Flood Management and Interlinking of Rivers: A Case Study of Brahmaputra in Assam

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Introduction

The River Brahmaputra originates in the Kailash range at an altitude of 5,150 metres above mean sea level and covers an area of 2880 square kilometre. The upper course of the river in Tibet is known as 'Tsangpo' which flows towards south from the Kailash range and reaches Manasarovar Lake and moves towards east till 'Namcha Barwa'. It then takes a sharp turn towards south to enter Arunachal Pradesh where it known as Dihang. Near Sadiya, the river Dihang joins with Lohit and Disang and takes the name of Brahmaputra and flows towards west. The Brahmaputra is a major transboundary river covering a drainage area of 580,000 square kilometre. The river touches Tibet, India, Bangladesh and Bhutan. There are innumerable tributaries, water channels and water bodies or 'beels' and 'Swamps' in all these regions. The river has a long course in the name of Tsango through the comparatively dry and flat region of the southern Tibet. It becomes a turbulent and dynamic river after it breaches the central Himalayas near the peak Namcha Barwa (7,755 metres). Here at the Lohit-Dihang-Dibang gorges in Arunachal Pradesh, heavy rains are forced in, so that at Sadiya, the river comes down to 135 metres above sea level. In India its basin is shared by Arunachal Pradesh, Assam, Nagaland, Meghalaya, Sikkim and West Bengal. The river Brahmaputra

turns immediately south after Dhubri around the natural spur of the Garo hills and flows through a sharp southward bend to enter Bangladesh plains and confluence with the river Padma and finally merges into the Bay of Bengal after taking the name Meghna.

The mighty river Brahmaputra and its innumerable tributaries control the entire drainage system of Assam. The distributional pattern of the rivers and divergent channels reveals that Assam as a whole is a riverine state, subjected to frequent floods and soil erosion every year. River Brahmaputra receives numerous tributaries on both its banks along the 750 kilometres long Assam valley because both the Purbachal Himalayas and the Shillong plateau receive heavy rainfall over the years. Most of the tributaries are large and they pour huge amounts of water and sediments into river Brahmaputra. Consequently, it carries an immense quantity of water. The river carries a large amount of silt and sand and deposits these sediments on the river bed, leading to the formation of almond shaped 'River Islands' called 'Char' or 'Chaparis'. The river's width varies from 1.2 kilometre at Pandu near Guwahati to 18.13 kilometre near Gumi. During the rainy season, the river oscillates from one bank to other for a width of 10 kilometres and being turbulent and heavily laden with silt, the channel is heavily braided and flows in a number of channels and cross channels. There is a constant silt movement resulting in instability of river regime, channel shifting and formation of sandy shoals. Thus the river basin is notorious for flooding and river bank erosion.

As many as 40 tributaries fall into it from the northern bank in Assam. The principal tributaries of the north bank are Barnadi at the border of Kamrup district, followed by Sesha, Puthimari, Boralia, Pagaldiya, Chowl, Khowa, Manas, Aii, Gauranga, Sonkosh and Gangadhar. These tributaries originate in the Bhutan Himalayas, are fed with heavy rainfall, supplemented by melting ice and results in a tremendous volume of water and heavy silt discharge. This shallows the river-bed, and that the tributaries get choked up, resulting in inundation. Since, tributaries lie in the seismic zone, it enables in shifting the course of the tributaries, and they run as a meandering river. This heavy discharge of river Brahmaputra affects its tributaries in terms of the water profile.

There are 20 tributaries in the southern bank. The major tributaries on south bank are Kalang at the border of Kamrup district, Um-Thana, Um-Shri, Um-Shayothi, Deosila, Dudhoni, Khrishnai, Bolbala, Kulshi and Jinjiram. Besides these, there are numerous minor water inlets as well as streams. Some of the important ones are Sajang, Tangmari, Taki Nadi, Takel Nadi, Agra Nadi, and Simbhu Nadi etc. There are numerous beels and swamps scattered over Brahmaputra Valley. Some of these are fairly large and deep and have water throughout the year, while others are shallow and turn into muddy puddles during season.

During monsoon season, rain coupled with melting ice from Himalayas, leads to devastating floods in the north bank of the river. Active bank erosion starts, fills the river-bed with sand and silt, and Brahmaputra loses its water holding capacity. More than half the bank length of Brahmaputra in Assam is prone to erosion. These conditions make the river swell, resulting into inundation in a vast area every year. The rivers sediment load of 0.8 to 1.0 per cent between November and April and 6 to 25 per cent between May and October. On the other hand, the south bank tributaries originate from the heavy rainfall areas of Meghalaya plateau and cause floods occasionally during summer days. These rivers are seasonal torrents and have less meandering courses than that of north bank tributaries. As already stated the river Brahmaputra receives numerous tributaries on both its banks in the 750 kilometre long Assam valley because both the Purbachal Himalaya and the Shillong plateau receive heavy rainfall. Most of the tributaries are large and they pour huge amount of water and sediments into Brahamputra. Consequently, it carries an immense quantity of water. Therefore the floods around it are frequent, which results in heavy damage to life and property as well as to the standing crops.

The mighty Brahmaputra alone carries an average annual flow of 400 million acres feet, which is about one-third of the combined annual flow of all rivers in India. The per capita water availability in North-Eastern region is about 10,610 cubic metre/year, which is about 10 times that of the Ganga (Report of the task force on Economic Development of Assam, volume-II, April 1988). The vastness of the water resource is due to surface water drained by many tributaries of Brahmaputra. The total catchment area of Brahmaputra system is around 59,00,00 square

kilometre of which 700 square kilometre lies in Assam, 337 square kilometre in Bangladesh and 2,93,000 square kilometre in Tibet. The river in North-Eastern region carries an average 420 million acre feet of water received from about 50 major tributaries in Tibet and Arunachal Pradesh. The main tributaries of the Brahmaputra that contribute to the annual yield of water individually are Dihang (35.7%), the Subansiri (11%), the Lohit (9%) and the Disang (7.54%). These four rivers together contribute two-third of the total runoff of Brahmaputra. The other tributaries that contribute to be annual yield of the Brahmaputra are the Manasa (7.25%), Jia Bharalu (5.00%), the Sankosh (348%), the Burhidihing (2.62%), the Kopili (1.8%), the Dhansiri (1.14%) and the Aie (1.14%). These eleven tributaries together contribute about 85.68% of the total yield and the contribution by all other tributaries together is only 14.3% of the runoff. On an average, the annual yield of Brahmaputra ranks second in the world, next to Amazon only. But the specific yield of the Brahmaputra is highest in the world.

The maximum observed discharge is at Pandu, which was 74,725 cumecs (2.56 million cumecs) occurring in August 1962 and the minimum discharge was 2,600 cumecs (92,000 cusec) occurring in February 1962. The peak annual discharge at Pandu is more than 2.5 million cusecs while the lowest discharge is 1,20,000 cusecs. 75 per cent of the total runoff of Brahmaputra flows during June to October. This combined with high specific yield causes floods in the plains of Brahmaputra basin every rainy season.

Objective

The objective of the study is to ascertain the causes of flood in Assam, the present flood management system, the suffering of people, the economic losses due to the recurrence of flood and whether the proposed linking of rivers with Brahmaputra would in any way help mitigating the flood problem in Assam.

Methodology

To study the problem associated with flood management and the proposed interlinking of rivers, information from secondary source was extensively used. The data and the scientific details

were drawn from newspapers, journals, periodicals, government reports and other published research studies.

Causes of Flood

Assam is surrounded by the Himalayan ranges in the north and east, Meghalaya in the middle and Mizoram in the south. In between, there are numerous hilly regions within the state. The North-East and South-West monsoon originating from the Bay of Bengal and the Arabian Sea respectively have the terminating point in the North-Eastern region. The North-East and South-West monsoon have immense impact by causing heavy showers in the North-Eastern region, which is surrounded by lofty mountain peaks. This has consequential effect of heavy rainfall in this area. Further Bhutan, Tibet, and China, the adjacent territories, located in the north, are at a high altitude. The rain waters of these territories rush to the lower platforms like Assam. The stored water sometimes come down on account of crack or breach of the dams or by suspected sabotage activities by these states. Likewise the rain waters in the foothills of Himalayan range, Meghalaya and other hill areas in Assam pour the water through the tributaries to Brahmaputra. After the earthquake of 1950 the bed of river has been raised considerably. The accumulation of silt, stone, and sand in the bottom has raised the density of the river bed considerably and this has affected the smooth flow of water. It is this reason why the river swells up and the tributary waters fail to make the way to Brahmaputra. The water spreads in plain areas and heavy floods break out.

Flood and rainfall are both natural phenomenon. The North-East India receives the highest rainfall in the world. Rainfall depends upon meteorological factors and physiography. Flood is a result of complex ecological process involving movement of enormous volumes of water and solids. Flood cover and land use practices carried out in the upper catchment areas play a significant role in shaping the nature and intensity of flood hazard in the Assam valley. The morphology and behaviour of the mighty Brahmaputra undergoes drastic changes in response to the flow regime and pattern of sediment transport following the seasonal rhythm of the monsoon and freeze — thaw cycle of Himalayan flow. That's why it is a unique and dynamic river system. This leads to frequent avulsions and channel instability.

Floods in Assam have become an annual ritual and every year it causes immense loss of life and property. Water flowing down from the Himalayan foothills in the north and east and from Meghalaya, rushes into the Brahmaputra through various tributaries. To this, rain contributes its share. Water from the tributaries merges with the Brahmaputra, whose ultimate course is the Bay of Bengal. Infact, as stated, the Brahmaputra has lost its degree of consistency to bear the voluminous water after the earthquake of 1950. Heavy silt deposits hinder the river's natural course and flow. Rise in the height of the river bed causes water from its tributaries to spill into the plains and causing floods.

Brahmaputra is one of the largest river systems and heavily sediment laden river of the world with a uniquely braided alluvial channel marked by the presence of numerous mid-channels as well as lateral bars. The dynamic fluvial regime of the river is marked by enormously high rates of water and sediment yield, unique pattern of the channel morphology, dramatic bank line migration, rapid bed level changes and accelerated rates of basin denudation. The river transports an annual suspended sediment load of 400 million tonnes with daily averaging 2.12 million tonnes during the monsoon months ranging from June to September. The average width of the channel of the river in the Assam section is approximately 8 kilometre and its bed is marked by a secular trend of aggradation. It is also a highly braided river, that is, one, which is broad and meandering, developing many channels especially in the dry months of winter. The river is highly braided in its entire reach of 640 kilometres in Assam. It is free from such braiding at a few locations, called nodal points where it is constricted due to natural, artificial and geological regions. Large scale deforestation in the hilly areas of the state as well as neighbouring areas more particularly in the catchment areas has resulted in accelerating soil erosion and increased quantum of water flowing since retention capacity in the hills has been decreased. The beds of the Brahmaputra and its tributaries are being gradually raised reducing the capacity to drain out of the increased volume of water. The channel bars of Brahmaputra river are mostly transient in nature, getting submerged during summer high flows and changing drastically their geometry and location. During the low flow season

(November through March) the river flows in a highly braided channel twining around myriads of sand-bars and islands. Moreover, the low lying areas such as beels which had traditionally acted as natural catchment within the plains of the state have also been reduced due to development and construction activities. Within the entire 720 kilometres length of the Brahmaputra through Assam, there are certain vulnerable points affected by severe erosion. The factors responsible for erosion are slumping, undercutting, shear slip circle, scour, soil defects, rising human settlement and deforestation and imbalance in the ground water level. North-East India falls in a seismic zone and disturbances of low magnitude occur frequently. This combined with the deforestation in the upper catchments of the Brahmaputra and the primal power of the waterways, which falls from great heights, results in heavy sedimentation particularly in the rainy season, which makes the river bed shallower and changes the course of the river. The Palasbari-Gumi area located on the southern bank of the Brahmaputra River near Guwahati represents one of the most severely erosion-prone sections of the river. Here the rate of bank line migration and channel shifts are extremely high and erratic, causing extensive damage and heavy loss of land. The erosion and incision caused by the river results in more than 20 square kilometre of prime land mass being lost every year. Owing to erosion, the river area has increased by 12.10 per cent during 1990–2002. During the floods, the banks are over topped and at this time the maximum velocity of water reaches to about 4 metre/second. The source of Brahmaputra is also the glaciers. Glaciers are slowly melting and the discharge volume of Brahmaputra varies according to the rate of melting.

Floods in Assam are not caused by spill over of excess water. The fact can be attributed to the reason that no significant increase in rainfall in the catchment areas and in the region has occurred during the last 50 years. Siltation of channels and wanton destruction and degeneration of the ecosystem are primarily responsible for such floods, which inundates vast areas on either bank. The problem of erosion and flood in Assam is fast assuming frightening proportion and rapidly heading for an irreversible state. Recent studies have shown that loss of 10 per cent of vegetation cover contributed to 12 per cent increase in the river's sediment load. Further the stored water of Bhutan,

China and Tibet make a downward trend due to breach of dams for which the Assam rivers swell up.

However the detailed knowledge of correlation of discharge, water level, sediment cross section, top width, erosion and deposition pattern, lateral migration behaviour with respect to space and time are yet to be predicted or calculated for effective flood assessment and management. Also there are many factors like condition of soil, quantum of rain that differ from year to year, amount of siltation that also varies, drainage system, and habitation etc., which contribute towards flood situation in Assam.

Flood Occurrence in Assam and the Extent of Damage

The Assam valley experiences three types of flood related problems — (1) Periodical submersion of agricultural land as well as homesteads; (2) Flashfloods in the upper reaches of rivers due to sudden increase in water discharge in narrow and shallow streams; (3) Bank erosion, meandering of river channels and consequent change in the river course. Flood management in Assam has never been scientific. The Meteorological Department always cautions the people of the approaching monsoon. The central water commission never fails in warning the people that Brahmaputra is rising. The officials ask for relief boats and truckloads of boats are rushed from Guwahati to other parts of the state. However the relief camps are never ready and the marooned people are hastily put in nearby relative safe schools. Relief in terms of food packets is provided to the areas where accessible and in other parts food packets are dropped through air. The ministers move in helicopters to see the damage caused. The state government officials come out with the estimate of damage caused and accordingly the state government asks the central government for help. After the flood, health department awakes up to provide medicines and the health officials are engaged in controlling diarrhoel diseases and respiratory infections. Compensations are provided to some families and no major rehabilitation efforts are made. And the same story continues year after year. In short, Assam is never prepared to come to the aid of its people during floods.

The siltation grade is determined by the depth and nature of sand or infertile silts. The annual property damage caused by

flooding is vast, running into thousands of crore of rupees. In addition, millions of people are displaced by the flood for months together. Since the floods occur during the main agricultural season, the loss caused due to submersion of standing crops is quite considerable in the Assam valley. The loss of crops, cattle, and livestock, homesteads and human life adds to the devastation, affecting the economy of the state to a large extent. The area affected by flood is also the most fertile and productive. As it is not possible to raise an alternative major food crop during the flood free period, production in the state has been greatly hampered. Over the years, the flood prone areas in the state have been increasing and it is not possible to delineate chronically and occasionally flood prone areas any longer.

Flood is common natural disaster during the later part of the monsoon period in Assam. It is estimated to affect 6.7 million hectares of land annually in India. The statistics of 10 years indicates that on an average in India about 30 million population are affected every year. Brahmaputra has catchment area of 10,98,600 square kilometres with an annual runoff of 55.01 m ha and annual recharge of 3.97 m ha. The rating of annual recharge to runoff is 9.42 per cent. The Brahmaputra valley had experienced major floods in 1954, 1962, 1966, 1972, 1978, 1983, 1986, 1988, 1996, 1998, 2000 and 2004. More than 40 per cent of its land surface is susceptible to flood damage, bringing untold miseries to the people and causing colossal loss of public property and infrastructure. The total flood prone area in the Brahmaputra Valley is 32 lakh hectares, which account for 9.6 per cent of the country's total. The floods affect on an average an area of 89,000 hectares of land annually. The average annual damage by floods per hectare of gross cropped area during the period 1953–1968 was highest in Assam as compared to all other states affected by flood (Irrigation and Power Projects statistical pocket book, Ministry of Irrigation and Power, Government of India, 1970, p. 27). The inundation causes enormous loss of life and property. Thousand are left homeless, causing immense suffering.

All the urban centres the industries and agricultural land supporting the bulk of the population are located in Brahmaputra valley. The Brahmaputra with its 35 tributaries cause havoc damage in it's valley year after year. The only areas in the valley

that are not subjected to regular floods are the tea garden areas, which occupy most of the high or well drained areas of the state. The vast majority of the remaining countryside in which the agricultural production is supposed to take place and where industries could come up are subjected to regular floods. Out of 78.5 lakh hectares farming area of the state, 29 lakh hectares suffer from regular floods. Apart from the chronically flood prone areas lying along the Brahmaputra and its major tributaries, there are vast majority areas some distance away from the river, which are also subjected to floods of varying intensities and durations and these being the result of high flood levels in the parent rivers and consequent backflow into some tributaries and spillover into the surrounding countryside. Areas, which were not known to be flood prone thirty years ago are now witnessing floods of severe intensity frequently. There has been a perceptible change in the pattern of flood situation in terms of uncertainty and predictability. One just cannot predict whether flood will or not occur in a particular year at a given place.

Over three quarter of the plain areas in Assam is flood prone. The problem of recurring floods has affected the growth of agricultural production very adversely, as the farmers are reluctant to invest in fertilizers, improved seeds or other inputs like labour that are essential for improving production, as they are apprehensive and rightly so that all their investments may be washed away by the ever threatening flood-waters. Also the absence of properly organised irrigation system has aggravated the situation, as cropping becomes difficult in flood free season due to lack of water (Report of the Task Force on Economic Development of Assam, Vol. 1, April 1988). This is paradoxical that there is too much water during the monsoon and too little during the lean season. As evident the problem of recurring floods in the state is a major constraint and deterrent to development. Therefore the study of Assam's flood problem deserves special treatment.

The floods that occurred in 2004 affected around 14.3 lakh farm families out of which 49.99 per cent were small and marginal farmers. It may be mentioned that Assam has a total number of 25,88,106 farmers' families (Assam Tribune, 27-09-04). Out of 26,247 villages 42.34 per cent of villages were affected.

As seen from the Table-1 the total crop area affected by flood stands at 9,49,951 hectares in 2004. The flood primarily affected

Table-1

Sl. No.	Crops	Area affected (in hectares)
1.	Kharif	5,99,300
2.	Ahu	1,48,500
3.	Bao	63,665
4.	Sali	74,335
5.	Sugarcane	3,939
6.	Jute	28,818
7.	Summer Vegetables	31,394
	Total	9,49,951

Source: Assam Tribune, 27.9.04.

the production of rice, which is the major crop of the state. Out of this the maximum area affected is of Kharif crop (5,99,300 hectares). The Ahu, Bao and Sali paddy are also damaged. The Ahu crop area affected by the flood is 1,48,500 hectares, Bao crop affected is 63,665 hectares and Sali is affected by 74,335 hectares. The area affected of Sugarcane is 3,939 hectares, Jute crop damaged is to the extent of 28,818 hectares and summer vegetable area affected stands at 31,394 hectares. The total loss caused by the floods to the farmland and crops in terms of rupees is estimated to be around 981.21 crores. Further the sediments brought by Brahmaputra and its numerous tributaries from the Himalayan region are deposited in Barak and Brahmaputra valley. The 2004 flood also damaged around 20,805 hectares of farmland by way of sand or silt deposits.

More than 5777.96 kilometres of roads and 836 bridges were damaged in floods in the state, which require an investment of Rs.755.34 crores to repair the damage. The break up of damage is 790 kilometres of National Highway, 136 kilometres of State Highway, 472 kilometres of Major District Roads, 3896 kilometres of rural roads, 483.96 kilometres of NEC Roads. Along with this, 36 RCC bridges and 800 wooden bridges were also damaged (Assam Tribune, 5-3-05). However the Government of India released 585.26 lakh for repairing the state roads and Rs. 2400 lakh for national highways.

There is also wastage of huge quantity of water during monsoon season causing irreparable damage to life and property every year. The damage caused by flood is increasing year after year due to steady rise of river beds in recent times. Previously, flood was limited to certain areas only, but now it causes

extensive damage. Most parts of the state except some hilly areas, remain submerged. Flood has become a chronic problem, affecting Assam almost four to five times in a year.

Floods also disrupt communication and the state government fails to address this particular issue year after year. Floods also cause water-logging in different areas. This also sometimes creates land slides. The aid provided is only in terms of relief and no long term plans is made for rehabilitation. The compensation given is only eyewash. The distressed flood victims become helpless during the flood and after the flood. There is no fair and equal distribution of both money and relief material.

Case Studies of Flood Affected Areas in Assam

The people of Nij Saharia (Morigaon) reside on the south bank of Brahmaputra and their lives depend on agriculture. The cultivators of these rich alluvial tracts, almost all the villages lost their homes and farm fields in the flood that occurred in 2004. Being affected by the flood, their livelihood and economic security was completely destroyed. The pressing needs for these people are the land for settlement. The erosion that followed the flood resulted in the displacement of thousands of people. Two hundred families took refuge in Jengpori Pathar, a place that was earlier a cremation ground (AST, 30-9-04). People were also seen in temporary dwellings spending their days. Flood erosion also affected other areas like Bihubari and Kachari Gaor where about 165 families took temporary shelter. Erosion also resulted in extensive loss to people in 12 adjoining villages. The villages were cut off from the adjoining regions. To take daily ration from Bhuragaon or Boralimari, the people have to walk five kilometres amidst flood water. Even the bare minimum required for survival doesn't reach the people stranded in Jengpari Pather. The state government doctors visited the villages only once and there was fear of epidemic without any proper sanitation. The NGO involved was the Morigaon Mahila Mehfil (MMM), which provided relief and assistance to the people. The entire relief assistance was sponsored by Oxfam GB, an international trust. The personnel from MMM, in spite of inaccessible terrain covered a wide area affected by flood and erosion. They distributed food and temporary building materials.

Majuli in Assam is one of the largest river islands in the world. It is the home to unique eco-systems and is the heart of Assam's Vaisanavite culture. It continues to be imperiled by the eroding might of the Brahmaputra. It has lost more than 470 square kilometre of land in its south and south-east in the last fifty years (Shillong Times, 11-09-04). More than five revenue villages in the east and South-West Majuli were eroded in the summer of 2004. More than 70 families lived in pathetic conditions as their homesteads were completely wiped out. The erosion completely disintegrated Darbar Sapori, near Kamalabari, the only farm land for the people of Butiamari village.

Water Management of Brahmaputra

Brahmaputra influences the lives and livelihood of tens of millions of lives in the three countries through which it flows. Its influence extends beyond these three countries as it forms part of a great natural river basin, along with the Ganga and the Barak rivers, which covers an area no less than 174 million hectares in four countries. In India alone, it covers a region of 109.84 million hectares.

The river is extensively used by local communities for transport, irrigation and agriculture. Assam today has the largest length of embankments of any part of the country, over 4,500 kilometres of them. Yet only 1.5 million hectares of nearly 32 million hectares of flood prone areas are protected (Assam Developmental Report, Planning Commission, Government of India). In spite of enormous volume of 420 MAF, according to experts only 10 per cent of the water is usable due to poor storage potential in the Brahmaputra river system. Studies made by the Technical Committee on advisability of construction of high dams and seismic zone puts the usable water of the Brahmaputra at 30 MAF while the Brahmaputra flood control committee assessed the exploitable water resource to the 31.6 MAF. The water can be utilised for power generation and irrigation by constructing suitable dams.

The Central Water Commission (CWC) under the ministry of water resources has taken the steps to use telemetry method to solve the problems of floods in the state. It has proposed to install sensors at about 90 sites in Arunachal Pradesh and Assam

to get spot information. The data then shall be relayed through satellite to the information collecting centres of the Central Water Commission. This can reduce the time lag and replace the old wireless system. It is well known that up-to-date and reliable hydrometorological and hydrological data base is pre-requisite for effective flood management. However the data is difficult to collect because the river Brahmaputra covers a drainage area of 580,000 square kilometre, of which 50.5 per cent is in China, 33.6 per cent in India, 8.1 per cent in Bangladesh and 7.8 per cent in Bhutan. In Bhutan, the CWC has 14 sites to get information on water level of rivers flowing into India. The CWC issues flood forecasts from May 15 every year. A forecast is considered to be reasonably accurate if the observed water level falls within 15 cm of the forecast level. In China, the CWC has three sites — Nugesha, Yangcun, and Nuxia, from where it gets information on rainfall, water level and discharge of water into Brahmaputra.

Interlinking of Rivers

Interlinking of rivers is a technical issue and has economic logic, which requires a comprehensive scientific and technical assessment for diversion of enormous volume of water from one channel to another. It is a water resource project plan, if successfully implemented has the potential to improve the living standard of the people of Assam. Further the right quality and quantity of water would be stored and delivered at the right time in right place. The purpose of interlinking of rivers is based on the concept of water resource development for supplementing, controlling and utilizing excess flows. There cannot be any objection, if surplus water of Brahmaputra is diverted to Uttar Pradesh, Madhya Pradesh and Rajasthan or any other place. But if water is taken disproportionately in the post-monsoon season, the high riverbed of the Brahmaputra may dry up. And this may reduce the agricultural productivity of the state further.

The river linking mega project, estimated to cost Rs. 500,000 to 600,000 crores will have major economic impact if planned and implemented judiciously. Quantitatively, Assam and North-East have by far the largest amount of surplus water for diversion through interlinking of Brahmaputra. It is also axiomatic that transfer of water to areas of shortage from areas of surplus will necessary bring more wealth from increased food production,

industrial growth and hence economic prosperity. Therefore Government of Assam is in a favourable position to transfer excess water beyond projected needs of the other states for a reasonable price that are willing to pay. But experience in India has shown that water sharing arrangement is a very sensitive issue and needs to be addressed scientifically.

The plan is for construction of storage on the main Ganga and Brahmaputra rivers and their principal tributaries in India and Nepal, so as to conserve monsoon flows for flood control, hydropower generation and irrigation. The excess water from the Brahmaputra valley has been proposed to be drained out through Manas-Sonkosh-Tista-Farrakka link, and the most probable mechanism to divert water from the tributaries of the Brahmaputra is via a reservoir constructed somewhere in hilly pockets around upper reaches of both the tributaries. Interlinking canal systems will be provided to transfer surplus flows of the Kosi, Gandak and Ghagra to the west. In addition, Brahmaputra — Ganga link will be constructed for augmenting dry weather flows of the Ganga. If the plan, materialises a substantial quantity of flood water may be arrested and the flood calamity to some extent may get mitigated.

The essence of other proposed interlinking of rivers is that with the construction of storage dams, the severity of floods and the extent of flood damage will be drastically reduced. When transferred to other basins with lower water endowment, the water thus stored would reduce the regional imbalances of water.

However it needs a survey of the topography of the catchment areas, the bed levels of the rivers to be linked, the silt changes of the rivers, and discharge data for at least 50 years. The complete history of the river during the last 50 years needs to be collected and analysed.

Brahmaputra flood flow is about 70,000 cumecs while the largest canal proposed by the taskforce is 100 metre wide and 10 metre deep which it can carry away sediment loaded flood water only about 1000 cumecs. It will provide no substantial relief and the remaining 69,00,00 cubic metres of water will accumulate every second during the flood flow period. So it will do practically nothing to relive flood, but the canal will take away 1000 cumecs during the lean flow season, when the people in Assam may need water.

The purpose of connecting rivers is to supplement control and utilise excess flows. A necessary precursor to economic growth is this development of water resource projects and infrastructure. Because Brahmaputra is an international river, international agreements will have to be signed and ratified by India, China, and Bangladesh. These agreements will have major impacts on the flow regime and availability of water to Assam. While floods may be attenuated to some extent and flows may be drastically reduced by such upstream development, but agreed upon required discharge in low flow season for downstream use in Bangladesh which will have an impact on what would be available for use in Assam and for diversion out of Assam. Besides this, agreements will have to be drawn up between Assam and Arunachal Pradesh, Nagaland, Meghalaya, Sikkim, and West Bengal in connection with development of water resource project that may affect the flow regime of the Brahmaputra. Drawing up agreements and memorandum of understanding for development of water resources projects is a long and arduous task. As of today each donor state look into proper quantification of available water for its own use into foreseeable future, say 50 to 75 years, with data at both ends of hydrological extremes i.e., floods and draughts. Assam being the major donor state has to ascertain how the valuable water transfer will impact its future economic growth. Long term needs to be evaluated taking into consideration of agriculture, livestock, municipalities, industry, power, mining, manufacturing, recreation, navigation, pisciculture wild life, maintenance, and enhancement of water quality in rivers, creeks and lakes, ground water recharge, maintenance of the ecology of the river and the wet-lands.

Methods and Strategy for Flood Control and Flood Management

It is a Herculean task to find a viable solution to the problem of floods in Assam, which is crisscrossed with innumerable rivers, hills and natural canals. However certain suggestions have been made to control the magnitude and frequency of flood to mitigate the suffering of the people to a certain extent. The exercise requires huge investment in both material and human expertise.

1. Focus on regulating the discharge at strategic points, harnessing energy, restoration of channel capacity and considering feasibility of creating water bodies at strategic points along with the course and endeavor to restore the ecosystem to the extent possible.
2. Taking appropriate anti-erosion and desiltation steps. It is not possible by either interlinking of rivers or by constructing embankments and dams. If desiltation is not done, perhaps no other method is available for controlling perennial flood problem.
3. The most common method adopted is the construction of flood embankments to prevent the river water entering into the field. Construction of dams, embankments, choking channels etc. are effective to certain extent, and are more applicable for small rivers with scanty yearly rainfall. So the focus should be on the tributaries from the northern and southern bank in Assam.
4. Storage reservoirs appear to be a must for flood control. A series of storage reservoirs on all major tributaries of Brahamaputra should be built for flood moderation and subsequently it will have benefits in the irrigation sector.
5. The greatest problem is raising the river bed, and the process of desiltation. This requires expertise and technical know how for identifying the site and modern equipments to tackle the problem effectively.
6. Flood of Assam can be controlled in cooperation with Arunachal Pradesh and Bhutan and constructing huge dams between hills with sluice gates. Also such dams can be constructed in suitable location in Assam.
7. Embankment and drainage technique, which had been practised in Assam since independence, has proved futile to control flood in Assam. The periodicity of the flood and their flood crest can be considerably controlled by constructing storage reservoirs in the upper reaches of the tributaries of the Brahmaputra. For controlling flood, steps have been initiated for construction of a reservoir on Pagladiya and Subonsiri. Construction of reservoir on Puthimari, Bharali, Manas, and Sonkosh will help in mitigating flood to a larger extent. These reservoirs can, apart from flood control, give

the benefits of hydel power, irrigation, inland transport and fisheries.

8. It will be necessary to improve the existing embankment system along with construction of storage reservoirs. An arrangement for local participation in maintaining and guarding these embankments is a must.
9. Priority should be given for digging Brahmaputra bed by dredgers with skilled manpower so that the deep bedded river may consume and carry substantial water to avoid such chronic calamities. If the river is tamed by making its bed deep, the proper exit of excess water will automatically be ensured and the far reaching solution to the flood problem may be possible.
10. There is also a need to construct raised platforms in low-lying areas to secure accommodation to hundreds of people during the flood regime.
11. Alternative modes of livelihood programmes may be initiated by the government and NGOs for the flood affected people.

Constraints

1. No scientific and technical details including technical information on the flows, storage, link canals, barrages and associated engineering structures, the ecological impacts on down stream areas of the basins, extent of involuntary displacement and likely costs and benefits of the proposal have been yet made available for open professional assessment by the ministry of water resources for interlinking of rivers.
2. The Himalayan Rivers carry among the highest sediment loads in the world and the basic dynamics of sediment generation, discharge and deposition characteristics are very complicated to develop mathematical models of hydraulic engineering.
3. Due to the verticality and the consequent fragility of the Himalayas, large dams on Himalayan Rivers will be prone to high level of seismic hazards. The project will have to be examined from various angles including ecological consideration, seismicity of the area and management system required for implementing and maintaining the project.

4. Complexity of eco-hydrology of the Himalayan Rivers requires extensive field observations spread over decades.
5. Efforts to control flood in the Himalayan Rivers have resulted in changes in the form of the floods. Loss from flood has not declined over the years. There is no clear scientific evidence of the ability of the proposed dams in controlling floods.
6. There is always the problem for settlement and rehabilitation of the displaced as thousands of people will be uprooted, and thousands of acres of cultivable land will be lost. This would reduce the landmass of Assam significantly. Further, transfer of water in large quantities can have serious social, ecological and environmental impacts which may perhaps be larger than and different from those of the conventional in basin development.
7. Compensation for environmental damages from the project is enormous. The Manas tiger project will be completely destroyed and the natural ecological and environmental condition will be greatly affected if such steps are initiated.
8. Sharing the benefits and costs of the project among the states may also be a difficult preposition as water has become a sensitive issue among the states sharing the same river basin.
9. Further complicacy will arise in cooperative management of the project in international river basins.
10. It may damage the natural ecosystem and cause losses to downstream population.
11. It would affect the downstream flow of water and give rise to navigational problem.
12. It may have repercussions on the riparian areas and there by take away the riparian rights in general.
13. The state may have less quantum of water as there is no fixed assessment of surplus water to be siphoned out during the summer. Studies may be necessary for quantification of reasonable diversion during the low flow regime in order to prevent potential damage to the ecology of the river.
14. There is a necessity to under take mathematical model studies for the reaches of the Brahmaputra from one node to another.

15. There is a necessity to develop a master plan for flood control. New technology has to be evolved for taking up large scale afforestation programme in the rugged terrain and aerial seeding is a must. In addition, the shifting course of the river during last 30 years needs to be demarcated in order to identify the vulnerable reaches.
16. These water transfer by their nature are inter-basin and these seem to violate the basic premise of 'Basin' as a hydrological unit for water development and management.

Conclusion

The perennial flood problem of Assam is much bigger and important than the proposed River-linking project. In spite of construction of many embankments, the river itself has changed its configuration often. Impact on human population in the period and after the flood is manifested in the form of deaths, diseases, disability and loss of livelihood. It also affects the services essential for human survival, shelter, water supply, food distribution system, sanitation and sewerage facilities. It calls for taking steps in anti-erosion measures and desiltation. Desiltation is impossible through River-linking process or by constructing embankments and dams. Therefore the theory of interlinking cannot be applied in the case of flood control. The attempt to bring the Brahmaputra under control is based on the theories developed on the smaller rivers. Hence there was no success in bringing the mighty river under control. So mathematical model studies should be taken up for the reaches of the Brahmaputra from one node to another. It is imperative that unless urgent remedial steps are implemented, Assam would have to endure a much enlarged flood plain with higher flood levels, great loss of prime land to stream bank erosion, severe drainage congestion, recurrent urban flood events and flood devastation to agriculture, which is the backbone of Assam's economy. Brahmaputra therefore requires tall embankments and construction of reservoirs to prevent flooding. The task of flood preparedness and providing immediate relief needs immediate attention. The organisations involved in rescue operation should have Baily Bridge spans, boats, motor launches etc., to deal with flood instead of looking for such equipment at the last

movement from various sources including the defence forces. The master plan for flood management should include the strategic points, both in flood chronic areas and marginal areas, from where flood fighting and relief measures would be launched and such points should be well stocked with equipments and relief measures before the onset of flood. Moreover, controlling floods fully is not a practical proposition either through construction of reservoirs or by interlinking of rivers. However it can help in moderating the intensity of floods and bring less damage to property and life of the people.

REFERENCES

Assam Developmental Report, Planning Commission, Government of India.

Bandyopadhyay, J. (2004), "Adoption of a New and Holistic Paradigm is a Precondition for Integrated Water Management in India" in G. Saha (ed.), *Water Security and Management of Water Resources*, National Atlas and Thematic Mapping Organisation, Kolkata.

Bandyopadhyay, J. and S. Perveen (2003), "River Interlinking in India: Questions on Scientific, Economic and Environmental Dimensions of The Proposal" in A.K. Ghosh, P.K. Sikdar and A.K. Dutta (eds.), *Interlinking of Indian Rivers*, ACB Publications, Kolkata.

Biswas, A.K. (1976), *Systems Approach to Water Management*, McGraw Hill, New York.

Lves, J.D. and B. Messerli (1989), *The Himalayan Dilemma*, Routledge, London.

Ministry of Irrigation and Power, Government of India (1970), *Irrigation and Power Projects Statistical Pocket Book*, p. 27.

National Commission on Integrated Water Resource Development Plan (1999), *Integrated Water Resource Development: A Plan for Action*, Ministry of Water Resources, New Delhi.

Report of the Task Force on Economic Development of Assam, Vol. 1, April 1988.

Serageldin, I. (1995), *Towards Sustainable Management of Water Resources*, The World Bank, Washington, DC.

TFILR (2003), "Inter Basin Water Transfer Proposals", Task Force on Interlinking of Rivers, Ministry of Water Resources, Government of India, New Delhi.

The Assam Tribune, 27-09-04.

Vaidyanathan, A. (2003), 'Interlinking of Rivers', *The Hindu*, Chennai, March 26.

World Commission on Dams (2000), *Dams and Development — A New Frame Work for Decision Making*, Earthscan Publishing, London.