
Water resources development of Nepal: A regional perspective

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Introduction

Nepal is rich in water, and so is the Ganges basin. The world's average water availability is $269,000 \text{ m}^3/\text{km}^2$, whereas water availability in the Ganges basin is $334,000 \text{ m}^3/\text{km}^2$ and that of Nepal is $1,182,000 \text{ m}^3/\text{km}^2$ (Table 7.1). But despite having four times more water availability than the world's average, Nepal has been able to irrigate only 50 per cent of its irrigable land, and only 60 per cent of the population has easy access to drinking water.

More diversions to provide year-round irrigation water will necessitate tremendous investment. Small and medium-size rivers have already been diverted for irrigation. Major rivers such as the Kosi, the Gandak, and the Mahakali have been diverted in the past, and agreements between India and Nepal to facilitate this were also concluded, but those diversions are mainly irrigating Indian land. Similarly, the Karnali has also been diverted by India constructing a barrage in Indian territory. To meet the year-round irrigation demand in Nepalese territory, new diversion schemes have to be implemented on all big rivers; on the one hand, these will require tremendous amounts of financial resources which at present are beyond Nepal's internal capacity, and on the other hand, for those structures being built on transboundary rivers, external investors will seek transboundary understandings before implementation. Calculation shows that Nepal requires only one-third of its total water and two-thirds

Table 7.1 Water availability in the Ganges basin

	Land surface (km ²)	Runoff (km ³ /annum)	Water availability (m ³ /km ² /annum)
Earth	148,900,000	40,000	269,000
Ganges	1,087,300	363 (at Hardinge Bridge)	334,000
Left tributaries of the Ganges			
Nepal and Tibet	180,700	208	1,107,000
Nepal	147,181	174	1,182,000

will flow downstream even after fulfilling the country's whole requirement, but the basic fact is that Nepal is not able to irrigate more than half of its irrigable land by diverting the abundant available surface flows. This syndrome means Nepal will have to develop its groundwater to irrigate the remaining irrigable terai land over the next 15 years on a conjunctive use pattern. It may be a similar situation in India and Bangladesh when year-round irrigation requirements have to be addressed in the Ganges basin area. But if a certain flow discharge is required for maintaining draft in the river for navigational purposes and also for controlling salinity in the coastal area, the situation becomes worse as regards available water for irrigation and other consumptive uses. So not only Nepal but all the partners of the Ganges basin are rich in water resources and poor in its utilization. To overcome this requires enormous financial resources, transparency, understanding, and combined willingness; only then will the Ganges basin, which is rich in water resources, become rich through its utilization.

Water availability

Water availability in Nepal has its own patterns, which have implications for the Ganges basin. The patterns are mainly due to its geographical location, high Himalayan mountain ranges, and seasonal variations. An abundance of water at one time becomes a scarcity at another time. To regulate these variations is a Herculean task. Total annual runoff from all the rivers flowing in and through Nepal is 208 bcm. The Ganges basin generates 502 bcm. The average annual runoff of the Ganges basin is 8,727 m³/ha (Verghese and Iyer 1994) of cultivable land and of Nepal is 77,700 m³/ha. Monsoon flow (June to October) accounts for 85 per cent of the total runoff. Reservoir sites identified in Nepal account for 77 bcm

of live storage capacity which will generate an additional flow of 4,950 cubic metres per second in the dry season (December to May).

Hydrology

Nepal's hydrology can be analysed in terms of river basin flows and groundwater reserves. Precipitation occurs in the form of rainfall and snowfall. Snowfall trapped in the high Himalayas augments the dry-season flows by melting, hence its contribution is accounted for in the Himalayan river flows. Permanent snow lies above 4,500 metres and accounts for 10 per cent of the total precipitation of the country. There is a wide variation of precipitation from east to west. The average annual rainfall is about 1,500 mm in a good monsoon regime. Depending upon the variations of precipitation around the country, flood peaks vary over time.

River basins

The quantum of water available in Nepal has to be analysed on the river basin approach, taking into account river flow characteristics. Rivers are grouped into three categories depending upon their origin and seasonal discharge variations: Himalayan rivers; Mahabharat rivers; and Churia rivers.

Himalayan rivers

Himalayan rivers are snowfed rivers and their dry-season flows are augmented by snow melts. The snow-capped Himalayas work as a reservoir and release their water in the dry season. High dry-season flows are needed for irrigation and other consumptive purposes, but only 15 per cent of the total amount of water is available during the dry season in comparison to 85 per cent of water available in the monsoon season. But the cost of diversion structures on these rivers is tremendous and hence it has not been possible to utilize the dry-weather flows to their maximum in Nepalese territory. The rivers that fall into this group are the Kosi, Gandaki, Karnali, and Mahakali. The ratios of maximum monthly flows to minimum monthly flows in the Kosi, Gandaki, Karnali, and Mahakali rivers are 15:5, 19:0, 14:3, and 11:2 respectively. If instantaneous flows are taken into account the ratios will be much more. In the case of the Karnali river it is about 130:1. Hence, the construction cost of the diversion structure will be many times more than the cost of diversion structures which can be constructed on regulated rivers. Construction of reservoirs in upstream reaches will drastically decrease the maximum design discharge. The total annual reserving capacities of the Mahakali, Karnali,

Gandaki, and Kosi river basins are estimated to be 7 bcm, 34 bcm, 18 bcm, and 14 bcm respectively. The mean monthly flows of Himalayan rivers are shown in Table 7.2.

The discharge in the monsoon season from June to October accounts for 82 per cent of the whole quantum of flow. Dry-weather flow, although appreciable for Nepalese consumptive requirements, is difficult to utilize. These rivers contribute significantly to the dry-weather flow of the Ganges river. High dams constructed on these rivers will augment the Ganges water by 170 per cent in the dry season, and lower riparian countries would benefit tremendously. The annual water volume flowing from these rivers is 176 bcm, which is 85 per cent of the total water available from Nepalese territory.

Mahabharat rivers

The Mahabharat rivers originating from the Mahabharat hills (mid hills) are not snowfed, hence dry-season flow is basically due to groundwater recession. The main rivers in this category are the Kankai, Kamala, Bagmati, West Rapti, and Babai. The total stream flow is 18 bcm, of which 87 per cent flows in the monsoon season (June–October). The percentage of dry-weather flow is less compared to Himalayan rivers. The basin areas of these rivers, especially the river valleys, are thickly populated and hence there are no feasible storage sites except on the Kankai. The water from these rivers contribute 9 per cent of the annual Nepalese flow. Table 7.3 shows the average monthly water availability from Mahabharat rivers.

Churia rivers

There are numerous seasonal rivers originating from the Churia hills which flow in Nepal or through to India. Due to the highly permeable character of the catchment area, dry-season flow becomes non-existent in many of these rivers, and only a few have a small amount of water flowing in the dry season. The total volume of water available in these rivers is estimated to be about 14 bcm, out of which 91 per cent flows in the monsoon season. Flood discharges are flashy in nature, and carry heavy silt during the monsoon period. There are no reservoir sites on these rivers, so monsoon flows in excess of water utilized for irrigation purposes cannot be stored for future utilization. Table 7.4 shows the volume of water available from the Churia rivers, which contribute only 6 per cent to the annual Nepalese flow. The dry-season flows where available and part of the monsoon flows have already been utilized traditionally by the farmers. The main fertile terai land lies in the catchment areas of these rivers.

The available monthly flow from all these rivers combined is shown in Table 7.5. The flow available during the monsoon season from June

Table 7.2 Mean monthly flows of Himalayan rivers (million cubic metres)

River	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mahakali	514	433	458	540	817	1,665	4,852	4,091	4,426	1,773	676	607	20,852
Karnali	1,015	832	954	1,177	1,928	4,046	9,106	11,884	7,960	3,576	1,672	1,224	45,374
Narayani (Gandaki)	1,063	784	801	1,016	1,679	4,720	12,883	14,903	10,052	4,786	2,317	1,450	56,454
Kosi	1,074	837	921	1,185	2,041	4,710	11,999	12,937	9,272	4,382	2,250	1,497	53,105
Total monthly flow	3,666	2,886	3,134	3,918	6,465	15,141	38,840	43,815	31,710	14,517	6,915	4,778	175,785
Monsoon flow from June to October	144,023 (82% of annual discharge) (85%)												

Table 7.3 Mean monthly flows of Mahabharat rivers (million cubic metres)

January	February	March	April	May	June	July	August	September	October	November	December	Annual
250	204	186	176	294	1,604	4,520	4,696	3,619	1,505	564	352	17,970
Monsoon flow from June to October												15,944 (87% of annual discharge)

Table 7.4 Mean monthly flow of Churia rivers (million cubic metres)

January	February	March	April	May	June	July	August	September	October	November	December	Annual
228	143	128	110	123	765	3,058	5,654	2,369	1,297	386	259	14,520
Monsoon flow from June to October										13,143	(91% of annual discharge)	

Table 7.5 Available monthly flow from all Nepalese rivers (million cubic metres)

January	February	March	April	May	June	July	August	September	October	November	December	Annual
4,144	3,233	3,448	4,204	6,882	17,510	46,418	54,165	37,698	17,319	7,865	5,389	208,275
Monsoon flow from June to October										173,110	(84% of annual discharge)	

to October accounts for 84 per cent of the total annual available discharge.

Groundwater

Groundwater is mainly available in the south of Nepal (the terai area), which is part of the Ganges alluvial plain. The extraction of groundwater in mountainous regions is not technically and economically feasible. The annual groundwater availability is 11,598 million cubic metres, as shown in Table 7.6; 76 per cent of its volume can be extracted for consumptive purposes. This volume will meet 14 per cent of the irrigation requirements of the terai area. Since groundwater contributes to the dry-season river discharge, extraction of groundwater means diminishing the dry-season flow in the river. These environmental considerations have an impact on the level of groundwater extraction. To keep the groundwater table within the limits, so that no waterlogging is created in the irrigable area and also a minimum river discharge is maintained for ecological purposes, proper limitations have to be imposed. Similarly, groundwater extractions have to be limited to allow salinity control in the coastal area. As groundwater contributes to the river flow, in terms of total water availability it cannot be counted separately.

Water requirements

Water requirements have to be analysed for both the present pattern and future projections. The present methodologies adopted for conveyance systems and usage patterns may not be applicable in the future, and present uses cannot be directly related to the future patterns. For example, currently open unlined channels may be lined in the future, or distribution systems at field levels may be through buried pipes. Similarly, domestic as well as industrial water requirements may change depending upon future consumption patterns. The total projected annual water requirement for future use is 64 bcm.

Irrigation

Irrigation requirements constitute the largest percentage of the whole consumptive requirement. As the irrigation water requirement depends upon cropping patterns, presently cultivation of paddy is consuming the greatest share. The cultivation of paddy, wheat, maize, oilseeds, vegetables, sugarcane, and jute, which are dominant crops at present, will also continue in future. The future requirement for year-round irrigation

Table 7.6 Recharge of shallow and deep aquifers in terai areas of Nepal

Zone	Gross area (km ²)	Estimated area of <i>bhabar</i> (km ²)	Surface area (km ²)	Arable land for irrigation (km ²)	Recharge to <i>bhabar</i> (million m ³)	Recharge shallow aquifer (million m ³)	Total recharge (million m ³)
Mahakali	1,273	125	1,148	1,121	80	421	501
Seti	1,876	244	1,632	1,599	157	646	803
Bheri	2,528	369	2,159	2,109	165	492	657
Rapti	2,995	437	2,558	783	144	842	986
Lumbini	4,841	625	4,216	3,162	681	1,994	2,675
Narayani	5,032	743	4,289	3,693	433	1,222	1,655
Janakpur	2,870	394	2,476	2,213	241	532	773
Sagarmatha	2,687	475	2,212	1,712	304	721	1,025
Koshi	2,648	344	2,304	1,889	296	1,028	1,324
Mechi	1,716	258	1,458	1,219	260	939	1,199
Total				19,500	2,761	8,837	11,598

Table 7.7 Irrigation water requirements – Nepal

Terai				
Months	East (area 981,851 ha)		West (area 761,513 ha)	
	Diversion requirement per 1,000 ha (million m ³)	Volume required (million m ³)	Diversion requirement per 1,000 ha (million m ³)	Volume required (million m ³)
January	1.477	1,450	1.612	1,228
February	1.775	1,743	1.868	1,422
March	3.061	3,005	2.934	2,234
April	4.406	4,326	2.443	1,860
May	3.277	3,218	1.076	819
June	1.524	1,496	1.600	1,218
July	1.819	1,786	1.295	986
August	2.932	2,879	1.468	1,118
September	1.529	1,501	1.363	1,038
October	2.589	2,542	2.405	1,831
November	2.219	2,179	2.403	1,830
December	1.254	1,231	1.394	1,062
Total		27,356		16,646
Annual requirement				44,002
Hill				
Months	East (area 187,547 ha)		West (area 186,201 ha)	
	Diversion requirement per 1,000 ha (million m ³)	Volume required (million m ³)	Diversion requirement per 1,000 ha (million m ³)	Volume required (million m ³)
January	1.294	243	1.410	263
February	1.598	300	1.518	283
March	3.219	604	2.625	489
April	3.080	578	2.115	394
May	1.783	334	0.860	160
June	4.496	843	3.610	672
July	5.969	1,119	5.668	1,055
August	5.278	990	6.070	1,130
September	5.923	1,111	5.019	935
October	7.611	1,427	6.212	1,157
November	3.694	693	3.985	742
December	0.577	108	0.557	104
Total		8,350		7,384
Annual requirement				15,734

Table 7.7 (cont.)

Months	Mountain			
	East (area 32,905 ha)		West (area 28,133 ha)	
	Diversion requirement per 1,000 ha (million m ³)	Volume required (million m ³)	Diversion requirement per 1,000 ha (million m ³)	Volume required (million m ³)
January	1.189	39	0.979	28
February	1.908	63	1.380	39
March	2.294	75	1.618	46
April	0.911	30	0.737	21
May	2.342	77	1.740	49
June	6.118	201	4.989	140
July	5.569	183	5.244	148
August	4.693	154	5.498	155
September	5.857	193	4.939	139
October	5.588	184	4.465	126
November	2.673	88	2.713	76
December	1.225	40	0.918	26
Total		1,327		993
Annual requirement				2,320

Source: Canadian International Water and Energy Consultants/East Consult 1989

will be 62 bcm annually, which represents 98 per cent of the total water requirement. Hence, if savings are to be made, cropping patterns and existing methodologies for water conveyance and field application have to be addressed. This will certainly require more investment. To make it economically viable the price of produce also has to be investigated.

The total irrigation water is not lost: 50 per cent of water flows into the groundwater reserves as a return flow and augments the river flows, but this occurs mainly on the downstream side. Volumes can only be evaluated by a total basin water-balance study, which is of great importance when assessing the total consumptive demand of the basin. The future water requirements for irrigation, based on ecological regions and total water requirement, are given in Tables 7.7 and 7.8. The total irrigable land available by region and by ecological belt is shown in Tables 7.9 and 7.10. Comparison reveals that numerous water sources are available in the mountains lying in the catchment of Himalayan rivers, whereas most of the irrigable land lies in the catchment of the Churia rivers where there is a scarcity of water.

Table 7.8 Total monthly irrigation water requirement (million m³)

Ecological belt	January	February	March	April	May	June	July	August	September	October	November	December	Total
Terai	2,678	3,165	5,239	6,186	4,037	2,714	2,772	3,997	2,539	4,373	4,009	2,293	44,002
Hill	506	583	1,093	972	494	1,515	2,174	2,120	2,046	2,584	1,435	212	15,734
Mountain	67	102	121	51	126	341	331	309	332	310	164	66	2,320
Total	3,251	3,850	6,453	7,209	4,657	4,570	5,277	6,426	4,917	7,267	5,608	2,571	62,056

Source: Canadian International Water and Energy Consultants/East Consult 1989

Table 7.9 Irrigable area by region – Nepal

Region	Terai (ha)	Hill (ha)	Mountain (ha)
Eastern	442,262	77,533	14,760
Central	539,589	110,014	18,145
Western	282,712	99,084	280
Mid-western	245,679	50,962	12,480
Far western	233,122	36,155	15,373
Total	1,743,364	373,748	61,038
Grand total			2,178,150

Source: Canadian International Water and Energy Consultants/East Consult 1989

Table 7.10 Irrigable area by ecological belt – Nepal

	Eastern (ha)	Western (ha)	Total (ha)
Terai	981,851	761,513	1,743,364
Hill	187,547	186,201	373,748
Mountain	32,905	28,133	61,038

Source: Canadian International Water and Energy Consultants/East Consult 1989

Domestic, commercial, and industrial

The future water requirement for drinking purposes and other commercial and industrial uses, according to recent reports, is 1.4 bcm annually, which is nearly 2.3 per cent of future irrigation requirements (Tables 7.11 and 7.12). Though domestic water requirements seem to be small in comparison to future water availability, the hard fact is that there is an acute scarcity of water in hill and mountain areas, and also in Kathmandu valley, mainly because the population concentration is away from the available water sources. It will require great effort and investment to provide easy access to potable drinking water to the future population.

Navigation

Navigation is quite important for Nepal's economy as transportation costs are drastically reduced if goods are transported via water routes. Being a landlocked country, having navigational routes would be a lifeline for Nepal. India has already declared that the Ganges will be a navigable river from the sea up to Allahabad. Nepal can be connected to the Ganges along the Kosi, Gandak, and Karnali rivers for navigational pur-

Table 7.11 Projection of rural daily domestic water requirement for 2026

Region	Population (000)	Domestic (m ³)	Livestock (m ³)	Students (m ³)	Health centre (m ³)	Healthpost (m ³)	Total (m ³)
Eastern	5,915	354,900	70,980	11,830	112	3,914	441,736
Central	9,253	555,180	111,036	16,822	133	6,547	689,718
Western	6,485	389,100	77,820	16,216	112	5,028	488,276
Mid-western	4,019	241,140	48,228	6,927	105	3,059	299,459
Far western	2,009	120,540	24,108	2,513	63	1,534	148,758
Total							2,067,947
Monthly future water demand		62.9 million m ³					
Annual future water demand		755.0 million m ³					

Source: Sharma 1996

poses. Though river routes, being natural routes, incur less cost for land acquisition and lower construction costs, river cross-sections which have stabilized to accommodate high flood discharge generate less draft during dry-weather flows and bigger ships cannot move. Hence, to maintain greater depth in the river a higher flow is needed. One way to minimize river flow and maintain draft is by providing locks as and where appropriate. A second alternative can be a controlled separate navigational channel, as mentioned in earlier literature. A non-consumptive water-use alternative should be discussed rather than a flowing water alternative required for maintaining the river draft. More joint studies are needed to reach an agreeable solution.

Salinity control

Salinity can be viewed as two separate problems, one due to use of fertilizers and pesticides in irrigated areas, and the other arising in coastal areas. In Nepal, high monsoon flows and comparatively steeper ground slopes accelerate the leaching effect of the salt and hence excess salinity is not a noticeable problem. In the Ganges basin, salinity has to be addressed in the coastal areas. The main countermeasure is to maintain a particular groundwater level and slope. This necessitates a controlled extraction of groundwater during dry weather, and recharging groundwater by diverting water for irrigation uses and also by maintaining a certain water level in the rivers near coastal areas. Maintaining water depth by water flow during the dry season demands high volumes of water, hence serious research work must be done to arrive at an economical and amicable solution.

Water requirement – a regional perspective

Spatial and temporal variation

From the graph shown in Figure 7.1 it is evident that the available water concentration is in monsoon season. Diverting water which is available in Himalayan rivers involves high construction costs, hence rivers have not been diverted for the maximum benefit of the irrigable land in Nepal. Diversions have been built in the Kosi as part of the Sunsari-Morang irrigation project and the Kosi pump canal scheme (irrigated area 71,000 ha). From the Gandak river 40,000 ha of land is being irrigated; similarly, the Mahakali river irrigates 11,000 ha of land. The terai area, which has 1.7 million ha of irrigable land (80 per cent of total land), can get water for irrigation only from the Mahabharat and Churia rivers, which cannot

Table 7.12 Projection of urban and industrial daily water requirement

Town	1996 pop.	Demand (million litres/day)	2001 pop.	Demand (million litres/day)	2011 pop.	Demand (million litres/day)	2026 pop.	Demand (million litres/day)
Kathmandu	562,981	93.2	752,383	127.1	1,343,785	237.2	3,207,495	599.3
Biratnagar	151,838	25.1	178,184	30.1	245,382	43.3	396,555	74.1
Lalitpur	139,411	23.1	167,742	28.3	242,846	42.9	423,023	79
Pokhara	135,895	22.5	193,811	32.7	394,210	69.6	1,143,539	213.7
Birganj	86,850	14.4	109,309	18.5	173,154	30.6	345,219	64.5
Dharan	83,643	13.8	105,273	17.8	166,760	29.4	332,472	62.1
Bharatpur	76,808	12.7	107,912	18.2	213,005	37.6	590,704	110.4
Mahendranagar	73,917	12.2	88,053	14.9	124,953	22.1	211,229	39.5
Bhaktapur	69,234	11.5	78,061	13.2	99,235	17.5	142,237	26.6
Janakpur	68,515	11.3	85,802	14.5	134,565	23.8	264,290	49.4
Hetauda	67,084	11.1	83,592	14.1	129,793	22.9	251,123	46.9
Dhangadi	57,464	9.5	73,785	12.5	121,651	21.5	257,536	48.1
Nepalgunj	56,680	9.4	67,183	11.3	94,389	16.7	157,185	29.4
Damak	53,430	8.8	69,087	11.7	115,512	20.4	249,728	46.7
Butwal	52,739	8.7	62,825	10.6	89,153	15.7	150,709	28.2
Bhairawa	52,228	8.6	69,104	11.7	120,979	21.4	280,232	52.4
Tribhuvanagar	34,433	5.7	40,814	7.7	57,341	10.1	95,490	17.8
Birendranagar	29,646	4.9	38,257	6.5	63,709	11.2	136,909	25.6
Rajbiraj	29,443	4.9	35,783	6	52,851	9.3	94,866	17.7
Tulsipur	26,986	4.5	32,148	5.4	45,620	8.1	77,118	14.4
Inarwa	23,180	3.8	28,971	4.9	45,255	8	88,350	16.5
Gaur	22,799	3.8	25,437	4.3	31,665	5.6	43,978	8.2
Lahan	22,430	3.7	26,453	4.5	36,796	6.5	60,364	11.3
Byas	22,041	3.6	24,141	4.1	28,960	5.1	38,050	7.1
Kalaiya	20,525	3.4	22,775	3.8	28,041	5	38,308	7.2
Taulihawa	20,442	3.4	24,400	4.1	34,765	6.1	59,122	11
Bidur	19,692	3.3	20,743	3.5	23,016	4.1	26,902	5

Jaleswor	19,274	3.2	20,537	3.5	23,319	4.1	28,212	5.3
Dhankuta	18,963	3.1	21,063	3.6	25,984	4.6	35,605	6.7
Bhadrapur	18,953	3.1	23,617	4	36,670	6.5	70,948	13.3
Malangwa	16,162	2.7	18,470	3.1	24,123	4.3	36,005	6.7
Ilam	15,333	2.5	17,814	3	24,047	4.2	37,712	7
Dipayal	14,090	2.3	16,062	2.7	20,873	3.7	30,922	5.8
Tansen	13,874	2.3	14,154	2.4	14,732	2.6	15,643	2.9
Banepa	13,731	2.3	15,040	2.5	18,042	3.2	23,705	4.4
Dhulikhel	11,630	1.9	13,785	2.3	19,368	3.4	32,253	6
Total	2,202,344	364.3	2,772,570	469.1	4,464,549	788.3	9,473,738	1,770.2
Monthly future water demand			53.84 million m ³					
Annual future water demand			646 million m ³					

Source: Bhattarai 1996

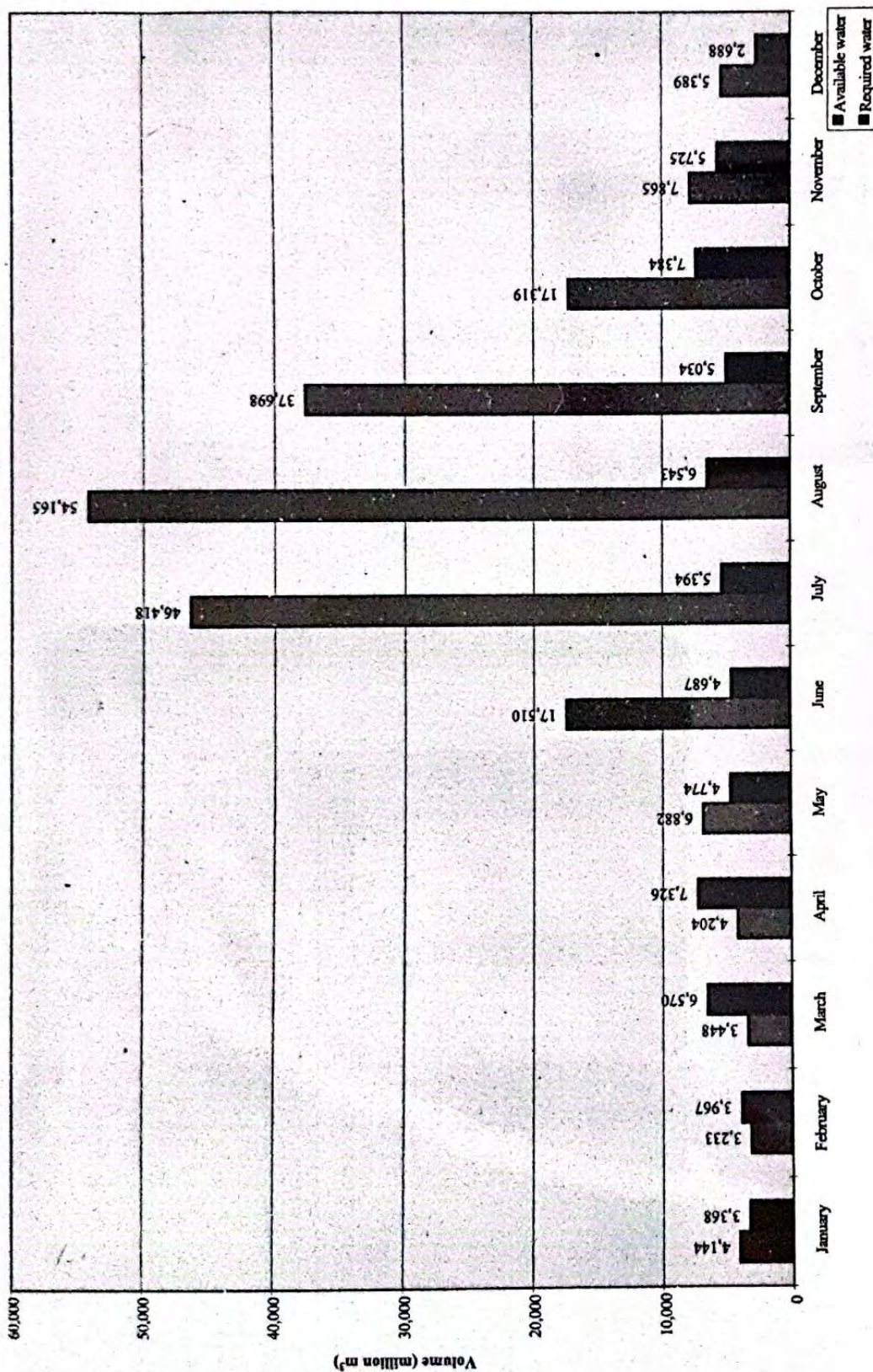


Figure 7.1 Monthly water requirement versus availability

supply year-round irrigation. Only about 50 per cent of presently irrigable land receives year-round irrigation. Almost all the dry-season water of the Mahabharat and Churia rivers is utilized in Nepalese territory, hence water downstream by surface flow becomes scarce. India has invested considerably in irrigation projects, and diversion structures have been constructed on many small rivers where there is a scarcity of water in the dry season. It would have been wise to have a joint dialogue before investing in these projects. If one major project with storage facilities had materialized, this would have been far more beneficial than having many small projects without water. Even the huge investment in the Kosi and Gandak projects, if analysed economically, will raise many questions. Regulation of flow is a must for optimization of net benefits.

Like seasonal variations of water flow, spatial variation of availability is imposing serious problems. In the Kathmandu valley round-the-clock water supply has not been possible and at present only 71 per cent of inhabitants get a water supply. In the hills many people have to walk for hours to fetch water for their daily requirements. Hill valleys are situated at such an elevation that gravitational water diversion imposes serious technical and economical problems. Simpler water diversion schemes, whether in the hills or the terai, have already been developed by the farmers themselves. Only diversion schemes which are technically more difficult and require more investment remain to be implemented. In the hills diversion of water for irrigation purposes has an adverse effect on slope stability. The abundance of water is thus not translated into an abundance of available water. Spatial and temporal variations in the availability of required water impose great constraints on overall development activities, especially that of agriculture, which is the major source of GDP.

Here it is appropriate to mention that when studying future demand for consumptive water for Nepal, it is easy to see that the dry-weather flows of Himalayan rivers are almost totally required for utilization within Nepal itself. The cropping pattern envisaged in the master plan for irrigation development in Nepal (Canadian International Water and Energy Consultants/East Consult 1989) shows a scarcity of water during February, March, and April of almost 40 per cent (see Figure 7.1), thus even Nepal's future requirement cannot be fulfilled by the available water in those months. This will certainly necessitate storage projects upstream.

Value-added augmentation

Any augmentation of the natural available water flow will require substantial investment. Investment in the present context of the world econ-

omy will require maximization of net benefits. For maximization of net benefits, basin development on a regional basis becomes inevitable. Country boundaries vanish and the river basin becomes a single unit. Lessons can be learned from the past. Major projects have been constructed where benefits were limited within a single country boundary; had those been developed on a maximization-of-benefits principle, maximum return would have been realized in terms of hydropower, irrigation, navigation, and flood control. But this cannot be achieved unless the countries involved have a will to work together and share all the achievable benefits accruing from a project. This will certainly involve sharing the cost in proportion to the benefits accruing, and every cumec of augmented flow will require the sharing of costs between the countries which utilize the water. But evaluation of benefits is very difficult. All the regional partners have to agree on the principle of evaluating the benefits, sharing the benefits, and sharing the cost.

Constraints

Augmentation of flow means creation of reservoirs in suitable locations. Nepal has very suitable reservoir sites which can store about 77 bcm of water and generate an average flow of $4,950 \text{ m}^3/\text{sec}$ in the dry season from December to May. A tremendous amount of benefit will accrue from this. But at what cost? Cost does not only include investment in physical facilities cost, but also the hazards associated with the development of the project, such as submergence, population displacement, increase in seismicity, ecological changes, and other environmental impacts. All hazards associated with these projects are borne by the country where the development takes place, and a proper mechanism should be formulated to account for them. Not only that, but natural resources have to be valued according to the availability of alternatives in the market for those resources, so that a proper justification can be given for valuing the benefits arising out of the resource. When we talk about augmentation of flow, catchment improvement schemes also have to be considered. Presently, the water carries thousands of tonnes of sediment through the rivers into the sea, which has an adverse effect on the storage capacity of the reservoirs, channel capacity, river erosion, navigational characteristics of the rivers, and other factors. Catchment improvement thus has to be thought of as a part of any reservoir project.

Diversification of water utilization

Present water use, whether for irrigation, navigation, or coastal salinity control, has to be readdressed. For consumptive use, irrigation water is the main requirement. Cropping patterns can be readdressed depending

upon the future food grain requirement and the possibility of export and import of food grain to and from other countries. The efficiency of irrigation can be improved by providing lined channels and buried-pipe distribution systems, sprinkler irrigation, and other methods of providing irrigation water.

For navigation use, a network of navigational waterways, whether through rivers or channels, has to be considered. Instead of maintaining draft by flowing water, navigational locks are an alternative. This will certainly require huge investment, but the possibility cannot be ignored. Detailed joint study with an exchange of data will be needed.

For salinity control in the coastal areas, the fresh water front has to be maintained at certain level depending upon the sea water levels. River locks to maintain fresh water fronts can be a solution. A study has to be conducted. Similarly, for controlling the advancement of the saline front, groundwater extraction has to be controlled. Upstream groundwater extraction may not have any impact on the saline fresh water front, but will certainly decrease the dry-weather river flow.

Waste water can be treated and reutilized, which will be better for environmental purposes. Reutilization can be considered for irrigation purposes.

Power development

The hydropower potential of Nepal has been estimated to be about 83,000 MW, out of which 42,000 MW has been identified as economically feasible. Hydropower development is associated with the development of multipurpose projects which also generate irrigation, flood control, and navigation benefits. The flow augmentation from multipurpose projects will meet the dry-season demand of Nepal and will also augment the flow of the Ganges. The electricity demand of Nepal by 2025 is projected to be nearly 1,700 MW, so there will be a vast surplus which can be made available in the region to multiply the growth rate in several sectors, including industry, agriculture, and tourism.

Hydropower should be visualized as an eco-friendly energy source which also provides peaking energy. It is a replenishable source of energy which, if utilized, will keep in reserve the finite energy sources such as coal and gas.

In the regional concept, power generation and high-voltage transmission lines can be planned, so that eco-friendly hydropower can be transmitted in the region to stimulate economic growth as a whole. Sitting on this vast potential source of energy without utilizing it will hinder future growth. This region, one of the poorest in the world, will remain so in future unless the countries involved work together.

Multipurpose hydropower projects need huge investment which is dif-

ficult to generate from within the region (Nepal, India, Bangladesh, and Bhutan), so private developers have to be called for. Private developers are mainly interested in selling electricity and seeking returns on energy sales. Other benefits such as irrigation, flood control, and navigation are not their immediate concern. So to achieve these benefits all the riparian countries have to agree, and a benefits-sharing principle should be worked out accordingly. Unless this is done, electricity will not be available at a cheaper rate and the full potential benefits cannot be realized.

Multiple trade-offs

Benefits from multipurpose water resources development projects should not only be shared on their own virtues, but can also be traded for other benefits needed by each riparian country. For example, Nepal needs navigational routes to sea and simpler trade and transit facilities. Indian needs more hydropower and water for its consumptive use, mostly for irrigation purposes. The vast fertile lands of the Ganges plain require huge amounts of water for year-round irrigation and inland navigation. Similarly, Bangladesh requires water for irrigation, navigation, and salinity control of coastal areas. So multimodal benefits should be shared according to individual countries' needs. This approach will help the countries concerned in their overall economic growth.

Regional understanding – a compulsion and not an option

Analysing the overall developments of water resources in the Ganges basin, there can be no option other than having a strong, effective, trustworthy regional understanding among the riparian countries. It calls for basin development and not development within individual countries. As has already been explained, there is a abundance of water from the total availability point of view, but at the same time there is temporal scarcity. In the past there has been acrimony over sharing water in the dry season when demand for water in the basin exceeded its availability. During the monsoon season when there is abundance, the heavy floods are detrimental to all parties. So there is a problem around the year, and in the present age of technological development regional understanding has become a compulsion and not an option. Future generations cannot be sustained without resolving these issues. Doubling of the population, water requirements, food grain requirements, and the deterioration of the environment in the coming decades are threatening us; we must act now or prepare for mass destruction. So regional cooperation and understanding is a must, and we cannot say "no". Such cooperation can be achieved at two levels: political and bureaucratic.

Politicians or people's representatives are the policy-makers. They are aware of the people's hardship and of national priorities. They should be made aware of the realities and policy frameworks should be agreed upon by high-level politicians. This policy guidance should be specific up to workable limits. But the desires of high-level politicians do not necessarily translate into actions. Policy matters unresolved at bureaucratic levels should be taken care of at political levels. Politicians of every side should have the logic behind the arguments of other sides explained to them, so that they talk openly.

Bureaucrats know the details of the issues more clearly and in more depth than politicians. In the past, negotiations have been held mostly at bureaucratic level, and have concentrated on theoretical discussions on minor issues without a practical outlook. Had this not been the case, we would not have been talking about these vast potential water resources for over four decades while there continued to be acute scarcity of water and energy. Whatever water diversion treaties were agreed upon were not accepted by people at large as balanced treaties. But now the realization has come. Treaties on the Mahakali river and Farakka barrage have shown positive signs that all the partners feel comfortable. But the bureaucratic hangover is still there, and few things are yet clarified. But people need the water resources potential to be exploited, as without this living conditions will deteriorate day by day and stagnation of economic growth may take place due to the increasing population. So an institution has to be created where overall Ganges basin development matters can be discussed, data exchanged, research and studies conducted, and further policies enumerated. At present discussions on the hydrological data, water availability, and effects of dry-weather flows are all developed by single sides and have not generated full trust. Even the hydrological data which are available are not very dependable and require further refinement. To develop trust among the parties, exchange of data, confirmation of data, and analysis of data are very important, otherwise doubt will continue. So let us create a common forum, discuss common goals, and achieve these jointly.

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Water resource development and the environment in Bhutan

Somnath Mukherjee

Introduction

Small is beautiful, and Bhutan demonstrates this. Half of the size of Arunachal Pradesh, Bhutan exudes charm. Its magnetic mountains, virgin forests, delightful people, and crystalline air invoke surrealism. Stretching from lush humid forests in the south to dry alpine steppe in the north, Bhutan is home to some of the best remaining representatives of Himalayan wildlife and habitat, and is considered one of the global "hot spots".

Buddhism has imbued a strong sense of respect for all forms of life, and thus conservation is not a new concept to Bhutan. But modern development is, at least in the way most people conceive of it. Surrounded by developing countries with desires for material luxuries, Bhutan cannot keep itself aloof from the process of development. But development needs money, and the small country of Bhutan, with limited resources, has little to sell except timber, hydropower, and tourism to raise the major part of the finance required for development. Bhutan, however, will have to tread cautiously in the new century to balance the development of environmental resources and the development process itself to make it sustainable.

This chapter makes an attempt to assess the potential of water resource development in Bhutan, and its environmental implications in the perception of the author.

Table 8.1 Catchment and subcatchments in Bhutan

Catchment	Subcatchment	Area (km ²)
Torsa	Jaldhaka	3,486.40
	Torsa	1,021.35
Raidak		2,465.05
		4,954.03
	Ha	976.69
	Paro	1,040.82
	Wongchu	1,365.80
Sankosh	Raidak	1,242.50
		10,434.16
Mao		1,856.28
Mangde Chu		75,522.63
	Mangdechu	4,444.20
Manas	Bumthang	3,079.43
		9,562.08
	Kuru	4,052.86
	Sheri	378.20
	Khulanchu	1,806.38
	Gawri	1,162.80
	Manas	1,771.94
	Diuri	390.50
Nyera		1,568.86
Dhansiri		865.56

Source: Negi 1983

The water resource scenario

The whole of Bhutan forms a part of the Brahmaputra basin. The main rivers forming the watershed catchment of Bhutan are the Torsa, Raidak, Sankosh, Mao, Manas, Nyera, and Dhansiri. The largest catchment area is that of the Sankosh. Table 8.1 shows the catchment and subcatchment areas of rivers, and Figure 8.1 shows the catchments on a map.

Except the Mao, Nyera, and Dhansiri, all the rivers representing the major catchments of Bhutan receive water from the high Himalayan glaciers. In recent times the phenomenon of global warming has been particularly evident in Bhutan and has caused enormous damage to the environment, life, and property. Due to global warming, the glacial snouts recede, leaving large quantities of morainic material and water. The water often gets banded by a morainic "dam". As the quantity of water increases due to further melting of glaciers, the morainic dams burst, resulting in the sudden release of large quantities of water into the nearby tributaries. The water flows down with great ferocity, causing havoc downstream. The Sankosh in particular is susceptible to such glacial bursts. During a glacial burst in 1994, hundreds of thousands of trees got

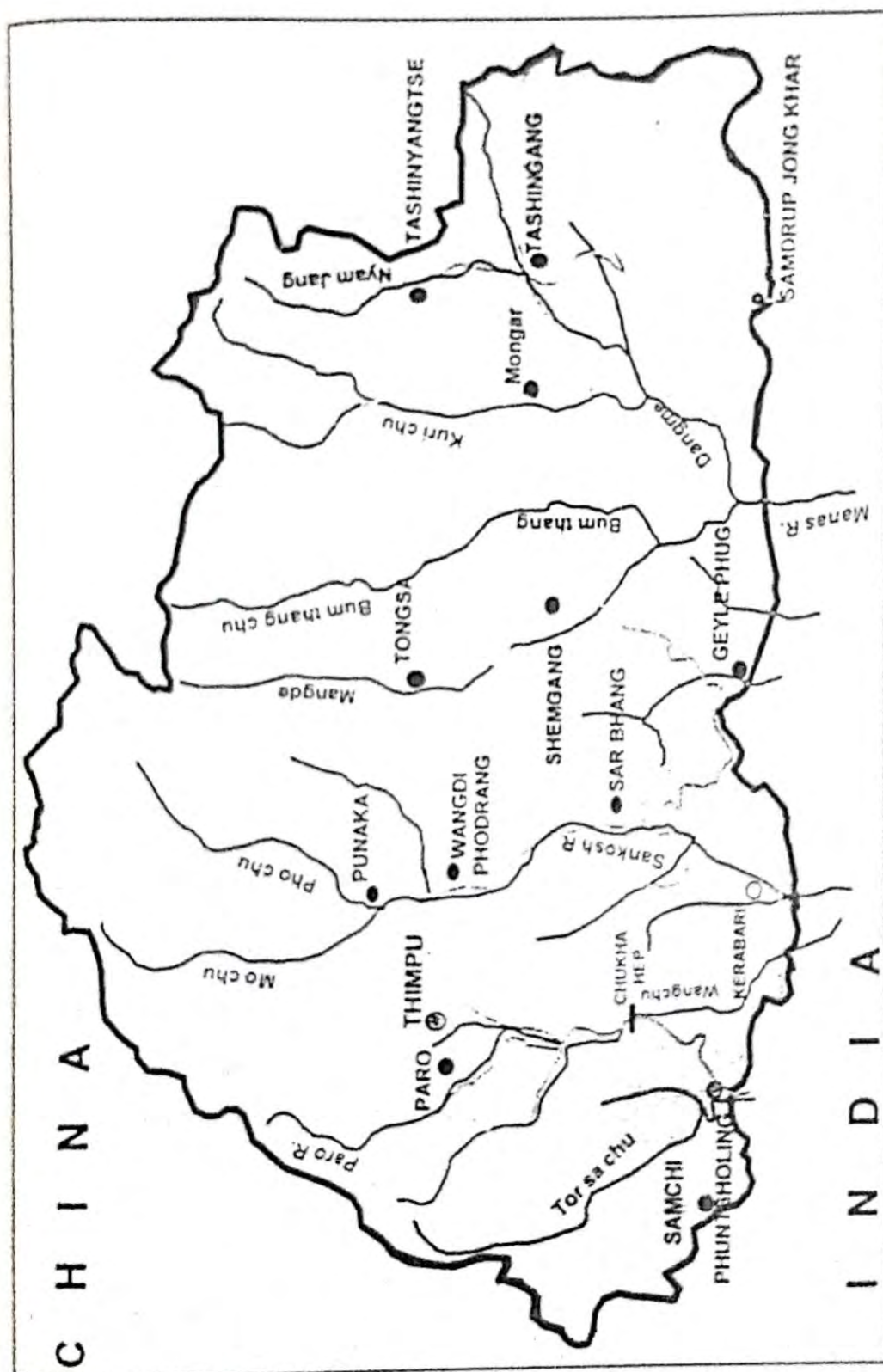


Figure 8.1 Bhutan river basins

washed away, innumerable cattle were killed, human life was lost, large tracts of agricultural fields along the valleys were engulfed, and part of Punakha *dzong* (district), probably the most sacred *dzong* in Bhutan, was destroyed.

The groundwater potential of Bhutan has not been investigated. There was some effort with Japanese assistance to estimate the groundwater potential in southern Bhutan at the beginning of the 1990s. A few test wells were planned, but had to be abandoned due to socio-political problems. However, the rural areas rely heavily on springs for domestic and irrigation use.

The quality of surface water is generally excellent. Due to higher gradients and cascades the DO (dissolved oxygen) levels are extremely high. As the population is scanty and scattered, the point source of untreated domestic effluent is negligible and therefore the BOD (biochemical oxygen demand) is minimal.

Bhutan does not have many large industries, and therefore the problem of water pollution due to effluents does not arise. Farmers use little or, in most cases, no fertilizer or pesticide, and water is free from pollutants that are commonly encountered in agricultural areas.

The majority of the rivers which originate in Bhutan flow through India and transverse through Bangladesh. The path Bhutan adopts for water resource development thus has implications in India and Bangladesh with respect to quantity and quality of available water.

Water-use potential

Availability of water is not a constraint in Bhutan – it is a country of springs, rapids, and rivers. But the basic problem relates to harnessing the water for various uses. The population density of Bhutan is extremely low and scattered. A small and scattered population means that the per capita cost of delivery of the resource to consumers is extremely high. In spite of this, Bhutan has done reasonably well in the water resource sector.

Most impressive is probably the drinking-water supply: the majority of the rural population have a piped water supply. Spring water is stored at a higher elevation in a cement tank, and water is supplied through gravity to the consumers by pipes. Since the source is at a higher elevation and mostly in remote locations, contamination of water is rare; only a few incidents of faecal contamination of the piped water supply have been reported. The most notable and recent water contamination happened in Chukha in 1994, when faecal contamination at the source resulted in an outbreak of cholera in the area. But with few exceptions, the quality and quantity of water supply is reasonably good and the way the water supply system is being managed needs to be appreciated.

Table 8.2 Major land-use categories in Bhutan

Land-use category	Area (km ²)	%
Perpetual snow	4,006.30	10.0
Barren exposed rocky areas and scrubland	3,762.64	8.7
Water spreads	522.92	1.3
Agricultural land, including settlements and orchards	3,558.74	8.8
Forests, including alpine pastures, and temperate and tropical forests	24,290.37	67.0
Degraded forest	1,415.90	3.0
Plantations	27.38	0.1

Source: Negi 1983

Major land-use categories in Bhutan are shown in Table 8.2. About 8.8 per cent of the land in Bhutan is under agricultural use (including orchards and settlements). The data (Dorji 1992) show that about 25 per cent of the cultivable land is irrigated and devoted mainly to paddy cultivation. Another 14 per cent of the cultivable land is under orchards, and about 1 per cent constitutes kitchen gardens. Shifting cultivation constitutes a prominent proportion and accounts for about 30 per cent of the agricultural land, occurring mainly in the rainfed areas. Per capita land and forest distribution in rural areas are shown in Table 8.3.

All over Bhutan, agricultural lands are scattered through small settlements. Terraced land mostly produces paddy. Much permanently used rainfed land is often not terraced, and therefore the use of water is not optimal. However, lack of water, as such, is not a constraint. What is a constraint is water management in terms of irrigation development and associated development of land by terracing.

Because of the geomorphologic characteristics, Bhutan has a good hydropower potential. The first hydro-electric power plant of 360 kW was commissioned in 1967 at Samtelingchu in Thimpu valley. So far only about 1.7 per cent of the total estimated theoretical potential of 20,000 MW has been harnessed (Tamang 1993). Bhutan at present has 11 hydro-electric stations with an installed capacity of 341.75 MW, out of which Chukha station alone generates 336 MW. The existing stations are shown in Figure 8.2. Apart from these stations Bhutan also has 11 mini-hydro stations which generate about 0.4 MW. The power master plan preliminary study (1991) listed 89 sites from a desktop study of topographical maps, with a potential of approximately 12,000 MW. Further, the power system master plan (PSMP) report of 1992 listed 24 sites which are economically feasible and have a cumulative identified potential of 10,988

Table 8.3 Per capita land and forest distribution in rural areas

Dzongkhad	Per capita (ha)	
	Land	Forest
Chirang	0.90	0.63
Dagana	3.62	3.10
Gasa	32.78	12.17
Gaylegphu	1.88	1.58
HA	11.43	2.67
Jakar	13.89	7.30
Luntshi	8.08	5.28
Mongar	2.89	2.50
Paro	5.05	4.07
Pensagatshel	1.47	1.00
Samchi	1.25	0.89
Samdrupjongkha	3.25	2.50
Shemgong	6.00	5.39
Tashigang	2.53	1.91
Thimpu	4.04	3.39
Tongsa	7.43	6.24
Wangdisphordang	9.90	6.73
Average	3.97	2.80

Source: Condensed from Negi 1983

MW. Most of the schemes are run-of-the-river type, with the exception of a few reservoir schemes, mainly along the southern border. The proposed sites in the PSMP report are shown in Figure 8.3. However, the PSMP figure needs revision, as the envisaged capacity of quite a few identified projects has been increased. For example, the Tala project is being constructed with an ultimate capacity of 1,025 MW instead of 265 MW as shown in Figure 8.2. Similarly, the Sankosh project has also undergone an upward revision to 4,000 MW instead of 376 MW. It is thus clear that the PSMP study needs to be updated and the economically feasible power projects can probably generate more than 15,372 MW.

Whatever the revised PSMP figure might be, it is evident that Bhutan has a hydropower potential of much more than 250 kW per square kilometre. Tamang (1993) calculated that the total household requirement of electricity for the whole of Bhutan is about 161 MW, considering a family size of six and dwelling space of 50 square metres per family. This means that if Bhutan decides not to go for dramatic industrial development, it has an power export potential of more than 15,200 MW. On the other hand, Bhutan's immediate neighbour, India, is a power-starved country. Though at present the eastern grid of India does not have much power demand, the gap between generation and demand is likely to

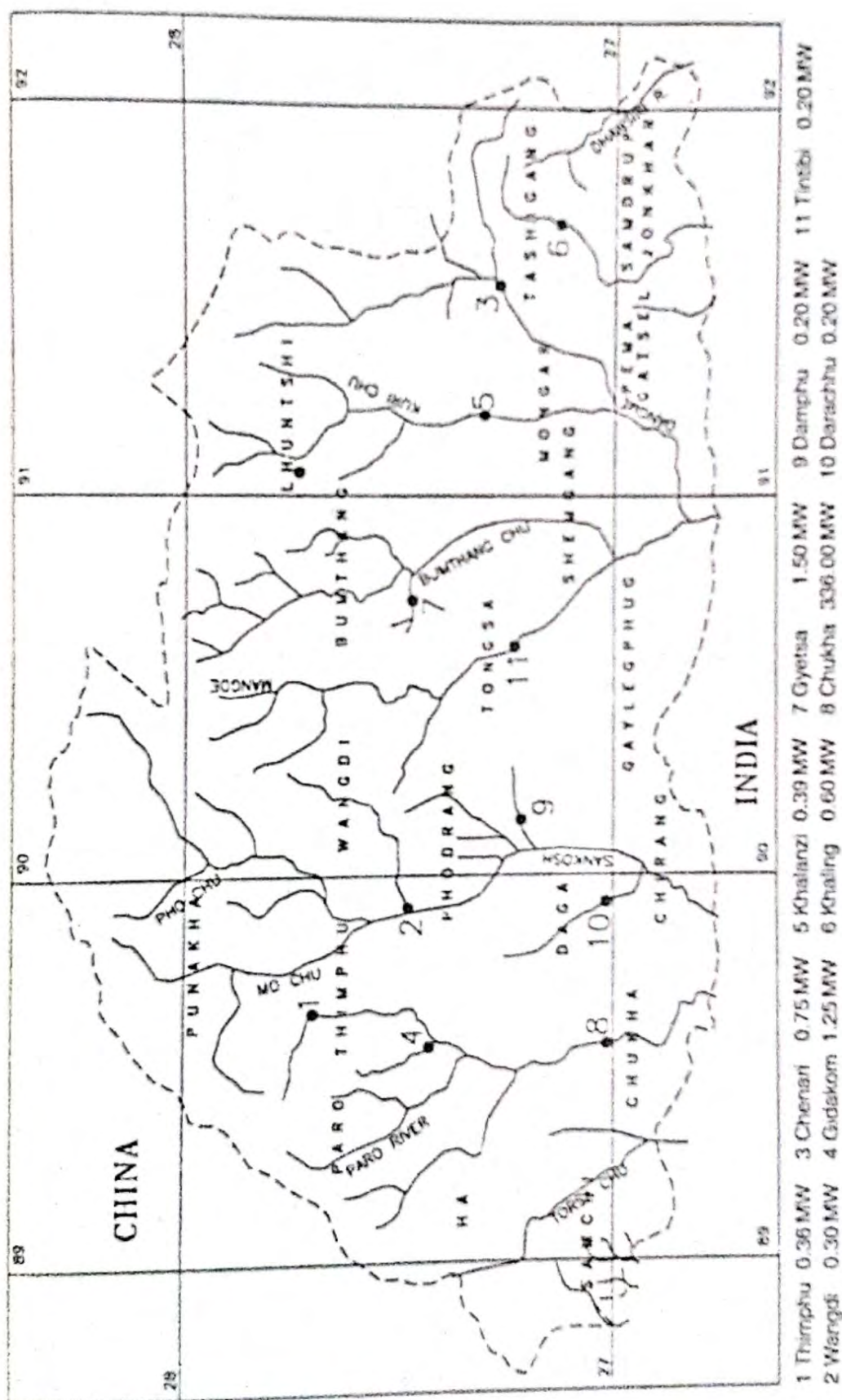


Figure 8.2 Bhutan – existing hydro-electric power plants

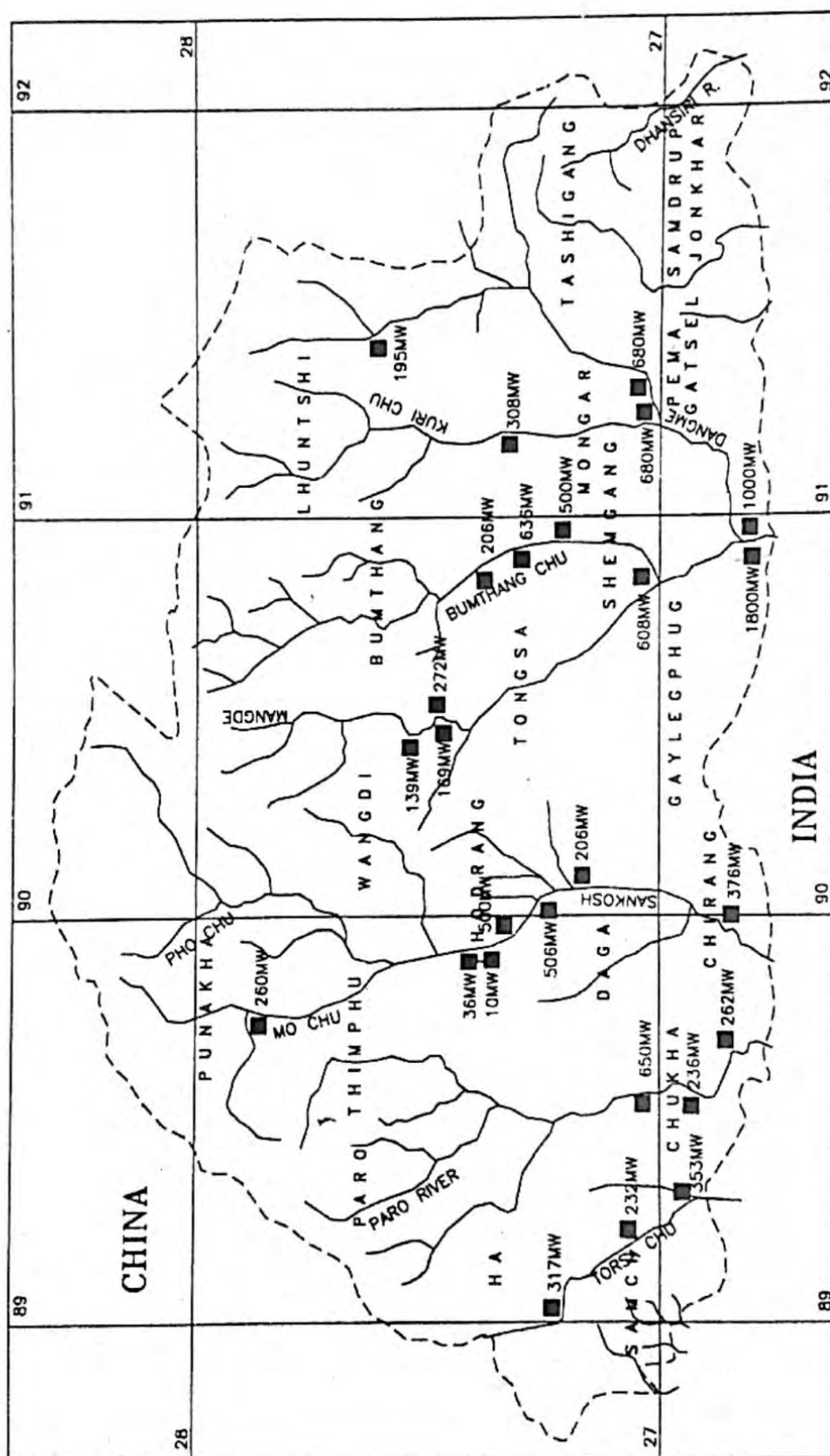


Figure 8.3 Bhutan – identified hydropower projects

widen as further industrial development occurs. Moreover, even if the demand in the eastern grid does not increase, the demand in other grids is predicted to increase drastically. Since the grids are connected, power from Bhutan in the eastern grid can flow to various parts of India.

The environmental scenario

Bhutan is one of the 10 global "hot spots" identified by the United Nations. Geographically, Bhutan combines two bio-geographic zones, namely the Palearctic and the Indo-Malayan, which account for the wide range of flora and fauna in the kingdom. With an altitude of 150 metres to more than 7,000 metres above sea level, the climate varies widely from warm and humid subtropical to permafrost types.

The eco-floristic zones of Bhutan are shown in Figure 8.4. The border between India and Bhutan contains probably one of the world's best examples of moist tropical forests. However, migration of population from India, Nepal, and Bangladesh threatens a large tract of prolific forests, especially in the Samchi and Chirag areas. Two of the bio-reserve areas of Bhutan are partly located along the lush, moist tropical zones. The moist subtropical ecofloristic zones are immediately adjacent to the band of moist tropical regions to the north. The subtropical forests exist mainly along the Sankosh, Tongsa, Kurichu, and Dangme valleys. Montane forests can be seen in the high hills of southern and central Bhutan, whereas alpine pastures are found in the northern high hills.

From Table 8.2, it is apparent that forests cover 67 per cent of the land in Bhutan. Table 8.4 gives the percentage of forest and non-forest land along the watershed catchments of Bhutan. Amongst the major watershed catchments, Manas has the largest tract of forest land (ignoring Raidak and Mao, which are small), whereas Sankosh has the maximum percentage of non-forest land. In the Punaka area (Sankosh valley), large-scale deforestation has taken place to make way for human habitation.

The faunal diversity of Bhutan is also substantial. The high hills are the home of takin, bluesheep, wolf, and clouded leopard. The southern portion supports tropical species like Asiatic elephants, one-horned rhino, tiger, etc. Golden langoor, one of the rare primates, are found in Bhutan. Though poaching is against the traditional ethics of Bhutanese people, of late it is common along the Indian border. Problems of militancy have increased the poaching in this area, as the market for wild animals harvests easy money without much risk of penal actions.

Bhutan has an impressive 23.2 per cent of its area declared as protected. These protected areas cover varied eco-floristic zones, and their management is being improved. However, lack of funds and experience

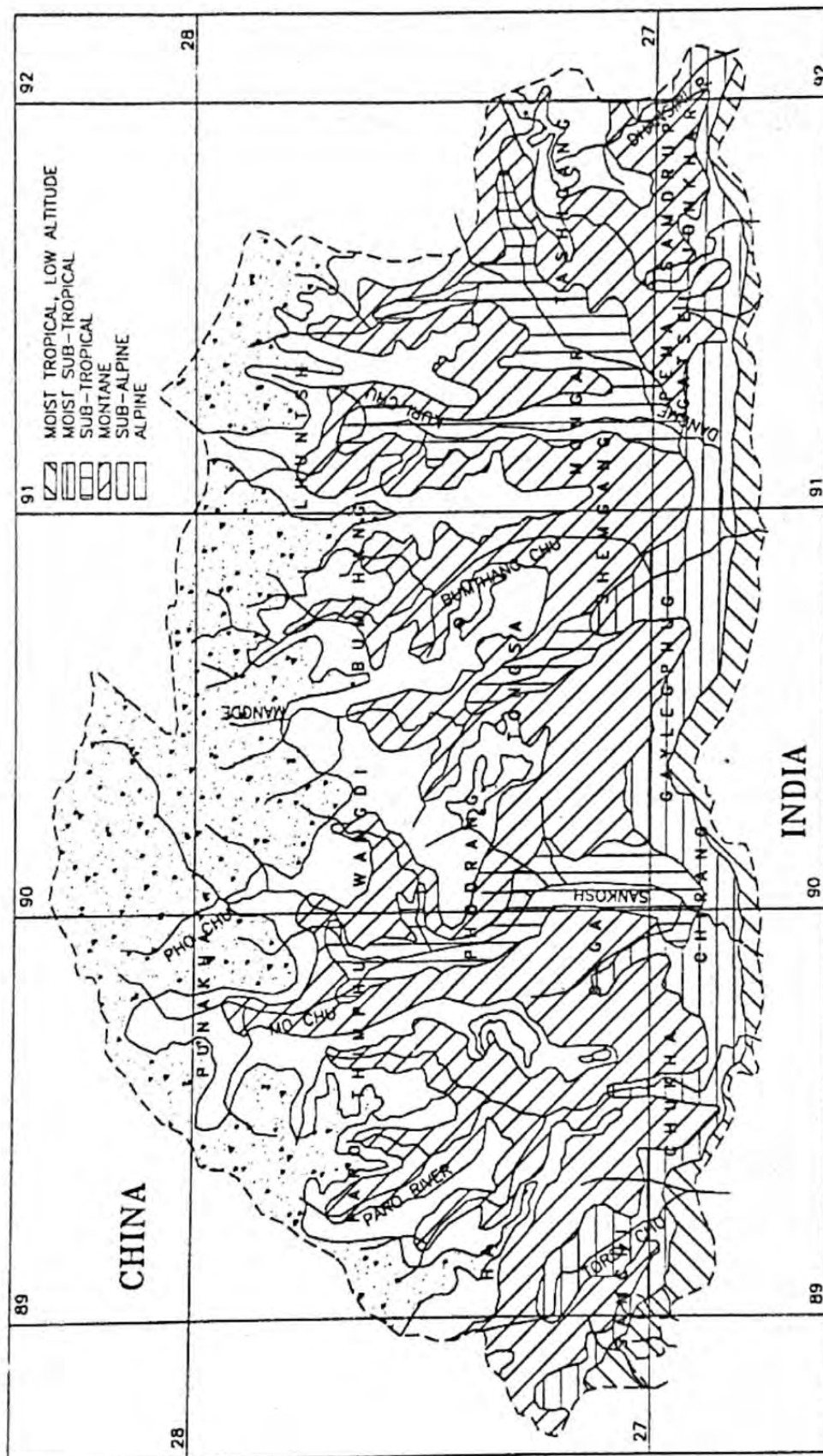


Figure 8.4 Bhutan – eco-floristic zones

Table 8.4 Forest and non-forest land by watershed catchment

Catchment	Non-forest (%)	Forested (%)	Total (%)
Torsa	24.8	75.2	100
Raidak	20.4	79.6	100
Sankosh	39.0	61.0	100
Mao	13.3	86.7	100
Mangdechu	33.9	66.1	100
Manas	27.1	72.9	100
Nyera	21.9	78.1	100
Dhansiri	20.4	79.6	100

Source: Negi 1983

of modern management systems leaves a large gap between the desired and the achieved goals.

Schiotz (1993) believes that Bhutan has taken a rather hesitant stand in the field of surveying its biodiversity. This is probably due to the feeling that there are higher priorities for the government and that such surveys can wait until Bhutan has its own trained ecologists. But it needs to be appreciated that time is probably running out for Bhutan, and a long-term programme could be developed with some appropriate and knowledgeable expatriate assistance.

Cost of development

Need for development

For centuries Bhutan has isolated itself from the rest of the world. The reason for this (geographical inaccessibility, self-imposed isolation, or political necessity) is not a point of argument. When the curtain lifts, we find a unique country with a rich natural heritage, traditional agricultural practices which allow nutrient preservation, and a people with a profound respect for nature. Bhutan, as many believe, could possibly provide a model for the world in nature conservation (Schiotz 1993).

The basic question here is, with such an ideal status, why should Bhutan develop? The country has sustained itself and its people for ages; why cannot Bhutan sustain itself for a few more centuries in the same way it has done in past? But high rates of population growth and political compulsions mean that Bhutan will probably have to adopt a development path which is different to the country's traditional practices.

Reliable data are not available on the precise annual population growth rate in Bhutan. Figures available vary from 2 per cent to more

than 3 per cent per year. The land-use planning project (LUPP), which is responsible for generation of data and land-use planning (under the Ministry of Agriculture), considers 3.1 per cent as a reasonable annual population growth rate and uses the same for planning purposes. A population growth of 3.1 per cent per year means that the population will double in 23 years. If Bhutan wants to maintain its status quo on food production and continue traditional agricultural practices, the agricultural land must be doubled in the next 23 years. This is an impossible task given the morphological characteristics of the Himalayas and Bhutan's present economy. At a population growth rate of 3.1 per cent, there will be an additional 98,900 persons in the next five years. Bhutan would need additional revenue to provide education, jobs, shelter, etc. to the next generation of Bhutanese. No country with a population growth rate of 3 per cent per annum has so far been able to maintain a rising standard of living for its people and have surplus to a planned use of its renewable resources. The only option Bhutan has is to generate additional financial resources through exports. The harnessed power from water resources can generate the additional revenue required. In fact, Bhutan is doing this at present: a major portion of Bhutan's revenue comes from export of power from Chukha.

The other reason Bhutan has to develop relates to the philosophy of its neighbour. India is opening its economy to the world. It is debatable if indigenous technology or knowledge improves because of such globalization; but it is certain that consumption patterns will change and consumerism will become evident. With the attractions of consumerism so close to hand, Bhutan may find it difficult to resist the temptation. According to Bhutanese tradition, the person who consumes the least is respected the most. Such a concept is bound to change in future. Bhutan cannot isolate itself as an island of ascetics. It will be a political compulsion to develop to meet the aspirations of its people.

Environmental cost and benefit of water resource development

The argument has been put forward above that it is necessary for Bhutan to generate additional revenue to keep the country going, and water resources, in the form of hydropower, are probably the only exportable commodity which can maintain a high GNP to offset the strains of population growth.

The technology in hydropower generation has improved over the years, and efficient turbines are available which can generate electricity with less damage to the ecology. Overlaying the eco-floristic zone map with the proposed hydropower station map would suggest that the proposed projects are spread over large and ecologically diverse areas.

Some of the feasible projects are located in highly ecologically sensitive areas.

Bhutan at present has forest cover of 70 per cent. Very few countries of the world can boast of such high forest cover, despite the fact that a sizeable part of northern Bhutan is under permanent snow cover. The rural Bhutanese have taken the environment for granted, and believe that the vast stretches of forest land will be always available for exploitation. This may be true at present in view of the low population density, but in the experience of the author most Bhutanese are not aware that with a higher population growth rate, the forest resources would be under pressure and may not be so easily available for exploitation. The élite clan is well aware of the problem, but often not aware of the solutions. A brighter aspect is that the environmental awareness of an average administrator or engineer in Bhutan is greater than in other developing countries; but they need more training to arrive at the best possible solution to the problems.

Due to the development of water resource projects, Bhutan is bound to lose some of its highly biodiverse areas, especially in the south where some large projects have been envisaged. The loss of forest due to a hydropower project is not restricted to the submerged area only – a significant amount of forest gets affected by factors like construction activity, accessibility of otherwise remote areas, concentration of population around the project site, etc. To understand the exact amount of loss and the benefits of a project is a difficult task. The forests in Bhutan have not been evaluated with respect to species diversity. The unspoiled ecosystem constitutes a reservoir of genetic material of unknown value, but we know that it cannot be replaced once it has been destroyed.

Apart from the terrestrial flora and fauna, the other victim of hydropower development would be the fish. Most of the Bhutan rivers contain a variety of fish that play an important role in providing adequate nutrition to the rural population. Some of these fish are migratory in nature, and will be affected due to the construction of dams across the river: they would not be able to migrate for spawning, especially where the dam heights are significant and fish ladders cannot be provided. Masheer (*tor tor*) is an example. However, some of the important migratory fish, like trout, could be protected with significant efforts as they can survive in colder waters and can migrate to upper segments of the river.

The rehabilitation and resettlement problems are much less in Bhutan compared to other countries in this region which are densely populated. Due to the small and scattered population, the displacement of population caused by projects in Bhutan is low. But it must be understood that even the displacement of a relatively small population could be a

problem for a small country like Bhutan where the options for rehabilitation and resettlement are extremely limited.

This probably gives a depressing scenario of water resource development, but the intention is not to underplay the benefits of development. Availability of power will not only generate financial resources but will also help in environmental conservation. The per capita fuelwood requirement of Bhutan is extremely high, and a good amount is used for heating in both rural and urban areas. Availability of electricity will substantially reduce the wood requirement for heating, thereby saving forests. Electricity will also help Bhutan to tackle the problem of achieving higher food production in future. The majority of Bhutan's rivers flow through gorges, and therefore the water cannot be used for irrigation. Availability of electricity will enable the country to pump water from the deep gorges to irrigate the fields. Groundwater can also be pumped and utilized for irrigation. The advantage of having electricity has thus never been questioned; what is important is how to trade off between having it and not having it.

Conflicts of conservation

Conservation in a developing country is often considered an élitist ideal with few beneficiaries. The fact is, in a poor country a vast population desperately depends on the exploitation of nature for fuel, food, and fodder. A poor population is concerned about today and has little inclination to think for tomorrow. Bhutan is no exception. Conservation imposes restrictions on forest-related activities which directly affect the economy of the rural poor. It is rather optimistic to think that poor people will cooperate with the government in forest conservation unless alternative means of income are provided to them to augment the loss. Emphasis on conservation is likely to bring friction between the government and the population who depend on forest resources for sustenance.

It is evident from past experience that the impact of degradation of environment in one part of the world is not restricted to the immediate vicinity but could affect faraway places. For example, Bhutan represents a sensitive ecosystem, and if large-scale deforestation takes place in the upper reaches of Bhutan, massive erosion may be a prominent phenomenon. A significant amount of silt from Bhutanese rivers will be deposited in India and Bangladesh, causing devastating floods. For this reason, many well-meaning environmentalists consider that a pristine environment is not only an asset to the country to which it belongs but is also an asset to the world. A sizeable amount of finance is available for environmental protection in the form of loans or donations from international

agencies. But many view the lenders and donors with suspicion. Loans often come with a tag which is not acceptable to many, so accepting large loans or donations for environmental conservation could create internal political problems which Bhutan may not like to face at present.

In many developed countries environmental protection rights are vested with trusts or even individual persons. Theodore Panayotou at Harvard University proposed a system in Bhutan where the right to develop an area could be sold to and bought by individuals in the country or abroad through transferable development rights (TDR). TDR will find a market value depending not only on the market value of the potential development but also on the environmental value of the area. Developing countries often view such concepts with caution. In Bhutan, or indeed in the whole region, such concepts may not be acceptable to a large section of the population.

Options for Bhutan

To develop or not to develop could be a question. But there is little doubt that Bhutan will have to develop, and on the same lines, willingly or unwillingly, as all other developing countries develop. The question is, what are the options available to Bhutan for environmentally sustainable development?

There are three sectors of development through which Bhutan could generate financial resources: timber export; power export; and tourism.

Timber exports directly affect the ecosystem and are often not renewable. Moreover, for a profitable timber business there is always a tendency to plant exotic species which are fast-growing and have greater timber value. Such species are, however, extremely harmful to the ecology. The local faunal character often gets totally altered or even eliminated due to planting exotic species. Timber exports, however, cannot be totally discontinued under the present circumstances, but should be kept at a low priority. Bhutan must undertake a review of the domestic use of timber. Most houses in rural areas use timber and mud as construction materials. The use of wood is not optimum, and a significant quantity is wasted. Logical design and better tools can prevent this wastage. In addition, the per capita use of fuelwood in Bhutan is too large. In areas producing *ara* (a local wine), consumption is as high as 6.7 kg per day per person. It was estimated by Raina (1992) that by the year 2000 the country's fuel consumption would increase up to 2,800 million kg. This means that about 400 ha of land must be denuded each year to meet the fuel requirement. With such a high rate of domestic consumption, the export of timber on a long-term basis cannot be sustainable.

Power export appears to be the most favourable option to generate financial resources for development. If the site and sizing of the project are judiciously selected, the ecological damage could be minimized. However, it must be realized that power projects have long gestation periods and are capital intensive. The projects will have to be planned well in advance to accrue benefits in time. The real demand for export and the capacity of the transmission system to evacuate power will have to be properly assessed before undertaking a project.

Tourism has become a major industry, especially for countries which are endowed with vast natural wealth. However, it can be culturally disruptive, especially where the tourists come from cultures which are very different from that of the country being toured. For that reason Bhutan has a most cautious tourist policy and has avoided the erosion of its cultural values (Schiotz 1993). Under the existing system the same policy is likely to continue, and therefore tourism has restricted potential.

From the above, it is concluded that power export has the maximum sustainable development potential. However, Bhutan has its own philosophy. The country may not want a quantum leap from the present state to a richness beyond imagination. Chukha has provided some comforts to the Bhutanese economy. Tala, a project about three times bigger than Chukha, is under construction and may provide surplus in the immediate future. Bhutan may like to wait and watch the impact of the surplus money before developing other projects. It may like to chew the amount it can digest rather than suffer from the obesity of electro-dollars. But certain measures could be adopted to ensure that the hydropower projects can operate without significant degradation to the environment.

The basic need for sustainable development is probably awareness: awareness of the fact that what is sustainable today may not be sustainable tomorrow. The whole environmental system must be appreciated in proper perspective. In this part of the world the developers and the environmentalists are always in confrontation. Appreciation of each other's point of view is totally lacking and the communication gap is often too wide to bridge. What both interest groups forget is that unless the development is sustainable, it is not development. Though the appreciation of environment in Bhutan is reasonable, much remains to be done through an appropriate curriculum at all levels.

The real genetic wealth of Bhutan is yet to be assessed scientifically. All we know is that it is enormous. A systematic study must be conducted to understand the genetic value of each area, so that the selection of project sites can be undertaken more logically. Based on such a study, it would be easier to designate areas which could be sacrificed for development purposes. Systematic data must be generated.

However, for a country like Bhutan, with widespread and biodiverse

areas, whichever site is chosen for development some loss of genetic material will be inevitable. To restrict the loss of genes, the concept of a gene bank could be considered. Under expert guidance, the genetic material which needs protection could be selected and stored for future use. In several parts of the world, including a few in India, such gene banks are operative.

Bhutan is in need of trained manpower. Since there is no university in Bhutan, most students are trained abroad and import foreign concepts which in some cases may not be applicable in the Bhutanese context. It is necessary to have in-house trained personnel who can utilize traditional available knowledge combined with modern techniques.

In addition, the following measures also need due consideration:

- clear indications of environmental losses;
- rehabilitation of degraded areas;
- a proper and sound watershed management system;
- development of the necessary environmental legislation;
- respect for and maintainance of indigenous lifestyles.

Conclusion

Bhutan has a large population growth rate and, due to morphological characteristics, the land resources are limited. To feed, educate, and provide other infrastructural facilities for the increasing population, Bhutan needs additional finances. It is desirable that Bhutan generates its own resources to meet these financial demands rather than depending on international loans, donations, etc. Export of power to its neighbouring countries appears to be a feasible option. To make the export sustainable, Bhutan will have to care for its environment. Bhutan has been wisely maintaining its environment in a very sustainable manner in the past, and has profound traditional knowledge about the environment. However, in the changing scenario this traditional knowledge may need augmentation.

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From dispute to dialogue to doing

B. G. Verghese

The Ganges-Brahmaputra-Meghna/Barak (GBM) system, child of the monsoon, cradled in the Himalayas, constitutes one of the world's greatest natural resources. This would be reason enough to harness its immense potential. But draining as it does a demographically exploding region, already home to over half a billion of the world's poorest people, makes this imperative. After decades of agonizing inter-regional disputation that stalled progress, a window of opportunity has fortunately opened at last.

These mighty rivers have long been used as waterways of commerce, and the Ganges has been diverted over the centuries to irrigate the rich alluvial Gangetic plain in India. The Brahmaputra and Barak/Meghna, however, remain largely untouched. Nepal and Bhutan, long secluded in the folds of the Himalayas, have more recently awakened to the need for developing their water resources, primarily to generate plentiful, cheap, clean energy. Nepal also has a need for irrigation and flood moderation. These requirements could be met by Himalayan storages, which would also mitigate flooding and augment lean-season flows in the Indo-Bangladesh plains below to stabilize and enlarge irrigation to feed growing numbers.

Bangladesh in turn suffers from flooding in the monsoon and drought and salinity ingress during the lean season, and seeks a remedy for this adverse alternation. Barring drainage from the Chittagong hill tracts, all its rivers originate in India or further up in Nepal, Bhutan, and Tibet, a

factor that compels cooperation with these upper riparians for redressal of its problems.

The absolute availability of water in the GBM basin is not insufficient for the divergent needs of all the riparian states, but its seasonal and spatial distribution are skewed. Prior appropriations, mostly by India as an early starter and, in respect of Bangladesh, an upper riparian, pose problems of equitable utilization. Where water resource development has cross-country implications, issues of cost-benefit sharing would also need resolution.

From zero-sum to win-win

The clutch of disputes spawned by divergent and piecemeal approaches to these issues over the past decades hampered progress, giving rise to lingering doubts and suspicions on all sides. Bhutan was the happy exception, and commenced harnessing its water resources in cooperation with India. Elsewhere, reducing water resource development to a narrowly focused zero-sum game entailed deadlock.

After many wasted years, the impasse has begun to yield. A changing political environment with new governments in place in Nepal and Bangladesh and the initiation of the Gujral doctrine, named after the then Indian United Front foreign minister who subsequently became prime minister, facilitated the process. Inder Kumar Gujral felt India should not demand strict reciprocity from asymmetrical partners in the interest of equity and confidence-building. It should also be prepared to accept the pace and pattern of cooperation dictated by its smaller neighbours.

This approach helped move India's long-stalled negotiations with Bangladesh and Nepal from the technical to the political plane, where they rightly belong. A new willingness to accommodate the political compulsions of its smaller partners facilitated the construction of a broad framework of mutual cooperation. The Mahakali treaty and Ganges sharing treaty were respectively concluded with Nepal and Bangladesh in 1996. Both are landmark agreements and signal progress towards win-win, positive-sum outcomes. The earlier history has been well rehearsed (Verghese 1990, 1996; Verghese and Lyer 1993, 1994). Opportunity beckons, and it is now for all concerned to grasp the future.

Both the Ganges and Mahakali accords essentially deal with a single major problem, namely that of lean-season sharing of Ganges flows by India and Bangladesh at Farakka, the apex of the Ganges delta below which it fans out and enters Bangladesh, and the proposed Pancheswar dam on the Mahakali river along the Indo-Nepal border. However, the import of these agreements is far wider. They enunciate principles that

should govern further cooperation on the basis of optimized, integrated basin development aimed at maximizing mutual benefits with least harm to either party.

Mahakali agreement

The Mahakali agreement, together with the letters exchanged in relation thereto, provide for a joint Indo-Nepal project on the basis of a 50:50 cost-benefit split, as the dam will straddle the border which lies along the median point of the river. Two power stations are projected, one on either bank, with an overall installed peaking capacity of between 5,500 and 6,480 MW at 20 per cent load factor operating four hours a day. These parameters will depend on the unit sizes that can be transported to the site, available cavern sizes to house the turbines, and the siting and height and, hence, reservoir capability of the proposed re-regulating dam.

A re-regulating dam could be built either at Poornagiri (180 metres high, 1,000 MW) or further upstream at Rupali Gad (about 60 metres high, 240 MW) to hold the waters passing through the Pancheswar turbines and provide regulated lean-season releases to irrigate designated commands in Nepal and India. The "total maximum net benefit" norm would favour Poornagiri over Rupali Gad, though it would cost considerably more. Both sites have to be properly investigated, and the prospects for overall funding for the total complex will have to be weighed before a final decision is taken.

Both parties are guaranteed an "equal entitlement" in the utilization of the waters of the Mahakali river "without prejudice to their respective existing consumptive uses". The Pancheswar dam will also provide a modest flood cushion.

The principles outlined commit both sides to design and operate the project as a single, integrated scheme to yield "the maximum total net benefit", with costs borne by both parties "in proportion to the benefits accruing to them". Thus, the net power benefit is to be assessed on the savings in cost compared with "relevant alternatives available"; that from irrigation on the basis of "incremental and additional benefits due to augmentation of river flow"; and that from flood moderation in proportion to "the value of works saved and damage avoided".

The avoided-cost principle of power tariff setting is straightforward enough. Thermal replacement projects could theoretically be coal, gas/oil, or nuclear fuelled, or even a hydro-electric scheme. The upper Mahakali valley above Pancheswar in India itself has a power potential of 5,000 MW or more. One norm that has been suggested by Nepalese spokesmen might be to average the sum of these comparative costs and split the

savings equally (Jha 1996). According to a Nepalese estimate, Pancheswar power may cost 3.6 US cents per unit as against a replacement cost of about 8 to 8.5 cents per unit, making a difference of 5 cents.

Over and beyond cost sharing, Nepal's water requirements are to be accorded primacy in the utilization of Mahakali waters. This is a commitment that India has more-or-less accepted across the board in respect of all of Nepal's major rivers. As it happens, the total irrigable area in the kingdom is limited, barely 1.3 million hectares of this lying in the terai or piedmont before the rivers enter the Indian plain. Thus Nepal's consumptive uses will necessarily be limited. Part of the irrigation return flows will also be regenerated downstream.

The Mahakali treaty subsumes all other Indo-Nepalese agreements relating to downstream projects on the river, including the Sarada barrage (1920) and the Tanakpur barrage with a 120 MW hydro-electric capability (1995). Both these are located downstream of Pancheswar before the river finally enters Indian territory, where it is known as the Sarada.

Under the treaty, the Pancheswar project and any others that follow (such as the proposed re-regulating dam powerhouse) shall be executed and operated by joint entities established by the two parties. The treaty as a whole is to be monitored by a Mahakali Commission on the basis of "equality, mutual benefit, and no harm to either party". In case of any unresolved dispute, there is provision for binding arbitration, with the chairperson of the three-member tribunal being named by the Secretary-General of the Permanent Court of Arbitration at The Hague if necessary.

The Pancheswar project as such is to be implemented by a joint Pancheswar Development Authority to be set up under an agreed time schedule from the date of the treaty's entry into force. There has, however, been some slippage in preparation of the detailed project report because of differences with regard to the meaning of "existing consumptive uses" which are to be protected and the phasing of the power component.

Girjapur controversy

This is a misunderstanding which it is being sought to overcome. The treaty provides for sharing of the tentatively estimated Rs 12,000 crores (US\$1.00 = Rs 44; 1 crore = 10,000,000) cost of the project (at 1996 prices) by both sides in proportion to the benefits received. In operational terms, the capital cost of the dam will have to be apportioned as between power, irrigation, and flood moderation. On a preliminary reckoning, the ratios may work out as approximately 80 per cent for power and 20 per

cent for irrigation, barring an incidental 1 per cent for flood moderation. On this basis, the burden of the irrigation component of 20 per cent of the total cost should be shared 50:50 provided the water benefit is utilized in equal proportions. However, should Nepal as the upper riparian not fully use its due share of the augmented flows, the side-letters exchanged "preclude the claim in any form by either party on the unutilised portion of the shares of the Mahakali river of that party".

Nevertheless, should India consequently use more than its agreed half-share of the augmented lean flows of the Mahakali below Pancheswar, it will be liable to bear an equivalent proportion of the capital cost attributable to the irrigation component of the dam. This is more-or-less established international practice and is perhaps not really in dispute.

Nepal is firm in stating that the ambit of the treaty is limited to that part of the river that more-or-less defines the Indo-Nepal border, which stretch is known as the Mahakali. It does not extend to the upper tributaries or the lower reach of the river, which is called the Sarada after it leaves Nepal and flows exclusively through India until it falls into the Ghaghra. Nepal thus protects the stipulated and existing quantum of irrigation from the Tanakpur and Banbassa barrages, and the upper Sarada canal taking off from Banbassa and commanding an area of 1.6 million hectares. Both these are specifically mentioned in the agreement. By the same token, the argument proceeds, it is not committed to protecting any "existing uses" from the lower Sarada or Girjapur barrage 160 km below the Nepalese border, which commands an additional 2 million hectares.

The Girjapur barrage is fed by a diversion from the Karnali, a far larger river, through the Sarada-Sahayak canal for just over eight months in the year. But on account of the heavy silt the Karnali carries between June and September, the Girjapur barrage draws Sarada waters during this period. Assuming 75 per cent dependability and the Pancheswar dam in place, simulation studies indicate that there should normally be sufficient water to meet the requirements of the Girjapur barrage together with regeneration and other inflows into the river below Pancheswar. There could, however, be occasional distress in July when paddy is sown, and maybe in October when the crop matures. The water passing through the Pancheswar turbines during these months may not by itself suffice to meet existing irrigation uses in the Tanakpur, Banbassa, and Girjapur commands in all years, coinciding as they largely do with the filling period of the reservoir. The problem, if any, is therefore related to the operation of the dam as a peaking station rather than to overall water availability.

It is perhaps for this reason that India had proposed phasing the power

component in two stages, with an installed capacity of 2,000 MW in the first instance and 5,500 to 6,480 MW in a second stage with a re-regulating dam in place. Nepal, on the other hand, would prefer to maximize total net (power) benefit, with Pancheswar as a peaking station from the very inception with a re-regulating dam to take care of irrigation commitments. India also appears to be coming round to the view that this would indeed be logical, as its power requirements are both urgent and important, while irrigation need not suffer as the re-regulating dam can be investigated and constructed before Pancheswar is commissioned.

Further, since Nepal's own planned Mahakali command of 93,000 hectares will take some years to develop fully, especially at the very high irrigation intensity proposed, any problem of overall water availability in the near future is likely to be further minimized. This offers added lead time for detailed studies and finding suitable alternatives to the extent required.

Water rights, not ownership

Any notion, whether implicit or explicit, that the Mahakali treaty implies 50:50 ownership by the two sides of the natural river flows of the Mahakali is mistaken. Ownership of water by the upper riparian was a claim embodied in the Harmon doctrine of territorial sovereignty asserted by the United States in 1898 in the course of a dispute with Mexico over the waters of the Rio Grande. The doctrine was subsequently given up. Though asserted from time to time, it has never found acceptance anywhere in the world as a legal principle any more than its mirror opposite, namely the theory of territorial integrity advocated by lower riparians to claim a prescriptive right to pristine stream flows entering their territories.

Section 3(a) of the side-letters exchanged with the Mahakali treaty leaves no room for ambiguity. It explicitly states that the "irrigation benefit shall be assessed on the basis of incremental and additional benefits due to augmentation of river flow". Hence any reference to ownership of half-shares relates only to augmented flows as a result of the storage created behind the dam, and not to the natural flow of the river. This same principle is set out in the understanding reached by the joint team of experts on the Sapta Kosi project at a meeting held in Kathmandu in January 1997.

The live storage to be created in the Pancheswar reservoir is estimated to yield a lean-season flow of around 582 cumecs. There is no problem in dividing the augmented flow equally between the two sides. However, Clause 3 of the treaty states that "both parties agree that they

have equal entitlement in the utilisation of the waters of the Mahakali river". Nepal accordingly claims an equal share in the natural flow of 144 cumecs generated in the catchment between Pancheswar and Banbassa as well – or, in other words, in the overall lean-season availability of 726 cumecs at Banbassa.

India requires 448 cumecs at Banbassa for the upper Sarada canal command (of which 200 cumecs is to secure a higher intensity of irrigation). Nepal demands roughly 160 cumecs to meet existing and planned uses. Together with the 10 cumecs mandated by the treaty to maintain the ecology of the Mahakali, this adds up to 618 cumecs. This still leaves a "surplus" of 108 cumecs, as against the requirement at Girjapur of 228 cumecs. The deficit of 120 cumecs should normally be made good by additional flows from the free catchment below Banbassa and through regeneration, except in lean years during June and possibly October as explained earlier.

Water availability to meet all existing uses is therefore more-or-less assured. What is at issue is the sharing of the capital cost of the Pancheswar project in relation to its estimated water component of approximately Rs 2,400 crores on the basis of the assessed irrigation benefits to the two sides. If the base figure of water availability is taken as 726 cumecs, India's actual utilization may work out to around 75 per cent, rather than the stipulated half-share, requiring it to pay some Rs 1,800 crores towards the capital cost of the irrigation component of the project.

What is at issue is this enhanced capital cost liability – which, however, will be less than the opportunity cost of a year's delay should the impasse be prolonged. Further, it would be counterproductive to disregard the political compulsions that weighed with the Nepalese government in projecting the interpretation of the treaty that it did in order to secure its ratification by the constitutionally required two-thirds majority.

It would be best to accept the situation as it has developed, while making it clear that it does not constitute a binding precedent. Both sides should be wiser for the experience. Certain basic principles must be reiterated and asserted for the future: water rights should not be confused with ownership of flowing water. Thus, Nepal cannot use the Mahakali "precedent" to claim ownership of the natural flows of the Kosi, Gandak, or other rivers. To accept this principle would be revert to the Harmon doctrine and could totally undermine India's international and federal water relations, with disastrous consequences.

Secondly, India must accept that prior appropriation is not an absolute principle if it results in what might approach expropriation in relation to late developers. Reasonable adjustments would be necessary should any such contingency arise in order to ensure equitable apportionment.

Thirdly, there could be an arguable case for payment of a one-time "royalty" for the dam site, a scarce natural resource and wasting asset to the extent that it tends to silt up over time. The Mahakali treaty is for 75 years: this may be taken as the life of the Pancheswar site over which period the dam might be depreciated, as against 50 years in respect of many Indian projects.

The power scenario

While the treaty bars any claim by Nepal for its share of unutilized augmented flows, it may, if it so desires, sell any or all of its share of power under the terms of the 1996 Indo-Nepal power trade agreement. This permits the two governments, semi-official agencies, or private parties to enter into agreements for the investigation, construction, and generation of power and its transmission between the two countries or to a third country.

Any authority or corporate entity in Nepal may accordingly use or promote inter-country grid links to export energy to consumers in India, or to wheel power through India to Bangladesh or Pakistan. Such possibilities are not far-fetched by any means. While the Indian market is going to remain power hungry in the foreseeable future, it would nevertheless provide assurance to Nepal were it able to sell power to third countries, breaking a potential Indian stranglehold as a monopoly buyer and widening and deepening its economic relations with other SAARC members.

Nepal has a hydro-electric potential of 83,000 MW, of which some 42,000 MW has been assessed as being techno-economically feasible. India currently has an installed generation capacity of around 90,000 MW with a significant energy and peaking deficit. According to earlier forecasts, the country must add another 112,000 MW by 2007 to match the expected growth of the economy. Not all of this will come from hydro-power, but there is widespread agreement on enhancing this component to arrest and reverse what has been a declining hydro-thermal mix.

Much of this additional capacity will come from within India itself, as large hydro and pumped-storage potential remains unexploited. Nevertheless, what this suggests is that Nepal and Bhutan's estimated hydro potentials could theoretically be absorbed in their entirety by the Indian market within the next few decades. This is a market opportunity that neither country nor international power companies and equipment suppliers are likely to want to miss, within the limits of economic, environmental, and political prudence.

Power development in Bhutan

Bhutan's hydropower development is, meanwhile, proceeding apace with Indian technical and financial assistance. The 336 MW run-of-the-river Chukha project on the Wangchu (Raidek) was commissioned in 1987 and has transformed the Bhutanese economic outlook in terms of energy, income, exports, technical development, and forest conservation. Whatever Bhutan cannot absorb is fed into the Indian grid. Encouraged by this success, the Wangchu cascade has been investigated and a series of projects are to be implemented in stages.

The Tala project (1,020 MW) is under construction, with the downstream Chukha Stage III (900 MW) and Bunakha (180 MW), in the head reaches of the river, to follow. A smaller project on the Kurichu (45 MW) is also under way in eastern Bhutan, while a project report with regard to the larger Sunkosh project (4,060 MW) is in an advanced stage of preparation. This adds up to a tidy 6,500 MW which in theory could be on stream by 2015–2020.

It would, however, be simplistic to assume that whatever is proposed will necessarily be approved and implemented without difficulty. The king of Bhutan is not anxious to catapult his unspoilt country into instant modernization, mindful of the social and cultural trauma that he fears this might entail. He would prefer to hasten slowly, ensure sustainability, and seek an outcome that assures high "gross national happiness" rather than a larger gross national product.

Nepal and India, too, will encounter environmental and other objections as they proceed with exploiting their water resources.

Ganges treaty

The Ganges treaty, likewise, has opened new windows of opportunity. While the principal focus is on "a fair and just solution" with regard to sharing the lean flows of the Ganges at Farakka "in a spirit of mutual accommodation", this is not the sole concern. It envisages the sharing of all the other international rivers flowing from India to Bangladesh. These include the Brahmaputra, the Barak/Meghna, and the Teesta, as well as 54 other medium or small rivers which have sometimes been grouped in clusters.

The call for "mutual accommodation" in regard to the Ganges again suggests a political rather than a technical approach to the problem. Further, the treaty enjoins "optimum utilisation" of the water resources of the "region" through integrated flood management, irrigation, "river

basin development", and generation of hydropower for mutual benefit. It underlines the principles of "equity, fairness and no harm to either party" and recognizes the need on the part of the two sides to cooperate in finding a solution "to the long-term problem of augmenting the flows of the Ganga/Ganges during the dry season".

Prior to this accord, Bangladesh had felt politically unable meaningfully to discuss and conclude agreements with India pertaining to any river other than the Ganges, let alone on matters unrelated to water resources such as transit and wider economic cooperation, until the Farakka issue was first settled or clearly on the way to settlement. This brought about an almost complete stalemate in Indo-Bangladesh relations but for some progress on trade under the rubric of SAARC. The Ganges treaty has now unlocked all doors, though certain internal political impediments may remain to be overcome on either side.

Unlike the 1977 accord, the 1996 treaty is for 30 years and separates sharing from augmentation. Further, it indicates flows in terms of 50 per cent rather than 75 per cent dependability as heretofore. This criterion enhances the yield below Farakka, as the assurance level has been reduced from three to two years out of four. The purpose was presumably to facilitate the notional allocation of a minimum 35,000 cusecs to Bangladesh during March-April, in order to match and even top the minimum 34,500 guaranteed to it under the 1977 schedule, while giving India the 40,000 cusecs it claims to safeguard Calcutta port. There is also a suggestion that the Gorai, a major deltaic spill channel serving the southwest region, can only draw water when the Ganges discharge exceeds 30,000 cusecs.

The actual schedule of distribution is set out in Annexure I to the Treaty (see Appendix). This stipulates an allocation of 40,000 cusecs to India and the balance to Bangladesh when arrivals at Farakka are in excess of 75,000 cusecs; 35,000 cusecs to Bangladesh and the balance to India when flows are between 70,000 and 75,000 cusecs; and equal sharing when flows are 70,000 cusecs or less, subject to the condition that each side shall be guaranteed 35,000 cusecs in six alternate 10-day periods between 1 March and 10 May.

The implications of this formula are illustratively set out in an "indicative schedule" in Annexure II, which mentions certain numbers "if actual availability corresponds to average flows of the period 1949 to 1988" (see Appendix). For its part, India is required to make "every effort" to protect existing flows at Farakka.

The treaty provides that should flows at any time fall below 50,000 cusecs, "the two Governments will enter into immediate consultations to make adjustments on an emergency basis in accordance with the principles of equity, fair play and no harm to either party". Both sides are

pledged to cooperate in finding a solution to the long-term problem of augmenting the dry flows of the Ganges.

Three problems

The working of the agreement was soon to reveal certain shortcomings that had been glossed over. First, while the treaty is clearly based on the sharing ratios set out in Annexure I, the more iffy, politically designed Annexure II was projected as if it contained the essence of the treaty. When the "illustrative flows" failed to match the reality over two 10-day periods in 1997 owing to a natural hydrological deficit, with flows briefly dipping marginally below 50,000 cusecs, there were accusations of default by India and bad faith on its part in abstracting more water upstream.

The treaty specifies "immediate consultation" in the event of flows dipping below 50,000 cusecs, but does not prescribe any particular mechanism or formula such as the 80 per cent guarantee clause embodied in the 1977 accord. The fall of the then Indian government in February–March 1997, precisely when flows did dip below the emergency level, and the absence from Delhi of the key Indian technical adviser, who was busy attending the UN session convened to adopt the draft declaration on the non-navigational uses of water, did cause an unfortunate hiatus for a few days. Fortunately, the flows soon rose above 50,000 cusecs, thereby solving the problem.

The switching of 10-day flows to guarantee one side or the other 35,000 cusecs during six alternating 10-day periods is technically unsafe, as the walls of the Farakka feeder canal could collapse with such abrupt changes in levels. This was known to both sides from previous negotiations. Even so, a stepped pattern was written into the treaty instead of a smoother gradient spread over a few days whereby the quantum of water delivered would have remained the same though with a different 10-day flow pattern. The Indian side had perforce to stagger the reduction and augmentation of releases over some days. This altered the pattern of scheduled deliveries in a few 10-day periods, with Bangladesh being compensated for any scheduled deficit in supplies in the ensuing period. This was cited as a treaty violation, though in point of fact the total quantum of water released to Bangladesh over the lean season as a whole was a little more than stipulated in Annexure II.

While releases and arrivals were being jointly monitored at Farakka and Hardinge Bridge respectively, a third problem arose as the character of the river changed from affluent to effluent in the course of the lean season. Thus, while there was regeneration up to the end of February between the two observation points, with Hardinge Bridge recording

higher figures than Farakka, there was degeneration for some time thereafter, with Hardinge Bridge recording 20 to 40 per cent less than the release figure at Farakka. There was an outcry that India was manipulating releases at Farakka despite joint monitoring.

Since there was no observed diversion of flows on either side between Farakka and Hardinge Bridge, some 120 km apart, the inference is that the "missing cusecs" may have disappeared into aquifers that began to be emptied after late February with groundwater pumping to irrigate the boro crop.

Indeed, such a possibility was forecast by the influential Bangladesh daily, *Sangbad*, on 2 January 1997. The paper reported that:

the Government [of Bangladesh] should pay special attention to the underground water level in the northwestern region for proper maintenance and usage of water flow received after signing the Ganges Water Agreement. Hydrologists have expressed their concern that during the lean period in March–April the exact quantum of water released from Farakka under the newly signed agreement may not be received at the Hardinge Point. This may happen as the affluent river condition which was prevailing five years ago is not there; rather influent river condition is existing ... [sic]. Opposition parties may misinterpret this to put the Government into trouble.

The paper explained that over 100,000 tubewells had been drilled under the Borendra project in a 7,692 square kilometre block from opposite Farakka to Hardinge Point. As much as 31,700 cusecs of water were being extracted here, against a safe limit of half that figure as advised by technical experts. As a result, the groundwater table had fallen from 25 feet to 60 feet over the past five years. The evidence was not conclusive, and a joint investigation has been mounted and will establish how and on which side there may have been losses to aquifers.

Joint consultations for amending the stepped release schedule over the six prescribed alternating 10-day periods, and for instituting a self-actuating mechanism and formula should flows dip below 50,000 cusecs, did not take place during the 1997 flush season despite a meeting proposed by India. However, a greater degree of transparency has been introduced in the joint observation procedures, with Bangladesh officials permitted to visit the observation sites at any time of day or night. It is now open under Article X of the treaty for either party "to seek the first review after two years (December 1998) to assess the impact and working of the sharing arrangements". Fortunately, arrivals at Farakka up to the middle of March 1998 were more than satisfactory.

It must also be said that both governments have throughout staunchly defended the treaty despite virulent criticism by political opponents.

The Gorai hump

There is a further and, in a sense, more complex problem. Bangladesh's grievance about diversions by India from the Ganges at Farakka has revolved around the acute distress said to have been caused in the south-west Khulna region on account of salinity ingress and a shortage of water for agriculture, fisheries, navigation, and sustenance of the sundari mangrove species. This area, because of the Gorai spill, which delivers upland fresh water supplies to the region, is left high and dry as the Ganges recedes.

While this is so, it would be erroneous to attribute the problem exclusively or mainly to diversions at Farakka. The entire Ganges system has been shifting east and north as a secular trend over the past century and more. The Bhagirathi, the westernmost spill, was the first casualty. Other streams, moving further east, have progressively deteriorated as the Ganges has shifted course. This has resulted in the closure of the Gorai mouth by a hard five-metre silt plug that is now said to measure almost 30 km from the outfall point to Gorai bridge.

The Bangladesh Land and Water Resources Study (Ministry of Water Resources 1972) is instructive. Para 6.12 has this to say:

Present dry season flows in the Gorai River are often decreased by sandbars that develop at the Ganges offtake. Without [the] sandbar, the minimum discharge varies historically between 10,000 and 18,000 cfs [cusecs], but with [the] sandbar the discharge had decreased to 5 cfs in February–May 1950, 2,900 cfs in January 1952, and to 500 cfs in May 1954. However, the effect of sandbars could be eliminated by dredging and a minimum discharge of some 15,000 cfs could be assured under the present circumstances.

Though Farakka diversions commenced in 1975, agreements with India were in place guaranteeing far more than 15,000 cusecs of Ganges flows below Farakka between 1977 and 1988. Nevertheless the Gorai deteriorated and has in recent years stopped drawing water even in January, when the discharge ranges between 50,000 and 60,000 cusecs. This being so, only a limited quantum of Ganges treaty releases during the lean-season trough enter the Gorai and none at all below a certain threshold related to the hump at the outfall, the elaborate formulations of alternating 10-day releases of 35,000 cusecs to either side in March–April notwithstanding.

In view of this situation, East Pakistan/Bangladesh in 1963, 1964, 1968, 1984, and 1994 had surveys and investigations carried out by local and foreign consultants to construct a Ganges barrage to pond the river and force water into the derelict Gorai channel. This would variously irrigate

670,000 to 1.5 million hectares of land in the south-west region and re-suscitate the Ganges-Kobadak project. The proposal has come alive again with the signing of the Ganges treaty.

Bangladesh has formally approached various multilateral agencies and India for assistance in funding and carrying out a feasibility study on the Ganges barrage project and its possible environmental impacts. The response encouraged the government to convene an international conference in Dhaka in March 1998 to pursue the matter. India has formally conveyed its willingness to share its design and technical experience regarding Farakka with Bangladesh.

A Gorai restoration programme is already contemplated, with World Bank and Dutch assistance. This envisages capital dredging of the Gorai outfall to permit lean-season inflows from the receding Ganges, followed by maintenance dredging to maintain this channel. This is seen as perhaps no more than an interim solution pending ponding the Ganges behind a barrage at Pangsa, 10 km below the Gorai outfall, thereby enabling the backwaters to flow into the moribund Gorai. However, instead of constructing an elaborate and expensive canal network, it is proposed that the Gorai restoration project should clear the clogged outfalls of all lower spill channels to restore as far as can be the original ecology of the Gorai system. This would enable farmers to irrigate their fields by groundwater and river lift. Such participative development is seen as more likely to ensure maintenance of the environment.

In view of these changed parameters, the World Bank, ADB, and Japanese government have persuaded Bangladesh to undertake certain preliminary studies through the Water Research and Planning Organization (WARPO) before they are willing to fund an actual Ganges barrage feasibility study. This proposal has been accepted, though it could mean a possible delay of up to a year or more before the commencement of that study.

A more balanced perception is now beginning to emerge in both Bangladesh and India, some hawks apart. This augurs well for future co-operation. While it is necessary to understand and draw lessons from the past, it is more important to seize the opportunity and chart the way forward.

Critics on both sides may chafe at one country or the other having received what they perceive to be a raw deal. The interests of Bihar and Uttar Pradesh have not been prejudiced. On the other hand, some in Bangladesh believe that sharing the residual flows of the Ganges at Farakka, after generous abstractions in upper India, is *per se* unfair. Is this really so? The Ganges has a smaller annual discharge than the Brahmaputra, which, virtually untapped as it is throughout its course even today, drops to not less than 110,000 cusecs at the Indo-Bangladesh

border when it troughs in early February. If one makes the somewhat generous assumption that the Ganges' lowest virgin flow at Farakka in March–April is as much, a 25–30 per cent share of this quantum is going to Bangladesh, which has less than 5 per cent of the basin area and 10 per cent of its population as compared with India. Is this unreasonable? This calculation obviously ignores the groundwater factor, but nevertheless offers an admittedly crude basis for making a comparison.

New role for Calcutta port

There are some in India who fear that Calcutta port will choke for lack of minimal headwater supplies during the critical lean months. While diversions into the Bhagirathi-Hooghly at Farakka have reduced salinity and enhanced drafts at Calcutta, the limits of significant improvement have been reached. Moreover, Calcutta port has been overtaken by events. The nature of shipping and freight has changed. Bends and bars in the river preclude vessels beyond a certain size negotiating the fairway to Calcutta. Haldia, 120 km downriver, has in consequence outgrown its auxiliary role to become the major partner in the twin-dock Calcutta port system. Vessels sailing to or from Calcutta have to be lightened or topped up here or elsewhere.

Freight composition has also changed. Bulk cargoes such as ore and coal move through Haldia, Paradeep, and other ports; liquid cargo is piped ashore at Haldia; and food grain imports have been replaced by grain stocks from Punjab, Haryana, and western Uttar Pradesh. Moreover, Calcutta is today no more the prime, let alone sole, ocean port at the head of the Bay of Bengal. It could, however, become a vibrant inland waterport handling a far larger volume of containerized and other traffic than at present. The city, the run-down dynamo of eastern India, cannot be restored to health if it continues to be miscast in the role of a great ocean terminus that it is simply unable and not called upon to play, as there are alternative ports and options. The pretence that more flushing will somehow improve matters and that reduced headwater flows for two months during the critical lean season will spell disaster for Calcutta are myths. The opportunity cost of flushing water is very high and rising fast. Bengal farmers are already pumping up to 8,000 cusecs from the Farakka feeder and resuscitated Bhagirati to water their fields. The Hooghly faces draft and shoaling problems well below Calcutta, and even at Haldia, and dredging costs have mounted.

India desperately needs more port capacity countrywide, and certainly so at the head of the Bay of Bengal. Calcutta, and even Haldia, cannot cope. Not only must Haldia be greatly expanded, but there is a clear need

for more deep-water port capacity in the vicinity. Several proposals are under consideration, including a small container terminal opposite Haldia at Kulpi, a major port on Sagar island at the mouth of the Hooghly, and perhaps a single-buoy mooring further out to sea. Against a mere 23 million tonnes handled by Calcutta-Haldia in 1997, freight forecasts indicate an overall bay port capacity requirement of 50–100 million tonnes and more in another decade to 25 years.

In such a scenario, a refurbished polynodal inland-water Calcutta port strung over the reach from Haldia to Farakka could hum with activity as a feeder and distributive node with containerized and other barge trains plying extensive inland, estuarine, and coastal waters. These vessels could negotiate the Farakka lock and travel up the Ganges to Patna and Allahabad, or go through the Sunderbans and Bangladesh up the Brahmaputra and Meghna/Barak to Guwahati-Dibrugarh and Karimganj, or move down the coastal canal to Orissa and further south along the Buckingham canal, both derelict systems that are being or could be revived. The existing rail-road transport corridors are under heavy pressure, and will need large investments and land for modernization and expansion. Some of that investment could usefully be diverted to developing waterways which are fuel-efficient and environmentally friendly.

Augmentation possibilities

The Ganges treaty speaks of augmenting lean-season flows below Farakka. Conservation and demand management on both sides of the border would be one route to this end. But additional flows could emanate from storages and diversions. The Sunkosh hydro-electric project (4,000 MW) investigated in Bhutan suggests the possibility of utilizing the existing Teesta-Mahananda barrages and canals as a ready-made alignment to divert up to 12,000 cusecs to Farakka. One advantage would be the prospect of utilizing some of this to firm up supplies for the twin Teesta projects in north Bengal and Bangladesh, which presently face significant shortages. A longer feeder canal realigned south of certain major game sanctuaries would save them from harm, but would still entail slicing through several tea plantations, whose owners would have to be suitably compensated. Environmental opposition and Bhutanese political sensitivities will have to be overcome.

Some of the proposed high dams in Nepal, especially that on the Sapta Kosi, could also augment flows below Farakka despite utilization in India. It will be some time before these projects are commissioned. There is no reason why Bangladesh's interests should not be accommodated, with an appropriate tripartite sharing of costs and benefits. It would be fanciful to

suppose that all such projects will be designed exclusively to serve the purpose of augmentation below Farakka. It is hydropower that makes them viable, with regulated releases of water for irrigation and flood moderation as by-products. India's energy market and, to a lesser extent, its still unsatiated irrigation needs are therefore likely to remain the determining factor in both the project design and benefit mix after fully meeting Nepal's own requirements.

Obviously, Bangladesh's water requirements are not limited to the Ganges alone. Of a cultivable area of just under 9 million hectares countrywide, only 3.14 million hectares lie in the Ganges basin as against 3.75 and 2.61 million hectares in the Brahmaputra and Meghna basins respectively. The Chittagong hill tracts and the plains district stand apart. However, almost the entire GBM flows enter Bangladesh from India or beyond. Regional cooperation is therefore a compelling necessity, whether for managing floods or drought.

There was for a while a feeling in Bangladesh that it could perhaps manage on its own with the flood action plan. This concept was unrealistic, and has now been abandoned in the manner originally conceived. The sharing of the lean flows of the Teesta and possible joint operation of the twin Teesta barrages are now being explored, alongside prospects of augmentation from the Sunkosh or any marginal Teesta storages possible in the Darjeeling-Sikkim hills.

Brahmaputra-Barak options

The other possibility would be a barrage across the Brahmaputra at Jogighopa in western Assam, with a canal that could divert water into the Teesta and Mahananda, or down the Karatoya-Atrai. This would augment lean flows in these rivers and, through the latter, in the Ganges. This is not to revive the hypothesized 100,000-cusec Brahmaputra-Ganges link canal proposed in 1978, which India has withdrawn, but to explore lesser variants along several different alignments as may be jointly evolved with Bangladesh. A diversion canal from a Jogighopa barrage near Dhubri in Assam could lead to Bangladesh's proposed Ganges barrage. It could be aligned to follow or join the Karatoya-Atrai or other river courses, and would irrigate considerable areas and stimulate fisheries and navigation en route.

A Brahmaputra barrage at Jogighopa could be a less expensive proposition, for reasons of topography, than a possible structure lower down. This might interest Bangladesh, as it has at various times contemplated a barrage at Bahadurabad from which it could irrigate the central part of the country and service its Ganges-dependent region as well.

The Brahmaputra accounts for 29 per cent of the total runoff of all of India's rivers, representing a huge per capita or per-unit-of-arable-land water availability that will always remain surplus to any possible consumptive uses within its own international basin. Hence India's long-term interest in developing a national water grid and diverting Brahmaputra waters west and south as part of this perspective to meet emerging water shortages in large parts of the country.

The notion that the Brahmaputra has surplus water is, however, challenged in Dhaka. In 1987-88 Bangladesh informed India that it would be satisfied with a 25,000-27,500 cusec minimum lean-season share in the Ganges provided it was given a half-share in all the other rivers and a 75 per cent share in the Brahmaputra. Its formula for the Brahmaputra was that each country might be allocated 25 per cent of the lean flows for consumptive uses, with the remaining 50 per cent being left to find its way to the sea as an ecological necessity. This thesis is said to find support in a study by a firm of international consultants which has reportedly cautioned against any depletion of the existing virgin lean-season flows of the Brahmaputra lest this harm the environment and permit salinity ingress.

Prime facie this would seem altogether too sweeping a claim, and requires detailed justification. Nevertheless, India's ability to divert Brahmaputra waters westwards is limited, while any proposed storages built in Arunachal or Bhutan for purposes of hydro development, flood management, and navigation would greatly augment lean-season flows.

The original Indian proposal for two mega-dams on the Dihang, the main stem of the Brahmaputra, and the Subansiri have had to be dropped because of strong opposition in Arunachal, as five politically important townships would have been submerged. The proposals are now being reworked in cascades of three dams each. These would avoid submerging any township while more-or-less maintaining a significant part of the originally proposed storage and installed hydro-electric capacity (around 20,000 MW). Flood peaks would still be lowered, while regulated flows would improve navigability in the Brahmaputra below Dibrugarh. Investigations are in progress, and the first feasibility and environmental impact studies should be available by 2000.

The Barak, as the Meghna is known in India, is also proposed to be harnessed at Tipaimukh in Manipur, very near its trijunction with Mizoram and Assam. The project is expected to provide a substantial flood cushion and an installed capacity of 1,500 MW, with added irrigation and navigation benefits which could be extended to Bangladesh, though no cost-benefit studies have been made in this regard. Such a study of downstream impacts has now been informally proposed to Bangladesh.

Unfortunately, the Tipaimukh project has run into difficulties in Man-

ipur on issues of submergence and displacement, which would partly appear to stem from misperceptions caused by lack of transparency at earlier stages. This underlines the importance of taking the local people and other stakeholders into confidence from the outset.

Strategies for Nepal

In Nepal, as in Bangladesh, there is every reason for expedition in harnessing the eastern Himalayan rivers. The Mahakali treaty is a framework agreement which sets out general parameters for overall water resource cooperation. The present impasse over Pancheswar is no more than a hiccup. Political uncertainties have clouded negotiations, and all three countries need to move forward resolutely, riding the momentum generated by the 1996 agreements. Both Nepal and India should use Pancheswar to make a new beginning rather than continue with tired arguments. The joint DPR (detailed project report) must be expedited in a spirit of mutual confidence. Overdependence on foreign consultants seeking a stake in the action can prove counterproductive. Hydropower is to Nepal what oil is to the Gulf. Possession is not enough; on the other hand, its exploitation could be transforming. The opportunity cost of delay can therefore be high.

The Indo-Nepal power trade agreement opens the door to private investment in water resource development. Private entrepreneurs are now allowed to sell energy to third parties. India need therefore no longer be a monopoly buyer. Bangladesh and Pakistan could also become partners with Bhutan and Nepal in a subcontinental power grid that would impart great flexibility and reliability to the system.

Apart from Pancheswar, there is an Indo-Nepal agreement for joint preparation of a detailed project report on the Sapta Kosi high dam and Sun Kosi hydro diversion into the Kamala basin which is to be financed by India. The inception report sets out certain broad parameters, including investigation of the feasibility of a navigation link by river or canal from the dam to the Ganges to give Nepal an outlet to the sea. However, progress has stalled with the impasse over the Mahakali. Since the Sapta Kosi project offers some real assurance of augmentation of Ganges flows below Farakka, Bangladesh should be brought into the discussions at an appropriate stage so that its interests can be built into the overall design in accordance with agreed cost-benefit principles.

With Nepal throwing open water resource development to the private sector, two hydro-electric projects, Khimti (60 MW) and upper Bhote Kosi (36 MW), have been taken up. An American corporation has staked an interest in the giant Karnali project (10,800 MW), which may only be

constructed in stages. Upper Karnali (300 MW) might get off the ground sooner.

Other private parties are reportedly interested in the 404 MW Arun-3 which was earlier canvassed by the Nepal Electricity Authority but finally rejected by the World Bank and ADB, its principal sponsors, on economic considerations. The long access road to the site was itself estimated to take six to seven years to complete and, as a front-end investment, threatened to price the power generated out of the market unless spread over the larger Arun cascade.

The need for an immediate replacement project to meet Nepal's load demand after 2000-02 was met by taking up the 144 MW Kali Gandaki-A project. The Australian Snowy Mountain Electricity Corporation (SMEC) has come to an agreement with the Nepal government on building a 750 MW hydro project on the west Seti, a tributary of the Karnali. A 30-year build-operate-own-transfer arrangement is mooted, with a tax on power exports. The SMEC is seeking prospective buyers for the energy to be produced among north Indian state electricity boards and bulk consumers.

The Nepalese government estimates that regulated releases from the west Seti will augment lean-season flows in the Karnali by some 30 per cent, which could beneficially be used by India some time in the future. In order to obviate any such an unrequited benefit, some in Nepal would like to explore a trade-off with India. They argue that certain medium irrigation projects earlier proposed by the kingdom on the Babai and Kankai were shunned by prospective foreign donors such as the ADB and Kuwait Development Fund after being informed of possible adverse effects on existing or proposed uses in Uttar Pradesh and Bihar. Hence it is being informally suggested that possible losses to India should these projects be implemented, or from the proposed Bheri hydro project which would divert water outside the Karnali valley, be set off against the augmentation of Karnali flows from the west Seti. Such a package merits consideration. Given the gestation period involved in any of these projects, India could switch irrigation in small terai commands to groundwater lift from the *bhabbar* springline that runs along this alignment. At a pinch, Nepal and India could trade water for energy.

Some of Nepal's irrigation needs from certain smaller schemes could over a longer term be subsumed in the larger commands created by mega-projects like Sapta Kosi and Karnali. These alternatives are not mutually exclusive and could optimize the system over time.

Not unexpectedly, debate has meanwhile been joined in Nepal on the merits of embarking on any of these mega-projects. The environmental objections will be examined later. These apart, critics fear that the kingdom will become hostage to the Indian economy; that Nepal must learn

to walk before it can run and should appropriately confine itself to small and medium projects in the immediate future until it is ready and able more confidently to embark on larger ventures; and that mega-projects could create social and regional distortions as annual investments and overall costs would be larger than the country's current annual budget or GDP. As a wag put it: "Will Nepal own Karnali or Karnali own Nepal?"

These fears may not be altogether unreal, but are exaggerated. Oil or gas can be left underground and exploited when required and marketed over vast distances. No so falling water. Hydro-electric energy not generated in any one season is lost for ever. Further, Nepal, like the rest of the GBM region, cannot afford to forgo the leverage of hydro development to roll back poverty and improve the quality of life of its growing population. And environmental constraints are likely to increase rather than diminish with time. As for regional imbalances, these can be evened out through appropriate policies and by investing income from mega-projects in other regions and sectors. Likewise, sale of large blocks of power to India would create a healthy relationship of interdependence that would compel greater respect for Nepal in India than if the latter's stakes in the kingdom are marginal. Building partnerships is good diplomacy.

The feeling that Nepal's earlier innocence was cunningly exploited by India in the Kosi and Gandak projects is again somewhat exaggerated. Nevertheless, that perception is a reality and can best be dispelled by the manner in which India now approaches its smaller neighbours. This is what the much-misunderstood Gujaral doctrine sets out to do by eschewing absolute reciprocity in dealing with asymmetrical relationships. That policy has paid off, and should be pursued. Seeming concessions in the short run will bring home dividends in time.

Environmental factors

The environment issue must of course be addressed. The Himalayas are a dynamic tectonic zone and, additionally, are under severe pressure over large areas from population and livestock growth, falling land-man ratios, unsound land use, cultivation of marginal slopes, adverse development impacts from careless road-building and mining, and excessive logging and felling of trees that have resulted in barren hills, erosion, degradation, the drying up of springs, and receding glaciers. All this may be true; but communities and governments are learning to do better. Some of Nepal's community forestry (and water) management programmes, like some of India's joint forest management schemes, point to new directions of participative management of common property resources. Watershed

and biodiversity management are aiding conservation and ecological restoration.

All new water resource projects mandate environmental impact studies and corrective action. These range from catchment area treatment and rim stabilization to reduce siltation to compensatory afforestation and protection of endangered faunal and floral species. Upper catchment and downstream effects are also being more carefully studied and rigorously addressed. Nevertheless, there is no getting away from the fact that tectonic shaking and mass wasting of the fragile Himalayas bring down more debris and silt into the rivers by far than the sum total of all man-made interventions. Dams will silt; but the process can be slowed down. There is no reason therefore to forgo projects whose overall social and economic cost-benefit ratios, both direct and indirect, are positive. Dam safety is obviously important, and modern technology now permits construction within acceptable limits of safety and social and political tolerance.

If there is a cost of doing something, the cost of not doing is all too often overlooked. This can be far greater. Many of those who some years ago worried about the negative environmental impacts of large dams are today more concerned about the greater danger to humankind from global warming through greenhouse gas emissions from coal-fired thermal stations. Hydropower, with nuclear energy, constitutes the cleanest form of electric power. Non-conventional and newer energy sources are still far away from being affordable or practical alternatives on the scale required.

Displacement of populations by submergence behind dams is a major concern. Here, the compensation offered and the resettlement and rehabilitation package has to be generous and caring. In third-world countries like Nepal and India, the involuntary migration of Malthusian refugees from degraded lands with shrinking economic opportunities imposes untold misery on millions. Only development can arrest, even if not reverse, this sorry process, and water resource development in turn more specifically redresses the accompanying gender inequity that condemns women to a lifetime of servitude in fetching fuel, fodder, and water over ever-increasing distances.

Insistence on rehabilitating displaced populations on the land is mistaken, except where land is readily available. Land is no more than a synonym for employment and social security, and could certainly be one but not necessarily the sole avenue for rehabilitation in densely populated regions. The gestation period before the dam rises and the reservoir begins to fill is sufficiently long to provide for education, training, or re-training in marketable skills and investments that generate gainful em-

ployment in areas including the pisciculture, tourism, and watershed management nurtured by the project.

Area development opportunities

Pancheswar offers India, and certainly Nepal, an opportunity to make a new start in reconceptualizing water resource projects and rehabilitation. Large dams in remote mountain locations essentially entail area development. Even before work can commence at the dam site, a great deal of basic infrastructure has to be put in place: access roads and bridges, electricity, water supply, telephone connections, medical facilities, transport and market linkages, and so forth. The intrusive process of opening up hitherto remote and neglected areas, environmental impacts, and displacement are disruptive of cultural networks and traditional patterns of living. All this could mean trauma or opportunity. Which should it be?

There is generally a dichotomy between those living above and below a dam. Most if not all benefits and newly created opportunities seem to flow downstream, whereas the costs of submergence, displacement, and other disruption are left to be borne by marginalized catchment area communities. The directly affected population may be compensated and relocated; but what of all those others who remain? Since governments are committed to poverty alleviation and social justice, why not use the triggering mechanism of large dam projects to transform their lives as well?

Take Pancheswar. Its construction will give an impetus to the area development of the backward far-west region of Nepal and Pithoragarh district in the Kumaon region of Uttar Pradesh. With the opening up of these hitherto sequestered hinterlands and the establishment of viable market links, catchment area treatment could shade into designing new and more eco-friendly land use and productive cropping patterns. Highly angular slopes and unirrigated terraces could be put under tree crops rather than grain, and land use gradually diverted towards the development of horticulture, vegetable farming, herbiculture, floriculture, and alpine dairying with stall-fed animals.

The complementarity of growing seasons between hill and plain offers a nice market fit. With the opening up of communications, Himalayan villages are assured of food security should they produce "winter" vegetables, instead of cereals in the summer, when supplies are scarce in the plains and prices are high. Disease-free vegetable seeds grown at alpine heights would in turn find a ready market for winter sowing in the plains. Cheap energy could power ropeways to carry hill produce from more

distant valleys to market hubs and agro-processing centres. Disciplined and trained ex-servicemen on either side of the border could constitute the nuclei of eco-development task forces to spearhead change.

This hydro-hardware programme could mesh with a parallel Mahakali basin human and area development programme in terms of education, health, nutrition, employment, and gender justice. A baseline quality-of-life survey could set minimal indices for social development which should be sought to be achieved within a given period. Such a programme would arrest and in some cases locally reverse the steady migration of people from degraded hills to the plains in search of employment.

Such a programme could be implemented by a Mahakali catchment area authority set up on either side of the border, initially financed by project funds for mandated activities such as catchment area treatment and rehabilitation. Later, a small upper-catchment development tax could be levied on the electricity generated to yield a steady income for the rest of the programme. Rehabilitation, in these circumstances, could be largely *in situ* rather than in distant locations, with the gestation period being used to educate and train the community to avail themselves of the new job opportunities planned to be created.

Wider regional cooperation

In the case of Indo-Bangladesh water resource development, too, while the direct benefits to both sides from specific projects and agreements are obvious, there is surely a larger purpose and more generous dividend to be gained. Water resource development is no more than an entry point to the bigger issue of alleviating poverty, hunger, and unemployment and leveraging a better quality of life for the large concentration of the world's poorest people who crowd the GBM basin. This too must be seen as a grand area development programme embracing a vibrant agriculture, the fashioning of new transport corridors and inter-modal carriage, port development, new patterns of hydro-electric/hydrocarbon/coal energy exchange, and the creation of new market opportunities and trans-border linkages. Optimization and synergy could be built into these loops.

Thus Chittagong could be a great entrepôt at the head of the Bay of Bengal, with Calcutta becoming a hub for inland waterways up the Ganges, Brahmaputra, and Barak. The restoration of connectivity between the north-east and the Indian heartland through Bangladesh and from all of this region to South-East Asia and south-west China through Myanmar could cement new regional relationships.

The World Bank and ADB have shown interest in subregional co-

operation within the GBM basin, as has Thailand, which has promoted the BIMSTEC quadrant consisting of Bangladesh, India, Sri Lanka, and Thailand, with Myanmar lined up to join the grouping as well.

Within the GBM region, the Chakma settlement negotiated by Bangladesh in the Chittagong hill tract invites the formation of a larger Mizoram-Tripura-CHT economic subregion, with inland waterways along the Karnaphuli and Feni rivers linking Mizoram and Tripura to the world beyond through Chittagong port. Chittagong needs connectivity and a large hinterland to markets beyond.

North-east passage

The north-east, above all, requires transit and market opportunities. Its isolation can be greatly eased by regional cooperation, especially with Bangladesh.

The region has vast hydro-electric resources which would be attractive for private investment to exploit provided the state electricity boards/departments are corporatized, granted autonomy, and made subject to an independent regulatory authority that would set tariffs at economic levels. It has modest hydrocarbon and coal reserves as well, while Bangladesh appears poised to discover very large gas deposits. A regional energy grid and energy exchange would make sense.

Likewise, the Jamuna bridge across the Brahmaputra at Sirajganj in Bangladesh could become a nodal point for the projected Asian highway and railway, in which interest has revived. These would provide a land route for transit between the north-east and the Indian heartland on the one hand and South-East Asia and south-west China on the other. A national commission on basic minimum needs and infrastructural lags in the north-east (Planning Commission 1997) recommended a Rs 25,000 crores investment programme over the next decade and another Rs 75,000 crores during the ensuing 15 years. Bangladesh senses a rich market opportunity here.

Vision 2025

Water resource development is central to this vision, as it could bind a divided and fragmented region, become an engine for generating income and employment, and give a major thrust to infrastructure development and market opportunity. The Indian National Water Development Agency, under the guidance of a National Commission for Integrated

Water Resource Development, is looking at how best to manage the emerging water shortage, with inter-basin transfers where necessary by 2025. Bangladesh is engaged in a parallel exercise of optimizing its water resource development within the same time-scale through its Water Research and Planning Organisation, WARPO. Nepal's Electricity Development Corporation (EDC) is making a similar study with the focus on power. It would seem eminently desirable and logical that these three bodies establish contact, howsoever informally for a start, so as to commence a process of interaction. They have common goals and are dealing with a common resource.

Global warming and carbon trading

Environmental objections and dam safety issues remain. Certainly transparency, sustainability, and proper rehabilitation are pivotal. Some projects or aspects thereof may be clearly problematic. But not all large water resource projects are bad *per se*. Those that argue this case are ideologues who seek a different pathway to development and growth. For them, any and every large dam is conceptually undesirable. There is no countering doomsday views. Nothing is necessarily ideal. But the cost of not doing could be far greater environmentally and in human terms than damage from going ahead with due care and appropriate compensatory investments.

After swinging away from large dams, international opinion has begun to grope towards what could be a more stable and reasoned position. Global warming has made some earlier critics come round to the view that it is better for large developing societies like China and India to generate more clean hydro energy than to depend increasingly on fossil fuels, especially if used in dirty coal-fired thermal stations. The idea of carbon trading has been mooted as a means of reducing greenhouse gases. With proper safeguards, this could be one way of financing some of the Himalayan hydro projects under discussion.

From dialogue to doing

Both regionally and globally, therefore, the omens are propitious for proceeding energetically with developing the huge potential of the GBM basin. For those living in the region, the Ganges and Mahakali agreements hold out real hope for a brighter future. A framework has been fashioned. Now is the time to move from dialogue to action.

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Appendix

Treaty between the Government of the People's Republic of Bangladesh and the Government of the Republic of India on Sharing of the Ganga/Ganges Water at the Farakka

THE GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH AND THE GOVERNMENT OF THE REPUBLIC OF INDIA,

DETERMINED to promote and strengthen their relations of friendship and good neighbourliness,

INSPIRED by the common desire of promoting the well-being of their peoples,

BEING desirous of sharing by mutual agreement the water of the international rivers flowing through the territories of the two countries and of making the optimum utilization of the water resources of their region in the fields of flood management, irrigation, river basin development and generation of hydro-power for the mutual benefit of the peoples of the two countries,

RECOGNIZING that the need for making an arrangement for sharing of the Ganga/Ganges waters at Farakka in a spirit of mutual accommodation and the need for a solution to the long-term problem of aug-

menting the flows of the Ganga/Ganges are in the mutual interests of the peoples of the two countries,

BEING desirous of finding a fair and just solution without affecting the rights and entitlements of either country other than those covered by this Treaty, or establishing any general principles of law or precedent,

HAVE AGREED AS FOLLOWS:

Article – I

The quantum of waters agreed to be released by India to Bangladesh will be at Farakka.

Article – II

- (i) The sharing between India and Bangladesh of the Ganga/Ganges waters at Farakka by 10-day periods from the 1st January to the 31st May every year will be with reference to the formula at Annexure I and an indicative schedule giving the implications of the sharing arrangement under Annexure I is at Annexure II.
- (ii) The indicative schedule at Annexure II, as referred to in sub-para (i) above, is based on 40 years (1949–1988) 10-day period average availability of water at Farakka. Every effort would be made by the upper riparian to protect flows of water at Farakka as in the 40 years average availability as mentioned above.
- (iii) In the event flow at Farakka falls below 50,000 cusecs in any 10-day period, the two Governments will enter into immediate consultations to make adjustments on an emergency basis, in accordance with the principles of equity, fair play and no harm to either party.

Article – III

The waters released to Bangladesh at Farakka under Article I shall not be reduced below Farakka except for reasonable uses of water, not exceeding 200 cusecs, by India between Farakka and the point on the Ganga/Ganges where both its banks are in Bangladesh.

Article – IV

A Committee consisting of representatives nominated by the two Governments in equal numbers (hereinafter called the Joint Committee) shall

be constituted following the signing of this Treaty. The Joint Committee shall set up suitable teams at Farakka and Hardinge Bridge to observe and record at Farakka the daily flows below Farakka Barrage, in the Feeder Canal, and at the Navigation Lock, as well as at the Hardinge Bridge.

Article – V

The Joint Committee shall decide its own procedure and method of functioning.

Article – VI

The Joint Committee shall submit to the two Governments all data collected by it and shall also submit a yearly report to both the Governments. Following submission of the reports the two Governments will meet at appropriate levels to decide upon such further actions as may be needed.

Article – VII

The Joint Committee shall be responsible for implementing the arrangements contained in this Treaty and examining any difficulty arising out of the implementation of the above arrangements and of the operation of Farakka Barrage. Any difference or dispute arising in this regard, if not resolved by the Joint Committee, shall be referred to the Indo-Bangladesh Joint Rivers Commission. If the difference or dispute still remains unresolved, it shall be referred to the two Governments, which shall meet urgently at the appropriate level to resolve it by mutual discussion.

Article – VIII

The two Governments recognize the need to cooperate with each other in finding a solution to the long-term problem of augmenting the flows of the Ganga/Ganges during the dry season.

Article – IX

Guided by the principles of equity, fairness and no harm to either party, both the Governments agree to conclude water-sharing Treaties/Agreements with regard to other common rivers.

Article – X

The sharing arrangement under this Treaty shall be reviewed by the two Governments at five years' interval or earlier, as required by either party and needed adjustments, based on principles of equity, fairness, and no harm to either party made thereto, if necessary. It would be open to either party to seek the first review after two years to assess the impact and working of the sharing arrangements as contained in this Treaty.

Article – XI

For the period of this Treaty, in the absence of mutual agreement of adjustments following reviews as mentioned in Article X, India shall release downstream of Farakka Barrange, water at a rate not less than 90% (ninety per cent) of Bangladesh's share according to the formula referred to in Article II, until such time as mutually agreed flows are decided upon.

Article – XII

This Treaty shall enter into force upon signature and shall remain in force for a period of thirty years and it shall be renewable on the basis of mutual consent.

IN WITNESS WHEREOF the undersigned, being duly authorized thereto by the respective Governments, have signed this Treaty.

DONE at New Delhi 12th December 1996 in Hindi, Bangla and English language. In the event of any conflict between the texts, the English text shall prevail.

Signed
(SHEIKH HASINA)

PRIME MINISTER,

PEOPLE'S REPUBLIC OF BANGLADESH

Signed

(H. D. DEVE GOWDA)

PRIME MINISTER,

REPUBLIC OF INDIA

Ganges Treaty: Annexure I

<i>Availability at Farakka</i>	<i>Share of India</i>	<i>Share of Bangladesh</i>
70,000 cusecs or less	50%	50%
70,000–75,000 cusecs	Balance of flow	35,000 cusecs
75,000 cusecs or more	40,000 cusecs	Balance of flow

Subject to the condition that India and Bangladesh each shall receive guaranteed 35,000 cusecs of water in alternate three 10-day periods during the period 1 March to 10 May.

Ganges Treaty: Annexure II

Sharing of waters a Farakka between 1 January and 31 May every year

If actual availability corresponds to average flows of the period 1949 to 1988, the implication of the formula in Annexure I for the share of each side is as shown below.

Period	Average of total flow 1949–1988 (cusecs)	India's share (cusecs)	Bangladesh's share (cusecs)
January			
1–10	107,516	40,000	67,516
11–20	97,673	40,000	57,673
21–31	90,154	40,000	50,154
February			
1–10	86,323	40,000	46,323
11–20	82,859	40,000	42,859
21–28	79,106	40,000	39,106
March			
1–10	74,419	39,419	35,000
11–20	68,931	33,931	35,000*
21–31	64,688	35,000*	29,688
April			
1–10	63,180	28,180	35,000*
11–20	62,633	35,000*	27,633
21–30	60,992	25,992	35,000*
May			
1–10	67,351	35,000*	32,351
11–20	73,590	38,590	35,000
21–31	81,854	40,000	41,854

* Three 10-day periods during which 35,000 cusecs shall be provided

Acronyms

ADB	Asian Development Bank
APP	Agriculture Perspective Plan (Nepal)
bcm	billion cubic metres
BIWTA	Bangladesh Inland Waterways Transport Authority
BWDB	Bangladesh Water Development Board
CEA	Central Electricity Authority (India)
CNRET	Centre for Natural Resources, Energy, and Transport (UN Department of Economic and Social Affairs)
DIWT	Department of Inland Water Transport (India)
DPR	detailed project report
EHV	extra-high voltage
FMIS	farmer-managed irrigation systems
GBM	Ganges-Brahmaputra-Meghna
GDA	Ganges-dependent area
GDP	gross domestic product
GNP	gross national product
HV	high voltage
IIMI	International Irrigation Management Institute
ILA	International Law Association
ILC	International Law Commission
JRC	Joint Rivers Commission (Indo-Bangladesh)
LUPP	land-use planning project (Bhutan)
NEA	Nepal Electricity Authority

PSMP	power system master plan (Bhutan)
SAARC	South Asian Association for Regional Cooperation
SPARRSO	Space Research and Remote Sensing Organization
TDR	transferable development rights
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WARPO	Water Research and Planning Organization (Bangladesh)
WHO	World Health Organization
ZACPLAN	Zambesi action plan

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