WATER ACCOUNTING AND WATER INSTITUTIONS' STUDY OF MANUSMARA RIVER BASIN

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ABSTRACT

Manusmara River Basin, a sub-basin of the Bagmati River Basin, lies in the Terai of Nepal. It lies in the sub-tropical climatic zone. The topography is almost flat with a very gentle slope towards the south. Up to the mid 1960s, a large portion was covered by dense, *Sal* forest. At present, only 6% of the area is occupied by forest. Over the last few decades, consumption of water especially for agriculture has increased tremendously. This paper draws out the history of agricultural development in the basin and its interface with the efforts made by the farmers to use the basin water resources.

Water accounting has revealed that Manusmara is an "open basin" and it still offers ample scope for transbasin transfers and further harnessing of the available water. Even during the driest year, only 46% of the available water resources is depleted. This leaves more than half of the basin's yield for undeclared uses. The basin is at the initial stage of development. On the basis of the water account and an institutional analysis, the paper offers some suggestions for integrated development of the basin.

INTRODUCTION: PHYSICAL AND SOCIAL SETTING

Manusmara River is a rain and spring fed perennial river originating from a forest area in the southwestern part of Sarlahi district. From its origin, the river runs south parallel to Bagmati River and joins it at Hathiul. The length of the mainstream is 53.7 km and its average slope is 1:2200. Laldiyar, Soti and Sother are its three tributaries.

The River Basin is a sub-basin of the Bagmati River Basin. The whole basin lies in Sarlahi district in the Terai of Nepal. The basin extends from Latitude 27°03' to 26°46' N and Longitude 85°20'to 85°29' E. Figure 1 shows the Location Map of the Basin. Total basin area is 156 Km^2. The topography is almost flat with the highest point and lowest points at 107.8 and 74.6 m above mean sea level. The deep surface soil varies from loam to fine loam.

The climate of the river basin is sub-tropical. The mean annual air temperature, is 25°C, with a mean annual maximum of 31°C and mean annual minimum of 19°C.

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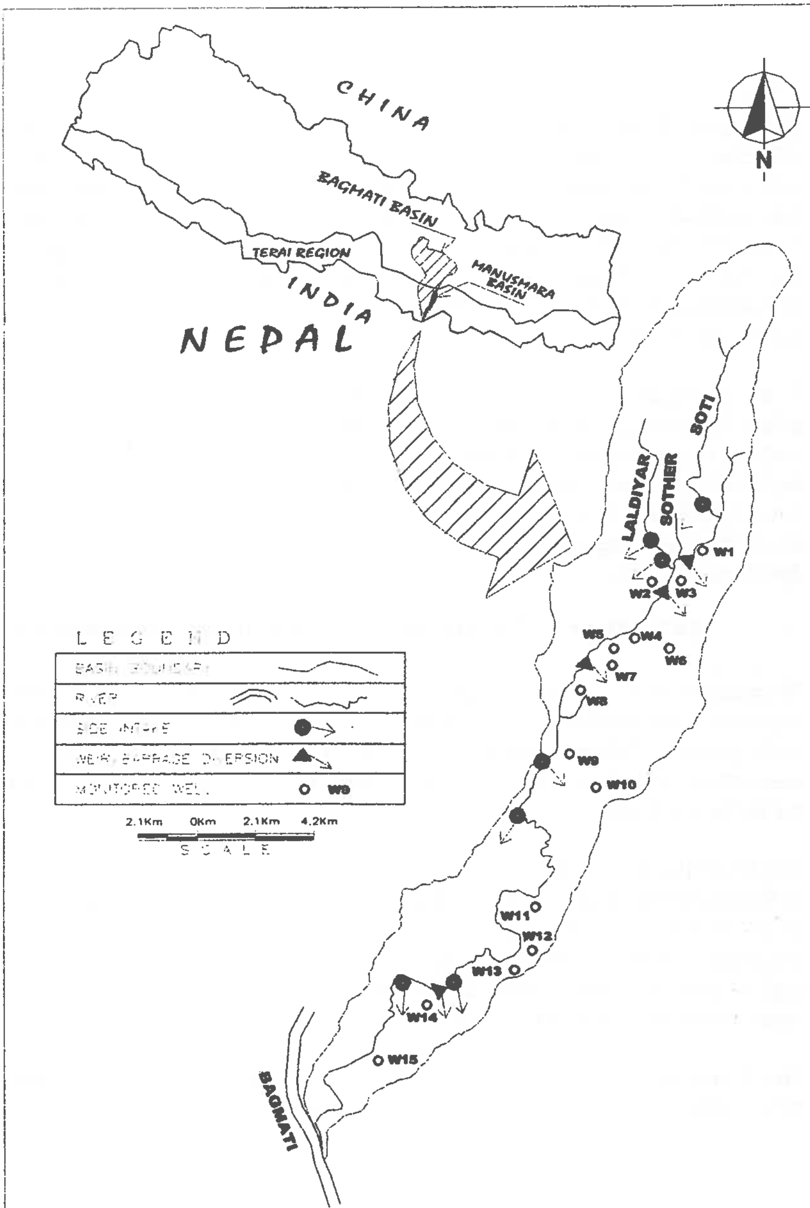

Figure 1. Layout Map of Manusmara River Basin

On the basis of the characterization of thermal regime, the study area lies in the verge of double rice based cropping system. The average relative humidity is about 75% and varies from 50% in the dry season to 90% in the rainy season. The daily sunshine hours averages 7 hrs/day, varying from 4 hrs/day in July to 8 hrs/day in April. The wind velocity averages 1.6 km/hrs.

The Average annual precipitation is 1427 mm. Computed by the WECS method, 80% reliable rainfall has been found to be 1054 mm. Rainfall occurs mainly from the middle of May to the end of October. It is concentrated during the monsoon, which occurs between the second week of June and the third week of September. Average monthly precipitation varies from a minimum of 6mm in November to a maximum of 422mm in July. Considering 1979 to 2000 as the period of analysis, 1980 was found to be the driest year, while 1987 was found to be the wettest year. The year 1993 was an average year.

Up to the mid 1960s, a large portion, especially of the northern part of the basin, was covered by dense forest. However, with the inflow of people into the basin during the 1950s and 60s, the forest was converted to agricultural land. Presently, only 6% of the basin area is occupied by forest. Even though the cropping pattern and cropping intensity vary significantly within the basin, the prevailing major crops are rice, sugarcane and wheat.

Except for Barathawa, which is gradually urbanizing, the basin area is mainly covered by rural settlement. The area, fully or partially, encompasses 24 VDCs[2] of Sarlahi district. The present population density is estimated to be 480/Km^2. Average family size of household is about 6 persons. More than eighty percent of the population is involved in agriculture. Average farm-size per household is small (about 1 ha). However, land is not uniformly distributed and a small minority of rich farmers own most of the land while the majority of the poor farmers have very small land holding.

NATURAL AND SOCIO-ECONOMIC LANDSCAPE CHANGES

History of human existence in the basin goes back more than 200 years. Archeological evidences of settlement ruins and legends of ethnohistory assure this fact. Huge and seemingly old *Pipal* trees are found peculiarly spaced in the locality standing alone or accompanied with Mango or *Sami* tree[3] amidst intensive agricultural land. Whether they were protected from the very beginning or grown by newer settlers, they suggest a long human occupation in the basin.

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[2] VDC stands for Village Development Committees. These are smaller political units of a district. In Sarlahi district there are 99 VDCs.
[3] These trees are celebrated in the Hindu religious life.

Oral lore of the local people of the *Yadav* community ratifies their historical presence in the area. Their livelihood based on cow herding probably existed before cropping was practiced in the locality, when the area was mainly covered by dense forest. The population density was very low and the sense of land possession was not developed. The people then are believed to have practiced subsistence farming with shifting cultivation of rainfed crops like *Aluwa* (Sweden Root), *Maduwa* (millet), *Kagono* (Barley), etc.

Rice is believed to have been introduced to the basin sometimes during the first half of the nineteenth century. With rice came the need for irrigation. Through the individual effort of local farmers, several *kulos* (indigenous irrigation systems)[4] were constructed. These simply consisted of an inundation earthen canal network dug from an appropriate location in the river. During the monsoon, the water level in the river would rise and the water would flow through these canals to irrigate the paddy fields. There was no mechanism to regulate the flow and only limited land could be irrigated. However, since the population density was low and rice initially was produced only for subsistence, this technology was sufficient for the time. Rice production is reported to have gradually increased towards the end of the nineteenth century as markets developed in nearby Indian villages. With the expansion of rice, the tradition of shifting cultivation gradually came to an end. People started to settle down in small clusters in slightly elevated areas in the vicinity of these paddy fields. Wells were dug in each village to fulfill their domestic water requirements.

Significant increase in crop coverage occurred during the Rana Regime[5]. During that period, more cultivation was encouraged by the state to generate more revenue. *Jimmidars* (local landlords who functioned as politico-administrative agents of the state for revenue collection from the peasants) were deputed for each village. Farmers were attracted from everywhere, particularly the Indian plain. The *Jimmidar* encouraged peasants to increase their agricultural production both by bring more land under cultivating and by practicing more labor-intensive agriculture in order to pay the high land revenue.

Increase in crop coverage resulted in the need for diversion of more water. Thus the technology of inundation canals was considered insufficient and was supplemented by earthen dams[6]. The main objective of these earthen dams was to

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[4] Among them, several, including *"Hakrai kulo"* (*kulo* having many branches) were constructed by Harkatawa people and are still functioning today.

[5] The Rana Regime prevailed in Nepal from 1846 to 1950.

[6] The tradition of earthen dam construction does not exist at present. It was very prevalent up until two decades ago. Among the earthen dams at that time, the one near Mahinathpur and the one near Hirapur constructed by the landlords and peasants of Gadaiya and Harkathwa respectively, were reported to be the most prominent.

address the critical requirements of rice during land preparation stage. Through initiative of local *Jimmidar*s, earthen dams were constructed at appropriate locations of the river. Small tenants also contributed voluntary labor and grains. Dam construction was taken as a religious ritual. People found an auspicious day to initiate dam construction every year and performed rites to Gods and local spirits. Each year these dams would be constructed before the monsoon, sometimes during the month of May. They would survive until a major flood in the river would destroy them. Thus dam construction was a continuous process.

The first attempt to construct a permanent structure to divert water in Manusmara river took place during the 1940s. Following the petition of influential landlords of the area, a permanent dam was constructed south of Hirapur through the initiative of the Rana Prime Minister Juddha Samsher Rana. The canal was named Juddha Canal[7] after him. Juddha Canal (its ruins presently known as Choruwa Kottha) was constructed between 1945-47. Later, this dam was completely destroyed by the flood of 1954. However, the construction of Juddha Canal opened the door to a cultivation boom in the locality.

Infrastructure developments in the locality such as construction of irrigation and road networks that took place during and after the 1950s[8] also attracted the population from the nearby hills to the area. Construction of the East-west highway, eradication of Malaria and the effort of the Land Distribution Commission were instrumental to the immigrant boom in the northern part of the basin after 1965. All these developments increased pressure on the land resources in the basin. The land holding size became smaller. Small farmers cultivated rice in some part of their land and used the rest for other staple crops, pulses, vegetables and fruits. Consequently the coverage of rice was slowly replaced by other crops. Moreover, winter crops like wheat and maize were introduced. Thus the cropping pattern rapidly became more intensified and diversified. This crop diversification was also augmented by the introduction of higher yielding varieties of cereals but requiring stricter water management than traditional ones.

This shift in cropping resulted in the need to have more control over water. Thus, in 1965, the first modern diversion (barrage) with steel gates allowing regulation of flow was constructed at Hirapur, upstream of the old destroyed dam. It became operational in 1968. About a decade later, another permanent diversion was constructed 6 km downstream of the first in the form of a concrete barrage at

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[7] Juddha Canal is Nepal's second oldest irrigation system with a modern diversion structure. Chandra Canal constructed in 1923 is the oldest and is also named after another Rana Prime Minister Chandra Samsher Rana.

[8] Elderly key informants have reported that the settlements towards the north of Basworiya Camp only developed after 1950. It is said that only Gadaiya, Dumariya, Bakainiya, Sissautiya, Dhangara, and Dhankaul were in existence during the early half of the last century.

Manpur. This diversion became operational in 1982. Under the Irrigation Sector Project (ISP[9]) another diversion was constructed further downstream at Sudama to irrigate 1630 ha. Then in the year 1996/97 under SISP, Laukat Irrigation System irrigating 375 ha was constructed 3-km upstream of Hirapur. Thus, a series of diversions are currently in use in the river.

The present cropping pattern is a mixture of many crops. Figure 2 shows the existing land use pattern of the basin.

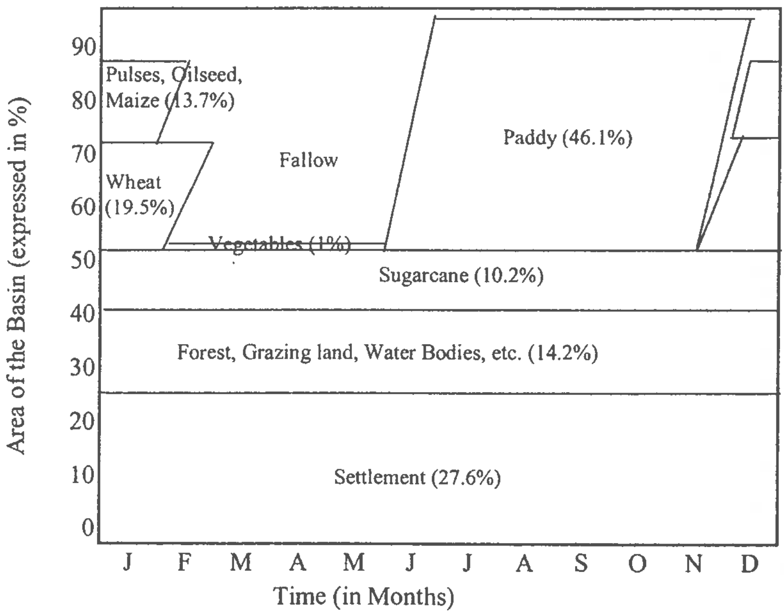

Figure 2. Landuse Pattern of the Basin

The intensity of sugarcane is presently increasing. This is thought to be a risk minimizing strategy against the potential failure of rice production for subsistence and market risks of sugarcane. Almost all the farmers, regardless of their social and economic status grow cane on about one third of their land. Other key crops

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[9] Irrigation Sector Project (ISP) was launched in Nepal from 1989 to 1993 through the loan assistance of Asian Development Bank. It aimed to provide irrigation facilities in 25000 ha of land in 35 districts of Nepal including Sarlahi. Due to the encouraging progress of the project and increasing demands of the farmers, the scope of the project was further increased to 33000 ha and under the banner of Second Irrigation Sector Project (SISP) is underway.

are rice during the summer and wheat, oil seeds and maize during the winter. The prevailing cropping system also allows poor farmers to go to Punjab both as on-farm and off-farm migrant labor in winter.

Cropping intensity decreases as one moves from north to south along the basin. The major reasons for this are higher coverage of short-term crops like maize and vegetable in the north and long-term crops like sugarcane in the south. Moreover, big and absentee landowners are more prevalent in the south. In the south, farmers cultivate land on *Hunda* (contract) or *Bataiya* (share cropping) bases.

WATER AVAILABILITY SCENARIO: INFLOWS AND STEAMFLOW

Inflow to the basin occurs from 3 sources: rainfall, ground water and irrigation supply from Bagmati Irrigation System. Rainfall in the basin is concentrated from the second week of June to the third week of September. Considering 1979 to 2000 as the period of analysis, 1980 was the driest year while 1987 was the wettest. 1993 was a normal year. Average monthly precipitation varies from a minimum of 6mm in November to a maximum of 422mm in July. On the basis of analysis of daily rainfall data from 1997 to 2000, the maximum 24-hr daily rainfall has been recorded to be up to 159mm on 21 June 1998.

Ground water is the second source of inflow to the basin. Inflow from the ground water table is observed to occur by three ways: firstly through river recharge, secondly through capillary rise into the root zone depth and thirdly through extraction by hand pumps. The ground water table over the basin area was observed and interpolated using 15 representative wells. In general, the ground water table of the basin is found to be quite high. On an average in a normal year, it was found to be about 2m below average ground level. Seasonal fluctuation was observed to be of the order of 1.8m. During the non-monsoon period (i.e., from October to May) the water table of almost the whole basin is below the average root zone level[10]. However, during the monsoon period (i.e., from June to September) the basin can be divided into 4 parts. The first part, comprising of 20% of the area of the basin, is the part where the ground water table never reaches the root zone level. The second part, comprising of 54 % of the basin, is the part where the ground water table reaches on an average 0.1m for about 12 days. The third and forth part, comprising of 13 % each, is the part where the ground water table reaches on an average 0.6m and 1m for 50 days and 82 days respectively.

Irrigation supply from Bagmati Irrigation System is the third source of inflow into the basin. The designed discharge of the secondary canal entering the basin is 1.2 m^3/s. Considering the operational schedule of the irrigation system, the discharge is estimated at 70% of this under normal conditions. Thus, for a normal year, the

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[10] Considering the existing crops average root zone depth has been taken as 1.2m.

annual inflow is 26.5 Mm^3. The operational period has been found to increase by ten percent during a dry year and decrease by 10% during a wet year.

Study of river's morphology has revealed that the river can be divided into three stages. From the origin up to Manpurgoth (a 13km stretch), the river has an average slope of 1:1000. It is quite straight and the alignment is significantly far away from Bagmati River. The 27.5 km stretch from Manpurgoth to Khairwa is very flat (average slope: 1:3300) and has a lot of meanders. Finally, the stretch (13.2km) from Khairwa to Hathiaul (the confluence point) with an average slope of 1:4200 is relatively straight. It appears that the first stretch gets its recharge from the spring line of the Bhabar zone, the second stretch gets recharge from the seepage water of Bagmati river and the third stretch gets surplus discharge by the flooding of Bagmati River.

Measurements of discharge carried out at the confluence point are found to vary between 7.4 m^3/s during the month of April to a maximum of 14.9 m^3/s during the month of August. The average discharge is found to be 10 m^3/s in a normal year. Thus the outflow from the basin is 316 Mm^3/year.

WATER USE SCENERIO OF THE BASIN

Water in the basin is being used for irrigation, domestic purposes and for animal husbandry. These uses have been considered as the `Process Depletion' of the basin. No industry exists within the basin. Among the various uses, irrigation is the most prominent in terms of volume. At present, a series of diversions exist in the river in order to divert water for irrigation purposes. These diversions can be broadly categorized into two types: permanent diversions and side intakes. Permanent diversions are concrete structures (barrage or weir) which divert water as per the requirements of the farmers while side intakes are off takes where water flows through inundation when the water reaches a certain level. For details of the diversions see Figure 3. As significant differences exist in the cropping pattern and cropping intensity within the basin, each irrigation command area has been treated differently for crop water requirement computations within the basin. The Penman Montheith method has been used for the computations. The diverted water is not only used within the basin but also goes beyond the basin boundary. This part has been counted as transbasin transfer.

For domestic purposes, no water supply system exists except for the hand pumps. Previously dugwells were used to fulfill domestic water requirements. Hand pumps were introduced in this area from the early 1970s. These were considered superior as they occupied less space, were less prone to contamination and were easier to operate. Thus, hand pumps slowly replaced the dugwells and their number is gradually increasing. Well-to-do families own up to 3 hand pumps, while in poor communities 3 to 5 families share one hand pump. Even though some tubewells go as deep as 20m, most tube wells in the area are 8 to 12m deep. A total of about 2400 tubewells exist in the whole basin area.

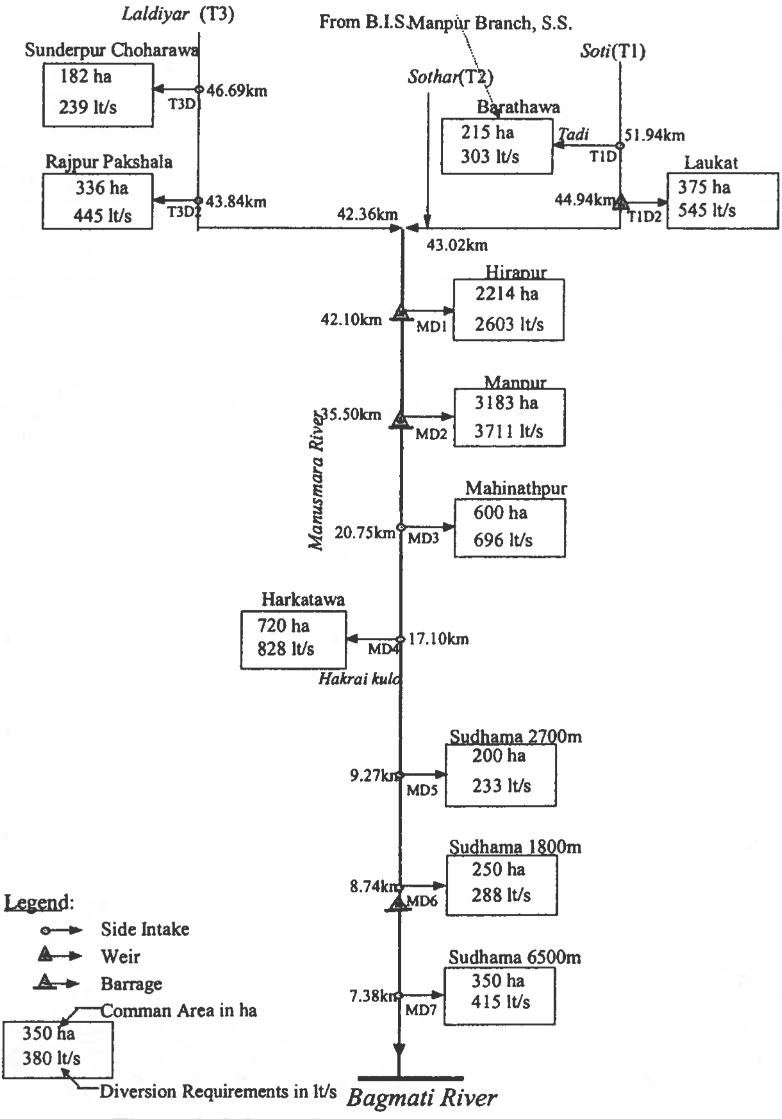

Figure 3. Schematic Diagram of Manusmara River

WATER BALANCE OF THE BASIN

Water balance of the basin is computed considering all the inflows, depletions (process, non-process and non-beneficial) and outflows. Analysis has been carried out considering all three cases of dry, wet and normal years (Table 1).

Table 1. Water Account Results

	Year Considered	Wettest Year (1987)		Normal Year (1993)		Driest Year (1980)	
	Previous Year	Normal		Dry		Normal	
Components	Sub-Component	$10^6 m^3$	%[11]	$10^6 m^3$	%	$10^6 m^3$	%
1 Gross Inflow	a. Rainfall	387.8	60.4	221.8	46.8	156.6	39.8
	b. Groundwater	222.8	34.7	218.4	46.1	214.0	54.4
	c. Bagmati I. P.	24.1	3.8	26.5	5.6	29.2	7.4
	Sub total	**634.7**	**98.9**	**466.7**	**98.5**	**399.8**	**101**
2 Storage Changes	a. Surface storage	0.9	0.1	0.7	0.1	0.2	0.1
	b. Ground storage	6.3	1.0	6.3	1.3	-6.3	-1.6
	Sub total	**7.2**	**1.1**	**7.0**	**1.5**	**-6.0**	**-1.5**
3 Net Inflow		**641.9**	**100**	**473.7**	**100**	**393.7**	**100**
4 Process Depletion	a. ET Paddy	43.6	6.8	43.6	9.2	43.6	11.1
	b. ET Wheat	13.9	2.2	13.9	2.9	13.9	3.5
	c. ET Sugarcane	16.0	2.5	16.0	3.4	16.0	4.1
	d. ET Pulses	6.5	1.0	6.5	1.4	6.5	1.7
	e. ET Maize	2.7	0.4	2.7	0.6	2.7	0.7
	f. ET Oilseed	1.5	0.2	1.5	0.3	1.5	0.4
	g. ET Vegetables	1.1	0.2	1.1	0.2	1.1	0.3
	h. Domestic uses	0.8	0.1	0.8	0.2	0.8	0.2
	i. Animal uses	0.3	0.0	0.3	0.1	0.3	0.1
	j. Trans-basin diversions	22.1	3.4	20.1	4.2	18.1	4.6
	Sub total	**108.5**	**16.9**	**106.5**	**22.5**	**104.5**	**26.5**
5 Non Process Depletion (beneficial)	a. ET Forest	6.6	1.0	6.2	1.3	5.9	1.5
	b. ET Canal forest	0.2	0.0	0.2	0.0	0.2	0.1
	c. ET Grass land	2.8	0.4	2.6	0.5	2.5	0.6
	d. ET Homestead	30.0	4.7	28.2	6.0	27.1	6.9
	Sub total	**39.6**	**6.2**	**37.2**	**7.9**	**35.7**	**9.1**
6 Non Process Depletion(non-benefit)	ET Barren land, flood plain and water bodies.	**5.6**	**0.9**	**5.2**	**1.1**	**5.0**	**1.3**
7 Out-flow	Runoff	**461.0**	**71.8**	**316.0**	**66.7**	**242.0**	**61.5**
Sum of depletion & surface run-off		**614.7**	**95.8**	**464.9**	**98.1**	**387.2**	**98.3**
	Deep percolation	**27.2**	**4.2**	**8.8**	**1.9**	**6.6**	**0.7**

[11] This value is the % of the component to Net Inflow into the basin.

Among the three sub-components contributing to inflow into the basin, rainfall has been found to be the most significant. However, this contribution is found to differ a lot between a wet and a dry year. On the other hand, contribution through subsurface inflow has been found to be more constant. "Storage Change"[12] is mainly due to change in ground water storage and change in soil moisture storage.

Process depletion includes depletion for use both within the basin and outside the basin through transbasin transfer. Committed flow has been assigned considering the environmental concern of fishes in the river. Since accurate assessment of deep percolation was not possible, the difference between total inflow and the sum of depletion and surface run-off has been taken as the value for deep percolation.

WATER INSTITUTIONS

Institutional analysis of the basin, including both the rules as well as the organizations governed by such rules, has also been carried out in detail. Water use institutions of the basin have been found to evolve and their role to change through time. In the olden times as permanent structures for the diversion of water did not exist, the main challenge for farmers was to mobilize resources for the acquisition and allocation of water. Even though the labor requirements were quit high, the social structure and norms were instrumental for such resource mobilization and need to have a formal organization for this activity was not evident.

With the expansion of agriculture, the need to have more control over water increased. As a result, not only were permanent diversion structures needed but also more formal organizations required. Thus, in all command areas where permanent diversions have been constructed by the government, Water Users' Associations (WUAs) have been formed. These associations mainly function to distribute water within their command area. Analysis of the decisions and actions taken by these associations clearly reflect the fact that their major concern is water management and resource mobilization for operation and maintenance of the irrigation system. No associations exist for command areas irrigated through inundation canals.

At the basin level, no organization is found to exist for ensuring effective water use of the basin as a whole. Even though it is understood to be the task of the government, the mechanism for its achievement is found to be ineffective. Very little attention is being given to the issue of water rights. Upstream diversions are constructed without any discussion or consensus from the downstream users. Construction of Laukat Irrigation System just 2.8km upstream of Hirapur Barrage

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[12] Storage change is the difference between storage at the beginning of the year and at the end of the year.

has been found to affect the water availability situation of Hirapur but this matter was not explored prior to the construction.

CONCLUSIONS OF THE BASIN STUDY

Historical review and the present water accounting computations of Manusmara River Basin indicate that within the last few decades many changes have occurred in the amount and pattern of water use in the basin. Process depletion has increased tremendously. Table 2 displays the present water account indicators of the basin.

Table 2. Computed Basin Water Account Indicators

S.N.	Indicators	Unit	Value	Remarks
1	Productivity of water	US$/m^3	0.1	@US$1=NRs 70
2	Depletion / Available water	%	46%	Driest year
3	Beneficial Process Consumption / Available water	%	33%	Driest year
4	Beneficial Consumption / Available water	%	44%	Driest year
5	Utilizable flow	%	50%	Driest year

Even though the major share of depletion goes to beneficial process consumption, the productivity of water is still low ($0.1/m^3). This owes to the fact that the water is not at all being used for commercial purposes like industries. It has been observed that even during the driest year, only 46% of the available water is depleted, leaving more than half of utilizable outflow to move out of the basin. In the wettest year this value of depleted water reduces to 27%. As utilizable outflow takes place throughout the year, the basin is an "open basin". This implies that there is a potential to harness utilizable outflow and use it productively both within and outside the basin.

The basin water account indicators reveal that the basin is still at the initial stage of development. The institutional mechanisms for integrated development of the available water in the basin are still weak. Since the use of water has increased drastically and is projected to further increase in the future, the need to develop a proper mechanism for this task has been urgently felt.

The basin is found to have good potential for development of ground water. Ground water has been found to contribute significantly not only to inflows but also in fulfilling the domestic water requirements. Ground water potential can be further harnessed to fulfill irrigation requirements as well. Conjunctive use of surface and ground water, with proper development of ground water during the winter is a good option.

No storage reservoir exists within the basin. In order to tap the high discharge during the monsoon, storage reservoirs would be an option. However, considering the flat topography, construction of storage reservoirs in this basin is not advisable. Rather, a more systematic development of diversions that further enhance water consumption not only within the basin but also to the neighboring basin is recommended.

In order to plan the use of outflows from the basin need of an appropriate institutional mechanism has been felt necessary. An institutional structure that enable participation of beneficiaries from each diversions with an apex body which works for the optimum use of the resources of the whole basin has been suggested to be formed in the near future.

REFERENCES

Aptec, (1997). Baseline Study of Manusmara Irrigation System. Research and Technology Development Branch, DOI.

District Water Supply Office, (1999). Status of Water Supply Systems in Sarlahi District. District Water Supply Office, Malangawa.

Molden, David and R. Sakthivadivel, (1999). Water Accounting to Assess Use and Productivity. Water Resources Development, vol 15 Nos. ½ 55-71.

Water and Energy Commission. (1987), Water Use Inventory Study of Sarlahi District. Water and Energy Resources Development Project.