bank and Denmark.

Dam break flood wave simulation: Worldwide many types of dam break models exist ranging from simple computations based on historical dam failure data that can be performed manually to complex models that require computer analysis. These models simulate the breach on the dam, and route the flood through the reservoir considering the breach, and subsequently route the flood hydrograph from the failed dam through the downstream valley. Such information is very useful for planning purposes.

Flood inundation mapping: For flood mitigation measures and land use planning, flood inundation mapping is an important activity. The Satellite remote sensing technology is extremely useful in monitoring the dynamics of water spreads during the floods. Analysis of remotely sensed data gives a reasonable accurate assessment of water spread directly from the satellite images.

Flood plain zoning: A flood plain zoning means categorizing various zones based on administrative legislations for planning and development of the flood plains for various purposes such as agricultural activities, play fields, industrial areas and residential areas etc. Preparation of flood plain zoning maps takes into consideration the inputs from flood inundation, flood hazard and flood risk zone maps (NIH, 1988-89). The important aspect of zoning is that it can be used to regulate what uses may be conducted and how uses are to be constructed or carried out. Zoning is also used to restrict riverine or coastal areas to particular uses, specify where the uses may be located and establish minimum elevation or flood proofing requirements for the uses. However, many flood prone states in India have not adopted the recommendations regarding flood plain zoning and a task committee for this purpose is essential.

Flood Insurance: In developed countries flood insurance scheme is found to be most effective method to regulate the land uses in the flood plain. Basically under this scheme, depending upon the nature and location of establishment in the flood plain, insurance premiums are charged. The insurance plan is in such a way that very high premium are charged from the persons going for the costly establishments in the flood plain very close to the river banks. In India, at present, this scheme is not yet implemented.

Decision support system for real time flood warning and management: Decision support system for issuing the flood warning and managing the flood in real time is an advance software which is capable of providing the information to the decision makers for taking the necessary measures for managing the flood in real time. Such system requires the spatial and temporal data bases which include the basin characteristics, hydrometreological variables, social and economical data etc. The data bases are linked to the mathematical models developed for each component of DSS. The temporal information about the hydrometreological variables are made available in the real time and the system provides the hydrographs of the river stages and corresponding

discharges at required lead times. Such information are very much useful for the decision makers to take necessary actions for preparing the evacuation plan in real time during the flood. For the development of such DSS in India, efforts are being made by some academic and research institutions on pilot scales. However, under the World Bank funded Hydrology Project II, which is likely to start in the month of October 2005, the development of DSS for real time flood forecasting is one of the important proposed activities. The hydrology project II is being implemented by Ministry of water resources. In this project 13 states and 8 Central agencies are participating.

International cooperation: India is drained by a number of international rivers that originate beyond its borders and flow into India. India shares river systems with six neighboring countries: Viz. Nepal, Bhutan, China, Myanmar, Bangladesh and Pakistan. Bilateral cooperation for various flood management measures is essential for India and the concerned country. Government of India has already taken some initiatives in this regard. However, more active participation in the subject is required

CONCLUDING REMARKS

In this technical paper, flood problems and management in India has been presented. Flood problems in India have been described dividing the country into regions, pointing out specific phenomena related to flood in the regions indicating the regional variability of the problem. Some special flood-problems, like dam-break flow and flood in the Tal areas, have also been mentioned. Various measures for flood management in India have been presented including both structural and non-structural measures. Non-structural measures are found to be more effective for the flood management. Thus, a combined approach may be adopted considering structural as well as non-structural measures together. Short term as well as long term strategies are required to be evolved to combat the floods so as to minimize its detrimental effect on the society. The use of modern tools like remote sensing and GIS may be increased for preparing the maps of flood hazard, flood risk and flood plain zones etc. There is a need for developing the decision support system to provide the knowledge and information about the areas to be submerged due to flood water in real time. It will helpful for the administrators in preparing the evacuation plans during the flood period to save the lives and properties of the people affected due to floods. There is a need to improve the cooperation and coordination between the scientific communities and appropriate local governments and civil defence agencies for developing the effective, workable response plans to flood disasters.

REFERENCES

i) Central Water Commission (1996). Report of the Working Group on Flood Management for the 9th five year plan (1997-2002), CWC, New Delhi, India.

ii) Dhar O.N. and Nandargi S. (1992). A Study of rainfall and floods in the 1987-1991 monsoon seasons over the contiguous Indian region, Journal of Meteorology 17(174), 330-336.

iii) Gole, C.V. and Chitale, S.V. (1966).Inland Delta Activity of Kosi River. J.of the Hydraulic Division, Proc. American Society of Civil Engineers, vol. 92, pp. 111-126.

iv) IWRS. (2001). Theme Paper on "Management of Floods and Drought", Indian Water Resources Society, Roorkee, India.

v) Mohapatra P.K., and R.D. Singh (2003). Flood Management in India, Journal of Natural Hazards, Vol. 28, No. 1 pp. 131-143.

vi) National Flood Commission (1980). Report of the Rashtriya Barh Ayog, New Delhi, India.

vii) NIH (1988-89). Flood Plain Zoning for Downstream Area of Machhu Dam II, Report No.TR-72, National Institute of Hydrology, Roorkee, India.

viii) Palaniappan, A. B. (1997). Dams and their failures, chapter 8, Lecture notes on "Dam Break Flow Analysis", National Institute of Hydrology, Roorkee, India.