

Brahmaputra: Issues in development

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Introduction

Background and scope

The South Asian region is one of the most populated regions of the world. High population density coupled with low per capita income and a predominantly rural agricultural-based population are distinguishing features of this area.

The general geographic region which can be called the Bay of Bengal basin, comprising the various river systems flowing into the Bay of Bengal, is a typical part of the South Asian region. This area is marked by some of the most fertile alluvial plains, and also high mountains and deltas. The region has considerable water resources which are rather unevenly distributed. Given the agrarian nature of the economy, water development is basic of the development of the area.

The Ganges-Brahmaputra-Meghna system is the main basin, covering approximately 1.65 million square kilometres. It has an average water potential exceeding 1,000 km³ per annum evenly distributed in a region which has the world's highest annual rainfall as well as semi-arid areas. The Ganges, the Brahmaputra, and the Barak-Meghna are separate sub-systems in the combined river system, but they have a common delta system providing a common terminus into the sea and have considerable potential for spatial integration, both through possible physical links be-

Table 4.1 Countrywise length and catchment area of the Brahmaputra

Country	Length (km)	Catchment area (km ²)
China	1,625	293,000
India	918	195,000
Bangladesh	363	47,000
	(up to Bay of Bengal)	(up to Goalando)

Table 4.2 Average annual flow of the Brahmaputra

River site	Period	Average annual yield (billion m ³)
Bechamara	1976-1983	269
Pandu	1955-1982	494
Jogighopa	1955-1957	537

tween the subsystems and in the possibility of shifting the water demand of the common delta to the water-rich subsystem in order to support larger development in other areas.

Such an approach towards the integrated development of the basin and the general region through the development of the Brahmaputra is the theme of this chapter. The local demands of the areas of the Brahmaputra subsystem need to be met as a priority before considering integrated basin or regional developments. For this purpose, a projection of the demands of the north-east region of India is presented here.

The author is of the view that even while the basin serves as a natural geographic unit for planning and management of water resources, the concept of the basin should be broad enough to encompass the engineering possibilities of integration and to address the commonality of problems of the various river systems. In most cases the sub-basins would not constitute a unitary whole and sub-basinwise planning may not be desirable.

The river system

The main stem of the Brahmaputra is known as Tsangpo in Tibet, Siang or Dehang in the upstream area in India, and Brahmaputra in the rest of India and Bangladesh. The approximate distribution of the length and catchment area is given in Table 4.1. The average annual flow of the Brahmaputra at some salient points is given in Table 4.2.

The Barak-Meghna subsystem consists of the Barak river originating in Myanmar, which flows to the state of Manipur in India; thereafter, the river flows through the Cachar plains into Bangladesh. The distribution

Table 4.3 Countrywise length and catchment area of the Barak

Country	Length (km)	Catchment (km ²)	Average annual yield (billion m ³)
Myanmar	—	752	—
India	564	26,193	29.6
Bangladesh	336	—	(Badarpurghat)

of the length, catchment area, and water resources of this subsystem is given in Table 4.3.

The broad development objectives

As stated earlier, the region has a predominantly rural agricultural population. Providing reasonable access to clean water for sustenance of life should be a high-priority objective. As economic development of the area would be closely linked with agricultural income, water use in the agricultural sector also requires considerable priority. Navigation is essential for sustaining the riverine ports and harbours in the area; also inland navigation would have a large role to play in opening up the hinterland for economic integration, and so the navigational demands for water require a comparatively higher priority than in the rest of the South Asian region. The area has considerable industrial potential on account of the availability of various minerals. There is also a large potential for developing groundwater resources. In this context, the unusually high hydroelectric potential available in the Brahmaputra-Meghna basin seems to hold the key to industrial, economic, and agricultural development of the sub-basin.

However, various environmental considerations and constraints – such as the need to provide for proper resettlement and rehabilitation of the people affected by storage reservoirs, the need for conjunctive use of surface water and groundwater to maintain groundwater levels within a desirable band, the need for maintaining the ecology of the riverine fish life, and the need to maintain the salinity levels and sedimentation pattern in the rivers – are also important in planning water development.

Both the Brahmaputra and the Barak-Meghna sub-basin suffer from severe flood and erosion problems. The floods of the Brahmaputra and Barak are an annual feature, although some 3,600 km of embankments have been built on the main Brahmaputra river and its tributaries and another 800 km on the Barak. The average annual flood damage amounts to around Rs. 450 million (1977 price level; US\$1 = Rs. 44) annually in

the north-east region of India, mostly in the Brahmaputra-Barak area. In the alluvial plains the river flows in a braided pattern, and because of the shifting braids, an area of land with a width of about 10–15 km is more or less unavailable for any other use. Considerable damage and loss of land by erosion is caused even where the land is much above the normal high-flood levels. There are possibilities of both flood control through long-term structural measures like storage reservoirs and further erosion control through large river protection works, including the possibilities of changing the braided nature of the river into a meandering nature. These possibilities of flood and erosion control are largely compatible with the need for navigation development.

Considering these aspects, the author would prioritize the sectoral water use within the two subsystems as firstly water supply, secondly agricultural use of water, including provision for flood control, and thirdly use of water for energy development and navigation. The use of water for environmental maintenance is not mentioned as a separate use, but needs to be considered as an essential constraint in planning and development.

In broad economic terms, economic efficiency would be the major but not the only consideration in planning water development. The problems of floods, erosion, and lack of transport seem to have acted as a considerable constraint in the economic development of the Brahmaputra and Barak areas in the past. It could be argued that this lack of development may have led to development in other areas. However, the redistribution of economic opportunities could be considered as an important goal to bring back these lost opportunities of the region. Similarly, possibilities of integrated water development would allow economic development of the comparatively water-poor areas of the Ganges-Brahmaputra-Meghna system. Such economic development would also allow more equitable availability of employment to the vast rural population of the region. Thus the redistribution objective and the consequent goals of greater flood and erosion control, more agricultural development through irrigation in the water-scarce areas of the Ganges subsystem, greater navigation potential, etc., should receive much importance in the planning and development of the Brahmaputra and Meghna.

Water demand in north-east India – 2050

Projection of population

The population in north-east India is growing faster than in the rest of the country. The overall annual growth rate from 1901 to 1991 was 2.2 per

cent per annum; in the decade 1981 to 1991, it was 2.4 per cent per annum. By 1991 the population was about 4 per cent of the all-India total. Presuming this to become 5 per cent by 2050, and using the medium projection of India's 2050 population at 1.64 billion, the population of north-east India by 2050 is estimated at about 80 million. This has been checked by a graphical extrapolation.

The present rate of urban population as a percentage of total population in India is 26.1 per cent, and that for north-east India is 13.9 per cent. It is presumed that the ratio for north-east India would equal 26.1 per cent by 2050. On this basis, the north-east India population in 2050 is taken as 21 million urban and 59 million rural.

The estimated large and small livestock populations by 2050 are 35 million and 46 million respectively.

Food requirement

On the basis of present consumption of around 500 gm per capita per day, the 2050 requirement of food grain per capita is taken as 590 gm per day. The projected 2050 population of 80 million in north-east India would, at this rate, require 16.4 million tonnes of food grain annually. However, development of irrigation in this region of India is not encouraging, and the region is food deficient: production of food grain in 1991–92 amounted to only 5.14 million tonnes. Unless adequate attention is paid to increasing food production, the region will have to depend largely on imports. However, considering the large water potential and available land, self-sufficiency is a desirable goal.

A plausible plan for irrigation development

The entire north-east region has a total cultivable area of 6.28 million hectares. The present gross cropped area is 5.29 million ha and the net cropped area is 3.729 million ha. Gross irrigation is practised presently in only 0.93 million ha. The yields are very poor: the yield of paddy in this region is only about 1.3 tonnes per hectare as against an achievable yield of 3–4 tonnes per hectare.

According to the report of the National Commission on Agriculture (1976), the scope of irrigation envisaged in Assam by 2025 is 2.5 million ha. The net irrigable area of Assam has been assessed as 3.27 million ha and that of the entire north-east region as 3.7 million ha. It is assumed that, by 2050, the entire net irrigable area of the north-east region may have to be covered by irrigation.

An estimation of potential irrigation development and food production is presented in Table 4.4.

Table 4.4 Plan for irrigation and food production in north-east India in 2050

Category	Present status	Probable scenario in 2050
	(million ha)	(million ha)
Geographical area	25.50	25.50
Cultivable area	6.30	6.30
Net sown area	3.70	4.70
Gross sown area	5.30	7.20
Area sown more than once	—	2.50
Gross irrigated area		
Surface source	0.95	2.30
Groundwater source	0.21	1.40
Gross area under rainfed crop	4.10	3.50
Irrigated area under food crop	—	3.30
Irrigated area under other crops	—	0.40
Rainfed area under food crop	—	3.20
Rainfed area under other crops	—	0.30
	(million tonnes)	(million tonnes)
Food production in equivalent		
Paddy		
Irrigated land @ 3.5 t/ha	—	11.55
Unirrigated land @ 1.6 t/ha		5.10
Total food production	—	16.65

Table 4.5 Estimated water demands

Category	Per capita requirement per day in litres (lpcd) (gross withdrawal)	
	1990	2050
Rural population	40	135
Small livestock	4	7
Large livestock	25	45
Urban population	90	200

Estimation of gross water demands

The rates of demand assumed for the rural and urban population, as well as small and large livestock, are given in Table 4.5. At these rates, the domestic and livestock demands are as given in Table 4.6.

For a preliminary assessment of industrial demand, it is assumed that the gross (withdrawal) requirement for industrial use would equal domestic (urban plus rural plus livestock) demand. For agricultural purposes, the average annual depth of irrigation water (gross) required for various crops is estimated as 1.6 metres for surface water sources and 1.2 metres for groundwater sources. An assessment of the monthly require-

Table 4.6 Gross domestic water requirement in 2050

Category	Population (million)	Water demand (lpcd)	Gross water requirement (million m ³ /d)
Rural	59	135	8.0
Urban	21	200	4.2
Small livestock	46	7	0.3
Large livestock	35	45	1.6
Total daily requirement			14.1
Total annual requirement (gross)			5.147 bcm

Table 4.7 Projected gross irrigation water requirement for north-east India, 2050

Month	Water requirement (bcm)						Total (Ground + surface)
	North bank		South bank		Total		
	Surface	Ground	Surface	Ground	Ground	Surface	
February	0.20	0.10	0.30	0.10	0.20	0.50	0.70
March	0.20	0.80	1.90	0.90	1.70	2.10	3.80
April	1.90	0.80	2.60	1.20	2.00	4.50	6.50
May	1.50	0.70	2.00	0.90	1.60	3.50	5.10
June							
July	0.80	0.40	1.00	0.50	0.90	1.80	2.70
August	0.90	0.40	1.20	0.50	0.90	2.10	3.00
September	1.70	0.80	2.30	1.10	1.90	4.00	5.90
October	1.10	0.50	1.50	0.70	1.20	2.60	3.80
November	1.50	0.70	2.00	0.90	1.60	3.50	5.10
December	1.40	0.60	1.90	0.90	1.50	3.30	4.80
January	1.30	0.60	2.20	1.00	1.60	3.50	5.10
Total	12.50	6.40	18.90	8.70	15.10	31.40	46.50

ment for various crops is presented in Table 4.7: the requirement of 46.50 billion cubic metres (bcm) is for an irrigable area of 3.30 million ha in Assam, a state in north-east India. On a pro-rata basis, the total requirement for 3.70 million ha of irrigable area in the north-east region of India would be about 52.15 bcm (35.21 bcm from surface water and 16.93 bcm from groundwater).

Estimation of evapotranspiration needs of all uses

A large portion of domestic, industrial, and irrigation water is available as return flow; by making certain assumptions, it is possible to estimate consumption.

For rural use, including livestock, it is assumed that 50 per cent of the withdrawal would evaporate from land irrigation, use in kitchen gardens, etc., or otherwise as uncontrolled evapotranspiration, and the rest would return to the river or be retained as groundwater. For urban domestic use, it is assumed that 30 per cent would be consumed in parks, gardens, water coolers, etc., and the rest would return to the river or be retained as groundwater. For industrial use, it is assumed that 20 per cent would be consumed and the rest would return to the river or be retained as groundwater.

For agricultural use (irrigation), the depth for surface irrigation has been assumed as 1.6 metres (gross, per head), on the presumption of paddy being the principal crop. The general distribution of this would be evapotranspiration 0.5 metres, deep percolation through fields 0.3 metres, losses from field channels 0.2 metres, and canal losses 0.6 metres. Thus, of the delta of 1.6 metres, only 0.5 metres will be used for crop evapotranspiration and 1.1 metres would be available for reuse/return through surface water and groundwater. However, it is presumed that of this 1.1 metres, another 0.2 metres is lost as uncontrolled evapotranspiration from swamps, etc. Thus the net evapotranspiration requirement would be 0.7 metres – 44 per cent of the gross requirement.

For groundwater the delta being used is 1.2 metres, assuming that distribution (canal) losses from groundwater would be very small at 0.2 metres. Again, assuming the additional swampy evaporation to be low, at 0.1 metres, the net evapotranspirational needs would 0.6 metres – 50 per cent of the gross requirement.

Total gross and net water demands

Total water requirement by 2050 for meeting domestic, industrial, livestock, and agricultural demands is presented in Table 4.8.

Non-consumptive in-situ requirements

The approximate navigational requirements would be 400 m³/sec on the Barak (draft exceeding five metres post storage), and 2,000 m³/sec on the Brahmaputra (draft of two to five metres).

Resource availability

Water resources of India

According to one assessment (CWC 1993), the average annual flow in the river systems of India is estimated to be 1,869 bcm. Replenish-

Table 4.8 Total gross and net water demands

Sector	Gross demand (bcm)	% of consumption	Net demand (bcm)
Domestic water supply			
Rural			
Domestic	2.920		
Livestock	0.694		
Total (rural)	3.614	50	1.807
Urban	1.533	30	0.459
Sub-total (1) (water supply)	5.147		2.266
Industrial (2)	5.147	20	1.060
Agricultural			
Surface water irrigation	35.200	44	15.500
Groundwater	16.900	50	8.500
Subtotal (3) (agriculture)	52.100		24.300
Total (1) + (2) + (3)	62.39		27.630

Table 4.9 Water resources availability in Bay of Bengal basin

River sub-basin	Average annual water potential (km ³ /annum)	Per capita flow availability (m ³ /annum)
Ganges-Brahmaputra-Meghna	1,110.62	18,061
Ganges	525.02	1,471
Brahmaputra	537.20	18,417
Barak	48.40	7,646
Minor rivers draining into Bangladesh and Myanmar	31.00	14,623
Godavari	110.54	2,048
Krishna	78.12	1,248
Cauvery	21.36	728
Subernarekha	12.37	1,307
Brahmani-Baitarani	28.48	2,915
Mahanadi	66.88	2,513
Pennar	6.32	651

able groundwater resources have been assessed as about 452 km³/annum. The water resources potential for some of the important river basins in the geographical Bay of Bengal basin is given in Table 4.9.

Table 4.10 Water resources potential in north-east India

Basin	Average availability (km ³ /annum)	Availability per ha of cultivable area (m ³ /ha/annum)	Utilizable	
			Surface water (m ³ /ha/annum)	Ground- water (m ³ /ha/annum)
Brahmaputra	537.2	44,232	24	27.9
Barak	48.4	43,447	–	1.8
Other rivers in Tripura, Manipur Mizoram and Nagaland	31.0	–	–	1.53

Water resources in north-east India

The total water resources potential of the river systems in the north-east region of India and per capita average annual availability as assessed is given in Table 4.10.

Storage possibilities

Since most of the precipitation of the region is received in the summer monsoon (April to October), storage development is essential for both conservation and flood control. In the Brahmaputra-Barak areas, which contribute about 32 per cent of India's surface water resources, the likely ultimate storage capacity is only about 72 bcm – only 12 per cent of average annual flows. Although storage capacity in the region is only about 19 per cent of the country's ultimate storage capacity, it has about 37 per cent of the country's estimated hydropower potential besides the potential to moderate floods in the Brahmaputra and Barak valleys to a great extent on a long-term basis.

One of the recommendations of the fourth national power plan formulated by the Central Electricity Authority in March 1997 is to accelerate the pace of hydropower development to add 58,000 MW of hydro capacity in the next 15 years. With this objective in view, hydropower development strategies in the north-east region need to be framed, to provide at least 50 per cent of this projected 58,000 MW of hydro development by 2030.

Development of all available storage sites in this region of India may not be practicable because of social constraints in the resettlement of populations and possible technical constraints. Keeping in view the huge power potential and excluding the storage sites having serious social constraints, the storage facilities given in Table 4.11 have been identified in the region and may be developed in a phased manner up to 2030.

Table 4.11 Storage sites identified for development

Basin/sub-basin	Live storage (bcm)	Installed capacity (MW)
By 2010		
Subansiri at Gerukamukh	0.64	600
Tipaimukh	9.00	1,500
Bairabi	1.78	75
Jadukata	0.72	450
Siang (lower)	0.80	2,000
Noa-dihing	0.13	75
Kulsi	0.69	36
Someswari	0.09	130
Um-N-got	0.03	710
Total	13.88	5,579
By 2020		
Subansiri	6.02	6,700
(upstream reservoirs)		
Lohit	2.75	3,000
Kameng	1.07	1,100
Kulsi	0.69	36
Total	10.53	10,800
By 2030		
Siang (Yinkiong)	5.30	10,700
Siyom (Kaying)	0.50	700
Debang	2.00	1,000
Total	7.80	12,400

It is thus proposed to develop about 32.21 bcm of storage capacity in the region by 2030, which is about 40 per cent of the ultimate storage potential of the region.

Engineering possibilities

Diversion

In the Indian context, 'run-of-the-river' diversions were developed first, up to 1950, and storage development followed, in order to augment water use. Major groundwater development also took place, notably after 1970, the timing being dictated perhaps more by the spread of rural electrification than by the exhaustion of the diversion possibilities. The relevance of this development pattern to north-east India needs examination.

The dependable flow of the Brahmaputra and Barak in the lean-flow

Table 4.12 Lean-season water requirement in north-east India

Use	February surface irrigation			March surface irrigation		
	(million m ³)	Gross (m ³ /s)	Net (m ³ /s)	(million m ³)	Gross (m ³ /s)	Net (m ³ /s)
Surface water irrigation	500	207	93	2,100	784	345
Groundwater irrigation	200	83	42	1,700	635	318
Water supply (at uniform annual rate)	429	166	73	429	166	73
Industrial water supply (at uniform annual rate)	429	166	33	429	166	33
Total		622	239		1,751	769

period would be of the order of 3,000 m³/sec and 45 m³/sec respectively at their exit points. The total groundwater potential of the two sub-basins, at about 31 bcm per year, can support for 240 days/annum a draft of about 1,500 m³/sec. From a simple hydrologic point of view, the groundwater draft may in the long run lead to more reduction in the surface flows. But together from both sources, about 3,000 m³/sec of water is available. Against this, the conservation requirements from these systems for two sample months are as given in Table 4.12.

Thus the net withdrawals from the system, including groundwater, would be of the order of 239 m³/sec and 769 m³/sec in February and March respectively, which is lower than the lean flow of 304 m³/sec. The actual effect of the withdrawal could be even less, as much return flow from the withdrawals in other months would also be flowing during the lean season. But even on a conservative basis, a reduced flow of the order of 2,500 m³/sec would be available in the river systems after all conservation use. The non-consumptive requirements, including the navigational requirements, have been discussed earlier. This estimate indicates that this low flow would be sufficient.

Therefore, if self-sufficiency in food grain in north-east India is to be attained, providing essential water supply and maintaining a limited navigational draft in the Brahmaputra and Barak are the only goals of development, and if electrical energy for groundwater development could be found from other sources, storage development is not essential. However, in the opinion of the author this would preclude many attractive development options. Storage-based hydropower development would be

essential for both agricultural and industrial development. The long-term flood control possible through storage facilities would shift economic activities to the flood-prone areas. These developments would require a much better transport network and riverine navigation with improved draft, which is possible with storage facilities. Also, the storage sites would facilitate a more equitable availability of water in the three sub-systems of the Ganges-Brahmaputra-Meghna basins.

The engineering possibilities for run-of-the-river development would consist of a series of weirs or barrages, which can be built at the places where tributaries of the Brahmaputra emerge out of the hills, and similar barrages on the Barak. Such structures have already been built on the Ganges and its tributaries. In the Brahmaputra basin, such barrages have been erected on the Dhansiri, Jamuna (a tributary in the Kopili Kolang basin), Shukla, Patrodisa, Hawaipur, Longa, Rajadubi (lift), Dikhari, etc. More schemes, like the Baralia and Bordikrai, are under construction. These schemes are undoubtedly small, and their construction and maintenance is sometimes problematic due to sedimentation, shifting courses, etc. However, they demonstrate the possibilities. Similarly, groundwater development is possible almost throughout the plains of the Brahmaputra and Barak valleys, provided electrical energy is available.

Storage development

As stated earlier, storage development of the order 30 bcm (live) is possible in the Brahmaputra and Barak sub-basins. An attempt is made to evaluate approximately how much additional water would be made available through these. It is assumed that 20 per cent of the storage space is reserved as an empty space to hold flood waters for a period of about 10 days during the peak river floods, by proper integrated operations. This would allow the cutting off of a peak of $15,000 \text{ m}^3/\text{sec}$, giving a small but significant flood relief. By proper rule-curve operation and use of joint flood conservational storage, a conservation storage of about 24 bcm would be available (lake evaporation, etc., being offset by the joint use). This could provide, in the three-month lean-flow period, an additional flow augmentation of the order of $3,100 \text{ m}^3/\text{sec}$. Again, by proper integrated operations, the augmentation of the lowest 10 daily flows by about $4,000 \text{ m}^3/\text{sec}$ appears practicable. This additional low flow can then be utilized for both additional navigational requirements in the Brahmaputra and Barak and augmentation of lean flows in the Ganges.

Flood management, drainage, and erosion

The north-east region of India, particularly the Brahmaputra and Barak valleys, is subjected to frequent and damaging floods almost every year,

Table 4.13 Land use in the Brahmaputra valley

Category	Area (ha)	%
Land	7,089	100.00
Forest cover	1,506	21.25
Agricultural land	3,917	55.23
Built-up area	18	0.26
Water bodies	551	7.79
Wasteland	127	1.80
Other	970	13.67

Table 4.14 Flood damage in Assam

	Maximum	Average
Total area affected (million ha)	3.820 (1988)	0.96
Crop area affected (million ha)	1.440 (1988)	0.23
Total damage to crops, houses and public utilities (million rupees)	6,638.4 (1988)	810
Lives lost (numbers)	226 (1988)	39
Population affected (in million)	12.46 (1988)	2.43

with the Brahmaputra becoming one wide sheet of water covering a large area during the monsoon. The monsoon flood problem in the Barak valley is equally severe. The land-use pattern of the Brahmaputra valley is given in Table 4.13.

The problem of floods in the flood plains of the Brahmaputra can be summarized as bank spilling, drainage congestion due to adverse outlet conditions, and morphologic problems caused by heavy sediment load related to land use and seismic activities. Flood damage statistics have been collected in India since 1953. Table 4.14 gives a picture of the maximum and average annual flood damage in Assam during the period 1953–1994, as compiled by the Central Water Commission of India. In addition to this damage, there is considerable indirect loss due to disruption of rail and road communication, lower crop production, and extra expenditure on relief and rehabilitation, etc.

No storage reservoirs have yet been created in north-east India in the Brahmaputra and Meghna river system for flood control measures. Measures taken so far are embankments, drainage channels, town protection, anti-erosion works, and sluices. Physical achievements up to 1988 in the Brahmaputra-Barak area are shown in Table 4.15.

During less severe floods the embankments, which are normally designed for a 25-year flood, have afforded some degree of protection, but during high floods they are often subjected to breaches, causing severe damage.

Table 4.15 Flood and erosion control measures in north-east India

Description	Brahmaputra valley	Barak valley	Total
Embankments (km)			4,448
(a) Brahmaputra/Barak	1,013	251	
(b) tributaries	2,634	550	
Anti-erosion schemes, including town protection works (km)	431	112	533
Drainage channels (km)	599	247	846
Sluices (number)	56	29	85

Measures suggested for flood management

Storage reservoirs

In India, single-purpose flood control reservoirs are normally not found economical, but multipurpose reservoirs often have flood control as an important objective.

The five major tributaries of the Brahmaputra, namely the Dehang, Jia-bharali (Kameng), Debang, Lohit, and Subansiri, together contribute about 70 per cent of the average annual yield of the Brahmaputra at Pandu. Storage reservoirs on these five rivers and on the Barak at Tipaimukh are under various stages of investigation, and can generate 28,500 MW of cheap eco-friendly peak hydropower besides moderating floods to a great extent.

Embankments

As stated, long embankments have already been constructed, and few additions are planned.

Drainage schemes

When storage reservoirs are constructed on some of the major tributaries and the flood peaks are brought down, most of the drainage-congested areas would automatically get cleared. However, to provide some interim solutions to minimize the difficulties created by drainage congestion, identified problem areas are to be studied and suitable remedial measures are to be taken up.

Anti-erosion measures

The Brahmaputra has braided channels in most of its traverse through the plains. One of the most important areas affected by erosion, amongst others, is Majuli, the largest river island in the world, on the north bank of the Brahmaputra. A number of erosion control measures are planned.

Table 4.16 Distribution of hydropower potential by tributary

River system	Potential at 60% lean flow (MW)
Upper Brahmaputra	789
Lohit	4,152
Dihang-Dibang	13,615
Subansiri	6,893
Kameng	1,982
Kalang (Kopili)	518
Barak and neighbouring rivers	3,908
Total (north-east India)	31,857
Tista, Jaldhaka	3,063
Total (Brahmaputra and Barak)	34,920

Non-structural measures

A flood warning system is already working effectively in the area. Flood-plain zoning, although desirable, has not been put into practice. Watershed management and discouragement of *jhooming* (shifting cultivation in hilly areas) is receiving much attention, particularly from an institute of the All-India Council of Agricultural Research established for the purpose. The present soil loss of 40 tonnes per hectare in the area under *jhoom* needs to be reduced. Socially acceptable alternative packages need to be developed and implemented.

Hydropower development*Hydropower potential*

Out of India's total hydropower potential of 84,044 MW (at 60 per cent of lean flow), about 59,160 MW is accounted for by the Himalayan river basins of the Indus, Ganges, and Brahmaputra, and about another 5,250 MW for the Barak and other southern tributaries of the basin. The north-east Himalayan rivers constitute about 55 per cent of the total Himalayan hydropower potential. According to a reassessment of hydropower potential in India carried out by the Central Electricity Authority, 226 schemes have been identified in the Brahmaputra and Barak river systems with a total hydro potential of 34,920 MW. The distribution by tributary is given in Table 4.16.

Present power scenario

The total electrical energy consumption in north-east India was 3,736 million units in 1995-96, which was only about 1.33 per cent of the total

energy consumption in the country. The per capita consumption in the region is of the order of 100 units, against all-India average of about 333 units for 1995-96.

The power supply position in north-east India changed from energy surplus (2.4 per cent) in 1984-85 to a deficit (-4.6 per cent) in 1990-91. According to the fourth national power plan prepared by the Central Electricity Authority in March 1997, the peak local demand of the region would increase from 1,313 MW (1997) to 3,661 MW (2011). Similarly, the energy demand would increase from 5,855 GWh (1997) to 17,553 GWh (2011).

Although the present installed capacity of about 1,628.95 MW is greater than the peak demand during 1996-97, the existing generating stations are not able to meet peak demand for various reasons, including the very low plant load factor of thermal units.

Although the present demand pattern may not justify setting up big hydropower projects, this would have to be considered in the wider context of accelerated economic development and transmission of cheap power to the power-starved regions of India and neighbouring countries.

Power for economic development

It is obvious that with the current pace of industrial development in the region, the development gap between the north-east region and the rest of India will continue to increase. To bridge the gap it would be necessary to plan for a much faster rate of development of industries and the agricultural sector. The irrigation development plan presented earlier in this chapter already requires large-scale pumping of groundwater. Both industrial development and groundwater development would require corresponding power development.

With the availability of cheap and assured power, it is likely that per capita income and rural electrification can grow at a faster rate. Every household in villages in north-east India, be they on the plains or in the hills, has at least one handloom unit each. Adopting composite weaving, reeling, and yearning farming and converting the handlooms to power-looms would give the rural economy a fillip.

The employment impact of the anticipated development programme would be significant. Currently, the employment-income ratio in the north-east region is higher than the all-India average. It is anticipated that with the development of various sectors of the economy in the region with judicious use of power, employment in the organized sector will rise to almost five times the present level within the next 25 years.

Table 4.17 Likely power transfers from north-east India

Planning scenario date	Installed capacity in north-east (MW)	Peaking capacity in north-east (MW)	Peak demand		Power evacuation (MW)
			North-east region (MW)	All India (MW)	
2010	7,593	5,698	3,200	170,000	2,495
2020	16,193	12,145	5,700	270,000	6,445
2030	28,893	21,670	8,200	355,000	13,470
2040	59,256	44,442	10,700	450,000	33,742

Note: Peaking capacity is assumed to be 75 per cent of installed capacity.

Development strategies for hydropower

Two of the important conclusions and recommendations of the fourth national power plan developed by the Central Electricity Authority in March 1997 are as follows.

- Additional capacity of over 150,000 MW is required to meet the 176,647 MW peak demand and 1,058 billion units of energy requirement by the end of 2012.
- The pace of hydro development must be accelerated to add 58,000 MW of hydro capacity over the next 15 years. In a low hydro development scenario, additional thermal capacity of 9,000 MW would be required. Effective measures to attract private investment within the country and outside will be required.

Much of the additional 58,000 MW of hydropower may have to come from the north-east region of India, particularly since the average generation cost in the region would be low and the population likely to be affected by the projects would also be low.

Transfer of power from north-east India

In view of the likely severe power shortages in other regions, which are likely to grow further in the years to come, the cheap hydropower of the north-east region can be beneficially transferred to the other regions of India and perhaps the neighbouring countries. Thus setting up large hydropower stations in the region within the next 10 years is a feasible proposition even if growth of demand for power in the region is moderate.

Table 4.17 shows the likely installed capacity in the north-east region, likely peak demand in the region, likely demand in India, and power likely to be evacuated to other regions of India in different planning scenarios.

Financial aspects

Development of the huge hydropower resources of north-east India will call for huge investment. Owing to the financial constraints in the government sector, the available resources may not be adequate to meet the envisaged power and allied sector development programme. Thus a policy needs to be evolved, with special consideration of the geographical and other constraints of the north-east region, for financing the mega-projects with private-sector funding. This could involve joint ventures or international participation for improving the health of the power and allied sectors and accelerating economic development.

Navigational development

Present scenario

At present the Department of Inland Water Transport (DIWT), a government organization, is operating 42 ferry services on the Brahmaputra and 24 ferry services on the Barak. With this ferry network, Assam carries nearly 60,000 passengers and 2,000 tonnes of freight every day. In addition to the people of Assam, the DIWT ferry operation has benefited the people from other north-eastern states of India, as some of the major ferry services connect Assam with the neighbouring states. The cargo-handling capacity of the commercial fleets, with seven tugs and 25 barges, is currently 11,900 tonnes. In 1996-97 the DIWT could carry only 2,117 tonnes. The region has the largest amount of navigable waterways in India, with a length of 3,844 km.

The national transport policy of India indicates that for bulk cargo like coal and fertilizers, navigational costs are substantially lower than road transport costs.

Development strategy

Navigational requirements in the region are considerable, particularly on the Brahmaputra. The present problem of increasing the navigational draft in the Brahmaputra seems related to the braided nature of the channel. The numerous braided channels not only occupy a considerable width of the valley, but also divide the low flow so that a defined and stable navigational channel is not available.

In the short term, local river control measures, including annual measures like *bandalling* (a method of seasonal maintenance of low-flow

navigational channels by inducing sedimentation elsewhere through bamboo bundles), if properly planned can much improve the navigability, or for the same level of draft reduce the flow requirement.

In the long term, there seems to be scope for jacketing the river at some points to convert, over a period of time, the river regime from that of a braided stream to that of a meandering stream mostly flowing through a single channel. Such transformations have been done for rivers like the Rhine, and there is a need to study the possibilities for the Brahmaputra on elaborate mathematical models depicting the flows and sediment transport. If this can be done, it would have the further advantages of improving navigability and increasing availability of land for agriculture and other uses.

Structural measures, such as provision of a series of barrages with navigational docks for increasing depths for navigation at lower flows, could be thought of. However, these may become practicable only if navigational requirements build up in a large way.

The Brahmaputra development strategy

The development strategy for the Brahmaputra and Barak proposed in this chapter, on the basis of the facts and discussions presented earlier, is as follows.

- There is a need for a holistic look at the needs of the Ganges-Brahmaputra-Meghna basin.
- The water-use plan should meet the following priority needs:
 - needs for domestic water supply (rural and urban) in the Brahmaputra-Meghna region;
 - needs of agriculture and flood control systems in the Brahmaputra-Meghna region;
 - industrial needs and needs for navigational improvement in this region;
 - needs for equitable distribution of water resources for all uses in the Ganges-Brahmaputra-Meghna basin;
 - needs for possible equitable distribution of water in a wider region, such as the geographical Bay of Bengal basin.
- With regard to the agricultural needs, the overall objective could be self-sufficiency in food grain in north-east India, combined with full utilization of land resources.
- In planning irrigation in north-east India, comparatively much greater stress on groundwater utilization is necessary. For this purpose, energy would have to be made available through hydropower development.
- Extending flood and erosion control is a priority need, so that eco-

conomic activities are attracted to the area and regional redistribution of income and employment is encouraged.

- An approximate estimation of water demands for various uses in the Brahmaputra-Barak areas of India has been made. Even while this estimate needs to be improved and expanded to include the downstream areas, some general results seem to emerge.
 - The water needs for domestic supply and agriculture are relatively small compared to the runoff of the river. This fact, combined with the large availability of groundwater, indicates a considerable possibility for achieving self-sufficiency in food grain even without large storage-based surface irrigation systems.
 - However, for adequate availability of electrical energy, for both agriculture and industry, hydro-electric storage facilities would be necessary. Similarly, for providing long-term flood control, storage development is necessary.
 - A hydro-electric potential of the order of 31,857 MW at 60 per cent of low flow is available. This will be enough to meet the regional demands and would provide considerable scope for earning revenue.
 - Significant flood control in the rivers can be achieved through integrated operation of a part of the storage space, to be reserved for the purpose.
 - The navigational demands for water are important. There is a considerable scope for improving navigation, even with lean low flows, by proper river training works.
- There is a scope for changing the regime of the Brahmaputra from a braided pattern to a meandering pattern through a long-term plan of large-scale river training. Such a plan, if implemented, will improve navigational conditions and also make more land available for agricultural and other purposes. Such possibilities require elaborate study through modelling.
- There is also scope, in the long term, for providing greater navigational depths on the Brahmaputra during smaller low flows through the construction of a series of barrages and locks. However, for the present such possibilities need not be considered because the large likely cost is not commensurate with navigational demands, and salinity control and other ecological considerations would require maintenance of a flow in the channel.
- A large augmentation of river low flows of the order of 4,000 cumecs would be possible through storage development.
- Even while the first priority for the augmented flow would be to meet the needs of the region (water supply, agriculture, navigational improvement, etc.), a substantial portion of the augmented flow would be available for priority uses elsewhere in the Ganges-Brahmaputra-Meghna basin.

- The Ganges-Brahmaputra-Meghna basin has considerable scope for water-use integration through interconnecting canals. Thus, the holistic development of the three subsystems through the integrated operation of storages and links is practicable. Such a plan would improve agriculture throughout the basin, provide greater navigational facilities in all the rivers, and allow generation of a large block of hydro-electric energy.

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Development and management of water resources in Bangladesh: Post-1996 treaty opportunities

Ainun Nishat

Introduction

The Ganges waters treaty, signed between India and Bangladesh in December 1996, has opened the doors of opportunity for development and management of water resources in the Ganges-Brahmaputra-Meghna (GBM) region in an integrated way. The national framework and plans will provide a basis for regional approaches and considerations. The treaty provides a framework for sharing the waters of the Ganges during the dry months and calls for sharing arrangements to be agreed for all other common rivers. Bangladesh can now plan, harness, and develop the water resources of the Ganges.

Bangladesh is situated in the deltaic part of the region through which three mighty rivers and their tributaries and distributaries flow, namely the Ganges, the Brahmaputra, and the Meghna. A huge volume of water enters the country from outside and flows into the Bay of Bengal. In fact, more water enters Bangladesh each year as surface inflow that can ever be used effectively – enough to submerge the country under more than nine metres of water, of which only 7 per cent originates from within the country. On average, during each monsoon season from June to September, one-third of Bangladesh is stricken by flood calamities and two-thirds of the country is vulnerable to flood. This apparent surfeit of water conceals important seasonal and spatial water shortages that prevail during the winter, which generate drought or drought-like conditions.

During the dry months (November to May), flows of major rivers decrease drastically. Fresh water becomes scarce for use in agriculture, fisheries, navigation, industries, drinking, or domestic purposes.

This annual pattern of too much water during the monsoon and too little during the dry season dominates life in Bangladesh. The cycle of floods due to overabundance through to droughts from dire water scarcity brings further suffering in the form of land salinization, siltation, and river instability. Bangladesh has unilaterally sought to reduce the severity of flooding, facilitate river transport, and improve irrigation, but national efforts alone cannot resolve problems in a multinational river basin. For the well-being of the hungry people in the region, it is essential that stream flow regulation, flood control, and water resources development should proceed in an integrated regional fashion. The prevailing wisdom is that investment in large surface water projects would reduce the element of uncertainty in the availability of water in the dry season as well as attenuate the flood levels. Another major benefit would be generation of hydropower, which would go a long way towards keeping the production of greenhouse gases to a much lower level.

As there was no effective water-sharing agreements for these international rivers, nor any efforts to develop water resources in an integrated and comprehensive manner, Bangladesh had to remain satisfied with what it could do within its own borders. No major surface water development project could be taken up, and planning scenarios were unnecessarily restricted to harnessing and utilization of groundwater.

This chapter gives a historical background to the 1996 treaty, and makes an analysis of the provisions and functioning the treaty in its first year of operation in the dry months of 1997. There is then a discussion of the need for a control structure over the Ganges, and opportunities and issues for other common rivers. Possible linkages with regional development opportunities such as navigation, hydropower generation, watershed management, and fish movement are also highlighted. In the concluding section the existing institutional framework and the role of the Joint Rivers Commission are evaluated.

The history of water disputes between Bangladesh and India

Dispute over the Ganges flow was recognized in 1951, when Pakistan protested to India about the proposed Farakka barrage. Negotiations have continued between India and Bangladesh (and prior to 1971, Pakistan) on this issue for the last 45 years. There were several short-term sharing agreements before the long-term treaty was signed in 1996. Several studies have analysed the background and history of the dispute and

reviewed the whole process; notable among them are the works of Abbas (1982), Begum (1987), Verghese and Iyer (1993), Crow (1995), and Nishat (1996). A brief review is given here to identify and recognize the some of the major issues, which need to be resolved before further co-operation in the GBM region can be ensured.

Crow (1995) divided the history into several phases based on political considerations. On the basis of approaches and progress at negotiations, the entire process may be into clustered six phases (Nishat 1996).

Phase I: 1951–1974

Focus was on finalization of respective shares of the Ganges waters before the barrage was commissioned. Discussions centred mostly on respective claims and their justifications. The Bangladesh side staked claim over the entire flow and expected that reservoirs at upstream locations should be able to meet India's requirements. They also contested the technical merit of the stated objective of the Farakka barrage, which was to save the port of Calcutta. India, on the other hand, took a position that Bangladesh may need only a small quantity of water and the water was presently flowing wasted into the Bay of Bengal. The Indian side would ensure that the respective shares were finalized before commissioning of the barrage. In 1972, the Joint Rivers Commission (JRC) was set up to facilitate development of waters of the common rivers.

Phase II: 1974–1976

The issue of augmentation of flow was brought in. Bangladesh proposed conservation of huge monsoon flows in India and Nepal; and India proposed diversion of a large volume of the flows of the Brahmaputra into the Ganges through a link canal. Negotiation failed to arrive at an agreed formula for sharing. Operation of the barrage began in 1975, with concurrence from Bangladesh. An interim arrangement was made for a test run of a flow of 11,000 to 16,000 cusecs through the diversion channel for a period of 41 days only, releasing the remainder for Bangladesh. Without a renewal of the arrangement, in 1976 India withdrew waters unilaterally, causing disastrous effects in the Ganges-dependent southwest region in Bangladesh. This situation was repeated in 1977. The issue was taken to the United Nations by Bangladesh, and the General Assembly adopted a consensus statement according to which India and Bangladesh decided to meet at Dhaka at ministerial level for negotiations with a view to arriving at a fair and expeditious settlement.

Phase III: 1977-1982

After negotiations, an agreement was signed on 5 November 1977 for sharing the Ganges water for a period of five years during the dry months between January and May. The agreement provided for 34,500 cusecs for Bangladesh and 20,500 cusecs for Calcutta port during the leanest 10-day period (21-30 April). The agreement specified a schedule of sharing the flow on a 10-day basis; a guaranteed minimum of 80 per cent of the quantum mentioned in the schedule to protect Bangladesh against withdrawals in upstream reaches; a joint committee comprising representatives of both the governments to implement sharing arrangements; and carrying out investigations leading to augmentation of the Ganges flow at Farakka within three years. During this period Bangladesh and India exchanged their proposals for augmentation of the Ganges flow, and these were reviewed jointly by the parties. The Bangladesh proposal envisaged construction of storage dams in the upper reaches of the Ganges in India and Nepal to conserve the monsoon flows for augmenting the dry-season flows. The Indian proposal was for transferring waters of the Brahmaputra through a link canal across Bangladesh to the Ganges above Farakka. Neither proposal was accepted by the other party. On the plea that the obligation under the agreement had not been fulfilled, the treaty was not renewed despite there being provisions to do so, and it was allowed to expire in November 1982.

Phase IV: 1982-1988

The governments of Bangladesh and India signed a memorandum of understanding (MOU) in October 1982 for sharing the flows of the Ganges for another two dry seasons in 1983 and 1984. The MOU of 1982 included provisions for burden-sharing instead of the guaranteed minimum flow. Both parties were asked to carry out a pre-feasibility study of the schemes for augmentation proposed earlier. Accordingly, in 1983, both sides exchanged their respective updated proposals, but in view of the differences of opinion it was not possible to make any acceptable recommendation with regard to the optimum solution for augmentation of the dry-season flows of the Ganges at Farakka which could be urgently implemented. The MOU expired in 1984, and no formal arrangements for sharing the flows in future years were made.

Bangladesh made serious efforts to reach a formal agreement, but without success. In the absence of any agreement, no sharing was done during the dry season of 1985. After painstaking efforts the two countries signed another MOU in November 1985 for sharing the waters of

the Ganges for three dry seasons commencing in 1986. Like the 1982 MOU, the MOU of 1985 included provision for burden-sharing instead of guaranteed flows. This time regional rivers were placed on the discussion table for arriving at sharing arrangements. Proposals on both sharing and augmentation of the Ganges flows were discussed. Both sides revised their proposals on augmentation and also rejected the other's schemes. A joint team of experts from India and Bangladesh visited Nepal for collection of data. Nepal showed keen interest in harnessing the waters as a joint programme between the three countries. The sharing arrangement of the Ganges flows according to the MOU of 1985 stopped in May 1988.

Phase V: 1988–1996

During this period negotiations for sharing continued, but without success. During a meeting the two heads of governments held in New Delhi in September 1988, the secretaries of water resources were assigned to work out an integrated formula for permanent/long-term sharing of flows of all the common rivers. In order to break the stalemate in the sharing arrangement, the Secretaries' Committee held six meetings alternatively in Dhaka and New Delhi over three years from April 1990 to February 1992. They emphasized the need for immediate allocation of the Ganges and Teesta waters on a priority basis, including sharing of other common river waters as mandated. The committee, however, could not find a general principle for sharing. The 1988 flood in Bangladesh created an institutional framework for cooperation in flood management. The relationship between sharing arrangements and augmentation proposals became a very critical issue. Bangladesh wanted to make progress in both aspects, but India made agreement to its augmentation proposal a precondition for sharing. India also continued to block any proposal for the involvement of Nepal in the discussions.

The prime ministers of the two countries agreed in 1992 that distress in Bangladesh need to be alleviated immediately, but no water-sharing arrangements could be finalized. In 1995 several rounds of discussions were held at foreign secretary level.

Phase VI: 1996 to date

With changes in government in both the countries, negotiations were revived at the foreign secretary level and very soon the framework of a solution was agreed upon. After hectic activities a treaty was signed in December 1996 which went into operation from 1 January 1997. The treaty will remain in force for 30 years. Stages have been set out for sharing the water resources of all common rivers. The treaty also makes

provision for augmentation of the flow of the Ganges. The flow arriving at Farakka was shared during the dry season of 1997. There were some minor problems in implementing the provisions of the treaty, which were resolved through consultations.

This historical background tells us that both sharing and augmentation must be resolved, but one should not be contingent upon the other. Now that the sharing issue has been resolved, serious efforts should be made towards solving the augmentation issue.

Brief features of the 1996 treaty

The full text of the 1996 Ganges water treaty is given in Appendix 1. The main features are:

- a more-or-less 50–50 sharing formula;
- three guaranteed 10-day periods for both countries when each will get 35,000 cusecs;
- the need for augmentation is recognized;
- the need for sharing all common rivers is recognized;
- principles of equity, fair play, and no harm to either party are recognized.

At the time of writing, the treaty had been in operation for two dry seasons. The flow arriving at Farakka and the share received by Bangladesh in 1997 and 1998 are given in Tables 5.1 and 5.2. One must take note that the flow being shared at Farakka is the residual flow after abstraction at upstream locations has taken place. Article II (ii) of the treaty states that the upper riparian will protect the flows at a specified level. This is a kind of guarantee to Bangladesh that there will be adequate flow at the point of sharing for meaningful operation of the treaty. Unfortunately, in the first year of operation the flow available for distribution was very low, which resulted in doubts being expressed about the sincerity of the upper riparian in honouring their commitments. However, the year ended with satisfaction for both the parties as the flow situation was brought within the expected range, and the flow received by the lower riparian in 1998 was satisfactory. As the flow arriving at Farakka was good, no difficulty was faced in implementing the provisions of the treaty.

Adverse impacts of reduction of the Ganges flow

The Ganges has been flowing through the territory of Bangladesh from time immemorial; the lives and livelihoods of its people, together with its flora and fauna, have been conditioned by the waters of this great river.

Table 5.1 Flows of the Ganges at Farakka and Hardinge bridge, 1997

Period	Actual flow reaching Farakka (cusecs)	Indian share as per formula given in Annexure-I of 1996 treaty (cusecs)	Bangladeshi share as per formula given in Annexure-I of 1996 treaty (cusecs)	Actual release to India (cusecs)	Actual release to Bangladesh (cusecs)	Observed flow of the Ganges at Hardinge bridge (cusecs)
January						
1-10	1,02,180	40,000	62,180	40,161	62,019	70,829
11-20	89,635	40,000	49,635	40,079	49,556	55,788
21-31	88,672	40,000	48,672	39,788	48,884	50,045
February						
1-10	85,604	40,000	45,604	40,000	45,604	48,430
11-20	81,015	40,000	41,015	39,986	41,029	38,319
21-28	77,399	40,000	37,399	39,012	38,387	25,689
March						
1-10	66,170	33,085	33,085	32,681	33,489	23,291
11-20	56,769	21,769	35,000	21,741	35,028	19,930
21-31	48,487	35,000	13,487	31,959	16,528	13,823
April						
1-10	50,481	15,481	35,000	20,344	30,137	17,857
11-20	54,526	35,000	19,526	28,913	25,613	24,559
21-30	63,933	28,933	35,000	28,868	35,065	27,695
May						
1-10	66,728	35,000	31,728	35,006	31,722	26,578
11-20	66,055	33,027	33,028	33,034	33,021	26,279
21-31	63,309	31,655	31,654	31,666	31,643	27,520

Table 5.2 Flows of the Ganges at Farakka and Hardinge bridge, 1998

Period	Actual flow reaching Farakka (cusecs)	Indian share as per formula given in Annexure-I of 1996 treaty (cusecs)	Bangladeshi share as per formula given in Annexure-I of 1996 treaty (cusecs)	Actual release to India (cusecs)	Actual release to Bangladesh (cusecs)	Observed flow of the Ganges at Hardinge bridge (cusecs)
January						
1-10	204,797	40,000	164,797	40,034	164,763	182,286
11-20	175,566	40,000	135,566	39,975	135,591	154,292
21-31	145,866	40,000	105,866	39,985	105,881	118,313
February						
1-10	128,186	40,000	88,186	40,005	88,181	88,363
11-20	101,841	40,000	61,841	40,010	61,831	73,584
21-28	94,738	40,000	54,738	40,027	54,711	54,242
March						
1-10	85,323	40,000	45,323	40,001	45,322	46,686
11-20	75,967	40,000	35,967	38,644	37,323	40,192
21-31	71,570	36,570	35,000	35,013	36,557	38,685
April						
1-10	78,588	40,000	38,588	38,114	40,474	43,960
11-20	90,955	40,000	50,955	35,003	55,952	53,241
21-30	87,901	40,000	47,901	40,025	47,876	53,627
May						
1-10	102,203	40,000	62,203	35,018	72,185	74,886
11-20	122,062	40,000	82,062	40,000	82,062	92,039
21-31	121,220	40,000	81,220	40,002	81,218	84,965

The river provides drinking water, sustains agriculture, forestry, fisheries, and inland navigation, helps to operate a quarter of the country's industrial activities, prevents salinity intrusion from the Bay of Bengal, and plays a determining role in maintaining the ecological balance of the country – especially that of the south-western region, which covers about a quarter of Bangladesh. The Gorai, which is the main tributary carrying water to the south-west region, now becomes totally dry at the beginning of the lean period.

Impacts of reduction of the Ganges flow in various sectors are inter-dependent and interlinked. In the following paragraphs sectoral overall damages are summarized. Some of these are quantifiable while others can only be discussed qualitatively.

Impact of reduction in supply of surface water

The economic life of the south-west region of Bangladesh is dependent on the Ganges. Of its distributaries, the Gorai plays the dominant role as it passes towards the industrial belt of Khulna, linking the Rupsa-Passur and Sibsa river systems and eventually emptying into the Bay of Bengal. The sweet water supply through the Gorai is vital for pushing back salinity and keeping an overall environmental balance. This distributary is also the source of potential irrigation development. The reduction of dry-season (January–May) natural flows in the Ganges in Bangladesh reduces the hydraulic efficiency of the channel to such an extent that even during high flows in the monsoon the progressive degradation of the channel and its hydraulic characteristics remains unabated.

Impact on groundwater

It has been observed that lowered river levels result in a reversal of the existing groundwater gradient, affecting the availability of groundwater. Since 1976 a fall in groundwater of about three metres has been observed in most of the wells along both banks of the Ganges, the Mohananda, and the Gorai-Modhumati from the pre-diversion normal level. The fall in groundwater level is greatest in the districts of Rajshahi and Pabna, followed by Kushtia and Jessore. The quality of groundwater has also deteriorated (Nishat 1996).

Channel morphology

The channel morphology of the Ganges and its distributaries has also been affected. A study of the longitudinal bed profile of the Ganges for

the years 1974 and 1989 from its confluence with the Brahmaputra to the Indo-Bangladesh border and a study of changes at several cross-sections between the years 1974 and 1991 revealed the fact that the bed of the Ganges has silted up substantially in the recent past.

Impact on navigation

A total of 685 km of waterways which were navigable during pre-diversion time have been adversely affected during the post-diversion period. The confluence of the Ganges and the Brahmaputra was affected by shoals. As a consequence, the BIWTA (Bangladesh Inland Water Transport Authority) ferries are facing severe problems and dredging requirements have increased.

Increases in salinity

The most devastating effect of the diversion of the Ganges water has been caused by the marked increase in salinity in both surface water and groundwater, leading to higher soil salinity in the south-west region of Bangladesh. The major direct adverse effect of salinity is felt in industry, agricultural production, fisheries, forestry, and power generation. In addition, and most significant, such marked increases in salinity have short- and long-term impacts on health, expected mortality, and the ecosystem as a whole. Since the Farakka withdrawals commenced, the salinity ingress pattern in the area has a tendency towards cumulative increase due to residual deposits; this would be further aggravated if the present pattern of Ganges flow continues.

Reduction in dry-season Ganges flow raised the salinity of the Khulna area from 380 micro-mhos/cm during the pre-diversion period (1974) to about 29,500 micro-mhos/cm in April 1992. The salinity front of 500 micro-mhos/cm moved through the Passur estuary from 145 km to about 219 km inland after the diversion. This has resulted in increased soil salinity, leading to crop damage and severe yield reduction.

Impact on fisheries

The reduction of wetlands has resulted in reduction in fish catches. The most adversely affected fish are those which used to migrate upstream for breeding and spawning. Hilsa, which is an anadromous fish that requires freshwater flow, used to migrate upstream to spawn. As a result of the barrage, this fish is no longer available in India and is in decline in Bangladesh.

Impact on domestic and municipal water supply and public health

The Ganges river is the main source of domestic and municipal water supplies to the Ganges-dependent area in Bangladesh. The people use both surface water and groundwater for domestic purposes. Due to the drastic reduction of surface water, the people have been totally dependent on groundwater. But the availability and quality of the groundwater have become constrained too, due to lowering of the groundwater table and salinity intrusion. During the pre-diversion period, the water quality was well within the acceptable limits; later these limits were regularly violated. Increased salinity in the area has caused adverse effects on the general health of the people living there. The effect of salinity has given rise to an increased incidence of various ailments among the people using waters in the saline-affected areas. Waterborne diseases like typhoid, infectious hepatitis, diarrhoea, cholera, etc. among the inhabitants of the south-western region have been reported in increasing numbers.

Impact on forestry

The Sundarbans, littoral mangrove forests adjacent to the Bay of Bengal and comprising an area of 1,006,000 acres in Bangladesh, are situated in the south-west of Khulna district. The forests extend about 80 kilometres north of the Bay of Bengal, and are bounded on the east by the Baleswar river and on the west by the international boundary with India. With the increase of salinity, sundari, the main species of the Sundarbans, started dying and the regeneration of the species also decreased. Sundari may ultimately disappear if the salinity goes above the tolerance limit.

Impact on agriculture

Shortage of water in the Ganges since the commissioning of the Farakka barrage in India has adversely impacted crop production in a substantial area where soil moisture depletion has led to water stress. Expansion of irrigation facilities in the area served by the Ganges suffered heavy setbacks that retarded growth in agriculture. The damages in the agriculture sector due to reduced dry-season flows during the entire post-diversion period are manifold, and have been quantified for individual causes like shortage of water in the crop fields, soil moisture depletion, soil and water salinity exceeding tolerable limits, a lowered groundwater table, and delayed planting.

Impact on ecology and environment

The flora and fauna of south-western Bangladesh have evolved in response to natural conditions to form a climax ecosystem, which is now threatened with degradation caused by the inadequate supply of fresh water. The actions which triggered the degradation process of the total ecosystem in this region can be grouped into two broad categories: salinity increases in soil and water (surface and ground) from tidal ingress; and accelerated siltation in channels. In specific terms, the manifestations of reduced water flow are in the form of the northward penetration of tidal water causing salinity increases in soil and water; the diminished potential of the Sundarbans mangrove ecosystem; massive siltation and shoaling resulting in drainage congestion; decreased navigational draft in inland waterways; degradation of wetlands and reduction of open-water-capture fisheries area; and deterioration of groundwater quantity and quality.

Steps towards offsetting these adverse effects

Increasing fresh water supply in the affected area is considered to be the main technical solution to these problems. Now that a definite quantum has been secured for the lower riparian, steps will soon be taken to restore flows through the river network of the area. Towards this the following phases are envisaged:

- removal of sediment deposit from the mouth of the Gorai;
- construction of a control structure on the Ganges at a suitable location;
- restoration of the network of rivers, the conditions of which have deteriorated significantly.

Potential for regional approaches to water resources development

The Ganges and the Brahmaputra have basins spread over China, Nepal, India, Bhutan, and Bangladesh. They have distinctly separate basins, but they drain out to the Bay of Bengal via a common outlet, known as the Meghna estuary. The waters of the Brahmaputra have not been harnessed so far, but the Ganges basin is highly developed, with a large number of dams and barrages constructed in India and Nepal.

Besides these two major rivers there are about 54 common rivers between Bangladesh and India. The Meghna (known as the Barak in India)

is also considered to be a major river. Among other rivers the Dharla, the Dudhkumar, the Teesta, the Monu, the Muhuri, the Khowai, the Gumati, the Mohananda, the Ichamati, and the Someshwari may be termed as medium-sized rivers while the rest are minor or small channels. All these watercourses may be termed as international rivers as they flow through two countries. Utilization of water resources of these rivers, and construction of bank protection and river training works in the border region, have been causes of dispute between the two countries. The main attention has, however, been on the Ganges.

Both the Ganges and the Brahmaputra have sufficient discharge on an annual basis to meet the present as well as the future water demands of the entire region. But in the dry season the flows become too small for meeting even the present requirements. Thus at one stage India and Bangladesh agreed to explore methods of augmentation of the dry-season flows of the Ganges. Bangladesh proposed conservation of the huge monsoon flows through storage reservoirs in the upper catchments in India and Nepal. India suggested diversion of 100,000 cusecs of flow of the Brahmaputra into the Ganges upstream of the Farakka barrage through a 200 km link canal. The proposals of one country have not been acceptable to the other for various reasons.

If an agreement could be reached on how to harness and utilize the water resources of all the rivers of the region effectively, tremendous benefits could be obtained in terms of irrigation facilities, hydropower generation, navigation routes, flood mitigation, fish production, and management of the environment and ecosystem. There is a shortage of water in the dry months, but the huge monsoon flow remains untapped. If a beginning could be made then the rivers of the region could become waters of hope, as aptly termed by Verghese (1990). Water is there, but not when needed.

A major dimension of the management and utilization of the GBM waters pivots around the concept of storage reservoirs in the upper reaches of the Ganges. The construction of reservoirs in upstream reaches for optimal and multiple use of water resources of the region could achieve flood-peak attenuation in lower reaches, augment dry-season flows, generate hydro-electricity, and offer irrigation as well as navigation opportunities. There are a number of good sites for creating reservoirs in the Ganges tributaries in the middle mountain belt of Nepal. Studies carried out by Bangladesh in 1978, and updated in 1983, outline a scheme for optimum development of the surface water resource of the Ganges basin through a coordinated and cooperative plan implemented by the co-basin countries – Nepal, India, and Bangladesh. The studies suggested construction of seven storage reservoirs in Nepal as well multiple storage dams in India, with a view to holding vast monsoon runoff

and increasing dry-season availability of the Ganges waters. Needless to say, these mega-constructions need huge investments of capital, and therefore the objective would have to include multiple uses accrued from the storage reservoirs which could be shared cooperatively by the co-basin countries.

Joint efforts in flood management

Floods are a recurrent problem in the GBM region, especially in Bangladesh and eastern and north-eastern India. Every year substantial damage is caused by floods in Nepal, India, and Bangladesh. Nepal's worst flood in six decades occurred in 1993, when over 2,000 people lost their lives. India also experienced one of its worst floods of the century in 1993 in the northern states. In 1988, nearly 60 per cent of Bangladesh's land area was submerged in widespread flooding of catastrophic proportions. Any mitigation plan for flood hazards needs mutual cooperation and efforts.

Flood forecasting

Flood forecasting is an important non-structural flood mitigation measure with much scope for inter-country cooperation. It can not only safeguard life and property in unprotected areas, but also prevent damage to engineering structures. In Bangladesh, the Flood Forecasting and Warning Centre of the Bangladesh Water Development Board (BWDB) is responsible for issuing flood warnings. The centre has a network of wireless stations for monitoring real-time water levels and rainfall data. It also has links with the Bangladesh Meteorological Department, and, during flood time, it receives satellite imagery from the Space Research and Remote Sensing Organization (SPARRSO). Under a joint-action programme of flood forecasting and warning, Bangladesh and India have had an agreement for transmission of real-time and forecast flood data since 1972. The present arrangement of transmission of data (whenever the water level is at or above warning stage) from India is limited to such stations as the Ganges at Farakka, the Brahmaputra at Goalpara and Dhubri, the Teesta at Domohoni, and the Barak (Meghna) at Silchar.

Current arrangements for flood forecasting data transmission do not allow lead times of more than 24 hours for central Bangladesh – and even less for the border areas. The cooperative arrangement between Bangladesh and India may be strengthened through making provisions for three-hourly real-time and daily forecast data transmission during the monsoon months of May to October, irrespective of warning stage. In order to

increase the forecast lead time in Bangladesh, the data should be transmitted from more upstream stations on the Ganges, Brahmaputra, Barak (Meghna), and Teesta. Arrangements can also be made between Bangladesh and Nepal for transmission of real-time water-level, discharge, and rainfall data which would be very useful for early warning of floods in the Ganges and disaster preparedness measures in downstream sites. Similar arrangements between Bangladesh and Bhutan would be useful for early warning of floods in the Brahmaputra.

Embankments

Embankments are an important structural intervention to achieve the objective of flood protection, and inter-country cooperation in this sector can be envisaged for the border rivers. Embankments have been constructed in Bangladesh for many years for protection against flood, and the ones which have been properly planned, constructed, and maintained have functioned well. In order to make them more effective, the embankments on both banks of all the common rivers must be tied up with those beyond the borders. Some embankments are already tied, but through mutual agreement and collaboration the gaps in the embankments along the common rivers like the Ganges, Brahmaputra, Dharla, Dudkhumar, Khowai, and others could be identified, and tying up could be completed in phases.

River training

River training is another engineering effort to prevent bank erosion, ensure flow regulation, protect settlements and infrastructures, maintain navigability in channels, and control sediment flow. The GBM countries may exchange experience and expertise in collaborative study and research in order to evaluate the various methods of river training in their respective countries.

Apportionment of waters of common rivers

Apportionment of waters from the rivers in the GBM basins (except for the Ganges between India and Bangladesh and the Mahakali between India and Nepal) is still an unresolved issue. With regard to the left bank tributaries of the Ganges basin, Nepal is the upper riparian in all except for a small stretch of the Mahakali, where it is a common river. On the other hand, India is the upper riparian of all the three river systems of Bangladesh – the Ganges, Brahmaputra, and Meghna. Being the lower

riparian, Bangladesh offers an outlet for the entire volume of the three rivers in the flood season, but remains dependent on the upper riparian for the lean-season flows. Hence, a cooperative and equitable agreement to share fresh water resources in the GBM region is essential.

Hydropower generation and trade

All the four countries of the GBM region, namely, Bangladesh, India, Nepal, and Bhutan, have a per capita consumption of commercial energy much lower than the global average. The most important characteristic of the energy economy of these countries is their high dependence on non-commercial energy – mainly derived from biomass. Non-commercial energy is extensively used in rural areas and by the urban poor, while commercial energy is largely urban-centred – confined to urban households, transportation, and industrial sectors.

The abundant supply of water and the favourable terrain offer excellent opportunities for hydropower development in Nepal, which can meet the energy requirements for the GBM region for many years to come. Hydro-electricity is environmentally friendly, clean, and renewable – hence, cooperative efforts in hydropower generation and its trade in the GBM region are another potentially important sector of regional co-operation. The installed capacity of electricity production in Nepal is about 250 MW, of which 227 MW is generated from water and the rest from diesel. The volume of water in Nepal's rivers has a theoretical hydro potential of 83,000 MW, of which the economically feasible energy potential is about 42,000 MW. The current production capacity (227 MW) is only 0.27 per cent of the theoretical potential – which underscores the enormous hydropower potential of Nepal.

Nepal's development of hydropower utilization had been slow due to the small size of the country, financial constraints, and the limited nature of the domestic market. However, the domestic demand for power is increasing, and currently Nepal does face a power shortage. The huge hydropower potential of the upper Ganges in Nepal must be assessed in the context of immediate geographic realities in the region. Besides the rising domestic demand, there is also an increasingly hungry market for power across the southern borders of Nepal. The ideal combination of an energy potential at home and a market for energy export in the neighbouring region is a sufficient justification for the exploitation of Nepal's water assets. The logical market is northern India, especially the states of Bihar and Uttar Pradesh. It is also feasible that, in the long run, Nepal might be able to transmit electricity across India into Pakistan and Bangladesh. However, the immediate potential for Nepal's hydropower exists

in the northern region of India, where – instead of constructing polluting thermal plants to meet rising energy demand – India can buy hydropower from Nepal. An ultimate cooperative arrangement could be envisaged through the interconnection of the grids of Nepal and northern India.

Navigation and access to the sea

Fuller utilization of water resources in the GBM region should also include an examination of the opportunities for cooperation in inland navigation and river transit. Nepal and Bhutan are two landlocked countries of the region, and are naturally interested in transit through another country for access to the sea. First, storage reservoirs in the upper Ganges could offer opportunities for improving the draft for inland water transport. Second, transit facilities for Nepal through the Ganges waterway or a link with the Jamuna-Padma system could be explored to give the country access to the Bay of Bengal.

Nepal has transit treaties with both Bangladesh and India. Most of Nepal's overseas trade is channelled through Calcutta, and greater co-operation in this field would undoubtedly provide an impetus to Nepal's economy. Feasibility studies should be carried out to explore the possibility of utilizing more upstream locations in the Ganges, which are closer to the Nepalese border and might be suitable for internodal cargo transfer.

The inland waterways of Bangladesh provide a theoretical opportunity for water transit facilities to West Bengal and north-eastern states of India. The potential for utilizing the navigation routes for transit through the Brahmaputra, Padma, and Meghna may be examined. However, before this opportunity can be realized, a complex host of politico-economic and security problems have to be solved. In a similar vein, one can also talk of linking the rivers of Bangladesh with those of eastern Nepal, which could provide significant transit potential for Nepal's commercial traffic to the outside world. An early proposal indicated the feasibility of constructing a 470 km water route linking Biratnagar in eastern Nepal with Bera in Pabna (Bangladesh), whence the traffic would utilize the existing waterways through the Padma and Meghna, and reach Mangla (south-western Bangladesh) via Chandpur. This water route requires the construction of canals to link with existing waterways in north-western Bangladesh, as well as some essential river training works and rail and road crossings. Nonetheless, the route remains an alternate maritime exit for Nepal, and it could also boost trading contacts between Nepal and Bangladesh.

A technical committee on transport under SAARC (South Asia Asso-

ciation for Regional Cooperation) sponsorship is understood to have deliberated on the improvement of transport infrastructure and transit facilities among the neighbouring countries. In the context of the changed and liberal global economic environment, it is perhaps not too much to expect that the GBM countries would also demonstrate a willingness to cooperate in the sector of inland navigation to their mutual benefit.

Catchment management

Catchment is a hydrologic unit of land area, and its dimension is a direct function of the aerial extent of the drainage basin/basins. Over 90 per cent of the catchments of the three major river systems of Bangladesh fall outside its territory; hence, Bangladesh has a natural concern for an objective and planned management of these catchments. Catchment management in the GBM region essentially involves forest management on a macro scale in order to rehabilitate badly denuded slopes, reduce runoff, and prevent soil erosion. The progressive rate of deforestation in the Himalayan slopes has exacerbated the problem of sedimentation in the river channels, which has been one of the contributory factors to increased flooding in downstream areas. Hence, it is beyond dispute that sound catchment management in the GBM region is imperative through programmes of soil conservation, reforestation, catchment area treatment, and strict land-use control. Bangladesh would be interested to share Indian, Nepalese, and Pakistani experiences in catchment management. Joint cooperative study, research, and investigation programmes could be undertaken among the SAARC countries for appropriate catchment management with a view to mitigating the adversities of top-soil erosion, landslides, sedimentation, and unplanned farmland encroachment of slopes.

Disaster management

The principal strategy of disaster management is disaster preparedness, with the objective of mitigating losses. Bangladesh has a comprehensive programme of disaster management aimed at dealing with such natural hazards as floods and tropical cyclones. A Disaster Management Bureau was formed in the Ministry of Disaster Management and Relief in 1993 with the prime objective of making people in disaster-prone areas aware of the hazards so that loss of life and property can be minimized. The bureau's primary concern is with the pre-disaster period, and it is also in the process of reviewing and updating the national guidelines – known as

standing orders – for disaster management. In order to provide national coverage for its activities and programmes, the bureau has already formed a hierarchy of disaster management committees from the national level down to district and union levels. Similar disaster management bodies also exist in various levels of operation in other SAARC countries. These might be concerned not only with floods and cyclones, but also other natural hazards like earthquakes, glacial lake outbursts, snowfall, avalanches, tornadoes, etc. All the SAARC countries would benefit immensely from the experience of each other in facing disasters through an exchange of information and expertise in their tasks of protecting the population from natural hazards.

Concluding remarks

The management of fresh water which crosses international borders is a matter of inter-country concern – it is a transboundary environmental resource and the environment does not recognize borders. The regional cooperation in water management in the sectors outlined above is, therefore, a quintessence for the GBM countries' sustainable development. This region is characterized by mass poverty and economic stagnation. Cooperative endeavours in the water sector could be a starting instrument for South Asia in the path toward self-reliance and sustainability. The bases of cooperation already exist. A multilateral body for water development in the GBM region may be formed under the SAARC umbrella with a mandate to examine and recommend measures of cooperation on the basis of social justice and equity. With positive thinking and respect for each other's rights and legitimate needs, it should not be difficult to identify avenues and modalities for cooperative ventures. There are several examples of cooperative water utilization programmes in transboundary river basins around the world which can be gainfully replicated in the GBM region. All that are needed to begin the task are a genuine desire to attain that goal and an agreement to reach a solution where everyone will be a winner and nobody will be a loser. The time has come to think about the institutional framework. Should we continue bilaterally or move towards a regional institution? This would require a significant adjustment in the political framework of the countries of the region.

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Harnessing the Himalayan waters of Nepal: A case for partnership for the Ganges basin

Iswer R. Onta

Introduction

General

Balanced development of water resources requires a multidisciplinary, multisectoral, integrated river basin approach. Since the water resources are shared by several groups and stakeholders within each river basin, the implications of each action affecting water quality and quantity must be taken into account. In the past, the perceived water development needs of various river basin sectors and stakeholders have been addressed separately by different governments and agencies.

The Ganges is an international river originating in the Himalayan peaks and draining off ultimately to the Bay of Bengal, with its basin spread over four sovereign nations: China, Nepal, India, and Bangladesh (Figure 6.1). The case of Tibet will not be discussed here as the potential for using the water resources is extremely limited there, be it in irrigation, hydropower, or any other sector.

The Ganges basin has a total area of 1,087,300 square kilometres. The proportions of basin area in China, Nepal, India, and Bangladesh are 3.08, 13.56, 79.10 and 4.26 per cent, respectively (India and Bangladesh also share the Brahmaputra basin, which has a total area of 552,000 square kilometres, in the proportions of 35.33 and 7.08 per cent respec-

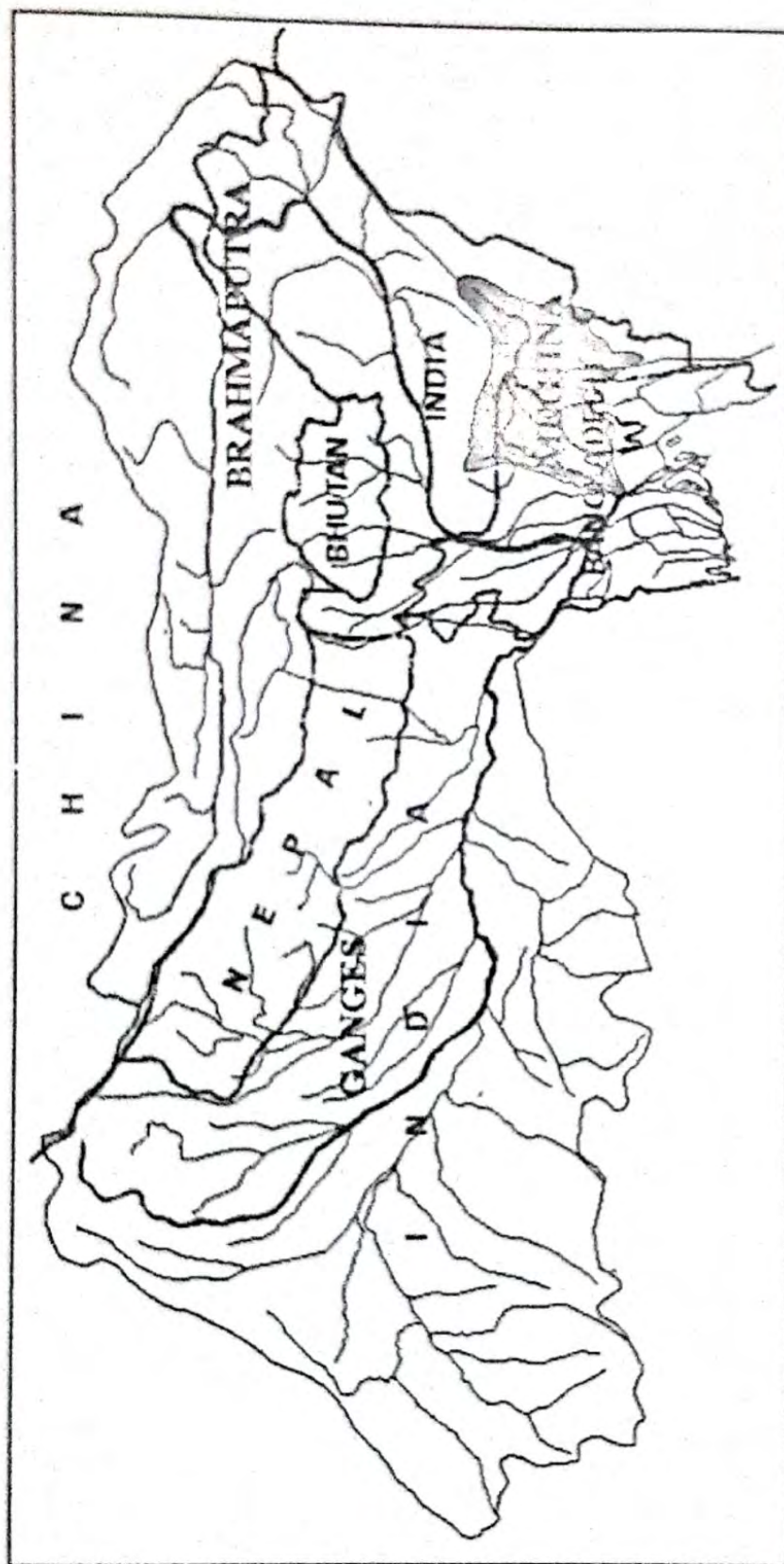


Figure 6.1 The regional setting – the Ganges, Brahmaputra, and Meghna river basins

Table 6.1 Ganges basin area distribution

Country	Basin area (km ²)	% of total area
China	33,520	3.08
Nepal	147,480	13.56
India	860,000	79.10
Bangladesh	46,300	4.26
Total	1,087,300	100.00

Source: Shrestha and Singh 1996

tively). The distribution of the Ganges basin area in each country is shown in Table 6.1.

The population of the Ganges basin is about 344 million people (270 million in India, 52 million in Bangladesh, and 22 million in Nepal). However, the Ganges-Brahmaputra basin has over 535 million inhabitants.

Water in the Ganges basin is abundant, and if properly developed and managed the region could really come out of the poverty trap it is in and start on a growth track. The so-called intractable issues hindering the optimal development of water resources in the Ganges basin over the last 50 years or so have been a subject of intense intellectual and technical discussions. The lesson learnt so far is that the best way to look at any given river system is from the source to the sea: the entire river basin should be viewed with a holistic and sustainable approach rather than a sectoral one (Biswas and Hashimoto 1996).

The situation becomes more complex when the basin is shared by more than one sovereign state (as is the case here), with different socio-economic and political realities and national interests and priorities (Bhadra 1997). The complexity is further increased when a co-riparian country has other major river basins within its territory, with the possibilities of inter-basin water transfers. This is the case for India and Bangladesh in the sharing of waters of the Ganges and Brahmaputra basins (Char 1997).

After the liberalization of economic measures taken a few years back in India, coupled with the democratization of polity of Nepal and Bangladesh in early 1990, serious dialogues among water professionals, bureaucrats, politicians, and the press have been initiated; this is a continuing process. Encouraging debates and discussions have taken place, and there are signs that a consensus has been reached on harnessing the potential of the Ganges and its tributaries for the overall balanced development of the people of the basin (Prasad 1997).

Overview of the Nepalese socio-economic scenario

Nepal is a landlocked country in Asia, bordered by China to the north and India to the south, east, and west; it is located between latitudes 26° 22' N–30° 27' N and longitudes 80° 4' E–88° 12' E. The country, covering a total area of 147,480 square kilometres, has very diverse physical characteristics in its topography, climate, geology, and land-use system. It is predominantly mountainous, with three broad agro-ecological zones: the terai plains (including the inner terai), hills, and mountains (including the Himalayas), covering respectively about 18, 58 and 24 per cent of the total land area. Administratively, Nepal is divided into five development regions, 14 zones, and 75 districts.

Nepal is one of the poorest and least developed countries of the world, with an ever-growing population of about 22 million (estimate of mid-1996), and an annual growth rate of 2.5 per cent. Only about 8 per cent of the population live in the mountains, the rest being almost equally divided between the hills and the terai. The annual per capita gross national product (GNP) is only US\$220, and the corresponding growth rate in per capita output has remained very low (less than 2 per cent) for many years.

Agriculture is the mainstay of the economy, contributing about 42 per cent to the gross domestic product (GDP) according to recent available estimates, and providing employment to more than 80 per cent of the working population. However, the performance of this sector has been less than satisfactory, with productivity declining or remaining stagnant over the years. The industrial sector contributes a little more than 22 per cent to the total GDP, and the services sectors contribute 35 per cent to the GDP. The data reveal that the structural transformation of the Nepalese economy has been minimal.

According to recent estimates, about 42 per cent of the Nepalese population have income levels below the poverty line. The major reason for such poverty is the lack of productive assets in the form of arable land. The average size of land-holding per cultivator household is less than 1 ha in the terai region and 0.3 ha in the hill region. Per capita arable land declined to 0.12 ha in 1996 from 0.60 ha in 1964.

The urban population has grown to 14 per cent, compared to 26 per cent in South Asia overall. Life expectancy at birth in Nepal is 55 years, whereas it is 61 years in South Asia. The infant mortality rate per 1,000 live births is 91 in Nepal, compared to 75 in South Asia. Access to safe water is available to only 60 per cent of the population and illiteracy is rampant, with 73 per cent of the population above the age of 15 being illiterate.

The total GDP of Nepal is estimated at US\$4.5 billion; the average annual growth in GDP is estimated at 4.7 per cent. Despite a modest increase in the real GDP, per capita income has remained more or less stagnant over the last two decades due to the high population growth.

At present, it is estimated that the total cultivated and irrigable lands are 2.64 and 2.18 million ha respectively. However, only 1.77 million ha represent suitable agriculture areas with irrigation potential. The majority, 1.34 million ha (76 per cent), lies in the terai, while the remaining suitable irrigable area is mainly located in the hill districts (Table 6.2). It is also estimated that, by the end of 1992, irrigation infrastructure had been developed by different agencies for about 1.09 million ha. It is estimated that 0.77 million ha (71 per cent) and 0.26 million ha (24 per cent) of these facilities exist in the terai and the hills, respectively. Irrigation is mainly supplementary during the monsoons, and year-round irrigation is available in much less than 50 per cent of the irrigated 1.09 million ha.

Water resources of Nepal

By and large Nepal's water resources are considered to be abundant. The average annual precipitation is about 1,500 mm (80 per cent of which occurs during the monsoon season from June to September). Although the rainfall is highly variable in specific locations, it is normally less in the terai than in the hills, and higher in eastern Nepal than in western Nepal. The total annual average runoff from Nepal is over 200 bcm. More than two-thirds of the annual runoff occurs during the monsoon period. Surface water resources are distributed in the river system, which consists of four major rivers, seven medium rivers, and a large number of small rivers. The spatial and temporal distribution of surface water resources, particularly due to the lack of storage facilities, creates surpluses at certain times and places and shortages at others. Besides surface water, Nepal is also endowed with extensive groundwater resources, mainly in the terai. Both shallow and deep aquifers may be utilized independently or in conjunction with surface water for irrigation purposes (Hillel 1997).

The major rivers originating from the snow-capped Himalayas are the Mahakali, the Karnali, the Gandaki, and the Saptakosi. The second group of medium rivers originate in the middle mountains, and are mostly rainfed and have low dry-season flows. The rivers in the third category are small catchments originating from the Churia hill ranges of Nepal. These rivers will have very little or no flows at all during the dry season. The total number of rivers is estimated at 6,000, and the total length of the water courses is about 45,000 km.

The mean annual flows from the Himalayan rivers, including flow from

Table 6.2 Distribution of irrigated and potentially irrigable land

Ecological belt	Potential irrigable land (net ha)				
	Irrigated area (ha)	Rainfed area (ha)	Total cultivated area (ha)	Total irrigable agricultural area	Irrigable non-agricultural area
Terai	780,900	578,100	1,359,000	1,338,000	406,000
Hills	199,400	855,600	1,055,000	368,000	5,000
Mountains	30,700	196,300	227,000	60,000	1,000
Total	1,011,000	1,630,000	2,641,000	1,766,000	412,000
				1,744,000	963,100
				373,000	173,600
				61,000	30,300
				2,178,000	1,167,000

Source: *Master Plan for Irrigation Development in Nepal*

Table 6.3 Estimated mean annual runoff – Nepal rivers

Category of basin	River	Basin area (km ²)	Estimated annual runoff (m ³ /sec)
Himalayan	Mahakali	15,640	656.88
	Karnali	44,000	1,430.00
	Gandaki	34,960	1,779.46
	Koshi	60,400	1,673.08
Mahabharat	Babai	3,252	82.28
	West Rapti	6,215	148.54
	Bagmati	3,681	217.91
	Kamala	1,786	52.15
	Kankai	1,317	65.06
Churia	(Various)	22,797	456.00
Total			6,561.36

Source: Institute for Integrated Development Studies 1995

outside the Nepalese territory, are estimated at about 5,539 m³/sec. The total runoff from the medium rivers of Nepal is estimated at 566 m³/sec and the runoff from the Churia rivers is estimated at 456 m³/sec (Table 6.3). Overall, the rivers of Nepal contribute more than 40 per cent of the total flow of the Ganges and over 70 per cent of its dry-season flow. Water storage potential in Nepal is 88 bcm. If properly planned and managed, development of this storage potential could yield tremendous benefits to Nepal and its neighbours in the form of hydropower generation, flood control during the monsoon, flow augmentation for downstream irrigation and navigation, and water supply. Hence it is natural that India has a vital concern about Nepalese waters and will have keen interest in Nepal's water resources development.

Overview of water resources development in Nepal

Water is needed for domestic consumption, food production, energy generation, industry, navigation, recreation, and sanitation.

Drinking water supply

Sixty per cent of the population of Nepal is assumed to have access to potable water, and it is estimated that at present 674 million litres of water per day are supplied to this population. A piped water supply system has been installed in all the 75 district headquarters of Nepal. The government of Nepal intended to provide drinking water facilities to 72

and 77 per cent of the rural and urban population, respectively, by the end of 1997.

The government had ambitious long-term plans to provide drinking water to the entire population by the turn of the century. However, the seasonality of flows has continued to impede the availability of safe and reliable water supplies, and past investments in infrastructure have not had the developmental and social impact originally expected.

Irrigation development

As mentioned earlier, out of 1.77 million ha of potential irrigable land, irrigation infrastructure has been developed for over 1.09 million ha. Large-scale irrigation is feasible only in the terai plains, where extensive and more uniform land is available. Most possible run-of-the-river projects have already been taken up for development, though intensive infrastructure development and quality water management are lacking.

Multipurpose projects like the Kankai, the Sunkosi-Kamala diversion project, the Bheri-Babai diversion project, the Karnali, etc., which have high potentials for year-round irrigation in the terai, are awaiting implementation (Onta, Agrawal, and Onta 1995).

Groundwater potential (the dynamic groundwater reserve is estimated at 8.8 bcm) for irrigation development in the terai is also very high, and the Agriculture Perspective Plan (APP) of Nepal envisages irrigation of 0.5 million ha of the terai land by exploiting this potential.

Farmer-managed irrigation systems (FMIS) have been operating successfully in the terai, hill, and mountain areas of Nepal for centuries. These systems have been rediscovered, and the government has adopted the FMIS community management system as a focus to manage irrigation development by incorporating it into its irrigation policy.

Hydropower situation

Nepal's theoretical hydropower potential is enormous, at 83,000 MW (identified power potential is 42,000 MW – see Table 6.4). However, to date, Nepal has developed just about 244 MW of its vast hydropower potential. The population having access to electricity was estimated at 12 per cent in 1996. At present, nearly all urban and semi-urban population centres have been electrified: 89 per cent of the urban population and only 4.5 per cent of the rural population receive electricity services.

Nepal has classified the hydropower schemes into three categories: small (up to 10 MW), medium (up to 500 MW), and large (more than 500 MW). The Nepal Electricity Authority (NEA) has classified the hydropower schemes into four categories: micro (up to 1 MW), small (1–10

Table 6.4 Identified hydropower potential in Nepal

River basin	No. of sites	Identified power potential (MW)
Sapta Koshi	40	10,860
Gandaki	12	5,270
Karnali	7	24,000
Mahakali	2	1,125
Other southern rivers	5	878
Total	66	42,133

Source: Institute for Integrated Development Studies 1995

MW), medium (10–300 MW), and large (more than 300 MW), to reflect the present situation and future requirements. The small-size schemes are designed to serve local grids in remote locations by harnessing numerous small rivers; the medium size to cater to national needs and export the excess; and large schemes mainly for export to neighbouring countries.

Currently, hydropower schemes with a total capacity of 280 MW, including the 144 MW Kaligandaki A project, are under construction. All of these schemes are run-of-the-river type and most should be available in the system by the year 2000. The next lot of hydro schemes, with generating capacity of 385 MW including the 240 MW Upper Karnali, are being studied at various levels and will meet the projected domestic electric energy needs, if implemented, till 2007–2010 depending upon the forecasts made by the NEA at different times in different situations (Table 6.5).

Other sectors

Development in other sectors related to water resources, including navigational needs, has been minimal and at the most potential projects and schemes have been identified.

Past experience in large-scale water resources development

The fact that the Himalayan rivers originate in Nepal holds a large potential for the development of hydropower as well as irrigation facilities, and to some extent inland water transport has been known to planners, scholars, and developers since the early twentieth century. The quantification of resources, which started to emerge only during the later stages, is currently being fine-tuned by governments of the region as well as by NGO research activities.

Table 6.5 NEA load forecasts

Year	Peak load (MW)	Energy (GWh/yr)	Load factor (%)
1996	281	1,272	51.7
1997	303	1,392	52.4
1998	328	1,530	53.2
1999	354	1,688	54.4
2000	383	1,860	55.4
2001	413	2,047	56.6
2002	452	2,261	57.1
2003	498	2,500	57.3
2004	549	2,767	57.5
2005	610	3,065	57.4
2006	676	3,392	57.3
2007	748	3,757	57.3
2008	824	4,153	57.5
2009	909	4,593	57.7
2010	1,002	5,081	57.9
2011	1,104	5,617	58.1
2012	1,215	6,216	58.4
2013	1,340	6,879	58.6
2014	1,483	7,641	58.8
2015	1,642	8,487	59.0

Source: Nepal Electricity Authority 1996

Past Indo-Nepal cooperation over international rivers

Nepal-India cooperation in large-scale water resources development dates back to the early years of this century (1920, during the British rule in India). The Sarada barrage on the border river Mahakali (known as the Sarada in India) was constructed by India after exchanging some land between Nepal and India. The barrage is situated wholly in India, and Nepal is entitled to a specified supply of water for irrigation.

After an interval of over 30 years, Nepal and India signed an agreement to construct the Kosi barrage in 1954. The agreement to construct the Gandak barrage was signed between Nepal and India in 1959. Both these barrages were constructed on or close to the Nepal-India border and were based on India's initiative and needs. They were wholly financed by India and mostly benefited India (with the only benefit to Nepal being a specified supply of water for irrigation and entitlement to power).

These early Indo-Nepal water resources projects, though considered reasonable from India's viewpoint, were seen as a "sell-out" by many in Nepal. Other water resources development in rivers in India close to

Nepal's border has been perceived as "not-so-friendly activities" by Nepal. The consequence has been such that the constitution of Nepal embodied Article 126, requiring any "treaty" pertaining to natural resources and certain other matters to be ratified by a two-thirds majority by the country's parliament, to safeguard Nepal's national interests. However, with the introduction of a liberal outlook in the economy in India in the early 1990s, and with the restoration of multi-party democracy in Nepal as well as in Bangladesh, the climate of economic co-operation and water resources exploitation has seen marked changes recently.

Issues related to regional cooperation

India needs the hydropower resources of Nepal: by developing its major rivers, Nepal can provide large hydro and storage projects to augment the low flows during the lean season as well as to moderate the flood situation. Northern India remains short of power to the tune of more than 50,000 MW, but Nepal can help mitigate this situation to a considerable extent (Institute for Integrated Development Studies 1997).

Bangladesh wants Nepal to construct large storage dams to regulate the lean-season flow of the Ganges and augment the Ganges water so that the needs of both India and Bangladesh in lean seasons could be catered for. Nepal, in return, would enjoy considerable benefits from selling hydropower to India and Bangladesh, and would also be compensated for the use of its reservoir dam sites for augmentation of low flow as well as flood control. Nepal would also like to benefit from enhanced/developed inland waterways in one of its major rivers, mainly the Kosi, to have access to the sea for its export trade. The issue is how best all these needs can be catered for and how best to achieve a "win-win" situation for all the parties involved. This is the problem that needs to be solved.

Potential schemes to address the immediate issues

Though it would have been a wise step to develop separate strategic master plans for each of the important river basins, such as the Mahakali, the Karnali, and the Kosi, for their long-term optimal utilization, identified projects like the Pancheswar high dam on the Mahakali, the Chisapani high dam on the Karnali, and the Sunkosi high dam on the Saptakosi cannot be ignored. The siting of these high-dam projects could be optimal even if the whole of each basin is considered (though rigorous study of the basins could prove otherwise).

Table 6.6 Pancheswar project specifications

Dam height	315 m
Installed capacity	6,480 MW
Irrigation benefits to Nepal	93,000 ha
Cost	US\$2.98 billion (1995 prices)
Live storage capacity	6.5 bcm

The Mahakali Pancheswar project

The Pancheswar high-dam project is part of the Mahakali river integrated development treaty, which underlines the provision made under the Sarada agreement of 1920 to provide upgraded benefits to Nepal from the Tanakpur project (8 km upstream from the Sarada barrage), and stipulates provisions in connection with the development of any project in the Mahakali river. A specific project agreement will, however, be necessary as and when new projects, including the Pancheswar, are developed.

The Pancheswar project was first identified by the Central Water and Power Commission of India in 1956. A project report was prepared by India in 1971, proposing the construction of a 232-metre-high concrete gravity dam having an installed capacity of 1,000 MW (500 MW on each side of the river).

Nepal and India decided to proceed with field investigations at the feasibility level, with each country working within its own territory. Based on the findings of the field investigation work and the project definition study, Nepal prepared a detailed project report in September 1993. There appears to be some divergence in the concepts of Nepal and India regarding the parameters of the project, specifically the height of the dam and the installed capacity of the power plant etc. The parameters as developed by Nepal are given in Table 6.6.

The Mahakali treaty was concluded in January 1996 between Nepal and India. Nepal sent the draft DPR (detailed project report) to India on 3 July 1996. The Nepalese parliament ratified the Mahakali treaty on 20 September 1996. In May 1997, India raised the issue of the lower Sarada project (the Sarada Sahayak canal), situated 160 km downstream of the Sarada barrage. The Mahakali treaty became effective on 5 June 1997 after an exchange of treaty documents during the visit of the Indian prime minister to Nepal.

Several joint meetings between Nepal and India have been held, but these meetings could not agree on the joint DPR mainly because basic issues like equal rights on water and the Sarada Sahayak canal could not be resolved. The parliament stricture to agree on the joint DPR within six months of ratifying the treaty could therefore not be achieved. A great

Table 6.7 Karnali project specifications

Height of rock-fill dam	270 m
Installed capacity	10,800 MW
Irrigation potential in Nepal	191,000 ha
Cost	US\$4.89 billion (1989 prices)
Live storage capacity	16.2 bcm

deal of effort would be necessary to proceed in line with the provisions made under the Mahakali treaty.

Karnali project (Chisapani dam)

This is one of the largest multipurpose projects, and has been under discussion between Nepal and India since the late 1960s. Various studies have been carried out and the latest detailed feasibility study, undertaken by a consortium of Canadian consultants, envisages the project with the parameters shown in Table 6.7.

In this case, India has expressed a preference for a lower dam height at Chisapani with a capacity of 7,000 MW.

The private developer ENRON has shown interest in developing the Chisapani dam project and has requested the government to grant permission to start necessary surveys. Recently, after several discussions and presentations made by ENRON, permission was withheld pending more inquiries.

Kosi high-dam project

Kosi is another major multipurpose project with flood control, irrigation, power, and navigation benefits; it has been under discussion between Nepal and India for a long time.

India proposed the project, to be sited near the Barahchhetra gorge, as far back as 1950. India prepared a feasibility report in 1981. Nepal identified the project during the preparation of the Kosi basin master plan in 1985.

The project proposed by Nepal has parameters which differ from the Indian proposal; both specifications are given in Table 6.8.

The height of the Kosi high dam in the Nepal proposal is lower in order to accommodate the Sunkosi-Kamala diversion project upstream near Kurule, which has the potential to generate a significant amount of power and irrigate substantial land in Nepal.

The latest expert meeting on the Kosi high-dam multipurpose project between Nepal and India was held in January 1997, when it was decided to conduct a detailed study of the project starting in mid-July 1997. The

Table 6.8 Kosi project specifications

	Nepal's proposal	India's proposal
Dam height	239 m	269 m
Installed capacity	—	3,300 MW
Gross storage capacity	8.5 bcm	—
Irrigable area	68,850 ha (in Nepal)	1,522,000 ha (in India)
Cost	US\$2.7 billion (1985 prices)	US\$4.6 billion (1991 prices)

study was to cover all aspects of benefits including irrigation, flood control, hydropower, and navigation, and the project was to be evaluated according to the principles established in the Mahakali treaty.

Regulatory provisions

The legal and regulatory requirements to harness and develop the water resources of Nepal have been given due consideration after the restoration of democracy in 1990. Without these instruments in place, it would have been mere rhetoric. The following instruments (enacted and incorporated) are indications of the Nepalese intention to face head-on the issues related to management and harnessing of the water resources of Nepal: the Water Resources Act (1992), the Electricity Act (1992), the Electricity Tariff Fixation Regulation (1993), the Water Resources Regulation (1993), the Electricity Regulation (1993), the Industrial Enterprise Act (1992), the Foreign Investment and Technology Transfer Act (1992), the irrigation policy (1992), and the hydropower development policy (1992). Nepal is planning to amend the Water Resources Act, the Electricity Act, and the hydropower development policy to suit the current investment climate as well as other challenges of the future, including large-scale export of electrical power and downstream benefits arising out of storage projects.

Nepal's viewpoint

Nepal is of the view that its domestic energy needs will be met by utilizing small and medium hydropower schemes identified for a foreseeable future. Nepal has projects already under construction that will take care of its domestic need till 2005. Nepal has also identified schemes and studies are being conducted on other schemes to cater for its power needs

for a few years beyond 2005. Some supply deficiency might occur during wintertime if peaking schemes are not undertaken to meet the peak demand.

Nepal has embarked upon the West Seti hydro-electric project (750 MW) with an agreement signed with a private developer, the Snowy Mountain Engineering Corporation (SMEC) of Australia, with the sole intention of exporting the substantial power to the Indian market. This is a storage project which could be used as a peaking station (if Nepal needs), and will be a test case in relation to power sales to India; it will also prove the efficacy of the power trade agreement that has been concluded with India.

High-dam projects, with the inherent risks associated with silt deposition, seismic activities, and environmental considerations, are not in the priority list of Nepal. These high-dam projects are also very expensive and investment funds are not likely to be acquired by Nepal. Besides, heavy investment in such schemes (which amount to more than Nepal's annual GDP) may not be a sound investment proposal (when competing projects in other sectors are available).

Though Nepal would like to earn revenue from selling power to India or Bangladesh to invest in important social sectors like drinking water, education, and health for long-term development, it will remain hesitant to make huge investments. At the same time, Nepal wants to extract its reasonable share from those proposed high-dam projects. Aspects like irrigation and flood control benefits are issues that cannot be left unaddressed. Nepal hopes that, sooner or later, India will listen to Nepal's concerns. The agreement on the Pancheswar project under the Mahakali treaty will be crucial, to both India and Nepal. This will be a unique project on the only large border river between the two countries.

The time has come for Nepal to approach India more meaningfully to work on a mutually beneficial agreement on multipurpose projects located wholly in Nepalese territory, wherein India buys not only power, but also cooperates in the integrated development of other benefits that come along. If these issues are ignored they will prove to be a big setback to the development process. In Nepal, the general opinion is that "no deal" is better than a bad deal. In the case of augmentation of low flow in the Ganges at the Farraka barrage (the lowest recorded flow of the Ganges at Farraka is 1,100 m³/sec), the Kosi high dam would be an appropriate scheme because of its proximity to Farraka, and Nepal should seek access to the sea by developing a navigational channel from Nepalese territory. The Kosi high dam could be a multi-country venture in sharing the benefits it accrues in terms of power, irrigation, flood control, low-flow augmentation, and navigation.

Initiation of partnership-building efforts

After visualizing the stalemate in the government sector in harnessing the water resources of the South Asia region, an effort (supported by the Ford Foundation in 1990) was made by scholars of the region to forge partnerships between/among countries of the GBM basins. The Ford Foundation offered to support such an effort built around a core group of scholars from India, Bangladesh, and Nepal. The core group consisted of the CPR (Centre for Policy Research) in Delhi, the BUP (Bangladesh Unnayan Parishad) in Dhaka, and the IIDS (Institute of Integrated Development Studies) in Kathmandu.

The first phase of the partnership came to an end in 1994, culminating with the publication of three country reports and a consensus book, *Converting Water into Wealth* (Verghese *et al.* 1994). The book came up with an excellent resumé of possibilities for bilateral (and possibly tri-lateral) cooperation.

The second phase of the study started in February 1995 and is under way. It has so far conducted five dissemination/follow-up seminars, held in Dhaka in August 1995 and March/April 1997, in Delhi in October 1996 and November 1997, and in Kathmandu in January 1997. It planned to prepare a regional report in March 1998.

The objectives of the seminars were to increase the level of understanding among the countries of the region and facilitate the process of achieving regional cooperation in the development of water resources by exchanging ideas and information contained in national and regional reports. The effort has been successful in bringing together members of parliament, politicians, media people, and scholars of the co-basin countries in a common forum, and has been conducive to the movement towards regional cooperation in the development of the Himalayan water resources.

During the period of this cooperative study, the treaties between Nepal and India on the Mahakali and between India and Bangladesh on Ganges water sharing at Farraka, signed in the later half of 1996, have been landmark achievements and have encouraged the scholars to go ahead with the concept of regional cooperation.

Also, under the aegis of the United Nations Development Programme, a preparatory workshop for a project on enhancing regional cooperation in South Asia through cooperation on energy and environment was held in Singapore in December 1995. Policy-makers and senior specialists from India, Nepal, and Pakistan participated in the workshop, and formed working groups on natural gas, hydropower, energy efficiency and renewable energy, and hazardous waste management. These working

groups identified a small number of topics on which specific proposals have been developed. The follow-up meeting of the group, the South Asia Forum, was held in Stockholm, Sweden, in July 1996.

Issues for detailed studies and research

There are many issues that need to be addressed further, not only for technical adequacy, but also to satisfy the public in the exercise of confidence-building. Some major issues of a technical nature are highlighted below, and are meant to be indicative rather than exhaustive.

River basins

Studies and deliberations held among scholars so far have clearly shown that unless scientific, technical, environmental, and socio-economic studies of the river basin as a whole are conducted, optimal utilization and sustainable exploitation of the water resources of the basin will not be achieved.

It is thus imperative that more rigorous basin, sub-basin, and micro-basin studies be carried out by each country, and the findings should be freely disseminated among national river basin institutions (to be established, if not in existence). A regional institution (such as the Ganges River Basin Authority) should be the custodian to collect, collate, package, retrieve, and disseminate the findings. This arrangement, however, should not be an impediment to the implementation of projects like Pancheswar and Karnali which are in advanced stages of development.

Hydrology and sedimentation

It has been surmised that the available hydrological data could be a thorny question when agreeing to certain technical parameters for a particular project. Fundamental questions like how much water is available, and when and where it is available, have still not been accurately answered. The temporal and spatial nature of monsoonal rainfall that prevails in the region has made it more difficult. The information available on hydrology is limited, with the quality of data varying. There is thus a need to analyse the data carefully and bring them up to a certain confidence level so as to be usable for project design.

The coverage of hydro-meteorological stations is inadequate, and to predict the trends, time-series historical data are needed; these are currently lacking. The available data are assessed to have less than 15 per cent reliability. An elaborate hydro-meteorological network and better management of the hydrological data should be given higher priority and monitored continuously on a regular basis through the process of ongoing research and analysis.

In storage projects, the major concern is the inflow of sediment mass and depletion of storage volume. The Ganges in general, and the Himalayan rivers like the Karnali, Gandaki, and Kosi in particular, are known to carry very high sediment loads. Continuous records of sediment loads of Nepalese rivers do not exist, but the total sediment load of Nepalese rivers from available data has been estimated to be 726 million imperial tons.

Any miscalculation in the estimation may lead to the premature sedimentation of reservoirs created by storage projects. The Kulekhani reservoir in Nepal is a classical example: in 1993 a cloudburst alone sedimented about 5 per cent (4.28 million m^3) of the reservoir capacity out of 83 million m^3 (designed value in 1982).

An elaborate network of stations on rivers of Nepal to collect sediment data should be established and research continued. At the same time, watershed studies and proper management should be given due importance in view of the river sedimentation.

Irrigation water management

It has been said many times and in many places that we need to practise economy in water use, to avoid wastage and get the most from a given amount of water. The irrigation sector is the largest consumer of water in South Asian society, and it is known that the irrigation efficiency at present in this region is less than 50 per cent. If the overall efficiency of water use can be increased, the issue of augmentation of low flow of the Ganges at Farakka may not arise at all. Hence, this aspect of water management needs more serious research, and best management practices should be looked for and propagated in the region. Continuous research and implementation efforts in this field are needed.

Environmental aspects

Storage projects generally have severe adverse environmental impacts in physical, biological, and socio-economic terms. The most significant impact is of course social, as large amounts of land are inundated and people have to be compulsorily resettled. This is one area which has gained considerable importance in recent times. In Nepal environmental impact assessment studies are mandatory in all hydro projects, and mitigation measures must be addressed as well. However, further research in this area is needed, and a more meaningful focus must be attached to it.

Dam safety and seismicity

The Himalayan belt encompassing Nepal is very active seismo-tectonically, and one of the most important design inputs is the design value of the

seismic load in terms of the seismic coefficient. As dam safety is of utmost concern, rigorous studies and research should be conducted; more importantly, the analysis and results need to be transparent to the public at large as well (Sharma 1997).

There are many other issues which are of utmost importance, such as participation (of local communities in particular), rehabilitation of displaced persons, capacity-building of local and regional institutions, and inland water transportation and access to the sea for Nepal. These need further detailed studies/research and consideration at all levels of society. If inland water transportation is achieved, it will bring a sea-change to how Nepal does business with India and the rest of the world.

Need for a supranational institution

Now that several partnership-building efforts have been continuing for some time and knowledge-based information has been generated (much more work is needed, however), the time has come to agree on a broad regional water agreement among the Ganges river basin countries to continue, strengthen, and support such activities for the betterment of the people of this river basin. International agreements and conventions on major rivers of the world do exist as examples which can be studied and pondered upon. However, it is evident that a high-level (preferably ministerial level) apex body has to be constituted under such an agreement. The high-level apex body should have broad objectives, such as "to promote and coordinate effective planning and management for the equitable, efficient, and sustainable use of land, water, and environmental resources of the Ganges basin". There should be a mechanism whereby community participation is ensured, such as constituting a community advisory committee representing regional and special-interest groups, to give independent advice to the apex body on the views of the basin's communities.

The apex body could be named the Ganges River Basin Authority/Council. Its specific goals could be to:

- ensure sustainable development and utilization of water resources;
- maintain and improve, where possible, water quantity and quality for all beneficial uses;
- conserve the natural environment of the basin.

This high-level apex body should be supported by well-designed regional and national organizations. The apex body must be supported by an autonomous executive arm, called perhaps the Ganges River Basin Commission, with equal representation of the participating governments. The commission should have a secretariat of its own, consisting of tech-

nical and support staff in the areas of river management, natural resources, finance and administration, and communication. This commission should be able to interface with the existing regional organization, such as the SAARC.

The commission should have a knowledge-based approach. Hence, at the outset, its main function should be to collate, collect, package, retrieve, and disseminate the available data and knowledge as well as to generate more knowledge in all aspects of comprehensive river basin planning. These data and knowledge should be available and adopted to formulate strategies and policies. Each participating country should have a similar organization with similar objectives to interface and interact with the regional body. This is a crucial requirement and must be agreed to. This is one of the possible scenarios of organization which could be deliberated upon by member countries.

Good governance

One of the hurdles identified that has impeded the harnessing of the immense water resources of the region is good governance and the lack of political will. And, when it comes to implementing policies, programmes, or projects, it often depends upon the overall capacity of public administration. One cannot negate the existence of government and its accompanying bureaucracy. And it is the bottom line, period.

Governments should be forced to make good policies. However, getting the policies right may not, by itself, be sufficient for successful development. Good governance is required to ensure that governments actually deliver promises to their citizens. The governments of this region have failed miserably on this score, so far.

Well-designed programmes are important, but so is the ability to implement them. Implementation capability reflects three fundamental elements in the strategic interactions between citizens and government officials. These fundamental elements – accountability, transparency, and predictability – determine the performance of policy.

The 1990s showed some progress towards regional policies and co-operation in the region. The liberal policy towards its neighbours adopted by India (the so-called *Guzral doctrine*) and the democratization of polity of Nepal and Bangladesh auger well in this direction.

But good governance does not come by wishing for or enunciating policies alone. It has to be strived for and needs to be designed properly and honestly, and adhered to (legislation and rules should be enacted and applied in spirit as well as in letter). The culture of good governance has to be imbibed, and its fundamental elements have to be propagated.

Corrupt practices are rampant in the region, and must be shunned by the governments as well as society at large.

The people and governments of the region must realize that unless good governance is pursued and practised, the cherished goal of harnessing the water resources of the region could well be a day-dream.

Conclusions

The region consisting of the Ganges river basin is inhabited by some of the poorest people of the world, living amidst plenty of natural water resources which have not been harnessed to optimal and sustainable use. One of the main reasons is the lack of political will.

Isolated efforts in each of the countries are continuing, while the holistic and integrated river basin approach has eluded those striving for the optimal and sustained development of the water resources.

Past efforts have not been conducive to the balanced development of the resources, and have been the source of antagonism between the riparian countries. However, the efforts have resulted in some developments on some rivers after long lapses of time (more than 30 years in the case of Nepal and India).

Cooperation and partnership have been fostered on some fronts between/among nations to harness the water resources to uplift the unsatisfactory living conditions of the people of this region. The political atmosphere, at present, seems conducive to pursue such an effort.

Possible schemes to exploit the resources have been identified. Regulatory provisions seem to be evolving, partnership efforts among NGOs and at the academic level have been initiated, and consensus-building activities are continuing.

The time has come to establish a permanent supranational institutions(s) to promote and coordinate effective planning and management of water resources in the Ganges basin. A good governance system in each of the participating basin countries should be instigated. Partnership must be forged. The development of water resources of the region is inevitable and will remain a long-drawn-out affair; it might take as long as a millennium to achieve the desirable level of development, but we must start now.

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