PARTICIPATORY STRATEGY FOR FLOOD MITIGATION IN EAST AND NORTHEAST INDIA: CASE STUDY OF THE GANGES–BRAHMAPUTRA–MEGHNA BASIN

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Abstract

Flood is an intense and recurrent natural hazard in the eastern and north-eastern part of India. The mighty Ganges, Brahmaputra and Barak rivers flow in this region and their seasonal flooding results in extensive damage to life and property. The eastern region of India comprising eastern Uttar Pradesh, Bihar, West Bengal, Assam and other north-eastern states is economically the most backward and poverty-stricken. Paradoxically this region happens to be richly endowed with natural resources, with almost 40 percent of the nation's mineral resources and 60 percent of its power potential. However, the region suffered severe floods in 1954, 1974, 1975, 1976, 1984, 1987, 1988, 1993, 1998 and 2000. Thus, water, which can potentially deliver untold benefits through multi-sectoral development, actually jeopardizes local developmental activities. The rightful prosperity of the region has to be based on the critical and vital role that water resources of the region play.

The region accounts for 50 percent of the country's land surface, 42 percent of its population, 61 percent of its flood-prone area and 85 percent of its flood losses. To mitigate flood losses, mostly earthen embankments (13 577 km), drainage channels and a number of town protection works have been undertaken. These measures have provided a reasonable degree of protection to only half of the region's flood-prone area. Several non-structural measures, such as flood forecasting and warning and flood-proofing programmes, have also been taken. During high floods, many breaches occur, causing inundation over vast areas for most of the monsoon months of June to September.

Studies show that flood levels up to two metres high could be contained in the Brahmaputra River and the severity of floods substantially reduced, in combination with the generation of hydropower of about 30 000 megawatts. Most of the suitable dam sites are located in neighbouring Nepal and Bhutan. The reservoir sites in Nepal are eminently suited to the construction of storages and development of water resources for both Nepal and India. Negotiation is going on between the two countries for the joint development of water resources for storage and watershed management, which could be most effective with people participation at all levels.

This paper deals with the effectiveness of the measures taken so far and with the future strategy to lessen the adverse impact of floods on socioeconomic conditions with special emphasis on participatory flood management and flood loss mitigation preparedness programmes.

The participatory flood management measures could be: (1) construction of embankments on a selective basis; (2) maintenance of embankments; (3) watershed management at micro and macro levels; (4) land use regulation; (5) soil conservation and afforestation; (6) flood emergencies; (7) disaster management and preparedness; (8) flood forecasting, issuance of warnings and their quick dissemination through signals; (9) change in cropping patterns; and (10) a flood-proofing programme.

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1.0 INTRODUCTION

The Ganges-Brahmaputra-Meghna (GBM) river system which flows through the northern, eastern and north-eastern parts of India exhibits a huge contradiction between huge water potential and destructive reality. This river basin covers an area of about 1.75 million km^2 stretching across Bangladesh (7.4 %), India (62.9 %), Nepal (8.0 %), Bhutan (2.6 %) and Tibet-China (19.1 %).

The mean annual rainfall is 1200 mm and 2300 mm in the Ganges and Brahmaputra-Meghna basins respectively. The system carries a peak flow of 141 000 m^3/s at its estuary and empties about 1,150 billion m^3 in the Bay of Bengal. The Brahmaputra and Ganges rivers rank tenth and twelfth in the world respectively in terms of discharge, and the GBM system is the largest in the world, second only to the Amazon's. The estimated population of the basin is about 535 million (75.8 % in India, 20 % in Bangladesh, 3.5 % in Nepal, 0.2 % in Bhutan and 0.5 % in Tibet-China). Although the basin has a rich heritage and tremendous opportunities for development, it is home to the largest concentration of the poor in the world; half of its population lives in poverty. On the other hand, it is richly endowed with water resources with huge power potential of the order of 150,000 MW. With fertile alluvial lands in the plains (79.8 million hectares) and a favourable climate, the majority of the population (ten percent of the world's) subsists on agriculture, which is the prime source of the economy. Labour resources and the urge for development are plentiful in the basin.

The water resources in the GBM basin have been assessed at about 59 percent of the country's, with those of the Ganges River alone representing 28 percent. However, water harnessed for irrigation and other beneficial purposes in the Brahmaputra and Barrak basins is only three percent and in the Ganges basin about 40 percent of usable water.

The flood problem has been present since time immemorial, quite needlessly so. It could have been overcome by the better utilization of the huge water resources of the region for poverty alleviation and sustainable development. Every year floods result in colossal damage.

The prosperity of the region lies in regional cooperation and people's participation. Since crucial natural links among the countries are provided by transboundary rivers, proper development and sharing of their waters could be an effective means of achieving the integrated development of the region. There is an urgent need to create a conductive environment for cooperation in order to solve outstanding regional water-related issues and undertake joint efforts for the benefit of all concerned. Technical experts have worked out all possible options for developing regional water resources in a sustainable way, which could change the face of the region, but actual decisions and implementation are a matter of political will. The region has chronic devastating flood problems which cannot be mitigated despite the construction at great cost of miles and miles of embankments unable to withstand the sudden onrush of storm water due to its high erosive power and to inadequate maintenance. Participatory flood management measures and disaster preparedness to mitigate the recurring flood losses have to be adopted in a comprehensive manner, not piecemeal as has been the case so far.

2.0 THE GANGES-BRAHMAPUTRA-MEGHNA DRAINAGE BASIN

India is a vast country, with a total land area of 3.29 million km^2. Due to its vastness, the different regions of the country have varied climates and rainfall patterns. The eastern and north-eastern part is often under the grip of severe floods due to excessive rainfall and geographical conditions. The Ganges-Brahmaputra-Meghna system is the largest river system not only of India but of the world in terms of water resources. Taken as a whole it comprises an area of 1.75 million km^2 and drains, on average, an annual flow of about 1,276 billion m^3 into the sea. An index map showing the Ganges-Brahmaputra-Meghna basin is enclosed as Figure 1.

The 2525-km-long Ganges River originates in the Gangotri glacier in the Himalayas in India and drains a vast area. Near its deltaic head at Farakka, it divides into two channels, the Bhajgirathi-

Hooghly and the Padma. The Bhajgirathi-Hooghly flows through West Bengal till it joins the Bay of Bengal. The Padma crosses over into Bangladesh and joins the Brahmaputra at Goalundo. The combined stream of the Brahmaputra and the Ganges continues to flow under the name of Padma for another 105 km until it meets the Meghna at Chandpur in Bangladesh. The principal tributaries of the Ganges in India are the Yamuna, Ghaghra, Gandak, Kosi, Mahananda and Sone.

The Brahmaputra is one of the largest rivers in the world. It originates from a glacier east of Mansarower and is known as Tsangpo in Tibet. After flowing 1625 km through Tibet, it enters India near Tuting in Arunachal Pradesh and is known as Siang or Dihang in India. The river runs through Arunachal Pradesh and Assam for 918 km and receives numerous tributaries from north and south. The principal tributaries are the Subansiri, Kameng, Dhansiri, Manas, Champamati, Sankosh, Noa Dihing, Buri Dihing, Disang, Dikhu and Kopili. The Brahmaputra finally enters the alluvial plains of Bangladesh where it flows for another 258 km before joining the Ganges at Goalundo.

The Barak River, the headstream of the Meghna, rises in the hills of Manipur in India and flows southwest for 250 km. At Lakhipur, it emerges from the hills and at Bhanga splits into the Surma and the Kushiyara, which cross over into Bangladesh near Karimganj. The Mokru, Irang, Tuivail, Jiri, Rikmi-Sonai, Kathakhal-Dhaleshwari, Langai, Chiri, Madhura and Jatinga are tributaries of the Kushiyara, there known as Kalni, and once it has received the Someshwari, Kangsa, Baulai and Mogra it finally assumes the name of Meghna.

The combined flows of the Ganges and the Brahmaputra join the Meghna at Chandpur and continue to flow for another 130 km as one mighty river, the Meghna, until it debouches into the Bay Bengal.

The Ganges, Brahmaputra and Meghna basins constitute the main areas and are endemically affected by severe floods. The main tributaries overflow their banks during the monsoon season almost every year. Comprehensive studies have been undertaken of the various aspects of floods and flood control and various structural and non-structural measures as shown in Figure 2 have been considered for the formulation and implementation of a flood control plan in the Ganges-Brahmaputra-Meghna basin.

The Brahmaputra, the Barrak and the northern tributaries of the Ganges are braided and unstable in their reaches. River instability is mainly attributed to high sediment charges, steep slopes and transverse gradients. Besides, the entire area is part of a seismic zone and periodic severe earthquakes are also a factor of river instability. The drainage networks of Assam in 1897 and 1950 and North Bihar in 1934 were considerably disturbed by earthquakes occurring in those years.

2.0.1 Hydrometeorology

The meteorological conditions in the catchment of the Brahmaputra in Tibet and in India are different and lie in different climatic zones. The zone in Tibet comprises plateau regions. The zone in India in respect of the Brahmaputra, Barrak and Ganges comprises hilly ranges in Bhutan, Nepal and India and the plains of the Assam valley and the Gangetic plain. The drainage area in India is subjected to cyclonic storms originating in the Bay of Bengal, particularly in the latter part of the monsoon season.

The mean annual rainfall varies widely from 800/1400 mm in the northern part of the Ganges basin to 2600 mm in the Brahmaputra basin. The rainfall is 11000 mm in Cherapunji in Meghalaya. Monsoon rainfall accounts for 75 to 80 percent of the annual rainfall.

3.0 FLOOD, DRAINAGE CONGESTION AND EROSION

3.1 Flood problem

The Ganges, Brahmaputra and Barrak river system is affected by frequent heavy flooding, drainage congestion and bank erosion, resulting in extensive submergence of land, loss of life and property and dislocation of the communication system. At times, the period of flood above danger level is 40 to 70 days. The impact of flooding was not felt to the same extent in the past as it is now. This is due to the rapid increase in population and consequent increase in the all-round activities of man. The flood plains are being increasingly crowded to meet ever-increasing requirements of food and fibre, and consequently the flood problem is exacerbated. Floods in the region occur due to a variety of causes:

a. River channels carrying flows in excess of the transporting capacity within their banks. This is due to excessive precipitation in north-eastern India.
b. Backing up of water in tributaries at their outfalls into the main river with or without synchronization of peak floods in them.
c. Heavy rainfall coinciding with river spills over a short period of time.
d. Landslides blocking stream courses and then sudden release of blockage.
e. Upland floods coinciding with high tides.
f. Heavy local rainfall.
g. Cyclonic storms.
h. Inadequate drainage to carry away surface water quickly.
i. Aggradation in the riverbed in the Brahmaputra River after the earthquake of 1950.
j. Inadequate waterways at rail and road crossings and encroachments in the flood plains.
k. Loss of soil mantle in Himalayan friable watersheds.
l. Lack of proper control of land use and developmental works resulting in obstruction of the natural flow.
m. Steep slopes of the rivers as they enter the plains and absence of easy outfall facilities.
n. Deforestation in the upper catchment areas reducing retaining capacity of water and holding soil and consequent soil erosion resulting in silting of riverbeds, which shift course.

3.2 Drainage congestion

Severe rainfall-induced drainage problems occur in naturally low land, and large areas (up to 2 million hectares) remain under water for a long time. Drainage congestion is due mainly to heavy rainfall of short duration coupled with high flow levels in the main river preventing rainwater from draining quickly into the riverbed. They can also be induced by construction of roads, railway tracks and embankments that obstruct natural flows, with encroachment on the riverine areas due to population pressure. Insufficient capacity of drainage channels and natural bowel-shaped topography of land resulting from defunct river courses also contributes to drainage congestion.

3.3 Erosion problem

Bank erosion by the Ganges, the Brahmaputra and their tributaries has become a matter of serious concern to both the people and the government, and erosion control works consume large chunks of the budget. In the past few years an average of more than 80 percent of total allocations made in the flood sector is being spent on anti-erosion works to check the erosion of land and marginal embankments constructed so far, leaving little for further protection works. Table 1 shows the expenditure incurred on anti-erosion works in the past few years. At many places, long stretches of riverbanks along towns, villages, fertile land, and lines of communication are eroded by the river.

The causes of heavy erosion are excessive sediment loads, steep bed gradients, transverse bed slopes, the erodible nature of bank material, the formation of char islands and consequent development of side channels. Erosion is mostly observed upstream and downstream of stable reaches or nodal points. It is also observed below the confluence of the main tributaries.

4.0 FLOOD DAMAGE

The magnitude of the flood problem is assessed in terms of the different types of damage brought out by floods. Flood damage information is helpful in providing a better understanding of a number of issues concerning flood problems. The floods in the Ganges basin in 1987 and in the Brahmaputra basin the following year were unprecedented and completely shattered the local economy. The sufferings of the people and damage to property have gradually increased despite measures taken on a large scale, due to population increase and to development lacking interdepartmental coordination and participatory flood management measures as well as disaster mitigation and preparedness. The magnitude of the damage incurred by the most vulnerable states in the past is shown in Table 2.

5.0 CASE STUDY OF PAST ATTEMPTS AT FLOOD MANAGEMENT

Water resources have been essential in turning the Gangetic plain into the cradle of Indian civilization and the credit is shared by the Ganges-Brahmaputra-Meghna river system. In the Indian context, this river system has played a key role in the continuing prosperity of the people of India. The human, agricultural and industrial resources produced in the Gangetic plain are shared by the entire country. Maintaining the river systems, and thus the water resource sector, for optimal results is of paramount importance, given the exponential increase in population and in water demand. Huge, repeated damage is hampering overall development and abundant water resources remain untapped. The floods of 1954, 1974, 1975, 1976, 1987, 1988, 1989, 1998 and 2000 were the worst in the history of the Ganges-Brahmaputra and Barak basin. In order to mitigate flood losses, a number of structural and non-structural measures have been taken over time. They have taken the form of embankments, drainage improvement, anti-erosion works and raising of villages, and non-structural measures such as the flood forecasting and warning system. They have no doubt provided a reasonable degree of protection against small to medium-sized floods over an area of 1.55 million hectares (for a flood-prone area of 3.10 million ha) in the north-eastern region and of 8.45 million ha (for a flood-prone area of 20.4 million ha) in the Ganges basin. However, during high floods a large number of breaches occur in the embankments and jeopardize the benefits envisaged in the schemes. The floods seriously threaten food security, livelihood and health. Despite substantial gains made in flood protection measures, the ever-growing flood problems and associated damage persist as a result of partially implemented schemes and insufficient maintenance due to inadequate funding. In order to improve the effectiveness of the embankments and their protection against water erosion, very costly anti-erosion works have been carried out, as detailed below.

5.1 Embankments

As stated earlier 13 577 km of embankments have been constructed in the Ganges, Brahmaputra and Barak basin on aggrading, degrading and poised rivers after the enunciation of the national policy on flood control in India in 1954. Most of the embankments were constructed during the 1950s and 1960s when reliable hydrologic data were not available; later on, they were found to offer inadequate protection. After studies in depth, the following deficiencies were found in river embankments:

1. The design-flood adopted for embankment design was lower than the high flood levels recorded in subsequent years.
2. Hydraulic gradients adopted were not based on actual tests.
3. Inadequate drainage sluices provided in the embankments resulted in drainage congestion behind the embankments.
4. Embankments built along the junction of main rivers and tributaries created pockets of drainage congestion.
5. Embankments were not aligned through a suitable foundation, resulting in seepage through the seat of the embankment.
6. Embankments were constructed close to the riverbanks to protect as many villages and towns as possible and thus costly anti-erosion works had to be undertaken subsequently to protect them.
7. Spurs constructed to protect the embankments had an adverse effect on the opposite bank.
8. Farmlands were deprived of silt-laden waters having fertilizing value.

5.2 Beneficial aspects of embankments

1. The embankments have provided a reasonable degree of protection against small and medium-sized floods.
2. They have provided all-weather means of communication in chronically flood-prone areas.
3. Large protected areas of flood plains have been brought under assured canal irrigation.
4. Shifting of river courses has been checked.
5. Several capital towns situated on riverbanks have been provided protection against 100-years' floods and are fully protected.
6. On poised reaches, the river is able by and large to transport whatever sediment comes in from the catchment. Construction of embankments does not have any adverse effect on the riverbed in such reaches. In fact, the flow confined within the embankments tends to deepen and widen the river to enable it to carry within the embankments what previously flowed over a larger spread. The increased height at the initial stage of construction of an embankment drops to pre-embankment flood height.

5.3 Case study of the Kosi River

5.3.1 The Kosi River system

The Kosi River is known as "the river of sorrow". Snow-fed and perennial, it originates at an altitude of over 7000 m in the Himalayas and lies between 85^o and 89^o E longitude and $25^o20'$ and 29^o N latitude. The upper catchment of the river system (62 620 km^2 or 85 percent of a total catchment area of 74 030 km^2 in the hilly reaches of the great Himalayan range) lies in Nepal and Tibet. The highest peaks in the world, Mount Everest and the Kanchenjunga, are in the Kosi catchment.

The Kosi has been notorious for the meandering behaviour of its east-to-west course: in its lower portion in India, it has shifted across a width of about 112 km over a period of 250 years (Figure 2). This has rendered useless some 1 295 km^2 of land in Nepal and 7 770 km^2 in India as a result of sand deposition.

Various studies carried out indicate that the lateral movement of the Kosi River occurred due to:

1. Steep gradient of 0.763 per 1000 (Table 4)
2. Heavy silt charge with excessive coarse sediment (Table X: average annual silt load 95 million m^3)
3. Low bed resistance
4. No boulders in steep reaches
5. High discharge against normal flood
6. Aggrading and degrading tendency of river (Table 3)
7. Considerable difference between valley gradient and bed gradient. This is one of the factors of Kosi changing course with a tendency to maximize its length to 'make' the valley gradient. This can be seen from Table 4.

5.3.2 *Socioeconomic benefits*

A 1 150m-span dam was built in 1959 at the India-Nepal border with a pond level of 77.72 metres for irrigation in the protected area and for flood regulation, along with a 468km-long marginal embankment upstream and downstream of barrage for flood protection purposes.

The annual loss in the pre-embankment period was of the order of Rs.100 million, a considerably higher amount at today's rates. This loss was reduced substantially with the construction of 468 kilometres of embankment along both banks at the cost of Rs.400 million. The other benefits were:

- A sense of security for the people.
- The shifting of the river course was checked.
- Assured irrigation was provided to 1.3 million ha of land in both Nepal and India and now to a further 0.35 million ha.

- The highest flood discharge of 25,856 m^3/s ever recorded in the Kosi was observed in 1968 after the construction of embankments but the damage was comparatively light and that too, because of four breaches in the lower reaches of the embankment. In other portions, the embankment stood well and prevented the recurrence of the 1954 flood disaster.
- 1.015 million ha of flood-prone land has been protected.

5.3.2 Adverse effects

The adverse effects were:

- Induced drainage congestion and waterlogging behind the embankments.
- Enhanced flood problems in unprotected area between the embankments.
- Continuous rise of the riverbed level.
- When severe water erosion developed, anti-erosion works like spurs, bed bars and revetment were undertaken on a large scale at huge cost. The average cost of maintaining flood protection and anti-erosion works has been found to be of the order of Rs.142 000 per km per year. Braiding and the shifting nature of the river along with aggradation of its bed are considered to be the direct consequences of the excess of silt brought down during the monsoon season.
- Prevented fertilizing silt on farmland, which used to boost crop productivity.

5.3.3 Pre- and post-dam morphology of the Kosi River

Based on the studies carried out in the whole reach of the Kosi, the results are as follows:

<u>Reach I</u>
Pre-dam period – The reach had a tendency to scour at a rate of 1.76 cm/year.
Post-dam period – Reach siltation has a rate of 12.34 cm/year, i.e. scouring has turned to silting after the construction of the dam.

<u>Reach II (15 km) just upstream of the dam</u>
Pre-barrage period – scouring at 12.34 cm/year
Post barrage period – silting at 10.7 cm/year
Result – degrading reach changed to aggrading

<u>Reach III (26 km) just downstream of the dam</u>
Rate of scouring reduced from 3.56 to 0.83 cm/year after construction of the dam

<u>Reach IV (34 km to 60 km downstream of the dam)</u>
Pre-dam period – scouring at 0.37 cm/year
Post-dam period – scouring increased to 1.86 cm/year

<u>Reach V (60-100 km downstream of the dam)</u>
Pre-dam period – silting at 9.56 cm/year
Post-dam period – silting reduced to 6.36 cm/year

<u>Reach VI (100-125 km downstream of the dam)</u>
After construction of the dam, silting at a high rate of 12.03 cm/year

From Table 3, it can be seen that from the gorge at Chatra (40 km upstream of the dam) in Nepal to 60 km downstream of the dam, i.e. over 100 km, the river had a degrading tendency during the period 1955-1962. During that period, for a length of 40 km beyond the 60 km downstream of the dam, there was marked aggrading. The effects of the structural measures on the Kosi River morphology can be summarized as follows:

- The annual silt deposit over the riverbed between the embankments during the period 1955-1962 was of about 16 million m^3 and of about 84 million m^3 during 1963-1974, indicating high siltation on the riverbed after construction of the dam.

- The spectacular effect of the project on the river regime was the combined effect of embankment and ponding upstream of the dam.
- Before construction, most silt used to spread in the floodplain and in the unconfined wider spilling area in the upper reaches.
- However, the impact of embankment has not been uniform in all reaches of the river. The impact on the average bed level and on the deepest bed level is not the same, as concluded after the analysis of cross-sections of the river.
- In the lower reaches about 100 km below dam level, there is a tendency to degradation.
- The deepest bed of the river did not show any tendency to aggradations, unlike the average bed level.
- In the post-project situation, some river reaches have a tendency of increased silt deposit with consequent aggradation of the average bed level, but in some reaches there is less aggradation.

5.3.4 Environmental evaluation

5.3.4.1 Waterlogging

Embankments over 459 km were constructed along both banks of the Kosi River in 1959 along with a canal system in the Kosi basin, which added to the drainage problem and thus exacerbated the waterlogging problem in the basin by intercepting the natural drainage system.

The countryside behind the eastern embankment has a wider waterlogged area due to the choking of outlet sluices in the embankment owing to the rise in the bed level of the river. The water table in the command area has shown significant rise due to seepage through embankments and canals, as observed in the various wells in the command area. The waterlogged area has been estimated to cover about 182 000 ha out of a total command area of 1.5 million ha. Control of waterlogging is planned by adopting measures such as:

- selected lining to distribution system;
- adequate maintenance of (a) protective works to check seepage of river water (b) outlets and outflow channels for the discharge of the countryside water into the river;
- land levelling and land shaping;
- utilization of groundwater from tube wells at suitable locations; and
- adopting integrated management and command development.

5.3.4.2 Siltation in river and canal systems due to excessive silt change in river water

The Kosi and its tributaries in the Himalayan catchment bear much sediment (about 200 million tons) resulting in erratic and unpredictable morphological changes and bank erosion at an annual maintenance cost of about Rp.100 million. The only solution adopted is to keep watch of the yearly behaviour of the river and protect embankments in likely vulnerable reaches in time.

Even though under-sluices and silt ejectors have been provided in the dam and main canals to restrict silt entry into the canals, they have proved to be ineffective due to excessive silt charge in river waters. The silt charge in the main canal resulted in the rise of the bed level by some 3 metres, which in turn reduced canal capacity to 30 percent, requiring maintenance of canal capacity at great cost.

Afforestation, horticulture, farm forestry and integrated catchment treatment and dam construction are proposed for silt management in the catchment.

5.3.4.3 Erosion problem

The Kosi dam and marginal embankments have greatly helped in mitigating the flood problem. The dam was commissioned in 1953 and marginal embankments were completed in 1959. These measures have successfully checked the alarming lateral westward shift of the river which used to engulf many villages and towns frequently. But now the marginal embankments on both banks are subjected to river water pressure and consequent severe erosion. In order to maintain the embankments in position, large-scale anti-erosion works in the form of spurs, studs and revetments are carried out, including retirement of embankments, every year before the flood season at vulnerable locations.

5.3.4.4 Resettlement and rehabilitation

Before the construction of the Kosi dam and embankments, villages and towns over a large area had to be rehabilitated due to the lateral shift of the river. The resettlement and rehabilitation of people in the Kosi region has been substantially controlled, and development of Sopaul and Saharsa district towns and other blocks has taken place after the project. Without embankments and dam, the Saharsha divisional town and Sopoul district town would not have existed.

5.3.4.5 Health hazard

The Kosi project has altered significantly the ecological balance of the area. However, there has been an increase in the waterlogged area but environmental impact assessment (EIA) studies indicate that mosquito density in the area has been largely controlled by improving socioeconomic conditions for the people in the area, and prevalence of malaria has been significantly reduced. The other possible reason is that the well-maintained reservoirs are not good breeding places for malaria-transmitting mosquitoes.

Even more remarkably, the provision of water of good quality in the protected area has resulted in a decrease in waterborne and other communicable diseases. Overall environmental considerations are shown in Figure 5.

Case study 2

The Pagladiya River is a north-bank tributary of the Brahmaputra and by virtue of its name and behaviour it is known as "the mad river". A case study of embankments constructed along both banks of the river was carried out and it was concluded that the Pagladiya is an aggrading river and carries excessive coarse silt and sand which deposit on the bed and banks, thereby raising the bed level of the river above the countryside. Such a condition is very dangerous: if the embankment breaks, the countryside may suffer catastrophic damage. This alarming situation necessitated anti-erosion works to protect the embankments and raise and strengthen them. The Pagladiya River had 87.60 km of embankments constructed at the cost of Rs.3.1 million in the 1950s. Subsequently Rs.1.55 million was spent raising and strengthening embankments and Rs.22 million on anti-erosion works. A further Rs.6.7 million was spent on maintenance of flood protection works and on flood damage repair. The study shows that maintenance of flood works is very costly due to the excessive silt charge carried by Himalayan rivers. Because of inadequate maintenance in recent years, breaches in the embankment tend to become more frequent in the north-eastern region, as shown below:

Year	No. of breaches and cuts
1987	124
1988	247
1989	128

The increase in the number of breaches is attributed to excessive silt charge brought down by river waters resulting in shoal formation, braiding of the riverbed and meandering of the river.

From the above two case studies, it can be seen that the ineffectiveness of the embankment is due to high silt in the rivers, which could be contained by watershed management works, i.e. catchment area treatment. A case study in this respect was conducted in the Ganges basin, as described in 6.2.2 below.

6.0 PROPOSED FLOOD MANAGEMENT STRATEGY

6.1 Structural measures

6.1.1 Construction of storage

The studies carried out by numerous experts and organizations conclude that suitably designed and properly operated reservoirs with adequate provision of flood cushion, along with embankments and an efficient flood forecasting and warning system, would be the ideal solution to the recurrent and intense flood problem of the Himalayan rivers. However, because of their high cost the reservoirs are not economically viable and justified exclusively for flood control, unless irrigation, power generation and domestic water supply components are incorporated.

Suitable reservoir sites located on the Himalayan rivers in the Ganges basin are located in Nepal. They are:

1. Kosi high dam

The Kosi high dam at Barakshetra in Nepal will moderate a maximum flood of about 1,100 m^3/s at Barakshetra and 540 m^3/s downstream. It will trap bulk quantities of coarse, medium and fine silt responsible for shifting of the river course, formation of shoals and braiding tendency. Afforestation and soil conservation in the river catchment will retain runoff, moderate flooding and reduce silt flows in the reservoir.

2. Kamla River storage project at Shishapani

This scheme is essentially for the survival of irrigation facilities already created both in India and Nepal. This would be a multipurpose project with flood cushion and power generation.

3. Multipurpose reservoir on the Bagmati River at Noonthore in Nepal

The project is aimed at power generation and flood cushion. Flood moderation in the river channel in India would check the spills of the river and greatly ease the chronic flood problem in North Bihar which results in annual huge damage.

The Brahmaputra and Meghna basin

1. Dihang Dam across the Brahmaputra

This project is very economical. It would generate at low cost 20 000 megawatts of hydropower and flood moderation of up to 2 metres high at Guwahati downstream. This would ease the flood problem in the entire Brahmaputra area in India to a great extent. The cheap huge power generated would bring about an age of prosperity.

2. Subansiri Dam on a Brahmaputra tributary

A dam is proposed across the Subansiri River, a tributary of the Brahmaputra, with power potential of 4 800 megawatts and a substantial flood reduction component. However, this scheme could not be taken up for implementation as the upstream interstate submergence problem is awaiting agreement for mutual benefit between the north-eastern states of Assam and Arunachal Pradesh.

3. Tipaimukh Dam on the Barrak River

The Tipaimukh Dam project envisages construction of a 161-metre-high rock-filled dam across the river Barak in its upstream reach with effective storage of 0.9 million ha. The reservoir simulation study using the ACRES simulation (ARSP) downstream of the reservoir shows that it would withstand 100-years' floods.

In addition, 1500 HP of uninterrupted power supply and assured irrigation through the canal system would bring an era of growth – growth that is socially, economically and environmentally sustainable.

6.2 **Future strategy**

6.2.1. *Participatory flood management*

The structural and non-structural measures taken so far in the GBM basin for the mitigation of flood hazards and their impact on people's welfare and the local economy need to be continued to a great extent. Government investment in flood management works has increased from year to year and more areas have been protected; yet, the estimated value of damage has also increased. Undoubtedly the measures taken have provided a reasonable degree of protection against low- and medium-level floods to half of the flood-prone area. But when high floods strike, a large number of breaches occur in the embankments mainly because of the lack of maintenance of existing works, encroachment of embankments, and encroachment in the free board due to deposition of silt in riverbeds and the erosive action of river waters.

Maintenance of existing works should be enhanced. Poor maintenance of flood protection and drainage improvement works greatly affects the life of the beneficiaries and it is therefore necessary that they be involved to a reasonable extent in the formulation and execution of the schemes. Unless people are aware of the benefits and usefulness of a project, it is not possible to enlist their cooperation. Projects should be discussed at the development committee level so as to elicit public response and cooperation, which are essential in planning, implementation and maintenance of flood protection and drainage schemes. Keeping this in view, flood management schemes at the planning stage are discussed in depth in one-day seminars involving the people of the basins, public representatives and the relevant government officials. These seminars are held near the project areas and the merits and demerits of the schemes are discussed in depth. After deliberation, provisions of the scheme may be modified according to the suggestions made, before implementation starts.

Some of the flood management programmes both of structural and non-structural types in which people's participation could be extremely useful are as follows:

1. Construction and maintenance of embankments
2. Watershed management
3. Soil conservation and afforestation
4. Land use regulations (flood-plain zoning)
5. Flood emergencies
6. Flood proofing
7. Flood forecasting and warning
8. Disaster management and preparedness
9. Cropping strategy
10. Drainage congestion improvement
11. Flood insurance

6.2.2 Construction and maintenance of embankments – case study of the Kosi embankment

Embankments have been extensively used for protection against floods of important towns and lands with the participation of the local people, and those that have been constructed so far have by and large served their purpose. The annual loss in the pre-embankment period was of the order of Rs.60 to 100 million depending on the intensity of flooding. This much has been prevented with the construction of embankments at the cost of Rs.400 million, including the cost of protective measures for embankments. The people in protected areas have developed a sense of security and river courses have been stabilized. The embankments are now the best means of communication in the flood-prone areas of the GBM basin and are being recklessly used for transportation of materials by tractors and other heavy vehicles.

Ramps are cut along embankments to allow crossing by tractors and bullock carts transporting farm produce, or soil and sand for house construction. Even the earth from the slopes of the embankments is dug to build houses with. During floods, people shift to the embankments for temporary shelter and often settle down there for good. Thus, embankments and their slopes become permanent settlements to flood victims and their livestock. This is a very common feature of the GBM basin. It messes up proper maintenance, and embankments become susceptible to breaches during floods. Whenever there are lapses in maintenance, the protected areas are exposed to serious flood hazards. If the people were involved in the planning, implementation and maintenance stages and were made to understand the merits and demerits of the schemes, they would be motivated enough to patrol the embankments and clear them of vegetation and further encroachment. They could also be called upon to fight floods by building emergency works such as dykes and dowels and by closing breaches. These measures essentially warrant people participation.

On the negative side, embankments have enhanced drainage congestion behind them due to inadequate anti-flood sluices and poor maintenance.

6.2.3 Watershed management

Watershed management means harmonious development of land water within the natural boundaries of a watershed so as to produce on a sustainable basis an abundance of plants and animals for the good of mankind while still delivering a controlled flow of clear water downstream. The main objectives of watershed management programmes are to:

1) increase infiltration into the soil;
2) control damaging excess runoff; and
3) manage and put runoff to useful purposes.

Implementation approach

Considering all the above action programmes involving local people, a pilot scheme programme was undertaken for watershed management of the Doon valley in the Ganges basin. It was funded jointly by the European Union and the government of Uttar Pradesh, and covered afforestation, grass planting, bunding and check-dams to fully use the watershed for the detention of water where it fell. These measures did increase rain water infiltration, detain water and silt, help to moderate floods and their impact downstream, and increase groundwater storage. Thus, the watershed management project greatly helped in flood mitigation. During the planning process the project staff took pains to motivate the local community by following a transparent process. Recharging groundwater resources proved to be highly beneficial.

6.2.4 Soil conservation and afforestation

6.2.3.1 Soil conservation

Under an integrated action plan for flood management in the Indo-Gangetic plain, soil conservation measures were taken in a few flood-prone catchments with limited available resources, with people participation. These measures remained limited to pilot and experimental applications. Their effectiveness in reducing the flood peak was encouraging. Soil conservation measures were found to have beneficial impact by way of a significant reduction in the quantity of silt flowing into the rivers (Table A). It was felt necessary to take soil conservation measures in the catchment area of rivers flowing down from Nepali hills to arrest the silt charge which settles in riverbeds and reduces the free board of embankments and which is responsible for riverbed braiding and shoal formation leading to breaches in the embankments. For this, the cooperation of the Nepali government is required.

Table A

Land use	**Soil loss (T/ha/year)**
Agricultural land without soil conservation	
Hilly areas	20 to 40
Plain areas	5.0 to 20
Agricultural land with soil conservation (varying from simple agronomic practices to engineering measures)	
Hilly areas	1 to 19
Plain areas	0.0 to 3.0

The main benefits of soil conservation in the early stage of projects taken up in Uttar Pradesh were ecological. The measures taken increased land utility and soil water conservation, resulting in 50-percent higher income from agriculture. The soil conservation programme became the biggest source of rural employment and it also created ponds and field bunds, productive assets that the people can use for all kinds of purpose.

6.2.3.2 Afforestation

Studies conducted so far indicate that limited deforestation in the Pathai and Ranipur catchments (Uttar Pradesh) have not resulted in higher floods. However, some effects were found on flood frequency (not flood intensity) in the Ratmau catchment.

Afforestation measures basically minimize soil loss and reduce sediment load in streams and rivers, thus moderating flash floods and controlling the meandering tendency of rivers, thereby minimizing the erosion of banks and embankments. The effect of afforestation is insignificant for large floods, however. People participation in afforestation efforts not only helps reduce soil erosion but also improves the socioeconomic conditions of the community. Soil eroded from the upper and hilly catchment areas of the GBM basin is flushed downriver through floodwaters; it settles in the riverbeds and results in braided formations and in inter se distribution into channels which shift from time to time. These braided channels subsequently trigger the erosion of riverbanks, and the protection works that have to be undertaken are very costly – of the order of Rs.1 500 to Rs.1750 million for the state of Bihar alone.

6.2.4 Flood plain regulation and zoning

Increased encroachment of flood plains has been responsible for ever-growing damage over the years. The basic concept of flood plain management is to regulate the land use in flood plains in order to restrict the damage due to floods, while deriving maximum benefit from them. This is done by determining the location and extent of the areas likely to be affected by floods of different magnitudes/frequencies and to develop those areas in such a fashion that the resulting damage is minimal. Flood-plain zoning, therefore, aims at disseminating information with the association of people, civil servants and NGOs on a wider basis so as to regulate indiscriminate and unplanned development in flood plains, both for unprotected and protected areas. Flood-plain zoning recognizes the basic fact that flood plains are essentially ruled by the whims of river flows, and as such all developmental activities in flood plains must be compatible with the flood risk involved. Sketches in figures 1 and 2 give an idea of the concept of flood plain zoning.

To regulate flood-plain use, the land has been divided into three categories:

1. Prohibitive river channel and floodway of design flood (100-years' flood);

2. Restrictive extent to which inundation is caused by design flood (50-years' flood); and
3. Warning extent to which the largest flood spreads (25-years' flood).

The working group of the planning commission on flood management of the government of India has adopted the following definitions:

1. First category: land is used for essential services such as hospitals, electrical installations, water supply, telephone exchange, aerodromes, railway stations, commercial centres, defence installations, industries, etc;
2. Second category : residential areas; and
3. Third category: parks and playgrounds.

The planning commission of the government of India has also suggested 0.75m above high flood level (HFL) as the highest plinth level.

Efforts were made by the field formations to implement the above recommendations – to no avail. Even administrative measures could not yield positive results. This is because of the lack of public awareness and cooperation. It is desirable therefore that the above views be made known to the public through NGOs by organizing seminars and symposiums and through mass communication. People participation is essential for land use regulation. In this context one-day seminars are being organized in the Indo-Gangetic basin, and the above messages are conveyed to the public and their representatives.

6.2.5 Flood emergency

Engineers are usually aware of the limitations of the flood management works that they design and build. But the people who live in the areas protected by these works usually feel that they are safe from floods forever. When flooding of great magnitude occurs, protective measures that were designed for lesser floods fail. As such, it is desirable that people be made aware of the limitations of the protective measures taken and be prepared for emergencies to face flood disasters. The people need to be associated to the plans to be taken during a flood emergency for the prevention or reduction of damage in both protected and unprotected areas. The actions to be taken with people participation should be carefully planned so that they come into effect as soon as an emergency arises. The emergency action could be evacuation, flood fighting and public health measures.

Evacuation of flood-prone areas of the GBM basin happens every year during the flood season. Communities have to rely exclusively on this form of action. Each year when flood waters starts rising, people and local authorities make preparations to evacuate the area to be flooded and take shelter on higher grounds, roads, embankments or raised platforms constructed for the purpose.

6.2.6 Flood proofing

Flood-proofing measures help greatly in mitigating people's distress in flood-prone areas. They consist in structural improvements along with emergency action without evacuation from the flood-affected area. They take the following forms:

Raising of villages
Raising of flood-prone villages above a predetermined flood level and connecting them to nearby roads and embankments. This measure has been taken mainly in Uttar Pradesh, West Bengal and Haryana in the Gangetic basin and in Assam in the Brahmaputra basin. It could not be extended further as people participation was not sought. Where communities were not involved in the implementation process, no public cooperation was available.

Raised platforms
These are raised earthen platforms to provide temporary shelter to people and livestock of the affected villages, which get marooned frequently and suffer from acute hardship due to

disruption of basic civic amenities and communication links. This scheme is being implemented at least every five years in those parts of North Bihar where village homestead areas are inundated. The platforms are built near or in the villages 60 cm above the 25-years'-flood level and are provided with food, fodder, drinking water and public conveniences. The platforms are connected to either all-weather roads or service roads on embankments for the emergency needs of the people. Provision of a motor boat or country boat is made for clusters of platforms where road communication is not possible or viable. The raised platforms are constructed with the participation of the people of the area and their maintenance is being done by village panchayats and local bodies.

Quick drainage facilities
Relieving drainage congestion efficiently alleviates hardship in chronically flood-prone areas. This scheme, which is under implementation in North Bihar with people participation, includes restoration of existing sluice gates and connected works, provision of additional drainage openings and improvement of approach and outfall channels in the sluices. The people who reside in the problem areas are fully aware of necessary corrective measures to be taken and readily extend their help.

Flood proofing of civic amenities
Civic amenities are made flood-proof to minimize the adverse effects of floods in the daily life of their victims.

6.2.7 Flood forecasting and warning system

Flood forecasting as a non-structural measure was brought into operation in 1969 by the Central Water Commission (CWC). By now it has assumed considerable importance for flood management. It is considered as the most reliable, cost- and time-effective measure for loss mitigation, planning evacuation of people and livestock in the flood plain, early harvesting of crops, transporting movable items and safeguarding the embankments. It has proved very useful for evacuation of the protected areas behind embankments, especially when high floods cause a large number of breaches in embankments.

At present forecasts for all important tributaries are issued by various methods with sufficient time lag. The forecasts are formulated after collecting the observed gauge, discharge and rainfall data through wireless and other communications and disseminating them to the administrative and state engineering agencies concerned with flood hazard mitigation. So far, the forecasts of incoming floods have been 98-percent correct.

Population density in the GBM basin is very high in some of the worst-flooded areas in comparison to the average density of the country. People are forced to occupy flood plains in increasing numbers every year. It is, therefore, essential that flood-plain dwellers be warned of incoming devastating floods and moved to safer places along with their livestock and movable assets. Accurate and reliable forecast of incoming floods with sufficient time lead is quite helpful in organizing evacuation and relief operations. Advance knowledge of an approaching flood allows engineering authorities to keep vigil for safeguarding already constructed embankments against breaches and failures and to arrange for construction materials for breach and erosion control. Harvesting crops ahead of time may be preferable to having them destroyed in a flood.

The flood havoc in the GBM basin has been persistently causing great concern to the people and the authorities. The flood forecasting and warning activity has proved to be a vital alternative to costly structural measures. It has been expanded and modernized to further mitigate the sufferings of the people in sub-basins. Accurate forecasts are made available efficiently to the authorities engaged in rescue, relief and flood-fighting. Close and timely interaction of all the concerned departments of the state government makes for quick transmission of flood warnings for maximum benefit. Automated water-level recorders at critical locations and an efficient communication system ensure that reliable up-to-the-minute data are available to the forecast formulation centre, whose warnings are promptly disseminated through upgraded telecommunication channels. Proper education of the people on how to react to warning signals to save life and property has top priority. The danger levels are marked at important public places such as bus stands, railway stations, hospitals, etc. Potential flood victims are notified in advance of where to move to in order to be safe.

6.2.8 Disaster preparedness and management

Disaster preparedness is designed to minimize loss of life and damage to property and to organize and facilitate timely and effective rescue, relief and rehabilitation.

Disaster preparedness can be classified into three categories: actions before, during and after the flood. Floods are natural phenomena and complete immunity from them for a given area is impossible in practice. Flood management measures can provide a measure of protection, however, and preparation for meeting flood disaster is important. Various steps by people, officials and NGO workers alike are needed to safeguard life and property during a disaster. Rehabilitation of the people in their original homes with facilities which will restore the communities, families and individuals to their normal living standards is the basic objective of post-disaster action. Side by side with the rehabilitation of the flood victims, rehabilitation of public services and amenities should also be carried out with a view to improving on them from their previous condition while taking into account what is socially, culturally and financially acceptable.

6.2.8.1 Disaster management strategy

Systemic approach

The Ganges-Brahmaputra-Meghna basin is the most flood-disaster-prone area in India. Every year, flooding in some part or other of the basin jeopardizes the development activities of the region. A clear understanding of a flood disaster in scientific and technological terms through a systemic approach can be obtained and, based on it, a comprehensive methodology involving engineering can be devised.

General methodology

- Communication
  A dependable telephone system, an extensive wireless network and the mass media are most useful during an emergency, and they have to be kept operational.

- Monitoring pre-flood protection works
  The monitoring of flood protection works before flood season is done by an expert group and based on their recommendations, measures are taken. Flood-fighting activities are carried out with people participation and in accordance with rules and regulations issued by the flood-control department. When a breach in the embankment occurs, evacuation of the people and their materials is done by the relief authorities. Flood victims are provided with relief materials such as boats, tarpaulin, food and fodder, drinking water, fuel and clothes.

  Medical facilities are made available to the sick and the lame and measures are taken to prevent the spread of diseases. Emergency measures are taken by the engineering department to plug breaches or to contain them in the shortest possible time in close coordination with the people of the area. Shelter platforms at places higher than the highest flood level are kept ready in advance along with adequate stocks of food and fodder, drinking water and fuel – at least in principle.

  In reality, however, lack of interaction between officials and the local people may mean that this is not achieved on time. Therefore, the need for a clear understanding by people and officials of the measures to be taken has to be stressed. Close coordination between officials and flood victims in regard to flood disaster mitigation, starting from the planning stage to the provision of relief and rehabilitation, is essential, as well as training of the personnel involved.

6.2.9 Cropping strategy

The economy of the basin is dependent on agriculture. Crop losses alone account on average for about 76 percent of the total damage caused by floods. The first flood generally occurs in June and damages standing crops of rice and jute. The flood from July to September is most devastating and damages the main *kharif* crops. It is difficult to protect standing crops during flooding and people in flood-prone areas will have to live with floods for many years to come. The cropping pattern must be changed as much as possible to ensure the stability of crop production.

Restructuring the cropping pattern

There is a wide scope for growing crops including rice during the flood-free period of the year, which is more productive because of better response to fertilizer and of more sunshine hours. Therefore, the best way to ensure production in flood-prone areas is to grow crops in the flood-free period. This requires restructuring the cropping pattern based on local agro-climatic conditions. Figure (b) presents a diagram for a cropping strategy for the flood-free period.

Crops such as wheat, rape, mustard, potato, lentil, summer mung, boro rice and almost all vegetables including fodder crops are usually grown in the flood-free period. Some adjustments in sowing period are required to grow black gram and green gram (mung) and for double cropping of rice and maize before and after the flood. Instead of growing rice from July to November/December, it would be necessary to grow rice from the end of September to December/January.

6.2.10 Drainage congestion relief

Improving drainage by building new channels or improving the discharge capacity of the existing drainage system has become an integral part of the flood management programme in the GBM basin. Surface water drainage congestion due to inadequate natural or manmade drainage channels damages agricultural crops. By involving themselves in such works, people benefit at two levels: they earn food for work and drainage congestion alleviation results in increased agricultural production.

Recently drainage improvement work was carried out at the initiative of the federal government in the Mokamah-tal area, which stretches over 100 km along the left bank of the Ganges east of Patna. The whole area has had acute drainage problems during the monsoon months well into November. Early drainage would facilitate cultivation of two crops, which would bring great changes in the local economy. The work started in April 2001 to resection the main Kiul-Harohhar channel emptying into the Ganges. Early drainage of the congested area has led to a marked improvement, but overall performance has yet to be assessed fully.

6.2.11 Flood insurance

Flood insurance has several advantages as a means of alleviating the loss burden. It enables property owners to spread an uncertain but potentially large loss uniformly over a long period of time. Insurance does not reduce flood loss potential. Yet, it has advantages for the public and for the government. It places part of the burden on those who enjoy the benefit of flood plain location as well as the losses that are associated with the latter rather than making it the responsibility of the public at large.

Flood insurance has yet to be implemented, but efforts are being made to insure crops against losses due to floods. This can be further extended to the people living in low and medium risk areas. Insurance of high flood risk zones has to be shared by the government out of the capital invested in the relief and rehabilitation of flood victims.

7.0 River basin organizations for participatory flood management

Most of the rivers causing destructive floods have interstate or international watercourses or both, and for all interstate rivers there is a need to set up river basin organizations, as forums for the relevant state government(s) and local bodies. Such organizations would consist of a general council and a standing committee. Their functions would be to:

- collect data;
- formulate integrated plans;
- consider proposals from the constituent states and local bodies;
- monitor the implementation of schemes; and
- ensure their maintenance.

The general council may consist of the relevant minister from each concerned state, the leader of the opposition of each state, the heads of district panchayats, the heads of the urban local bodies at district level, and representatives of the NGOs involved in the flood sector.

8.0 Financial aspects of flood management schemes

Maintenance of flood management works is hampered by a lack of financial resources, but since it is of paramount importance, ten percent of the annual outlay of the flood sector should be earmarked for maintenance and a suitable flood cess gathered from the beneficiaries in urban areas, especially industrial estates and other productive centres.

9.0 Socioeconomic and environmental aspects of flood management measures

Flood management works such as embankments, drainage channels and anti-erosion works bring significant changes to the environment on account of loss of plants and trees, interference with stream flows, creation of swamps and waterlogging, pollution of water bodies by chemicals due to improved agricultural activities in the protected area, and others. Embankments result in changes of velocity and depth of water and deprive areas behind them from fertilizing silt. Breaches in embankments cause devastating damage and disrupt normal activities. Receding floods leave behind swamps that may turn into breeding grounds for parasites. Reservoirs involve large-scale deforestation, affect the habitat of the local fauna, induce waterlogging due to the rise in the water table, increase health hazards and cause displacement of people. Reduction in flows due to the construction of a reservoir may deprive downstream dwellers of water and increase pollution hazard.

On the other hand, the benefits provided by flood management works are enormous. Reservoirs make for assured irrigation in the protected area, generate large amounts of cheap hydropower, provide adequate draft for uninterrupted navigation and improve the climate. They also provide recreational facilities and scope for improved and increased fish culture. Manmade lakes provide habitat for migratory birds and perennial water to wild life, and soon turn into wild-life sanctuaries.

Flood management projects are being critically examined in India for their impact on the environment in the light of the environment protection act of 1986. Due attention must be paid to the pros and cons of the environmental changes brought about by existing and future projects, and measures taken to reduce the environmental degradation likely to ensue. Also, at the design stage of flood-loss prevention structures, some attention should be given to the visual quality of projects and their impact on river and flood plain landscapes. Environmental management considerations are shown in Figure 4.

10.0 Conclusion

The focus of this paper has been on the management of floods in the Ganges-Brahmaputra-Meghna basin, as it is of crucial importance for the economic development of the region. Flood management has been studied in detail. The current proposals need careful review. Construction of multipurpose dams in the region is essential to mitigate floods but requires considerable time, and the agreement of neighbouring countries. In the meantime, optimum protection of flood-prone areas can be achieved through various measures which have been reviewed in this contribution. In India flood management is almost entirely done by government agencies. The need to ensure people participation at the planning, implementation and maintenance stages of the fight against floods has been recognized for quite some time, however, and several attempts and experiments in this direction have been made over the years. In emergency situations, people's involvement has had encouraging results. In such circumstances, the complex rules and regulations of public agencies tend to prevent timely intervention, resulting in huge damage suffered by the community. A revision of administrative procedures is therefore needed to eliminate delays in the speedy implementation of emergency works.