Basin No.	Name of River Basin
VIII	Narayani/Gandaki river system
IX	Southern border river group No.4
X	Bagmati river system
XI	Southern border river group No.5
XII	Kamala river system
XIII	Southern border river group No.6
XIV	Kosi river system
XV	Southern border river group No.7
XVI	Kankai river system
XVII	Southern border river group No. 8

The numbering of basic unit of river basin is made from the west to the east.

Each basic unit of river basin system is progressively divided, upto a maximum of four times for the major basins, two and three times for the small or comparatively minor basins respectively. The division is made such that the rivers of fourth division are the tributaries of the third division, the rivers of third division are the tributaries of the second division, and the rivers of the second division are the tributaries of the first division, that is, the basic unit. The division is prepared as listed in Appendix 1 based on the topographic maps and other reference books/reports. It may be necessary to revise or add the name of rivers/river-basins later. As far as the basic frame of division is concerned, reasonable and comparatively simple frame should be prepared so that the revision would not be difficult. The actual river course will be occasionally different from the maps and the river name is often different between the local name and that on maps. The river division of these basic units with the second division only for the major three rivers (the Karnali, Gandaki and Kosi) is shown in Table 3.1 which would be the practical division of basic unit.

The map of river and river basins in Nepal is shown in Fig. 3.1 and the schematic map of river basin division prepared for easier understanding is shown in Fig. 3.2.

3.3 General Features of Rivers and River Basins

3.3.1 General

Most of surface water in Nepal drains through four major rivers - Kosi(Sapta Kosi), Gandaki (Narayani), Karnali and Mahakali and their tributaries. These are all perennial rivers forging through varied mountain ranges and originating from Himalayan mountains or Tibet Plateau. Other major rivers originate from the Mahabharat ranges. They are the Mechi, Kankai,

Kamala, Bagmati, Tinau, Rapti, Babai and Mahakali. The Mahakali and Mechi rivers act as international boundaries between Nepal and India. There are several lakes located mainly in the Himalayan Zone. The major lakes are Rara, Phoksundo, and Tilicho, etc. Glaciers of varied dimensions also exist in the Himalayan region. The major glaciers are Khumbu, Langtang, Kanchanjunga, Yolung, Ramitang, Barun, etc.

The principal features of major rivers/river-basins are summarized in Tables 3.2 (1/2) and (2/2). These features are obtained from the reference book/reports as well as the topographical maps. It would be necessary to confirm the figures more in detail when the reliable detailed figures are required for studies in the future.

Depending on their sources of dry-season discharge, the rivers of Nepal are of three grades. The first grade rivers are Mahakali, Karnali, Gandaki/Narayani and Kosi/Sapta Koshi along with some of their tributaries, having their sources in the snow and glaciers in the Himalayan region.

Snow in the northern Nepal covers about 10 percent of the total precipitation. The snow covered area is about 14,795 sq.km including the areas of adjoining country. Although permanent snow lies above 4,570 m., glaciers come as low as 3,000 meters in the western Nepal. The snow-fed rivers carry significant flows in the dry season, and hence, are important for the purpose of irrigation and power generation.

The second grade rivers are Bagmati, Rapti, Kamala, Mechi, Kankai, Babai etc., originating from the Mahabharat range below the snow line. They are fed by ground water including springs. Hence, they do not dry up during the low flow period, and are also good for irrigation and hydropower purposes. The third grade rivers having their origins in the Siwalik (Chure or Churia) range are Tilawe, Sirsia, Manusmara, Hardinath, Sunsari, Banganga etc. They are not suitable for perennial irrigation and hydropower generation as they have either very low amount of water or dry up during the low-flow season.

There are innumerable lakes and ponds, covering about 2 percent of the total runoff. Most of the oxbow lakes are found in the Terai. There are several hot springs known as "Tatopani" in Nepal. Most of them exist in the river valleys. A hot spring with very hot sulphurated water exists about 1 km south of Kodari Check post in the Sunkosi valley. In Janakpur also there are three hot springs containing sodium, potassium, sulphate, carbonate and chlorine ions.

There are about 6,000 rivers in Nepal, 1,000 of which are more than 11 kms long and about 100 of them are longer than 160 kms. The total length of all streams and rivulets exceeds

45,000 km. Thus, the drainage density expressing closeness of spacing of channels is approximately 0.3 km. per sq.km.

Considering only the three snow-fed major river systems (The Karnali, Gandaki and Koshi) with their total drainage area around 139,360 sq.km. The estimated annual mean stream flow is found to be 4,700 cubic meters/second equivalent to the annual runoff of 148,000 million cu.meters. This amounts to 74% of the annual surface runoff of about 6,400 cu.m/sec or 202,000 million cubic meters. The total annual runoff from the territory of Nepal only is 4,877 cu.m/sec or 153,800 million cubic meters which if distributed over the whole country is enough to cover the whole of Nepal 1,086 mm deep. The total drainage area of all rivers amounts to about 191,000 sq.km of which 74% lies in Nepal only. The average annual runoff coefficient is about 71.6%. About 80 to 85% of annual surface runoff occurs during the monsoon period.

The attention is paid also to the sediments and the influence to the Ganges river, the main river of the major rivers in Nepal. The Ganges Basin which covers parts of four countries, China, Nepal, India and Bangladesh, is experiencing intensive erosion due to natural geomorphological conditions, intense rainfall, frequent seismic activity and inappropriate land use practices. The Ganges river system carries and delivers a large quantity of sediment each year into the Bay of Bengal. The entire area of Nepal lies within the Ganges Basin and Nepal occupying the central part of the highest range of the Himalayan Mountain System, the gravity of the problem of soil erosion is very critical. The combined action of natural geological processes and the accelerated erosion due to human activities has resulted in catastrophic consequences, both in terms of loss of top soil and potential agricultural land. Landslips, slumps, rock failures, and river channel erosion dominate the erosion picture in much of the Himalaya, and most of these are of natural origin. The sediment load from mountainous areas is believed to be derived extensively from localized mass wasting (landslides) rather than from generalized surface erosion. Moreover, a number of Glacial Lake Outburst Floods (GLOFS) occurred in the region causing severe erosion and landslides along the river channel. This phenomena has mobilized vast quantities of materials and resulted in massive sedimentation in the river system. Thus, in tectonically uplifting Himalaya much of the erosion is natural. But accelerated soil erosion is caused by human activities. Continuing population imbalance in the Mountain and Hill areas has increased pressure for bringing more lands into cultivation, either by moving into much steeper land adjoining farms or by removing forests of nearby steep areas. The result of movement into such marginal land has been the primary cause of accelerated soil erosion, declining of soil fertility through the loss of topsoil and productivity. The ever increasing population pressure on land has reduced the average size of individual family land holdings below economically viable limits and has severely aggravated the soil

erosion problem. Moreover, the combination of fuelwood and fodder extraction in Mountain and Hill forests, overgrazing and improper cultivation on steeper slopes have resulted in soil erosion and sedimentation. The development activities like construction of roads and irrigation systems in the region could further accelerate the soil erosion and landslides. Almost 5% of Nepal's mass movement problem is caused by road and trails.

The field reconnaissance by the river engineer was carried out three times during this 29 days assignment as follows:

(a) Reconnaissance of Terai rivers by car and walking

(b) Reconnaissance of mountain rivers mainly by walking

(c) Inspection of Terai and mountain rivers by helicopter

It was comparatively hard to carry out the field reconnaissance in this season as it is quite hot and the road condition is generally bad due to monsoon rain. However, the field reconnaissance was effective to see the river conditions directly, at this monsoon period, and to obtain the information from the local people. Some general comments on the river conditions are given below.

(a) The river flow contains much sediment loads in rainy season while the flow is generally clear in dry season.

(b) The flow discharge, as well as the velocity is also remarkably different between the rainy season and the dry season. It is said that about 85% of annual runoff occurs in rainy season. The ratio of high flow and low flow is generally 100-1000 times.

(c) In Terai plain, the rivers generally meander on the flat plain and the flow channels braid in the comparatively wider river section. Many sand bars are seen in the Terai rivers.

(d) The river training works are generally scarce. It is generally limited at the other river related structures such as bridges, irrigation intakes and barrages. The river training works which are not related to the other structures are dikes spurs, revetment etc. Such structures were usually constructed after the flood damage in the past or for the purpose to use a part of river bed as agricultural land. However, it was found or informed that some existing river training works are not adequate in design and/or construction (quality).(e) In Terai, there are many farmer managed irrigation schemes besides the big governmental irrigation schemes. Such schemes take a part of river flow at many points. The total intake discharge would be a remarkable percentage of the total natural discharge during dry season.

(f) At some small rivers in Terai, the rivers are sometimes connected by irrigation canals.

(g) In rainy season, the flood inundation frequently happens in Terai rivers. However, the inundation area is generally limited in narrow low land along the river.

The inundation becomes wide, longer and serious when the drainage of inundation is not sufficient generally due to improper river related structures.

(h) In mountain areas, the rivers run in steep valleys. The river width is changeable even in the same river. At narrow river section, the valley is also narrow and the river makes a gorge. At wider river section, the gradient is comparatively gentle and the flow section is a part of river course where sand, gravel and boulders are sedimented. The slope of mountains is quite steep almost in any places. At some sections, the river terraces are seen and villages and agricultural lands are located generally on such terraces.

(i) There are different types of tributaries which join the main stem in the mountain area. Some tributaries make fans at the confluence, some join through waterfalls, and some join with almost the same channel conditions as those of main stem. The river gradient of the tributary is steeper than that of main stem in almost any case.

(j) The river channel section is generally stable in the mountain area and relatively unstable in the Terai.

(k) In general, the river bed in mountain area is degrading while that in Terai is aggravating.

(l) The vegetation is seen generally upto the height of aproxi. 3,000 m - 4,000 m although the height is different for different seasons

(m) In mountain area, the land sliding is seen at some places along each river. Some of them are large in scale and make the narrow river flow section at these points.

(n) The river density seems high in Nepal. It is said that there are more than 1,000 rivers which are longer than 11 km. It would be difficult to count the river number exactly as there are many small rivers and some of them become rivers only during heavy rain.

Soil erosion in Nepal is one of the serious concerns at present from the viewpoints of ecology and flood inundation in the downstream reaches. It is usually linked with the population increase and deforestation. It would be difficult to measure or estimate the quantity of erosion and sediments in rivers. Although some estimates are available, these are always assumptions based on some limited data. One assumption is that about 5 -10 tons/ha of soil is eroded every year in Nepal. That means about 2.5 - 5 m^3/ha or 0.2 - 0.5 mm depth of soils is removed annually. The average sediment load of rivers in Indian - Pakistan and Nepal ranges has also been estimated to be in the range between 1,000 and 10,000 tons/km^2/year. The extent of erosion of land and sediment loads in rivers differ much by the location as well as by the

rivers. The sediment loads in Nepal rivers estimated by Laban.P is presented for reference as follows:

Sediment load in some Nepal rivers

River	Catchment Area (km^2)	Total annual sediment load (m^3)	Sediment load (t/ha/yr)	Erosion rate (t/ha/yr)
Tamur	5,900	29.6×10^6	80	240
Arun	36,500	34.6×10^6	15	45
Sunkosi	19,200	54.2×10^6	45	135
Bagmati	600	2.7×10^6	45.5	96
Trisuli	4,100	7.6×10^6	18.5	55
Karnali	42,900	220×10^6	51	153

Overall erosion rate in different areas

Churia hill (east)	7.8 - 36.8	t/ha/yr
Churia hill (west)	20 - 200	t/ha/yr
Mahabarat lekh	31.5 - 140	t/ha/yr
Central Nepal	63 - 420	t/ha/yr
Middle mountain	27 - 45	t/ha/yr

In regard to the erosion and sediments, the Water Induced Disaster Prevention Center recently established by JICA will contribute to obtain more reliable and detailed data.

It is noted that there are some different ways of calling river in Nepal. The representative names are "Khola" and "Nadi". The "Khola" is generally used for small river, however, it seems that there is actually no definite difference between the two names.

3.3.2 Mahakali River

(A) The Mahakali river is 223 km long, having its origin in Api Himal of the Himalayan range, is a international river located on the western border of Nepal and India. The total catchment area is approximately 15,260 km^2 and about 5,400 km^2 (about 35%) is located in Nepal. The river starts from Milan glacier of India and from the Lipulekn of Nepal. It flows southwest making numerous oxbow lakes in the Indian territory. The main tributaries in the Nepal side are Surna Gad river and Chamlia river. The Mahakali Irrigation Project is under operation and execution in the Terai plain. There is no other

existing project nor definite plan of water resources development at least in the Nepal side.

(B) Mahakali is in dolomite upto Jhulaghat, whereas, in the south, it is in gneiss and dolomite and near Rangun khola it is in the Churia formation.

(C) The river is in a gorge about 300 m deep and approximately in the upper region. The following gradients in rivers channels at some representative stretches are reported in a reference book.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Mahakali (Main stem)				
(a) Samser dampa (1,200)	Dengsi	(600)	45	13
(b) Dengsi	Bermdeomandi	(300)	109	3
Chamila				
(a) Guljar (1,800)	Mathkhola	(1,200)	3	190
(b) Mathkhola	Churani	(1,050)	8	19
(c) Churani	Sirmoli	(600)	32	14
(d) Sirmoli	Lumsal	(500)	13	6
Surnagad				
(a) Kathmandu (1,800)	Niauli	(600)	32	38
(b) Niauli (600)	Jakh	(400)	13	14

This indicates that the Mahakali river and tributaries have high gradient. The channels are deep in the eastern part as compared to the western side.

Mahakali river divides into two channels near Lamsari which again join together at Suklapura. The old channel delineates the border of Nepal with India. Many Oxbow lakes pointing concave side towards north are found in the Mahakali plain of Indian territory.

(D) The Mahakali river meets the Karnali river in India. Its estimated yearly mean runoff is 557 cubic meters per second.

(E) In the Nepal-India border area, but officially located in Indian territory at present, there is Sarda Barrage crossing the Mahakali river. As an international river, the water right of

Mahakali river causes long-term argument between both countries. An article of a magazine introduces the situation as follows:

"In 1929, the British Government reached to an agreement with Rana Prime Minister Chandra Shumshere to an unequal swap. India would build the Sarda Barrage on the border river of Mahakali in Nepal's west and receive some Nepali territory for the purpose. In return, Nepal would get 4,000 acres of salforest in Allahabad Presidency District which lay to the east and fifty thousand rupees."

The salforest is long gone, but under the agreement, the Sarda Barrage continues to take away most of the water of the Mahakali. The Mahakali has a mean annual flow between 1,100 to 1,300 cubic meters per second (cumec), and the Sarda canal takes away about 400 cumec. When, in the 1970s, with World Bank help, Nepal initiated the Mahakali Irrigation Project just above the Sarda Barrage, it was allowed to withdraw about 460 cumec of water as per the old agreement.

In the early 1980s, when Nepal first heard of Indian plans for a power project upstream at Tanakpur and made enquiries, it is reliably learnt, New Delhi denied the existence of any such design. Subsequently, when the earth works could not be hidden, the Indian side came back and said that the Tanakpur Power Project (for that was what it was) would not affect Nepal in any way. Actually, this 125 MW Tanakpur hydro-electric project, completed in 1988, had serious physical implications for the Mahakali Irrigation Project. Initial plans were to divert most of the Mahakali water to the power house and direct the exiting water through a tail-race channel into the Sarda Canal. Because, apparently, the canal cannot take so much water it has now been agreed that the outflow from Tanakpur will be released back into the Mahakali, above the Sarda Barrage and the Mahakali Irrigation intake.

In order to capture the Mahakali water for the Tanakpur power house, Indian engineers built a weir at a part way across the river. However, rivers do not always follow the engineer's dictates, and the Mahakali flowed away from the weir, in the process taking away 33 acres of Nepali land. The Indian side now wants permission from Kathmandu to extend the weir ("afflux bund") all the way across the river into Nepal so that the Mahakali is better controlled and Tanakpur Power Plant properly supplied.

If there is a "common river" in the Himalaya, it is the Mahakali which flows between Nepal and India. Its water should, under the ideal conditions, be shared equally. Through a quick of history (Chandra Shumshere's deal with the British), the Indian side happens to own both sides of this common river at the point where the Sarda Barrage is built. As a result, both the power to be made as well as the land to be irrigated out of the Mahakali water from projects to date benefit India overwhelmingly.

In order to save Tanakpur, Nepal is now being asked to allow the construction of a weir across the Mahakali which would intrude into Nepal territory. What should Nepal do? Show magnanimity, obviously. What should India do? Perhaps right a British wrong and come up with a formula for more equitable sharing of the Mahakali waters. Perhaps half of Tanakpur's electricity output, or perhaps half of the river's flow, or perhaps something in between.

3.3.3 Rivers in Southern Border River Group No.1

(A) The area is surrounded by the Mahakali river on the west, the Karnali river on the east, the either or the two river basins on the north, and the Indian border on the south. The total area is approximately 3,800 km^2. There are several rivers, comparatively short ones, originated at Churia hills of 1,000 - 1,500 m in elevation. Major rivers are as listed below.

- Bahamati river
- Mohana river*
- Khatiya river*
- Dhuraha river
- Kanara river- Patharaiya river*

All the rivers have significant potential of water resources development, especially for agriculture. However, the rivers with * mark will be relatively important at present as there are existing irrigation projects as listed below.

- Mohana Irrigation Project
- Khutia Irrigation Project
- Patharaiya Irrigation Project

These rivers have little water in the dry season and are flashy in the rainy season. The channels are not very deep, generally, 1.5 - 2 m below the average ground. The width of channel varies generally 400 - 800 m. The rivers have general gradient of 4 m per km in the eastern part, whereas, 1 m per km in the western side.

3.3.4 Karnali River

(1) River System and Main Stem

(A) The Karnali river, one of the three major rivers in Nepal originates from the south of Mansarovar and Rokas lakes located in China (Tibet) and enters in Nepal near Khojarnath flowing in southeast direction. The drainage area in China is approximately 2,500 km^2 and that of Nepal territory is approximately 41,500 km^2. Therefore the total drainage area is estimated at approxi. 44,000 km^2. In Nepal, it becomes Humla- Karnali. It makes a sharp bend at Naralagna himal. From there, it flows towards east and to south-west at Nima-pipalang. There it is joined by Mugu Karnali and Kharte khola meets at Sukhadik. In between these two tributaries the Raradaha (a big lake) is situated. The length of Mugu-Karnali is 160 km and Humla-Karnali has 100 km. In Nepal, Karnali is joined by Sinja khola at Peripalni which drains out Jumla area. Karnali appears to be pushed north-westward by Jumla granite. Due to this, the Karnali and its tributary Sinja both go north westerly, thus forming a U bend, before coming to the south. From the confluence of Humala and Mugu Karnali up to the U bend, the Karnali river flows nearly 40 km in the western direction, then changes the course due east. Before entering in the Terai plain, it has already covered a further distance of 50 km. In Terai it flows a distance of 30 km inside Nepal before entering the Indian border.

Compared to other rivers, the Karnali valley is steep and confined in narrow gorges except at the Jaksi Ghat to Sundargaon reach where it swells to approximately 800 m width, and the rest of the valley is not good for cultivation.

Bheri, Seti, Thuligad and Burhiganga are the main tributaries of Karnali river.

(B) Karnali in upper part is in granite and gneiss whereas, in midland mostly in chlorite schist and dolomite. Near the U bend, it is in the thrust plane and quartzite and near Chisapani it is in the Churia formation.

(C) River channel conditions

The gradients in river channels at some representative stretches are reported in a reference book as shown below.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
1. Kunar Khola (Karnali)				
(a) Sankhalagna (4,450)	Confluence of Karnali	(1,350)	52	327
2. Karnali (Humla)				
(a) Simikot Dandagoan (2,100)	Chhengi	(1,800)	32	9
(b) Puima (1,340)	Raskot	(1,050)	51	6
(c) Raskot	Manma	(970)	14 6	
3. Karnali (Main)				
(a) Sirpato (1,350)	Bhankot	(750)	67	9
4.	Karnali (Mugu)			
(a) Mengiri (2,100)	Ruga	(1,930)	13	15
(b) Ruga Confluence	Karnali	(1,500)	26	17
5. Sinja Khola				
(a) Riyan (3,000)	Peripalni	(1,200)	70	26

(D) The Mugu Karnali coming out of Laddakh Himal joins the Humla Karnali originating from China (Tibet) at Galwa, giving rise to the Karnali river also known as Ghagra in India, which meets the Ganges. The Karnali, 507 km in length, with its shift currents, forms several gorges. The Seti and the Bheri are the major tributaries of Karnali.

The Seti, 202 km long, has its source in Vyas, Api and Saipal Himal of the Himalayan range, and joins the Karnali river in Doti of the Dundras Hill. The Bheri, 264 km long, issues forth from the Jagdula lake in Kanjiroba Himal, and meets the Karnali near Kuneghat in Surkhet.

The Kali Gad and the Burhi Ganga are the main tributaries of Seti. The Thuli Bheri emerging out of the inner Himalayas, joins the Bheri river north of Simi in Tibrikot. The Sani Bheri originates from Dhaulagiri near Dhorepaten, flows to Rukumkot, at Uttara Ganga, and meets the Bheri river, east of Jakarkot.

The total drainage area of the Karnali river is 44,000 sq.km out of which 41,550 sq.km (94.43%) lies in Nepal only. The catchment areas of the Seti and Bheri are respectively

7,500 and 12,400 sq.km. The estimated yearly mean runoffs of Karnali, Seti, and Bheri are 1,368, 317 and 432 cu.m/sec respectively.

(E) There is no remarkable river structure in Karnali river and its tributaries at present. The east-west highway is cut at the Karnali river as there is no bridge at present. It is possible to cross the river by ferry boat only in dry season at present. However, a bridge at Chisapani is under construction and shall be probably completed in 1992.

(F) The feasibility study of the Karnali (Chisapani) Multi-purpose Project was completed by Himalayan Power Consultants and some joint venture engineering companies recently. However, the project with 270 m high dam and 10,800 MW of peaking energy lies on the table of discussion in regard to the further step for construction. It seems that the project has various problems at present.

(2) Seti River

(A) The Seti, approximately 7,500 km^2 in drainage area and approxi. 200 km long, starts from the south-eastern face of Rikhi Himal and makes south easterly course and near Chainpur it changes its course to south west. There it makes wide flood plains cultivable from Sunigad to Kachali khola, important ones are at Dewal and Golal. And finally, it changes course to south-east at Silgarhi-Doti and with narrow gorge it joins with Karnali. The main tributaries are Kaligad, Saur khola and Burhiganga. Kaligad starts from Guljarlekh and is joined by Sangang river at Mutibar. Burhiganga has also very steep valley at the both ends whereas it is wide at Khalsain.

(B) Seti river is one of the important tributaries of Karnali and near Doti it makes a sharp bend and makes steep valley and slowly flattens above the channel. The channel is nearly 150 m wide and 1:2.5 in bank slope.

The gradients in river channels at some representative stretches are reported in a reference book as shown below.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Seti (Salmorkhola)				
(a) Head (4,500)	Mouth	(3,750)	6	47
(b) Granphu (3,900)	Dahachaur	(3,600)	8	30
(c) Dahachaur	Dhuli	(2,550)	21	51
(d) Dhuli	Talkot	(1,460)	22	49
(e) Talkot	Chainpur	(1,350)	13	9
(f) Chainpur	Thalara	(1,290)	22	3
(g) Thalara	Tillar	(600)	32	22
(h) Tillar	Dipal	(520)	19	4
(i) Dipal	Chaprokhola	(370)	32	5
Seti (Kaligad)				
(a) Korali (1,800)	Pipalkot	(1,200)	8	62
(b) Pipalkot	Muttibar	(840)	19	20
Seti (Thalara River)				
(a) Head (2,400)	Mouth	(1,440)	6	173

(3) Bheri River

(A) The Bheri river, the biggest tributary of Karnali with the drainage area of approxi. 12,400 km^2 and the length of 125 km, meets Karnali river at Kuneghat. The Bheri starts from Langu Valley at Charkabhot. It is called Yakung khola and flows due north-west and makes a U bend pointing north in the Mukut Himal and then it goes straight to the east and again to the north west. Later on it is joined by Uttar-ganga and Pelma khola which drains the Phagunedhuri. The Uttarganga flows due north west and then to south-west. The Bheri joins with the Karnali at Kuneghat.

(B) The Bheri river in the north east of Surkhet is in schist and quartzite whereas, near Gumichula hill it is near the main boundary thrust and in E-W course it is in Churia formation alongwith the weak contact.

(C) The gradients in river channels at some representative stretches are reported in a reference book as shown below.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
1. Bheri (Mustang khola)				
(a) Barikot				
(1,800)	Dali	(1,200)	22	27
2. Bheri				
(a) Shimi (1,500)	Confluence of Sani Bheri	(850)	48	14

(4) Other Major Tributaries of Karnali River

(A) There are some other large tributaries such as Thuli-Gad, Lahare (1,050 km^2), Buriganga (1,700 km^2), and Tila (3,500 km^2).

(B) The gradients in river channels at some representative stretches are reported in a reference book as shown below.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Thuligad				
(a) Khargaon				
(1,200)	Masiagaon	(900)	10	31 N-S
(b) Rithara				
(1,200)	Masiagaon		16	188 E-W
(c) Bistagaon				
(1,200)	Atari	(720)	16	30 N-S
(d) Masiagaon	Atari		13	14 E-W
(e) Beliagaon				
(1,200)	Atari		16	30 N-W
Rao Khola				
(a) Kotlinara				
(1,200)	Tillar	(600)	18	34 S-W
Buriganga				
(a) Chaurantha				
(1,650)	Kunrikot	(1,200)	10	48
(b) Kunrikot	Jhalgaon	(840)	11	32
(c) Jhalgaon	Sampi	(600)	19	12
(d) Sampi	Mautiyana	(450)	6	23

3.3.5 Babai River

(A) The Babai river with the drainage area of approximately 3,300 km^2 and the length of 190 km flows first south-west and then parallel to Dang valley in the western area and later on parallel to Churia hill. Finally it makes a bend at Kumaragaon and flows due south in the plains.

(B) The Babai river follows the strike of the Churia formation and also some fault contact. The rocks are clay and sandstone alternately bedded with the result of dip slope valleys are common.

(C) The Babai river makes a valley of 4 - 5 m deep from the normal ground level and the channel is generally confined compared to the west Rapti.

(D) The discharge of Babai river is as follows:

	Drainage area km	Max. Min. m^3/s	Average m^3/s
Babai (at Kumragaon)	3,000	2,120-3	67

3.3.6 Rivers in Southern Border River Group No.2

(A) The area is surrounded by the Babai river on the west and north, the (west) Rapti river on the east, and the Indian border on the south. The total area is approxi. 950 km^2. There are only a few short rivers in this area which originate from the Churia hill. The major one is the Man river.

(B) The east-west highway crosses all these rivers by bridges.

3.3.7 Rapti River

(A) The (West) Rapti river has in its upper basin, two major tributaries, namely, Jhimuruk Khola and Mari Khola. Both the rivers originate from the Mahabharat range and flow south until they join at Airawati from which location the West Rapti begins. About 25 km below the confluence of Mari and Jhimruk Kholas, the West Rapti river meets the Siwalik range from where it meanders into the Terai belt.

The Rapti river, of approxi. 257 km long, has an estimated yearly mean runoff about 125 cu.m/sec. with total drainage area of about to 6,500 sq.km.

(B) The Mari khola draining Tin Bhaini lekh goes first due south-east and near Pyuthan it become south-westerly. From Kitghat zone its trend becomes south-east. It makes a U bend and joins with Arung khola which drains north western part. From there it flows mostly south east. The Mari has 1980 sq. km. as drainage area. The average discharge is 57.20 m^3/sec. The maximum is 880 m^3/sec. The Mari and Arung provide sample flat land along their banks in Pyuthan area.

From the confluence they make westerly bend and it is named as Rapti river which flows in Dheokhuri area in east-west direction following the structural trend and in Nepalganj area it makes a sharp bend and flows to the south.

(C) The Arung khola follows the anticlinal axis and is in chlorite phyllite. The Rapti, most of the time when in Rapti valley, is also in the strike of the Churia formation.

(D) The Mari is one of the tributaries of the Rapti river. The Mari has narrow i.e. 150 m channel and the valley is flat. The Rapti valley widens from 150 m to 500 m. The slope is 1:3 whereas, Mari has 1:3.5. In plain, the Rapti has 1:10. The gradient of Mari khola is approx. 7 m per km as shown below.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Libangaon (900)	Ramdikot	(640)	35	7.4

(E) The Rapti channel is wide and is full of silt, the bank and the river bed is hardly 60 cm of elevation difference. The Rapti creates flooding in the low lying area. The low lying area is 6 m below the normal terrain hence ultimate effect is less foreseen.

(F) The Rapti at Jalkundi has the discharges shown below.

Drainage area	5,150 km
Max. Discharge	2,500 m^3/s
Min. Discharge	1 m^3/s
Average Discharge	103 m^3/s

3.3.8 Rivers in Southern Border River Group No.3

(A) The area is surrounded by the Rapti river on the west to north- west, the Gandaki/Narayani river on the east to north east, and the Indian border on the south. The area is quite narrow in the western area. The total area is approxi. 4,900 km^2. There are more than 10 rivers originating from the Churia hill and running down to south. Major rivers are listed below.

- Banganga river
- Kathi river
- Kanchan river
- Tinau river
- Rohini river

There are the following irrigation projects under-operation/construction in this area.

- Bhairawa-Lumbini Tubewell project
- Pushaha irrigation project
- Girwari irrigation project
- West Gandak irrigation project

Besides the above there are some farmers managed schemes as well as potential irrigation development areas.

(B) The Tinau starts from Mariphant and Khasauli and is joined by Dobhan khola which starts from Sattevati. Before Churia hill, the trend is east-west. It finally goes to the south from the Dobhan and makes south westerly trend. The drainage area is 544 sq. km. The average discharge is 24.79 m^3/sec whereas maximum is 6,000 m^3/sec. In June 1970, the river had washed out Khasauli Dawretol area killing more than a hundred people. The water level rose nearly 4 m in Butwal and 12 m in south of Dobhan. The main cause was heavy rain (approxi. 38 cm within twenty four hours).

(C) Geologically, the Tinau river follows the strike of Churia formation and the main Boundary Thrust. From Dobhan to Butwal, it is confined in steeply dipping Churia formation. South of the Tansen it follows the shale of Eocene formation.

(D) In western Nepal, Tinau, Banganga and Rohini are important rivers of Lumbini Zone. Like others the discharge of these rivers in dry season amounts to a few cumecs only. The Tinau is a dangerous river and it has built a 7 km equilateral triangular fan on its mouth with two channels, Dano and Tinau.

(E) The gradients of Tinau and Banganga are as follows:

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Tinau				
(a) Tinau, Pokhara-thok (750)	Lager	(600)	13	12
(b) Lager	Doban	(450)	5	31
(c) Doban	Butwal	(300)	3	47
(d) Butwal	Manglapur	(150)	19	8
(e) Manglapur	Betenian	(90)	13	5
Banganga				
(a) Jinhawa (300)	Bhagalpur	(150)	16	9
(b) Bhagalpur	Taulihawa	(135)	13	1

(F) The Tinau river has deep valley 7.5 m from the land surface in Nepalese territory as indicated by the sharp gradient. In case of Banganga, meandering starts south of Taulihawa whereas, Dano and Tinau at the south east of Lumbini temple.

3.3.9 Gandaki/Narayani River

(1) General

(A) The Gandaki is called Narayani in plains. It drains the region between Dhaulagiri and Gosainthan. It starts from Photu pass to Mustang area in northern Tethys 2 one. It is joined by Trisuliganga, Burhingandaki, Seti and Marsyangdi rivers in the midland part of Nepal. It cuts Churia hill at Tribenighat and enters in the plains. It has been found that this river has been changing the course in Terai to the westward like Saptakosi river and the drift amounts to several kilometers.

(B) In Terai plain the river channel is confined to 300 m with flood plain of 1.6 km on either side. The valley is hardly 150 m above the channel. Braided character is seen where Narayani in Terai makes two channels of 300 m width each.

The gradients of some of the tributaries of Gandaki/Narayani river are obtained from a reference book as follows:

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Marsyangdi				
(a) Braga (3,300)	Naje	(2,000)	38	32
(b) Naje	Tagring	(1,050)	18	74
(c) Tagring	Chepeghat	(450)	46	16
Chepe				
(a) Olang (1,500)	Bhankhol	(750)	14	52
(b) Bhankhol	Chepeghat	(450)	14	21
Madi				
(a) Taprang (1,800)	Mauza	(1,500)	31	
(b) Mauza	Prajuli	(450)	19	55
Maidamkhola				
(a) Head (1,500)	Singhi	(750)	16	47
Seti khola				
(a) Peak (2,000)	Aragaon	(750)	6	141
(b) Arahala	Aragaon	(750)	6	47
(c) Aragaon	Chirangdi	(600)	13	12
(d) Chirangdi	Bathala	(450)	11	14
Kali Gandaki				
(a) River bazar (600)	Hungighat	(450)	27	5

(C) The Kali Gandaki flowing out of Mustang Bhot Himal, joins the Trishuli river, north of Narayangarh, and then from Devghat onwards is known as the Narayani river which is also called Sapta Gandaki. The Myagdi, Andhi Khola and Modi are the main tributaries of the Kali Gandaki. There are several deep gorges along the Kali Gandaki, the deepest one being of about 1,200 m in depth between the Dhaulagiri and Annapurna peaks.

The Trishuli river ensures from Gosainkund - Dhunche of the Himalayan range. Burhi Gandaki, Marsyangdi, Seti etc. are the tributaries, of Trishuli. It joins the Kali Gandaki at Devghat in Chitwan. Burhi Gandaki joins the Trishuli at Benighat in Dhading. Coming out of Damodar Himal, the Marsyangdi river joins the Trishuli in Trivenighat. It has a gorge of 1,400 m deep, between the Annapurna and Manaslu peaks. The Seti, originating from Annapurna Himal, flows through Pokhara and joins the Trishuli at Khonre.

Mayagdi originating from the southern slopes of the Dhaulagiri, Madi emerging from the Annapurna Himal, and Barigad Khola issuing forth from Dhaulagiri near Dhorepatan, all join the Kali Gandaki respectively at Benighat, Kalya near Kusma, and Aeselu Chaur, north-east of Riri - Bazar.

Also known as the Gandaki, the Narayani joins the Ganges in India. About 86.07% of its total catchment area of 34,960 sq.km, lies in Nepal. Its estimated yearly mean runoff is 1,767 cu.m/sec.

(D) The downstream stretch from the confluence with the Marsyangdi river is called generally as Narayani river and the downstream stretch from the confluence with the Kaligandaki river is generally called as Sapt Gandaki which collect seven major rivers, namely, Darondi, Seti Gandaki, Madi, Kali Gandaki, Marsyangdi, Buri Gandaki and Trisuli. The Sapt Gandaki river drains the area of approximately 31,100 km^2 at the confluence with the Kaligandaki river and the annual mean runoff is approximately 1,500 m^3/s at the same point.

(2) Trisuli River

(A) The Trisuli (means Trident) comes from Tibet and crosses Nepal at Rasua pass. It meets Chilime khola and Langtang khola at Syabrubensi and Mailung khola a little down. The Trisuli khola comes from the Gasainkund and joins with it near Dunche village. The river flows due south and meets Tadi khola at Battar bazar. Near Battar it makes a wide and long terraces of Battar which is around 60 m high from the river. Up to this point Trisuli makes journey of 70 km in Nepal. It flows towards west near Bettar bazar and receives Burigandaki at Benighat. It makes bend pointing north at Kurlinghat and joins Marsyangdi at Muglintar. From there, it meanders and meets the Seti river at Gaighat and Kali joins at Devighat. From Battar to Devighat, the stretch of the river is 60 km thus totaling 130 km. The Trisulinganga makes gorges at north of Trisuli bazar but in the southern part numerous terraces of 60 m high above the riverbed are developed at different places upto Mulingtar. The notable terraces are Battar Beltar, Gajuri, Bishaltar, Kurintar and Muglingtar. In fact the Trisuli provides more flat terraces compared to the Kaligandaki.

(B) In the northern part, from Kodari to Syabrubensi, the rock is composed of quartzose gneiss and phyllite. From Dhunche to Trisuli bazar it is practically in gorge section right angle to the strike of anticlinal fold. The rock consist of mostly phyllite. From Trisuli to the confluence of Seti, the river follows the strike of the rock type consisting mostly of phyllite in the eastern side whereas, cherty dolomite in the Mungling section. In dolRmite rock portions, the river makes gorges.

(C) The Trisuli river in the north practically follows the gorge with practically steep-wall. Old terrace is found at some portions and the valley slope is generally steep. It is approximately 1:1 in the bottom part to 1:3 in upper part. The cross sectional area is low per foot depth.

Whereas the same valley becomes wide and slope is less steep in the lower part.

The river gradients at some representative sections are obtained from a reference book as follows:

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Trisuli River				
1. Rasuwa (1,800)	Syabrubensi	(1,500)	13	23
2. Syabrubensi	Jharakatteri	(750)	19	47
Tributaries				
1. Langtang khola				
(a) Syrpagaon (2,400)	Jharkatteri	(1,500)	8	112
2. Chilemekhola				
(a) Head (2,200)	near Syabrubensi	(1,600)	10	71
3. Mailing Khola				
(a) Mailungpati (3,000)	Karmang	(900)	10	234

(3) Marsyangdi River and Burhi Gandaki River

(A) The Marsyangdi with the drainage area of approxi. 4,600 km^2 and the length of approxi. 153 km starts from the south eastern flank of Muktinath Himal where it is called there as Jargung khola. It meets Naur khola coming from Mustang and Peri Himal. The total length of river is 140 km. General trend from Managbhot is south-east and from Thonte to the south. In lower part, due to fault, the course changes to south-east. One of the main tributaries is Chepe khola. Chepe makes a wide valley and low height terraces, good for agriculture.

The Burhigandaki with the drainage area of approxi. 3,600 km^2 and the length of approxi. 145 km comes from the Tibet and flows south-west and then south-east as Siringi khola. Near Labubensi its course is straight south and finally it is south-west. It has the Ankhu as principle tributary Ankhu drains western flank of Ganesh Himal and is 65 km long.

(B) The Marsyangdi and Burhi consist mostly phyllite quartzite in its course except at the head region, while joining the Trisuli, they cross dolomite zone with the result of deep

gorges. The famous Bandipur slate and dolomite are seen in Marsyangdi and Trisuli sections.

(C) Like the Trisuli, the Burhigandaki is a tributary of Narayani system which has sedimented in lower part and behaves as a mature river and hence it is named Burhi (means in Nepalese language old). The Burhigandaki has very steep gorges in the upper part where a big slide occurred in the past. The channel is narrow and the bed slope is nearly 1:2.3. The same valley becomes smooth and wide near Arughat bazaar. The valley slope there is nearly 1:8.5. The gradients of some representative sections are shown below.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Burhingandaki				
1. Bih (1,500)	Labu	(750)	36	21
2. Labu	Arughat	(600)	14	10
Darondi				
1. Dhansira (1,200)	Kusunde	(750)	11	40
2. Kusunde	Sangu	(450)	16	19

(4) Seti River

(A) The Seti river starts its journey from Machhapuchare and passes through the Pokhara Valley. Its drainage area is approxi. 2,850 km^2. In the upper part it has easterly bend and then a loop is developed pointing north at Manegkot and, afterwards,it flows down in south direction. It meanders at Leaster pointing east and joins with Trisuli river. From Annapurna it is N-S and the moment it enters in Pokhara valley it becomes easterly. It leaves the basin in N-S and then it becomes easterly to join the Trisuli. The Seti river provides flat land in the Pokhara valley with river terraces. It has the Madi as tributary which flows parallel to the Seti and provides flat land for agricultureal purpose. Rest of Seti valley is deep with few flat terraces on either side. The total length is approxi. 125 km.

(B) The Seti river in north of Pokhara is in gneissic rock, at Pokhara it is mostly in calcareous conglomerate with basement of quartzite and phyllite and south in the Bandipur section it is in cherty dolomite.

(5) Kaligandaki River

(A) The Kaligandaki river with the drainage area of approxi. 11,600 km^2 and the length of approxi. 320 km is the biggest tributary of the Gandaki river system. The river sometimes considers as the main stem of the Gandaki basin. The whole basin is located in Nepal territory.

(B) In the upper reaches the Kali gandaki is called Muktinath khola. It flows due south west. While cutting the deepest gorge around 5,400 m, it makes bend toward west at Dhumpu, then it is deflected to the south and is joined by Myangdi khola at Beni. The Mayangdi khola drains out the Dhaulagiri himal. The Modi khola draining Annapurna himal meets with Kaligandaki at the Kusma village. The Nisti khola drains Chauribuki Patan and it flows south-east and it is named as Barigad, which joins Kali at Taksar, from there the Kaligandaki moves to the south and makes a easterly bend at Riribazar where it receives easterly flowing Riri khola. From the Riri bazaar upto Khalte, i.e. nearly 100 km, it flows straight to the east with wide and deep valley and meandering at couple of the places. From there it runs to the south and again to the north east at Kalinkitar. Finally, it joins with the Narayani river at Devighat just upstream of Narayangarh. Compared to other rivers, the Kaligandaki valley is practically in the gorge. It gives rise to two terraces, Rampur phant and Chapakot tar. The terraces are around 120 m high from the river bed. otherwise very few flood plain areas for cultivations are found in Kaligandaki Valley. Among the tributaries of Kaligandaki the most beneficial is Andhi khola, which makes wide flat flood plains on either sides of the valley. Before it enters Kaligandaki it makes a narrow gorge in the dolomite region. Other tributaries have less importance from agricultural viewpoints. The Argalli terrace at Leguwa provides flat land for cultivation. The maximum land resources is developed in the Riri khola basin.

(C) In the upper part upto Dana the chlorite, phyllite and dolomite continues, while crossing the main Himalayan ranges it is in the migmatite and gneiss. The Kaligandaki from the Riri bazaar to Ramdighat is in dolomite and makes deep and narrow gorge section, whereas in the rest of the area it is either in the recent deposit of Chapakot and Rampur Tars or chlorite-schist and quartzite and near the Devghat it is in the Churia formation. The river follows the axis of anticline or fault. The Andhi khola, a tributary, follows the dip of the rock most of the time, the rock consists of chlorite, phyllite and quartzite except when it enters into dolomite zone south of Waling and Galebhanjyang.

(6) Rapti River

(A) The Rapti river with drainage area of approxi. 3,100 km^2 and the length of approxi. 125 km heads in the Mahabharat range located at about 25 km southwest of Kathmandu,

flows to the south, and then turns to the west near Hetauda town. At Hetauda, the Rapti river emerges from the Mahabharat range in which the river is confined in narrow and steep gorges. Consequently the Rapti river has deposited a huge volume of sand and gravel there and flows east to west forming wide and meandering course. This wide valley is called the Chitwan Valley. In Chitwan Valley, the Rapti river is joined by several tributaries mainly from the north, which are the Manahari, Lothar, Mardar, Pampa, Budhi Rapti, Kari and Khageri river from the east to west. The Manahari and Lothar rivers are the major tributaries and originate in the Mahabharat range so as to deposit into the Rapti river tremendous amount of rock fragments of old formations, such as metamor phic rocks of Paleozoic and Pre-Cambrian and granite, including large boulders. Other tributaries originate on the southern slope of the Mahabharat range and/or in the Siwalik hills.

Tributaries joining from the south originate in the Churia hills and have rather small catchment areas. The Harda khola joins the Rapti river from the south at just downstream stretch of the confluence with the Lothar river. It is noted that the Chitwan national park is located on the southern side of the Rapti river.

(B) The Rapti river flows for about 70 km in Chitwan Valley, enclosed by the Siwalik hills on the north and by the Churia hills on the south and east. The Siwalik hills form the front of Himalayan orogeny bounded with the Mahabarat range by a distictive fault zone referred as the Main Boundary Thrust and comprise Molasse like thick sedimentary formations of the Tertiary age. The Churia hills comprise upper Siwalik group attributed to the age of Plio-Plistocene. The Chitwan Valley is a tectonical depression of widely undulated Siwalik groups and has been buried beneath thick alluvial deposits.

(7) Other Rivers

(A) There are many other tributaries which join with the main stem of Gandaki river system directly. Some representative tributaries are listed below although the description of each river is omitted.

(a) Malekhu Khola

(b) Riu Khola

(c) Arun river

(d) Binai river

3.3.10 Rivers in Southern Border River Group No.4

(A) The area is surrounded by the Narayani/Gandaki river on the west and north, the Bagmati river on the east, and the Indian border on the south. The total area is approxi. 3,500 km^2. The northern part of this area is Churia hill and the southern part is the Terai plain. The Terai plain is used for agricultural land. The different parts of Narayani Irrigation Project is under stages of operation, construction and plan of operation. There are more than 10 short rivers running down to south in this area. The major rivers are as follows:

- Bhaluyahi river
- Bhebani river
- Pasha river
- Thali river
- Arwa (Aruwa) river
- Bakeya river

3.3.11 Bagmati River

(A) General

The Bagmati river with the drainage area of approxi. 3,600 km^2 and the length of approxi. 160 km starts from the southern slope of Sheopurilekh, north of Kathmandu basin and flows straight to south- west cutting the Mahabharat range. It appears that the present nature of river came into existence in Pleistocene times when the Kathmandu lake disappeared. The Bagmati first flows to south west from Kathmandu upto Jhanalkot from there to Gangate in south and later on south east and makes a U bend at Betehani upto Hariharpurgarhi to south easterly direction, and finally to the south. The average discharge is reported to be approxi. 210.6 m^3/s.

(B) Geological conditions

Bagmati river course follows at right angle to the strike of rock types; phyllite, quartzite and dolomite in the hills. In dolomite sections the gorge is narrow. When it reaches the Terai, it crosses the Main Boundary Thrust and Churia hill formations.

(C) The Bagmati river has its origin in Vag-dhara (Vag-dwar or Bagh- Dwar) which is at an altitude of 2,650 m south-east of the Shivapuri hill. Nagmati and Syalmati join Bagmati (Vag-mati) near Sundarijal. Its main tributary is the Vishnumati with its origin in Vishnap south of Shivapuri, at the altitude of 2,430 m. Other tributaries of the Bagmati

are Prabhawati, Bhadramati, Rudramati (Dhobi Khola), Manamati (Manohara), Hanumati, Ikhumati (Tukucha), Nakhu Khola, Kulekhani, etc.

(D) The Bagmati river joins the Ganges in India.

(E) The Bagmati barrage/weir is located at just upstream of the bridge crossing the east-west highway. The river water is taken from the both sides to irrigate areas located in the lower Terai and is presently under expansion by the DOI.

(F) The Kulekhani dam with reservoir for hydro-electric power generation is located in the Kulekhani river. The water used at power station No.I and No.II is released to the Rapti river. The Kulekhani dam is the only large scale dam in Nepal at present.

3.3.12 Rivers in Southern Border River Group No.5

(A) The area is surrounded by the Bagmati river on the west to northwest, the Kamala river on the east to northeast, and the Indian border on the south. The total area is approxi. 3,000 km^2. There are approxi. 10 short rivers running down to south. The major ones, as selected, are listed below.
- Jhim river
- Hardinath river
- Magha river

3.3.13 Kamala River

(A) The Kamala river with the drainage area of approxi. 2,200 km^2 and the length of approxi. 120 km originates from Sindhuligarhi and flows to south. Then it makes easterly trend parallel to Churia hill and flows towards Thunchi. It makes a U bend near Mari and goes to Chisapani. From there it is directed to the south. Similarly, Mari khola flows in the west and then bends towards south at Judpani.

(B) The Kamala river rises in the upper reaches of Mahabharat range. Most of the time its course follows the strike of the rocks of Churia range. The rocks are sandstone and shale in cyclic order. Sometimes the course touches the Main Boundary Thrust while the course is E-W in the hills.

(C) The river gradients of some representative sections are shown as follows:.

River	From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Kamla					
	Tintale (450)	Gras	(300)	16	28
	Gras	Guiha	(150)	6	23
	Guiha	Bisharbara	(75)	13	6
	Bisharbara	Manurwa India	(60)	16	1

This indicates that Kamala also looses gradient fast by the time it reaches Indo-Nepal border of Terai.

(D) There is Kamala Irrigation Project of DOI which intakes the river flow from the Kamala Barrage/Weir located just upstream of the bridge crossing the east-west highway.

3.3.14 Rivers in Southern Border River Group No.6

(A) The area with approxi. 1,900 km^2 is surrounded by the Kamala river on the west to northwest, the Kosi river on the west to northwest, and the Indian border on the south. There are several short rivers running down from the low hill to the Terai plain. The major rivers, as selected, are listed below.

- Bhatiwalan river
- Khado river

The Terai plain is mainly used for agricultural land.

3.3.15 Kosi/Sapta Kosi River

(1) River System

(A) The 'Sapt' means seven and 'Kosi' is taken from the name of Rishi Kaushik who used to live hermit life on the bank of this river. The Sapt Kosi, a collective name of "Seven rivers", drains the eastern part of the country with its seven tributaries - Sun Kosi, Indravati, Tama Kosi, Likhu Khola, Dudh Kosi, Tamur and Arun. The area drained by these rivers is popularly known as the Kosi basin. The Saptakosi river is the biggest river of Nepal and said to be next to Indus and Brahmaputra of Indian sub-continent. It drains out the eastern Nepal, particularly east of Gosainthan (north of Kathmandu) and west of Kangchenjunga. It has three main affluents:

- Sunkosi in the west
- Arun in the central part
- Tamur in the eastern part

The main stream of Arun rises in the Tibet, and flows parallel to the Himalayas to the east and enters south along a faulted axis of a N-S anticline and to the midland by cutting the main range of Himalayas. On reaching the Churia hill it is joined by Tamur of the east and Sunkosi river of the west. A comparison of the three rivers is shown below:

	Rivers at Tribeni	Catchment area	Annual Sediment load
1.	Sunkosi	19,120 sq. km	54.2 x 10^2 m^2
2.	Arun	36,533 sq. km	34.6 x 10^2 m^2
3.	Tamur	5,900 sq. km.	29.6 x 10^2 m^2
	Total	61,663 sq. km	118.4 x 10^2 m^2

In 1953 flood period the discharge of Sunkosi was between 10,000 to 12,000 m^3/sec. Usual low water discharge is estimated between 120 to 130 m^3/sec.

(B) Flowing through the Sapta Koshi river basin are Indrawati, Tamakoshi, Likhu, Dudh Koshi, Sun Koshi, Arun and Tamur which have their sources in Jugal Himal, the eastern slopes of Kalinchok mountain, Rolwaling Himal, Dudh Pokhari in Mahalangur Himal, the western slopes of Kalinchok mountain, Tibet and Kumbhakarna Himal respectively.

The Indrawati meets the Sun Koshi at Dolalghat, Tama Koshi, Likhu, Dudh Koshi and Bhote Koshi join the Sun Koshi respectively at Benighat near Melung in Ramechhap, at Kilanjor, southeast of Ramechhap, near Jayaramghat in Okhaldhunga,and at Sun Koshi Bazar near Barabise.

The Arun and the Sun Koshi meet each other near Pagnam in Bhojpur, and then join the Tamur little downstream to form the Sapta Koshi which merges with the Ganga in India. The total drainage area of the Sapta Koshi is 60,400 sq.km. out of which 28,140 sq.km (46.6%) lies in Nepal. Its estimated yearly mean runoff is about 1,566 cu.m/sec.

(2) Main Stem (Bhote Kosi/Sun Kosi River)

(A) General

The Sunkosi is called Bhotekosi in the head region and comes from Tibet. It enters into Nepal at Kodari and from there it flows to the south-west and meets the Sunkosi river near the Sunkosi bazar.

The Balephi khola which drains out Dorje Lakpa range joins Kosi at Balephi Dobhan and with Indrawati river at Dolalghat. Upto Dolalghat, the total distance travelled by the river is 50 km. Arniko highway catches the Sunkosi near Dolalghat and continues on western bank upto Barhbise where it crosses the Sunkosi by a bridge and from there the road is confined to the east and finally at Kodari it is on the western bank. In this section hill slope is flat on either side and river is wide, whereas, it narrows down from Barhbise to north with steep cliff on either side. Old time suspension bridges are found at different places like Palephi Dobhan and Barhbise.

From Dolalghat, the river takes south-eastern course up to Dumja, where it meets Rosi khola. At Dumja, the river valley is nearly 1/2 to 1 km wide. From Dumja the river course becomes more easterly and parallel to the hill ranges. River channel starts meandering sometime cutting the northern bank and other times touching the southern bank. Wide and long flood plains occur on the either side of the meander in alternate fashion where people grow rice and other cropes.

At Benighat, it is joined by Tambakosi which flows south westerly from Panch-pokhari (Five lakes) of Siranchock region. The Sunkosi meets Likhu at Kulanjer, the river makes a bend; towards south-west and receives Dudhkosi at Kurule. The Dudhkosi which drains out the Mount Everest region, flows due south-west. From Kurule the Kosi makes sharp bend and flows towards south and makes right angle bend at Kampughat, onward it flows towards east to meet the Arun and Tamur rivers at Tribenighat. From Dolalghat to this confluence, the total distance is nearly 170 km.

The Balephi flows more or less N-S, parallel to Sunkosi. The river valley is wide, with a suspension bridge at Jalbire. On the peak of western slope Chautara bazaar is situated. It drains Chang Samarphu and Bhairavkund Lekh. Bhairavkund is located in the watershed of Sunkosi and Balephi.

The Indrawati also flows practically N-S in the upper part and near Sipaghat the channel is wide and river makes an easterly bend. It has Melamchi khola, Jhyarani khola and Chalk khola as main tributaries. Other tributaries are numerous.

The Tambakosi has 80 km length and flows south-west. The main tributaries are Khimti khola, Charnawati khola and Bhotekosi. In upper part the valley is wide but becomes narrower down in the south. Likhu khola also has about 80 km long channel and the Valley of Likhu is comparatively narrow and steep.

The Dudhkosi also flow N-S in upper part and parallel to Likhu in the lower part. The valley of Dudhkosi is nearly 112 km long. The river course meanders in loops due to fault from Jubing to Panjan. In the lower part, the river valley is wide and on the west and east of the lower part of the valley few high altitude terraces are found, Rumjatar,

Nechedanda in the west and Buipa in the east, which might had relation with places of river movement or ice movement.

(B) From Tribeni to Chatra section in the south of Barahchetra mostly indurated Churia sandstones and variegated shales dipping 30_ to 60_ N are exposed. The rocks are fractured and jointed hence weak at several places. Main Boundary Thrust is seen at Barahchetra. The site of proposed Kothar dam is located in the midway of Chatra and Barahchetra.

Between Dumja and Tribeni the river practically follows the axis of anticline. On the both sides of the river valley the rocks consist dominantly of phyllite and quartzite and rarely dolomite. The river becomes narrow after L bend that is near Dudhkosi confluence, where dolomite is exposed. Near Kampughat a series of thrust planes and Main Boundary Thrust touch the river course and Churia formation comes close to the river bed.

From Kodari to Dumja the river follows against the dip of the rock i.e. right angle to the strike. In this section, north of Barahbise dolomite is observed, whereas, the rest of the section consists of Pre-Cambrian gritty phyllite, schist and quartzite. Near Kodari, the rock consist mostly of augen gneiss and quartzite.

(C) The Sunkosi in the upper reaches near Balepi khola has narrow valley with the channel width approximately, 300 m whereas, Balephi has also the same but valley slope is flat. The valley slope is 1:2.5 on Sunkosi whereas on Balephi 1:2.

The river valley is flat in the northern side and steep in southern side when it follows the E-W trend. This is seen in Ramechap section. The river channel is 600 m wide and the northern valley slope is 1:7.6 whereas the southern is 1:3.3. This characteristics is most common of the rivers, if they are following the E-W trend.

In hard rock, like dolomite and gneiss, the valley becomes narrow practically vertical and channel width is 150 m.

(D) The river gradients at some representative sections are presented below.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Sunkosi:				
1. Kodari (1,500)	Chakhukhola	(1,350)	8	20
2. Chakhukhola	Ghumtang	(1,200)	10	16
3. Ghumtang	Gurdum	(1,050)	16	9
4. Gurdum	Tokarbu	(900)	16	16
5. Tokarbu	Chuka	(750)	18	8
6. Chuka	Pankhar	(600)	19	8 E.W.
7. Pankhar	Benighat	(550)	16	3 E.W.
8. Benighat	Suruug Kodule	(450)	61	2
Tamba kosi				
KHIMTI				
1. Lomsa (3,000)	Purnagoan	(1,500)	19	78
2. Purnagoan	Arkhaule	(750)	13	58
3. Arkhaule	Benighat	(550)	26	8
LIKHU:				
1. Ranganag (2,250)	Ekgaon	1,500)	13	58
2. Ekgaon	Gothpani	(750)	22	33
3. Gothpani	Dihi	(600)	13	12
4. Dihi	Kolanger	(510)	6	14

(3) Dudhkosi River

(A) The Dudhkosi river with the drainage area of approxi. 4,100 km^2 and the length of approxi. 120 km is found to make narrow gorges, in the north of Wapsa copper mine. The rocks consist mostly of quartzite, quartzose phyllite and gneiss. The rocks dip mostly due north. In the southern course, the rock is mainly phyllite and occasionally quartzite.

(B) The river bed gradients at some representative sections are shown below.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Dudhkosi				
1. Jubing (1,500)	Chisankhughat	(750)	38	20
2. Chisanku	Kharpa	(600)	6	23
3. Kharpa	Kudule	(460)	29	5

(4) Arun River

(A) The Arun river originates from the Yebokanjial Glacier on the north slope of Mt. Xixabanga (8,012 m) in Tibet, flow parallel to the Himalayas for 160 km north of the Everest and there it makes a right angle southerly turn, flows 80 km south and enters into Nepal at Nahatang. It flows nearly 128 km before Tribeni. It makes S-W bend with a few loops in the upper part. From there it flows to south-west till it starts changing the direction towards south-east at Goiriangla. The nature of bend is convex face towards west. The amplitude is 16 km and wave length is 48 km. Finally it again switches to west at the Leguwaghat. Later on its course becomes south westerly before the Tribenighat, where it joins with Sunkosi and Tamur rivers. The Arun has got wide valleys with heavy silt load. River flood plain and terraces for cultivation are few.

(B) Near Nepal-China border, it makes deep and narrow gorge in the augen gneiss, and quartzite. Rest of its course in the midland upto Tribeni lies in the chlorite schist, phyllite, quartzite and gneiss.

(C) Arun has very sharp valley in the Himalayan zone. In which the river channels is approx. 1,200 m deep and valley peak is 3,600 to 4,200 m with a valley slope of 1:3.1 to 3.69 (vertical to horizontal).

Whereas, near the midland it becomes 1:5.6 and in the lower part of midland it is 1:4.8. The width of river channel in upper part is approximately 300 m, whereas in the midland it is nearly 600 m.

(D) The gradient at some representative sections are presented in the following table.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Arun				
(a) Tibet (3,000)	Naktang	(2,280)	10	74
(b) Naktang	Sedua	(1,220)	58	18 (deep gorges)
(c) Sedua	Maleng	(750)	11	42
(d) Maleng	Ramche	(600)	22	7 (wide valley sandbars)
(e) Ramche	Mughaghat	(450)	48	3

It indicates that Arun river is very steep in the Tibet whereas, it again becomes steep while entering the midland and in the midland its gradient is reduced, deposition starts and valley becomes wide i.e. nearly 0.8 km.

(E) The Arun river, which rises in Tibet where over 80% of its basin lies, predates the uplifting of the Himalayas: in its passage south into Nepal it has cut a deep, narrow gorge through the Himalayan range. From there it flows south for a further 155 km, fed by a number of tributaries, before it joins with the Sun Kosi and Tamur to form the Sapta Kosi. The total drainage area within Tibet, lying between latitudes 27_ 49' and 29_ 05' North and longitudes 85_ 57' East, has been estimated to be 25,307 km^2. The area of the Basin within Nepal has been calculated to be 5,028 km^2 or 16.6% of the total area of the Basin.

(F) The river predates the uplifting of the Himalayas and its down-cutting has kept pace with this uplifting, so that at least an 8,000 metre thick rock sequence has been eroded by the river in its passage from the Tibetan Marginal Range through the Great Himalaya ranges : the gorge thus cut is deep and narrow and the gradient of the river bed is steep (1:50). As it passes through the High Mountain physiographic division in Sankhuwasabha, Nepal, the gradient becomes more gentle, 1:360, and continues thus until it reaches the Siwaliks shortly before the confluence with the Tamur and Sun- Koshi, where the three rivers form the Sapta Koshi, one of the four major rivers of Nepal.

(G) The total length of the Arun is 531 km, of which 155 km are in Nepal. Only limited river discharge measurements are available but a high, steady discharge is known to occur throughout the year. This is a result of snowmelt and slow drainage from Tibet in the winter and spring and the high (3- 5 m) rainfall in the area between Tumlingtar and Hatiya from late June to late September: the latter supplies the greater proportion of the annual run-off. The annual discharge of water from the Arun into the Sapta Koshi is estimated to be 18,300 million cubic metres.

(H) It was identified in 1986 that there exist at least 50 ice- dammed or moraine-dammed lakes - mostly in Tibet (Xizang) and the potential hazards of Glacial Lake Outburst Floods (GLOF) from these lakes. Subsequently, further investigations identified; that there are 229 glacier lakes with a total area of 46.746 km^2 and water reserves of 1.2309 km^3. It was pointed out that "glacier lakes play an important part in adjusting the run-off circulation, are thus significant in reducing flood disasters and serve as natural water regulators if properly managed, they may become a source of regulated water for electric power generation, irrigation water supply etc". While the potentially devastating damage that can be caused by outburst floods was appreciated, it was noted that most of the glacier lakes in the Arun drainage basin seem stable. Furthermore, of the very small proportion prone to outburst, some will not cause unacceptable damage. It also seems possible that such outbursts can be predicted and prevented.

(I) Within Nepal, the area of valley bottom of the Arun river and its main tributaries is very limited and much of the lower slopes of the middle hills are steep with shallow soils.

There is thus little habitation or cultivation in the areas near to the rivers. As a result, there is very limited existing or potential use of gravity-fed water supply for drinking water or irrigation schemes. Two town hydro-electric schemes - Dhankuta and Khandbari - have been established.

(5) Tamur River

(A) The Tamur river with the drainage area of approxi. 5,900 km^2 and the length of approxi. 200 km starts from Kangchenjunga glacier and flows due south-west. It meets Yogma khola at Saka. It makes easterly bend at Taplejung and receives Kabeli khola which comes from the east. The Tamur river meanders a while at Angbung and from there it become south-westerly to westerly and joins the Sunkosi and Arun rivers at Tribeni.

(B) The river follows the strike of rock types in its E-W course. The rocks are mostly chloritic phyllite, and quartzite. Near its N-S course at Taplejung augen gneiss is found.

(C) The river Tamur has a very steep and narrow valley in the north of Taplejung whereas, at the Taplejung it becomes comparatively wide. The river channel is 300 m and flood plain and old terraces are 900 m wide. The valley slope is 1:4, and near Kabeli river the valley is wide with terraces on the both sides. The river has cut terraces of about 60 m in height and the river channel is confined to approxi. 150 m in width. The valley slope there is 1:4. In hard rock section the Tamur becomes much narrow and the valley is generally 60 m wide and practically 1:1 in side slope.

The river bed gradients at some representative sections are as follows:

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Tamur				
1. Sakathum (1,500)	Khokling	(750)	26	29
2. Khokling	Angbung	(600)	19	8
3. Angbung	Mahasar	(450)	22	6.5

(6) Trijuga River

(A) The Trijuga starts from Namantedanda and flows to south-west. It takes easterly trend at Gunte village in the Churia hills following mostly the fault plain parallel to the strike of rock types and meets the Sapta Kosi river.

(B) The Trijuga river is mostly confined in the Churia formation and follows the strike of rocks and a fault. The southern hill consists of loose and less indurated, sand and clay

formation (upper Churia) whereas, the northern side is well indurated and the dip is north.

(7) Other Rivers

(A) There are some other tributaries which directly join the main stem of Kosi river system. The representative rivers are listed below.

(a) Tama Kosi river (4,100 km , 115 km)

(b) Likhu river

(c) Maulun river

(d) Sapsu river

(B) Among them, the Tama Kosi river is one of big tributaries of Kosi river system. The upstream basin is located in Tibet. The drainage basin in Nepal territory is approxi. 2,600 km^2 (about 63% of the whole basin). The Khimti river is the main tributary of the Tama Kosi. The whole basin is located in mountain area including Himalaya zone.

(C) The Likhu river located on the eastern side of the Tama Kosi river is also the big tributary of which drainage area is over 1,000 km^2.

3.3.16 Rivers in Southern Border River Group No.7

(A) The area with approxi. 3,500 km^2 is surrounded by the Kosi river on the west and north, the Kankai river on the east, and the Indian border on the south. There are several rivers running down from the hills on the north to the Terai plain on the south where the land is used for agriculture. The major rivers in this area are listed as follows:

- Lorandra river
- Ratuwa river
- Budhi river

3.3.17 Kankai River

(A) The Kankai river drains out Illam area. It is flowing towards south-west and makes typical easterly bend near Soktim. From there it flows to Bhatbat and finally to the south. The Kankai has approxi. 1,150 km^2 as drainage area and approxi. 110 km in length. The average discharge is 60 m^3/sec.

(B) The Kankai river follows the Main Boundary Thrust in E-W course near Soktim. In the upper reaches the rock is chlorite schist and gneiss. South of Soktim, it follows the Churia formation which also dips due north. The southern side consists of more indurated rocks as compared to the north.

(C) The river gradients at some representative sections are presented as follows.

From (El. m)	To (El. m)		Distance in km	Gradient in m/km
Kankai				
1. Rangapani (450)	Sirkot	(300)	6	23
2. Sirkot	Bhatbhat	(150)	26	6
3. Bhatbhat	Butabara	(75)	34	2

(D) In the eastern Nepal, the Terai rivers have gradient of 10 - 12 m per km in the upper reaches, whereas, 5 - 6 m in the middle part and 1 m near Indo-Nepal border. The Kankai river is a little steeper than the others.

(E) In the upper reaches of these rivers, they are generally degrading whereas partly sedimenting in the middle and in the south. The Kankai river has almost the same conditions.

(F) The source of the Kankai Mai river is Chhintapu hill in the Mahabharat range. Puwa Khola, Jogmai Khola, Deomai Khola and Mai Khola are its main tributaries.

3.3.18 Rivers in Southern Border River Group No.8

(A) The area with approxi. 1,300 km^2 is located on the south eastern end of Nepal. The Kankai river runs on the west border and the Mechi river runs on the east border which is the international river between Nepal and India. There are a few short rivers between the Kankai river and Mechi river. The major one is the Birin river.

4. RIVER/RIVER RELATED STRUCTURES

The considerable projects or schemes/works of river/river-related structures are listed as follows:

- Hydro-power development projects
- Irrigation development projects
- Municipal/industrial water supply projects
- Transportation improvement projects
- Flood-control / river-improvement projects
- Sabo works projects
- Environmental conservation projects

For these projects/schemes, there are various kinds of structures constructed in and/or along rivers as listed as follows:

- Bridge
- Dam & Reservoir
- Weir/Barrage
- Power station
- Revetment
- Dyke
- Groin
- Intake
- Water gate/sluice
- Consolidation work
- Pumping station

The investigation of the river structures in Nepal was carried out by the following methods.

- Check in reference reports/books
- Field reconnaissance
- Information from Nepalese engineers

The results of investigation were obtained as summarized in Table 4.1 and Fig. 4.1 which show respectively the major features and the locations of dams and reservoirs, power stations, and weirs/barrages. The other structures are omitted in this investigation due to the following reasons.

(A) There are too many bridges (from small ones to bigger ones). It is impossible to carry out survey of bridges in the whole nation. The bridges generally do not appreciably interfere with the stream flow such that the flow conditions (discharge, velocity, etc.)

remains almost the same in both upstream and downstream sides. However, the following general information is to be noted here.

(a) In Terai, the East-West Highway connects the both ends of Nepal. Bridges exist at most rivers crossed by the highway. However, at present, there are no bridges at Babai and Karnali rivers. New bridges are under construction at both these rivers and are expected to be completed in 1992.

(b) In the mountain and hilly areas, suspension bridges are present at the main trails for river crossings.

(B) Dam & reservoir and weir/barrage are the structures which significantly affect the river flow. The flow conditions are changed with these structures. In addition, the structures are generally big in scale and cross or encroach into the river.

(C) There are different types of power stations, but it is commonly known that the power hydro stations affect the river flow discharge. The survey of power stations was carried out only for the comparatively large scale ones. The power stations of small scale are generally located on the small streams and seem to be not so significant for the flow of major rivers.

(D) The survey for the other structures (revetment, dyke, groin, intake, water gate/sluice, consolidation work, pumping station, etc.) will need much time and not so significant for the purpose of this project/study. There are many these structures and most of them are small in scale. The survey for these structures will be carried out for a limited area when it becomes necessary for the study later.

Though there have been numerous studies in the past with regards to the potential future development in river related structures, projects or schemes, there still seem to be uncertainity or lack of any definite plans for their implementation or construction.

5. FLOOD AND INUNDATION

(1) General

Flooding in Nepal is caused by a combination of several factors as discussed below.

(A) Natural Causes

- High monsoon precipitation almost in all the catchments within a short span of time resulting into huge monsoon flows within and from across the borders and the consequent high water levels in the rivers;
- Runoff generated by heavy local precipitation that cannot drain out due to high stage in the outfall river;
- Landslide and Glacier Lake Outbursts that result into high sedimentation in the river course;
- Coincidence of snow and glacier melt with monsoon precipitation;
- Synchronization of peak flows of the major rivers.

(B) Man-made Causes

- River structures which are inadequately designed/constructed;
- Deforestation and denudation in the upper catchments for fuelwood, fodder, over grazing and expansion of agriculture land;
- Living in areas/zones with risks of inundation;
- Drainage congestions due to uncoordinated development activities.

These factors, individually or in combination with each other, cause flood. Obviously, the intensity or magnitude of flooding would depend considerably on the pattern of occurrence and synchronization of these factors.

The major floods experienced in the Himalaya and mountains are mainly due to Glacier Lakes Outbursts or cloud outbursts. Rockslides and landslides which are common in Nepal also aggravate flooding problems by reducing river capacity or even temporarily damming up the rivers. There have been a large number of cases of extraordinary floods due to outbursts of temporary dams erected by rockslides and landslides in the rivers. The extraordinary flood experienced in the Burhi Gandaki river in August 1968 was a typical example of such event. However, these flood havoc are local in character. They cause destruction of bridges, highway, roads and paddy fields on the river banks situated near the source of incidence upto a distance of some 40 to 50 km downstream where valleys widen enough to attenuate the flood.

The floods in the plain, the Terai area, occur generally during the rainy season, June to September. The flood inundation seems to be not big in scale although the damage would be serious for the inhabitants. The inundation area is generally limited in certain areas and the inundation period is not so long possibly due to the slope of topography. The Terai plain is flat but with some slope in comparison with the plains in India and Bangladesh. There is no reliable record which compile the past flood inundation and damages. The information of flood disaster could be obtained in fragments. As far as the information obtained in this time, the flood damage was serious when the existing structures (usually dykes) suffered damage. For example, the flood happened in late August 1990 in the Rapti river of Gandaki river system overflowed and broke the existing tyke in Chitwan district. Then the flow caused the serious damage in the district which include the loss of inhabitants (more than 10 people) as well as loss of paddy and village houses.

In addition, it should be described that the disaster caused by land sliding and rockfalling have been quite often in Nepal. The major damage is the blockage of traffic roads. The road network in Nepal is not yet developed well so that the blockage of main roads would cause serious damages/problems for socio-economic activities.

(2) Influence to Flooding of the Ganges River

It has been discussed that the flood in Nepal causes the serious and large-scale damages in Bangladesh due to flooding in the Ganges river. The Ganges river rises from the Gongotri glacier in the Himalayas at an elevation of about 7,010 m near the Indo-Chinese border. From Hardwar to Allahabad, the river flows generally in a south-easterly direction and in the lower reaches it flows eastward. The length of the main river is about 2,550 km. The Ganges basin practically covers the whole of the northern India between the Himalayas and the Vindhyas except the states of Punjab and Jammu and Kashmir. While flowing in eastward direction, the river receives big tributaries like Mahakali (border river between Nepal and India), Karnali, Gandaki and Sapta Kosi originated from Nepal Himalayas and then ultimately enters Bangladesh near Rajshahi. The three Himalayan tributaries - the Karnali, Sapta Gandaki, and Sapt Kosi from Nepal-contribute about 71% of the natural dry season flow and 41% of the total annual flow of the Ganges.

The country of Bangladish has suffered significant disasters in the past like the cases in 1988 and 1991. The flood information and the control of flood discharge and sediments from/in Nepal would be essential.

(3) Flooding by Snow and Glacier

The flooding caused by melting snow and/or glaciers is a particular phenomenon in Nepal. A reference report describe about this matter as follows:

Melting of snow starts in March and has its peak in May or late June. With the onset of monsoon the solar radiation decreases and hence reduces snow melting. However, melting of snow and ice is continued during monsoon but the proportion of flow contributed by glacier is much larger than snow melting.

The flood is essentially generated by rainfall and hence occurs in the period of monsoon from June to September when about 80 percent of the total precipitation falls. At this period of the year, the snow line is also at its maximum height.

The three major rivers, the Kosi, the Gandaki and the Karnali originate in the Himalaya or in the Tibetan Plateau and are snow and glacier fed. A large part of their drainage area is covered by snow and glacier throughout the year. Additionally a large number of glaciers and glacier lakes are located in the northern part of the basins. Snow and glaciers play a significant role in the hydrologic regime of the river systems. From a hydrologic point of view, snow and glacier are both balancing reservoirs, from which the melt water will reappear as runoff in a delayed temporal pattern. Therefore, these rivers have relatively high sustained flow.

Snow and glaciers make significant contribution to runoff in the major river basins of Nepal. The snow and glacier melt pattern and its variation depends largely upon solar radiation, fluctuations in temperature, form of precipitation and the percentage of snow and glacier covered area.

Being situated on the southern flank of the Himalaya, these rivers receive abundant runoff from the heavy rainfall which results in monsoon floods. The form of rainfall in high mountain areas mainly depends on critical air temperature. The precipitation at elevation higher than El. 5,500 m is usually in the form of snow and it is the only source which nourishes the glaciers. Generally, in the southern slope of the Himalaya the snow line rises as high as El. 5,500 m in summer, while in winter it descends as low as El. 3,500 m. Snow melting from the seasonal snow covered areas and glacier melt supply water in the dry pre-monsoon months as well as in monsoon months. The influence of snow and glacier melt decreases from north to south. Measurements of snow-pack water equivalent, glacier mass balances and snow and glacier melt rates are essentially non-existent. Thus, the proportion of annual flow contributed by melting of snow and ice in each of the basins has not yet been established. Attempts are being made to collect important parameters like, solar radiation, temperature, rainfall, wind speed, humidity

and water levels from the hydrological and meteorological stations established at Langtang, Annapurna and Khumbu region. An extensive study and investigation are needed for understanding snow and glacier hydrology in the Himalaya.

The occurrence of Glacier Lake Outburst Floods (GLOF) is often reported in the areas such as the Himalayas, Alaska, European Alps, Northern Europe, Andes, etc. where rivers have their origins in glacial ranges. According to recent studies, it becomes clear that occurrence of GLOF is not a such rare event in the above-stated areas.

In Nepal, the big floods by GLOF caused heavy damages on the river structures in recent years 1981 and 1985. In view of the above, the effects of GLOF on the structures planned on the river having glaciers at its origin like this project have to be carefully taken into consideration, in addition to those of common flood caused by rainfall.

The investigation and study on GLOF have been made by some engineers, professors,and study team in these years. The brief explanation of GLOF records in some representative cases of Nepal is presented below.

(A) Pokhara (approx. 600 years ago)

It was estimated that the glacier lake of about 10 km^2 in area size located behind the Mt. Machhapuchare burst about 600 years ago and the Pokhara valley was covered with tremendous amount of earth and sand (average 50 to 60 m in thickness).

(B) Arun river (around 1964)

According to inhabitants in the Arun river basin, it is reported that the remains of timber, concrete, truck bodies, etc., presumably from Tibet, were flushed together with enormous volume of debris around 1964 (another predates a little).

(C) Bhote Kosi (1964 and 1981)

The Bhote Kosi river is the upper reach of the Sun Kosi river and is called as the Boqu river in China. In this area, large flood twice occurred at the end of the Zhangzangbo glacier and subsequently confirmed as GLOF in 1964 and 1981. Though the 1964 GLOF is of rather small scale, the peak discharge of that in 1981 is estimated at 15,920 m^3/s which cut the Nepal-China Highway connecting Nepal and China at many points and also damaged the sluice-way gate of the Sun Kosi power station.

(D) Dudh Kosi, Mingbo Valley (Sept. 3, 1977)

The Dudh Kosi is a tributary of the Sun Kosi river and originates in the Khumbu area near Mt. Everest. The size of glacier lake (at the end of Nare glacier) is presumed to be 4 x $106m^3$ to 5 x $106m^3$ in volume and is known to have produced a serious flood in the down stream area.

(E) Tamur river (July 24 to 25, 1980)

GLOF occurred at the Tamur river though the details such as the origin, size, etc. are not known. It is reported that all trees upto 20 m high above the river bed were flushed over a 30 km stretch along the river.

(F) Bhote Kosi, Langmoche valley (August 4, 1985)

Similarly to the case of above (D), GLOF occurred at the Langmoche glacier in the Khumbu area and its size is presumed to be 6 x $106m^3$ to 10 x $106m^3$ in total volume and peak discharge of around 2,000 m^3/s. In this case, all facilities of the Namche Small Hydel Project nearing completion were totally destroyed.

(4) Information through Field Reconnaissance and DOI

It was informed that the houses/villages located on the lower bank/terraces along the river are inundated annually or once in few years in the mountain areas. However, the damages are generally not serious as they already know that their structures/facilities are located in risky areas. Human loss due to flood in mountain areas is seldom reported.

In the Terai area (excluding the Indian border zones), as far as the information obtained through the interview to inhabitants, the flood inundation is quite local one which is generally low land along the river and the damage is not so serious as the inundation time is not so long and the water depth is not so high. The inundation area is usually limited in paddy fields. A serious problem due to flood is road blockage. At many rivers in Terai plain there is no permanent bridges. Therefore, it is usual that road blockage of several hours to several days happen in every rainy season. That is the reason why the transportation of goods as well as people is more frequent between Nepal and India (North-South direction) than between east-west direction in Nepal.

In the Terai along the border line to India, the information and data were obtained mainly through the river training section (Mr. M. Belbashe) of DOI. It was found that the flood inundation in some areas located close to the border is serious. The information can be summarized below.

(a) The flood inundation becomes serious due to structures (dykes, ring bund, barrage, etc.) inacdeoquantey or inconsiderately lstructed by India in the border zones of Nepal and/or India.

(b) The flood inundation is short and low in depth if there is no such structures, however, the Indian-made structures cause clogging of water flow and consequently the border zones in Nepal suffer longer and deeper inundation.

(c) Indian government also recognized the situation and the both governments agreed to establish the committee aimed at solving these problems. The first meeting was held in July 1986 and since then the meeting was opened 6 times. Although the meeting will be held continuously every year, the agreement and decision become comparatively definite and fruitful. The river training section of DOI is the representative of Nepalese side

(d) There are 31 problems/locations of flood inundation proposed by Nepalese side and at present 15 problems of them have already been dropped as the both parties agreed that these are not so serious or the problems with less priority. Therefore, 16 problems are now under discussion or in process of taking countermeasures as indicated in Fig. 5.1.

(e) Most of all problems are located in the zones within 5 - 10 km from the border. Some representative problems with more concern at present are briefly introduced in Appendix 2.

(f) The damages are generally loss of crops, transportation cut and hindrance of daily & economic activities. There is usually no problems of human loss.

(g) It is the fact that the relocation of people/villages is much cheaper than the construction of flood control works in many cases. Therefore, this fact will be one of the essential points of discussion.

(h) The detailed contents of meeting of the standing committee are compiled as the Minutes (English) and the summary of problems is compiled in a report (in Nepalese).

(i) The inundation problems in Nepal became serious quite recently due to the immigration of people from the mountain areas to the Terai plain. Such people generally have to select cheaper land where the disaster potential is relatively high.

(j) The multi-purpose dam (including flood and sediment control) will be necessary in the long-term plan in some major rivers as the flood control by dykes is a tentative measure in consideration of constant rising of river bed due to gentle river slope and remarkable supply of sediments from the upstream reaches.

(k) The sabo works in the upper catchment areas will be essential for the long-term basis flood control. The countermeasures only by river structures would not be sufficient. The Water Induced Disaster Prevention Training Center was recently established by the

assistance of JICA. The cooperation and coordination with the center will be important and necessary.

In the previous Standing Committee meetings, 16 items were selected out of 31 inundation problem sites and discussed as shown in Fig. 5.1. Subsequent to the above, the eighth meeting of the Standing Committee was held in Kathmandu on 22nd to 25th September 1992.

The following description are summary of the eighth meeting:

1) There was no discussion on Item No. 10, 17 and 19.

2) Items No. 1, 2, 3(a), 5 and 6 fall in the scheme of embankment extension along Lalbakeya, Bagmati, Kamala and Khando rivers and problems will be solved by implementation of the scheme.

3) Items No. 3(b), 4, 11, 13, 21, 27 and 28 will need joint survey, observation and further discussion.

4) Items No. 29 and 30 were dropped.

5) New item No. 32 in the Gagan river in the Siraha District was discussed, which would need further inspection and discussion.

6) The Joint Team for extension of embankments of rivers Lalbakeya, Bagmati, Kamala and Khando has prepared the Project Reports and estimates. The Committee decided to recommend the taking up of the schemes finalized by the Joint Expert Group on the extension of embankments for execution at the earliest.

TABLES

Table 2.1 LIST OF MAJOR DATA USED (1/2)

1. Nepal in Maps, prepared by S.H. Shrestha (Tribhuvan) University and published by Educational Enterprise PVT. Ltd. in 1988.

2. Master Plan for Irrigation Development in Nepal prepared by Canadian International Water and Energy Consultants in Feb. 1990.

3. Master Plan of Hydroelectric Power Development in Nepal, Sept. 1974 (JICA).

4. Sapt Gandaki Hydroelectric Power Development Project, Feasibility Report, JICA, Jan. 1983.

5. Design Manuals for Irrigation Project in Nepal prepared by Sir M. Macdonald & Partner Ltd. in Feb. 1990 (UNDP).

6. Inception Report for Study on Nationwide Hydro-meteorological Data Management Project by JICA in March 1991.

7. River System of Nepal Prepared by Chandra K. Sharma in July 1977.

8. User's Manual of Hydrological Data Base of DOHM (UNDP/WMO).

9. Surface Water Records of Nepal, Supplement No.9, 1974 (Department of Irrigation, Hydrology & Meteorology).

10. Report of Nepal-Bangladesh Joint Study Team on Flood Mitigation Measures and Multipurpose Use of Water Resources, Aug. 1989.

11. Erosion and Sedimentation in the Nepal Himalaya, an Assessment of River Processes, May 1987 (WECS of MOWR).

12. Pancheshwar (Mahakali) Multipurpose Project, May 1985.

13. Jhimruk Power Development Feasibility Study, July, 1987.

14. Western Rapti, Multipurpose Project, Pre-Feasibility Study, June 1976.;, 3

15. Project Aid Proposal for Feasibility Study on Naumure Multipurpose Project, Jan. 1989.

16. Marsyangdi Hydroelectric Project, Feasibility Study, Jan. 1979.

17. Feasibility Report on Sapt Gandaki Hydroelectric Power Development Project, Jan. 1983.

Table 2.1 LIST OF MAJOR DATA USED (2/2)

18. Feasibility Report on Kulekhani Hydroelectric Project, Sep. 1974.

19. Third Kulekhani Hydroelectric Project, Feasibility Study Report, Jan. 1988.

20. Master Plan Study on the Kosi River Water Resources Development, March 1985.

21. Feasibility Study on Arun-3 Hydroelectric Power Development Project, March 1987.

22. Mountain Environmental Management in the Arun River Basin of Nepal.

23. Bhote Kosi Hydroelectric Project Prefeasibility Study, July 1987.

24. East Rapti Irrigation Project Feasibility Study Report, 1986.

25. Natural Hazards and Man Made Impacts in the Nepal Himalaya, by D.K. Sharma 1988.

26. Water and Energy Resources of the Himalayan Block (Nepal,Bhutan, Bangladesh, Pakistan and India) by C.K. Sharma, 1983.

27. Nepal Nature's Paradise by T.C. Majupuria, 1984-85.

28. Itemize Minutes of Standing Committee between Nepal and India on Inundation Problems, Jan. 1991.

29. HIMAL, MAY/JUNE 1991.

Table 3.1 LIST OF RIVER/RIVER BASINS IN NEPAL BASED ON PRACTICAL BASIC DIVISION

Basin No.	Name of River/River Basin
I	Mahakali River System
II	Southern Border River Group No.1
III	Karnali River System
1	Humla Karnali
2	Mugu Karnali
3	Sinja/Tila
4	Seti (West)
5	Bheri
6	Karnali Main (Others)
IV	Babai River System
V	Southern Border River Group No.2
VI	Rapti (West) River System
VII	Southern Border River Group No.3
VII	Gandaki River System
1	Trisuli
2	Budhigandaki
3	Marsyangdi
4	Seti (Gandaki)
5	Kaligandaki
6	Rapti (Gandaki)
7	Narayani/Gandaki Main (Others)
IX	Southern Border River Group No.4
X	Bagmati River System
XI	Southern Border River Group No.5
XII	Kamala River System
XIII	Southern Border River Group No.6
XIV	Kosi/Sapta Kosi River System
1	Bhote Kosi/Sun Kosi
2	Tama Kosi
3	Dudh Kosi
4	Arun
5	Tamar/Tamur
6	Kosi/Sapta Kosi Main (Others)
XV	Southern Border River Group No.7
XVI	Kankai River System
XVII	Southern Border River Group No.8

Table 3.2 PRINCIPAL FEATURES OF MAJOR RIVERS/RIVER-BASINS (1/2)

River/River System	Catchment Area (km^2)		Length of Main Steam (km)	Annual Mean Discharge (m^3/s)
Mahakali	15,260	(5,317)	223	557
Karnali	44,000	(43,227)	507	1,368
Babai	3,270	(3,252)	190	72
West Rapti	6,500	(6,215)	257	126
Narayani/Gandaki	34,960	(31,726)	332	1,767
Bagmati	3,610	(3,681)	163	214
Kamala	2,160	(1,786)	117	75
Sapta Koshi/Koshi	60,400	(27,863)	513	1,566
Kankai	1,575	(1,317)	108	73
Others	19,272	(22,797)	-	578
Total	199,007	(147,181)	-	-

Note: Catchment areas in parentheses are those in Nepal territory. The total areas include those in India and/or China.

Table 3.2 PRINCIPAL FEATURES OF MAJOR RIVERS/RIVER-BASINS (2/2)

No.	Name of the rivers	Main river basins	Catchment area (km)	Length (km)	Total fall (m)	Average gradient
1.	Sun-Kosi	Sapta-Kosi	14,500	256	1,585	0.0062
			18,000	334		
	Indrawati		1,180	68	3,500	0.0520
	Tamba-Kosi		2,580	90	2,820	0.0313
			4,100	115		
	Dudh-Koshi		4,100	122	5,340	0.0436
2.	Arun	Sapta-Kosi	5,240	152	2,045	0.0134
			34,000	513	4,500	0.0088
3.	Tamur	Sapta-Kosi	5,900	198	5,400	0.0276
4.	Trisuli-Ganga	Sapta-Gandaki	15,380	127	1,460	0.0115
			20,000	224		
	Buri-Gandaki		3,640	117	4,950	0.0424
			5,840			
	Marsyangdi		4,600	153	6,000	0.0390
	Seti		3,000	125	4,800	0.0385
	Madi		1,120	74	5,070	0.0685
5.	Kali-Gandaki	Sapta-Gandaki	11,600	316	4,080	0.0129
			11,850	332	5,200	0.0156
	Mayangdi Khola		1,110	68	4,110	0.0605
	Bari-Gad		2,080	85	2,810	0.0330
6.	East Rapti	Sapta-Gandaki	3,110	122	1,370	0.0110
7.	Karnali (Humla		41,550	433	3,600	0.0083
	as main stem)	The Ganges	44,000	507		
	Tanke Khola		1,400	65	3,170	0.0488
	Mugu-Karnali		6,060	195	4,880	0.0250
	Tila		3,480	109	4,700	0.0440
	Lohare		1,040	44	1,905	0.0433
	Seti		7,500	202	5,100	0.0253
	Buri-Ganga		1,710	84	4,650	0.0554
	Bheri		12,400	264	4,640	0.0175
	Thuli-Bheri		3,320	136	4,575	0.0336
	Sani-Bheri		2,650	98	4,080	0.0415
8.	Mahakali (up to Banbassa)		15,260	223	4,900	0.0220
		Chamlia	1,610	81	4,670	0.0576
9.	West Rapti	Gogra	6,500	257	2,320	0.0090
	Jhimruk		1,080	81	2,220	0.0272
10.	Babai	Gogra	3,270	190	1,400	0.0074
11.	Bagmati	The Ganges	3,610	163	1,845	0.0113
12.	Kamala	Sapta-Kosi	2,160	117	1,190	0.0101
13.	Kankai-Mai	The-Ganges	1,575	108	2,345	0.0216

Note: Values in the denominator includes the area, length and fall in Tibet also.
Source: Nepal Nature's Paradise by T.C. Maju Puria, 1984-85.

Table 4.1 LIST OF MAJOR RIVER/RIVER-RELATED STRUCTURES IN NEPAL

River (River System)	Kind of Structure	Principal Features and Present Conditions, etc.
Mahakali	Barrage (Irri.)	Called Sanda Barrage, located in India territory
Mohana	Weir (Irri.)	Under construction (to be completed in 1991)
Babai	Weir (Irri.)	190.5m long, 4 sluice gates
Tinau	Weir (Irri.)	No function at present
Gandaki	Barrage (Irri.)	750m long, located at Nepal-India border
Seti	Weir (Irri.) and P.S.	80m long x 4m high, 3 sluice gates
Seti	Dam and P.S.	Dam height 15.50m, 52.3m long cre(Phewa lake) st width of crest 6m.
Seti (Begnas)	Dam (Irri.)	540m long x 6.8m high Earthfill type
Marsyandi	Weir and P.S.	Gated-over flow type weir, net width of weir openings 60m, 6 nos Radial gates 13.5m height and 10 m width.
Trisuli	Weir and P.S.	Installed Power generation capacity 21.0 MW and concrete weir
Kulekhani	Dam and P.S.	107m high x 406m long zoned rockfill type
Sunkosi	Dam and P.S.	Installed power generation capacity 10.1 MW and concrete dam.
Bagmati	Barrage (Irri.)	400m long, 39 spans of 6.5m and scouring sluices of 8 bays of 6.5m
Kamala	Barrage (Irri.)	650 m long diversion weir, overflow weir length 513 m, weir height 1.45m 137m long under sluice of 2 x 67.5m, Gates of 6.5m x 8 x 2 with piers width 2.0m.
Kosi	Barrage (Irri.)	1149m long barrage, located near Nepal -India border in Eastern Region.
Kankai	Weir (Irri.)	126m long x 1.85m high with 3 sluice gates of 3.5m x 1.85m

FIGURES

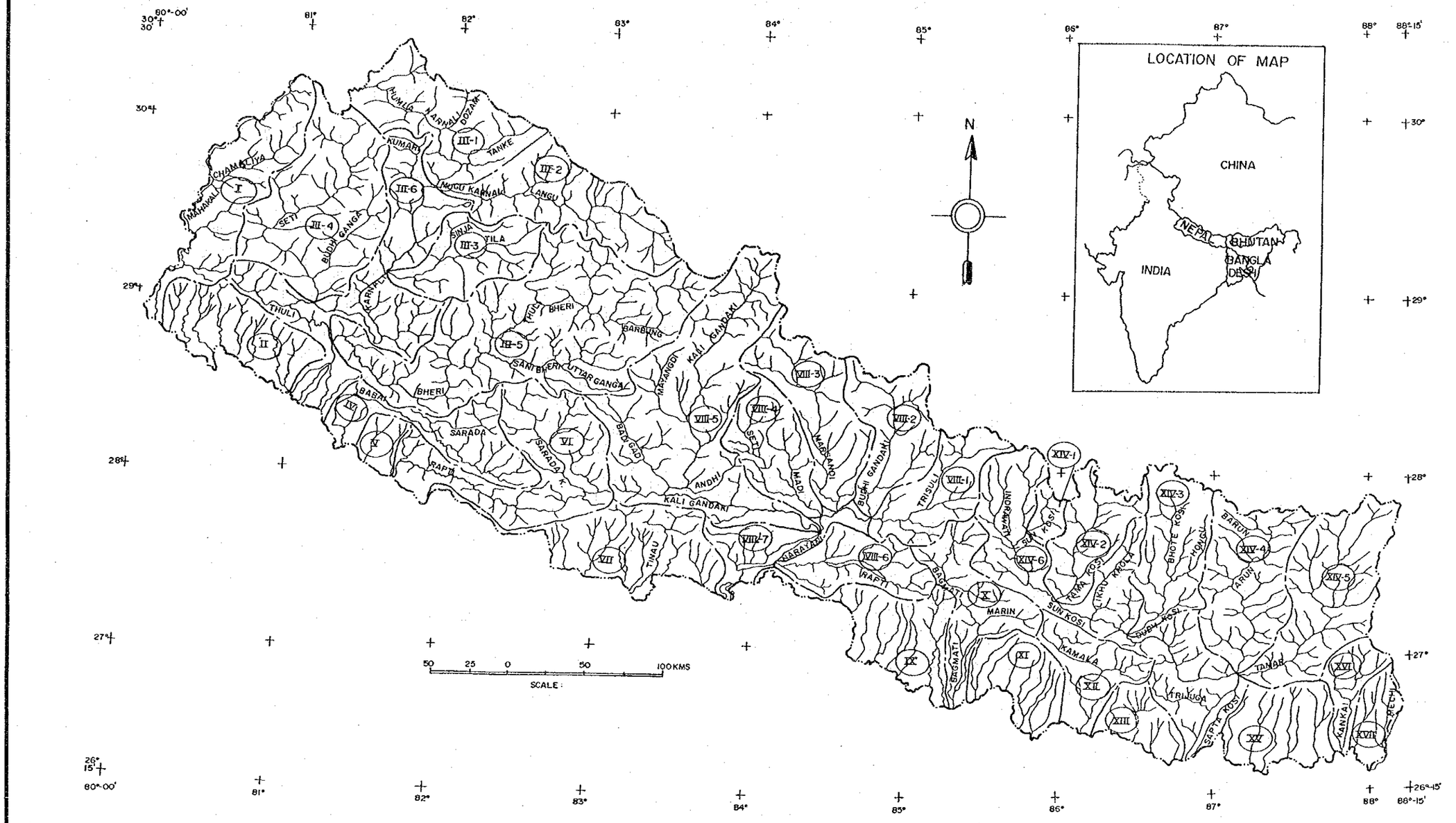


Fig. 3.1 RIVER AND RIVER BASIN IN NEPAL

NOTE : See Table 3.1 for Basin Name.

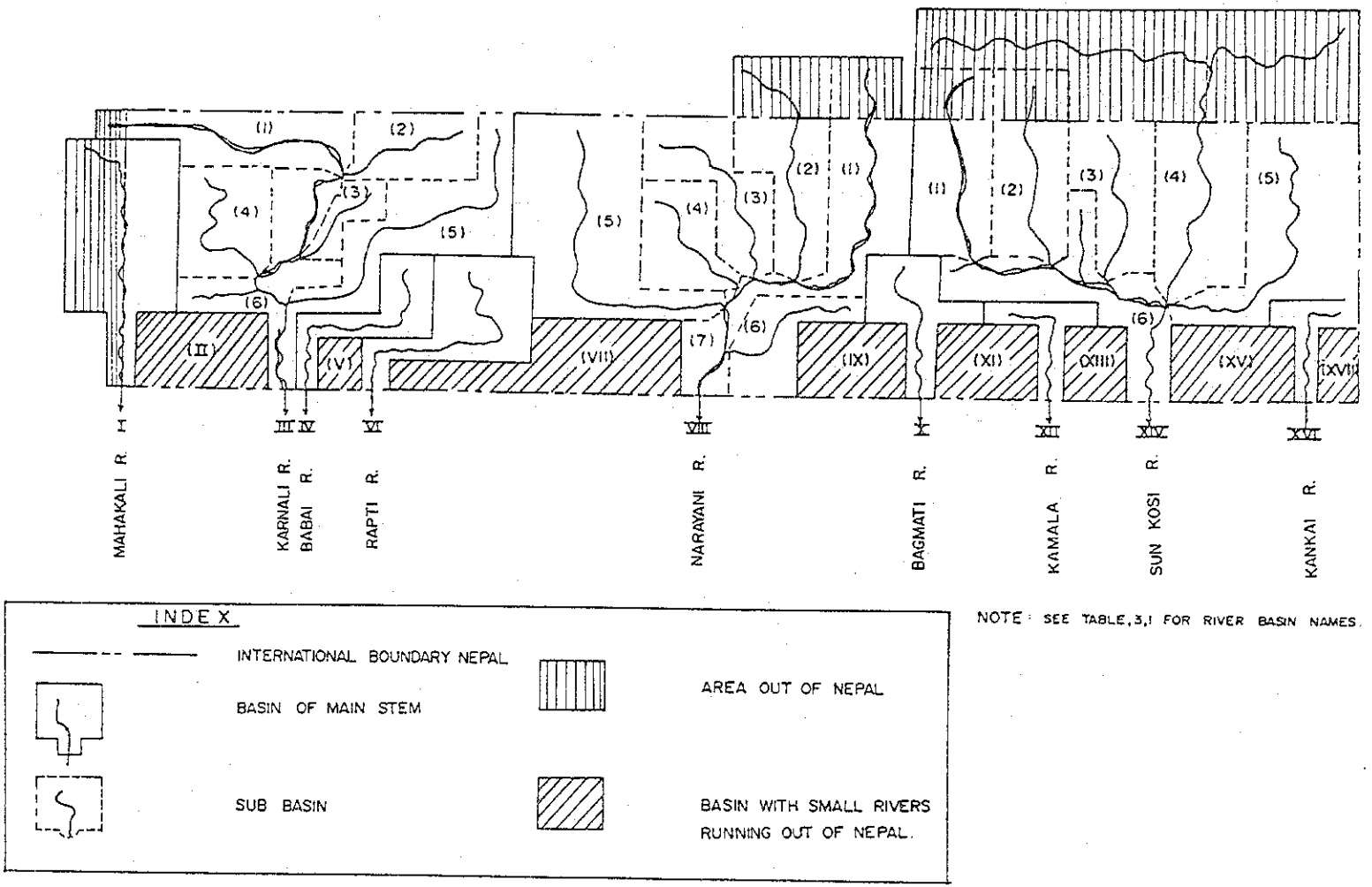


Fig. 3.2 SCHEMATIC MAP OF RIVER BASIN IN NEPAL

NOTE : See Table 3.1 for Basin Name.

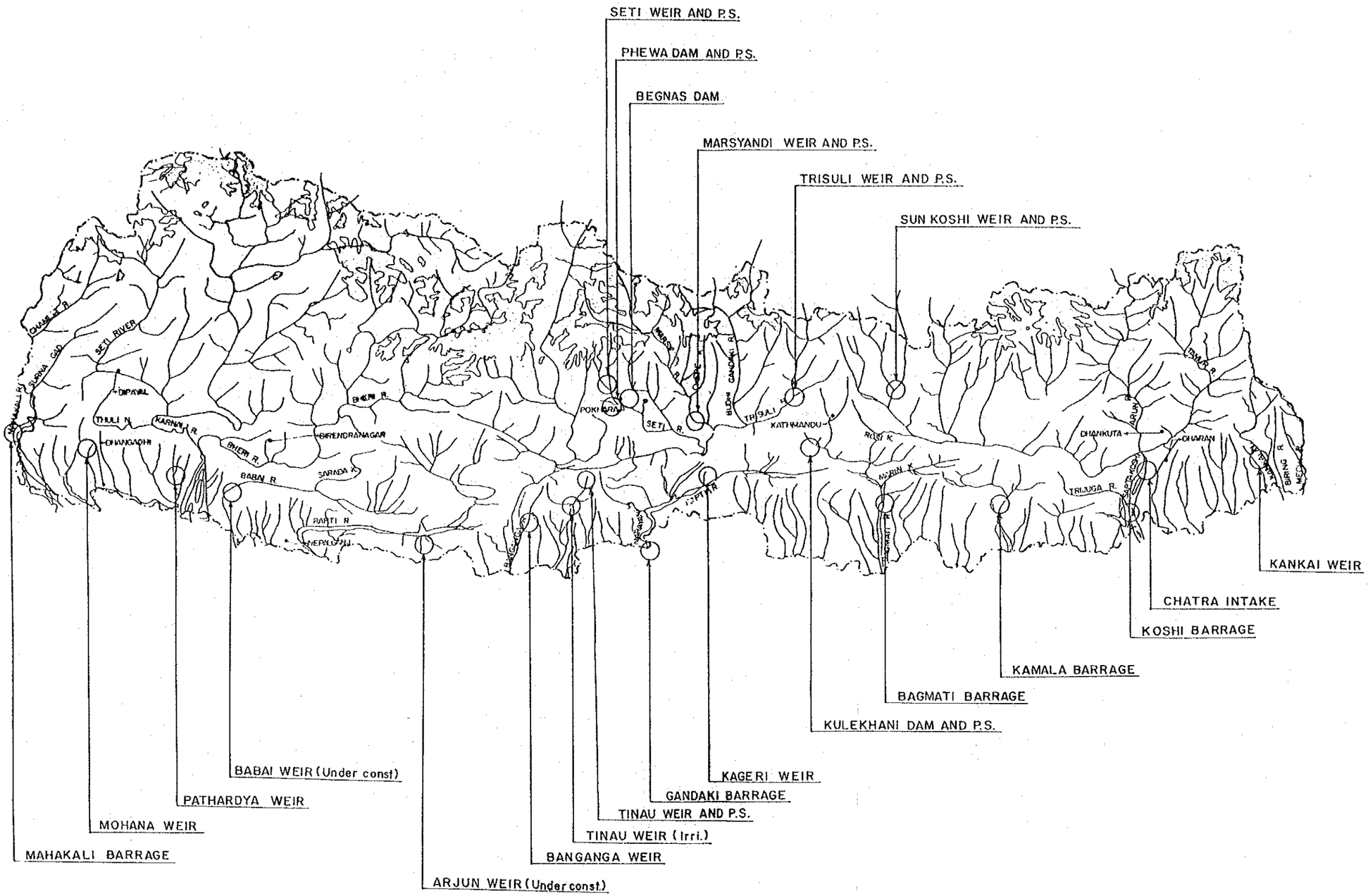


Fig. 4.1 LOCATIONS OF MAJOR RIVER RELATED STRUCTURES

NOTE : Some Medium Scale Structures are Included. There are Some Other Medium Scale Structures Which are Not Shown Above.

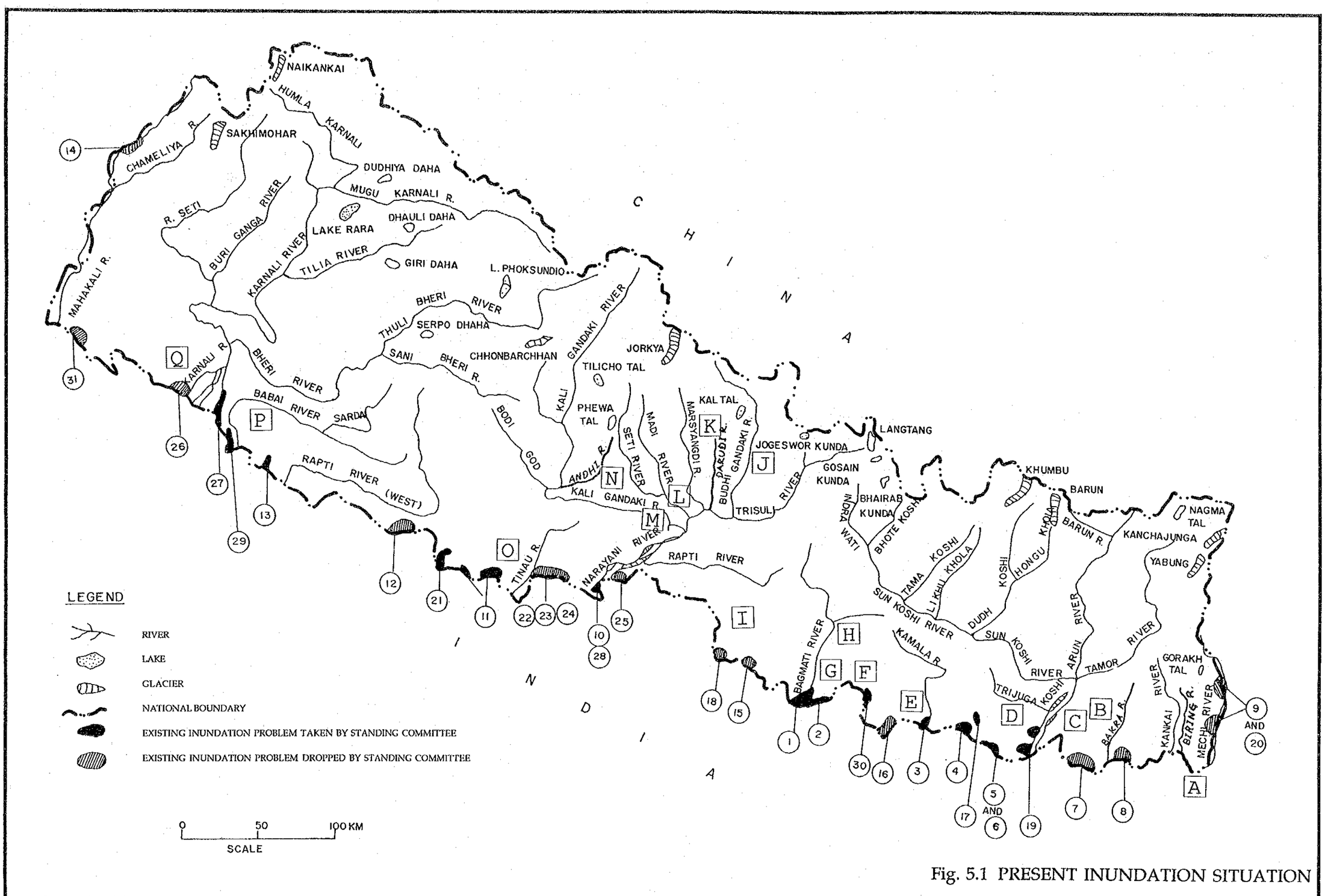


Fig. 5.1 PRESENT INUNDATION SITUATION

NOTE : List of the Problem Area is Shown in Table 2.6 in Annex D.

APPENDIXES

APPENDIX-1

LIST OF RIVERS IN NEPAL

LIST OF RIVER IN NEPAL (1/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
I	Mahakali			
(1)		Tinkar r.		
(2)		Chamliya r.		
(3)		Sumaya Gad		
(4)		Rangun k.		
(5)		Mahakali Main (Others)		
II	Southern B. No.1			
(1)		Pathraiya nadi		
(2)		Korah nadi		
(3)		Kandra nadi		
(4)		Kula nadi		
(5)		Kateni nadi		
(6)		Ghurra nadi		
(7)		Khutia		
(8)		Mohana r.		
(9)		Dondra r.		
(10)		Sihali nadi		
A			Bausara nadi	
(11)		Chaundhar nadi		
(12)		Bamhani nadi		
III	Karnali			
III-1		Humla Karnali		
(1)			Lurungya k.	
(2)			Dozam chu	
(3)			Galwa k.	
(4)			Biljara	
(5)			Nehar k.	
III-2		Mugu Karnali		
(1)			Shoba k.	
(2)			Ghatta k.	
(3)			Gumgad	
(4)			Luma	
(5)			Ruma	
(6)			Bumcha	
(7)			Tala	
(8)			Chilang	
(9)			Langu	
(10)			Tanari	
(11)			Puwa	
(12)			Ghatta	
(13)			Sim	
(14)			Phurkha	
(15)			Chebni	
(16)			Rigda	
(17)			Sota	
III-3		Sinja k.		
(1)			Mindrabali	
(2)			Jaijala	
(3)			Lahgad	
III-4		(West) Seti		
(1)			Salimor k.	
(2)			Seti k.	
(3)			Niuna k.	
(4)			Kayo	
(5)			Kaula	
(6)			Ghat	
(7)			Lainigad	
(8)			Ganaigad	
(9)			Panimulnala	

LIST OF RIVER IN NEPAL (2/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(10)			Lisnigad	
(11)			Lamagad	
(12)			Dunigad	
(13)			Bhaita	
(14)			Ramaita	
(15)			Talkoti	
(16)			Sunigad	
(17)			Dhungri k.	
(18)			Raidhar k.	
(19)			Dilgad	
(20)			Kachaligad	
(21)			Gandi gad	
(22)			Dhairigad	
(23)			Shiv k.	
(24)			Sherati k.	
(25)			Kachali k.	
(26)			Ayant k.	
(27)			Magna k.	
(28)			Bheri k.	
(29)			Dwarrigad	
(30)			Lichhigad	
(31)			Tarugad	
(32)			Nadar k.	
(33)			Bauligad (Jeoligad)	
(34)			Tunnagad	
(35)			Buri Ganga	
a				Kaikash k.
b				Buriganga
(36)			Galagad	
(37)			Sangli k.	
(38)			Susnegad	
(39)			Chairo k.	
(40)			Siyanban r.	
(41)			Tarugad	
(42)			Odarugad	
(43)			Banis k.	
(44)			Chapro k.	
(45)			Kaligad	
(46)			Saur k.	
III-5		Bheri river		
(1)			Thuli Bheri r.	
a				Chhundka
b				Thadagad
c				Jairi
d				Khuman
e				Sali
f				Suligad
g				Rogad
h				Khur k.
(2)			Sano Bheri	
a				Uttarganga
b				Lukum k.
c				Pelma k.
d				Sisne k.
e				Dobagiya
f				Pabang
g				Baulaha
h				Tubang
i				Ching
j				Rukum
(3)			Jhari k.	

LIST OF RIVER IN NEPAL (3/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(4)			Marma k.	
(5)			Sama k.	
a				Mustang k.
b				Sama k.
(6)			Ludh k.	
(7)			Holu k.	
(8)			Pasagarnala	
(9)			Ibargad	
(10)			Lyure k.	
(11)			Koda k.	
(12)			Bagdiya	
(13)			Sanabara	
(14)			Thala	
(15)			Ranchaur	
(16)			Kabligad	
(17)			Kim k.	
(18)			Sarugad	
(19)			Juge k.	
(20)			Aul k.	
(21)			Simta k.	
(22)			Bangar	
(23)			Chaina	
(24)			Goruodhar	
(25)			Balewan	
(26)			Khopri	
(27)			Tasu	
(28)			Jaldigad	
(29)			Tatargad	
(30)			Khumaruyo k.	
(31)			Kharkara k.	
(32)			Gijagad	
(33)			Nal Syangudag	
(34)			Narsoti k.	
(35)			Ghursu k.	
(36)			Dhulepani	
(37)			Kalapani	
(38)			Bulbule	
(39)			Chhinchu	
(40)			Jhupra	
(41)			Chingar	
(42)			Chhinachuli	
(43)			Phalate	
(44)			Khare	
(45)			Magar	
(46)			Jhegarni	
(47)			Battisi k.	
(48)			Chambre	
(49)			Katasia	
(50)			Bar k.	
(51)			Rujkha k.	
(52)			Batiaghate	
(53)			Girighat	
(54)			Nikas	
III-6		Karnali Main (Others)		
(1)			Paduka k.	
(2)			Lohare k.	
a				Sot k.
b				Ralli k.
c				Parajul
d				Malhela
e				Nadsaini

Appendix -1

LIST OF RIVER IN NEPAL (4/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
f				Chhamgad
(3)			Thuligad k.	
a				Ghurka k.
b				Gorka
c				Garhpandera k.
d				Kataunji k.
e				Sayal k.
f				Kotkena k.
g				Binesaon k.
h				Salle k.
i				Bhojya k.
j				Ova k.
k				Ghattaya k.
l				Nigali k.
(4)			Kusaci k.	
(5)			Khater k.	
(6)			Kunda k.	
(7)			Tibgad k.	
(8)			Phugad	
(9)			Sannigad	
(10)			Jateogad	
(11)			Ramgad	
(12)			Kamalu k.	
(13)			Sisnegad	
(14)			Lodyagad	
IV	Babai			
(1)		Jagwa k.		
A			Gurje	
B			Sewar k.	
a				Thulo
b				Tosh
(2)		Hapur		
A			Chahuwa	
B			Bansgajeri	
C			Hathi	
D			Khara	
(3)		Sisneri		
(4)		Naraina Sota		
(5)		Gawar		
A			Dhorbang	
B			Sabdanda k.	
C			Erugar	
D			Garpa	
E			Raingar	
(6)		Kalleri		
(7)		Sarda		
A			Jum k.	
B			Aranya k.	
C			Lawam k.	
D			Baus k.	
E			Tilcha k.	
F			Kharangara	
G			Latekar	
H			Tinbang	
I			Khali	
J			Mokhala	
K			Chakligad	
L			Jhargaon	
M			Ghat	
N			Sui	
O			Bhun	

LIST OF RIVER IN NEPAL (5/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
P			Korbang	
Q			Gupt	
R			Maus	
S			Kawai	
T			Kulne	
U			Durun	
(8)		Patu k.		
A			Gate k.	
B			Bhamil	
(9)		Katawa		
(10)		Kotre nadi		
(11)		Ratamate		
(12)		Bagdare		
(13)		Mul k.		
(14)		Dhandanda		
(15)		Kharepani		
(16)		Badosota		
(17)		Sukheli		
(18)		Mul k.		
(19)		Guranse		
(20)		Ranjha		
(21)		Miring		
(22)		Mumu		
(23)		Ekpate		
(24)		Garepani		
(25)		Sot k.		
(26)		Khappre		
(27)		Dharbas		
V	Southern B. No.2			
(1)		Man		
(2)		Giruwa		
(3)		Kauriala		
VI	Rapti (West)			
(1)		Jhimruk k.		
A			Gaon k.	
B			Libang	
C			Dhoato	
D			Timru	
E			Gawdi	
F			Hangarh	
G			Gartang	
H			Lung	
a				Erkate k.
b				Gawai k.
c				Kante k.
d				Balde
e				Andheri
I			Khapring	
J			Dunga	
K			Saribang	
L			Jumli	
a				Jung k.
b				Dhant k.
M			Sirse	
N			Kachar	
O			Dhanbang	
P			Kairam	
Q			Andheri	
(2)		Mari k.		
A			Bhirting	
B			Hirang	

Appendix -1

LIST OF RIVER IN NEPAL (6/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
C			Jhenglang	
D			Arung	
	a			Jibang
	b			Narung
	c			Mila
	d			Kurlu
	e			Guntu
	f			Dhau k.
	g			Khurpi
	h			Rupla
	i			Dabang
	j			Masure
E			Banay	
F			Kochhap	
G			Ghora	
H			Lungri	
	a			Gaja k.
	b			Gam
	c			Ghushang
	d			Langri
	e			Mun
	f			Chiure
I			Dhanbang	
J			Bhalu	
K			Jari	
L			Ghati	
M			Kap Kati	
(3)		Sit k.		
(4)		Silung k.		
(5)		Ganah k.		
A			Surgri k.	
B			Ghos	
C			Puthe	
D			Seti	
(6)		Supalia		
(7)		Arjan k.		
A			Khar k.	
B			Bhitri k.	
C			Suka k.	
D			Tisuwa k.	
E			Khurle	
F			Masot	
G			Gorakhe	
(8)		Kakrah k.		
(9)		Rangsing k.		
A			Kusmu k.	
B			Kathe	
C			Sisne	
D			Dhan	
E			Mathura	
(10)		Gurung k.		
(11)		Lomari k.		
(12)		Nar Khandra k.		
(13)		Khairahwa k.		
(14)		Karri k.		
(15)		Karanga		
(16)		Mungre		
(17)		Gangdi		
(18)		Nepu		
(19)		Haraiya		
(20)		Sikta		

LIST OF RIVER IN NEPAL (7/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(21)		Khangra		
(22)		Bathbiya		
(23)		Riu		
(24)		Burhi		
(25)		Bahurwa		
(26)		Simrisota		
(27)		Shankarwa		
(28)		Gidhuwa k.		
(29)		Gangre k.		
(30)		Supalia		
(31)		Sikanwa		
(32)		Burlaya		
A			Dolai k.	
B			Bhukia k.	
C			Ghambhiriya	
(33)		Lumwa		
(34)		Jhuri Nala		
(35)		Sukhar		
(36)		Khairi k.		
(37)		Modanga Sota		
(38)		Gojarhawa Nala		
(39)		Dundra nadi		
(40)		Mungawa k.		
(41)		Parwa Sate		
(42)		Kaudia k.		
VII	Southern B. No.3			
(1)		Dhanewa		
(2)		Baluhi		
(3)		Jharia		
(4)		Turia		
(5)		Rohini		
(6)		Tinau		
A			Jhumsa k.	
B			Dobhan	
a				Kurman
b				Amile
c				Bewre
C			Bhainsikatta k.	
D			Majhare	
E			Tinau	
F			Chohar k.	
(7)		Danau		
A			Kachan nadi	
a				Pahila nadi
b				Kanchan nadi
B			Syari nadi	
C			Bauraha k.	
D			Ingura	
E			Naukhania	
F			Thulibilia	
G			Ganaha	
(8)		Kothi		
A			Bete	
(9)		Banganga		
A			Kuneri k.	
B			Ageni k.	
C			Chirahwa nadi	
D			Belwagurudwa nadi	
E			Bel nadi	
F			Baubel k.	
G			Maunahar k.	

LIST OF RIVER IN NEPAL (8/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(10)		Mainaha k.		
(11)		Gural k.		
(12)		Arrah r.		
(13)		Binay nadi		
A			Khor k.	
B			Khedi k.	
C			Jimuri k.	
D			Gangati k.	
E			Binai k.	
a				Khakhra k.
b				Dangari k.
c				Khorandi k.
d				Sonai k.
e				Sukha k.
(14)		Arung		
(15)		Girwari		
(16)		Bhaula k.		
(17)		Khair k.		
(18)		Madari k.		
(19)		Bhudrung k.		
(20)		Motioya k.		
VIII	Narayani			
VIII-1		Trisuli		
(1)			Lende k.	
(2)			Bhurlung k.	
(3)			Chilme k.	
a				Bridang k.
(4)			Lantang k.	
(5)			Trisuli k.	
a				Gosaikund k.
(6)			Mailung k.	
(7)			Tadi k.	
a				Lokhu k.
b				Sindhure k.
c				Chhare k.
d				Darme k.
e				Betini k.
f				Amari k.
(8)			Phalangu k.	
(9)			Silanku k.	
(10)			Gerkhu k.	
(11)			Betrawati k.	
(12)			Samri k.	
(13)			Chainpur k.	
(14)			Bhanraur k.	
(15)			Khani k.	
(16)			Kalphu k.	
a				Panchase k.
b				Chauthe k.
(17)			Mahesh k.	
a				Khesate k.
VIII-2		Budhi Gandaki		
(1)			Budhi Gandaki	
a				Tam/Mawang k.
b				Sringi k.
c				Chuling k.
d				Shiar k.
e				Bhalu k.
f				Yaru k.
g				Dobhan k.
h				Namrung k.

LIST OF RIVER IN NEPAL (9/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
i				Samno k.
j				Machha k.
k				Richet k.
l				Dundari k.
m				Mangbang k.
n				Arkhet k.
o				Manu k.
p				Kaste k.
q				Istul k.
r				Borlang k.
(2)			Ankhu k.	
a				Manjeet k.
b				Aul k.
c				Kintang k.
d				Baguwa k.
e				Lapang k.
(3)			Darondi	
a				Hununu k.
b				Chhicha k.
c				Sambhu k.
d				Radlung k.
e				Mahabir k.
f				Andhare k.
g				Jhala k.
h				Sandi k.
i				Hundi k.
j				Landi k.
k				Lundi k.
l				Jarang k.
m				Khare k.
n				Masel k.
o				Dumshri k.
p				Khahre k.
q				Bhusundi k.
r				Beni k.
VIII-3		Marsyangdi		
(1)			Marsyandgi k.	
a				Miyardi k.
b				Galdu k.
c				Chharchhare k.
d				Randi k.
e				Nyadi k.
f				Khudi k.
g				Bhachok k.
(2)			Chepe k.	
a				Chyadi k.
b				Landi k.
c				Andheri k.
d				Kovala k.
e				Sandi k.
f				Chihli k.
g				Kishanti k.
(3)			Dordi k.	
a				Chhangdi
b				Chepe k.
c				Dordi k.
d				Kishanti k.
(4)			Musi k.	
(5)			Khudi k.	
a				Sunder k.
b				Kichemiche k.

LIST OF RIVER IN NEPAL (10/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(6)			Phul k.	
(7)			Dudh k.	
(8)			Paundi k.	
VIII-4		Seti		
(1)			Suranti k.	
(2)			Lidi k.	
(3)			Batase k.	
(4)			Vijaypur k.	
(5)			Phusre k.	
(6)			Khudi k.	
a				Anpu k.
b				Tal k.
c				Thar k.
(7)			Saraudi k.	
(8)			Kyangdi k.	
(9)			Syangdi k.	
a				Jamdi k.
b				Medhi k.
(10)				
a				Midam k.
b				Madi k.
c				Kalesti
d				Mudkyum k.
e				Chhar k.
f				Rudi k.
g				Bhujang k.
h				Kaun k.
i				Balam k.
j				Sardi k.
k				Mibje k.
l				Pisti k.
m				Vironi k.
n				Khalte k.
o				Risti k.
(11)			Chundi k.	
(12)			Kali k.	
(13)			Marse k.	
VIII-5		Kaligandaki		
(1)			Mayangdi k.	
(2)			Modi k.	
(3)			Barigad k.	
a				Challi k.
b				Nisti k.
c				Ghanruk k.
(4)			Riri k.	
a				Sardeva k.
b				Riri k.
c				Mathura k.
d				Kharni k.
e				Kordi k.
f				Hardi k.
g				Chal k.
h				Godli k.
i				Harip k.
j				Kharjang k.
k				Kendra k.
(5)			Andhi k.	
a				Mardi k.
b				Armadi k.
(6)			Jyagdi k.	
a				Lungdi k.

Appendix -1

LIST OF RIVER IN NEPAL (11/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
b				Gaira k.
c				Jyagdi k.
(7)			Nistinadi k.	
a				Kuhar k.
b				Kehar k.
c				Purba k.
(8)			Turundi k.	
(9)			Keladi k.	
(10)			Maiti k.	
(11)			Kuru k.	
VIII-6		Rapti		
(1)			Manahari	
(2)			Lothar	
(3)			Riu	
VIII-7		Gandaki Main (Others)		
(1)			Belkhu k.	
(2)			Galdu k.	
(3)			Malekhu k.	
(4)			Thapleh k.	
(5)			Charangdi k.	
(6)			Hutgati k.	
(7)			Nudi k.	
(8)			Kiran k.	
(9)			Arun r.	
(10)			Rinai k.	
IX	Southern B. No.4			
(1)		Lal Balye nadi		
(2)		Annuruwa nadi		
(3)		Tiar		
(4)		Pasah nadi		
X	Bagmati			
(1)		Manohara		
A			Salinadi	
B			Madara	
C			Hanumante	
a				Godavari
b				Charkhanda
c				Lubhu
d				Chisapani
e				Dunga Khani
(2)		Dhobi		
(3)		Bishnumoti		
(4)		Balkhu		
(5)		Nakhu		
A			Lele	
B			Naldu (Bhardeo)	
XI	Southern B. No.5			
(1)		Bachhraja		
(2)		Belauti nadi		
A			Charnath	
B			Balua	
(3)		Amari nadi		
(4)		Koh		
(5)		Hardinath		
A			Jagdhar nadi	
(6)		Ghaghar		
(7)		Bighi		
(8)		Rata		
(9)		Madha		
A			Jhanga	
(10)		Banki Thakuri		

Appendix -1

LIST OF RIVER IN NEPAL (12/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(11)		Jhim		
(12)		Lakhandehi		
XII	Kamala			
(1)		Tawa		
(2)		Chanda		
(3)		Thakur		
(4)		Langur		
(5)		Jurga		
(6)		Bhalu		
(7)		Goang		
(8)		Selar		
(9)		Mainawati		
(10)		Ghurmi		
(11)		Juwa		
XIII	Southern B. No.6			
(1)		Maula		
(2)		Trijuga nadi		
A			Kanga nadi	
B			Beriyani	
C			Babia	
D			Baruwa	
(3)		Tilujuga nadi		
A			Khando nadi	
(4)		Kajara nadi		
(5)		Ghorda nadi		
(6)		Panchi nadi		
(7)		Chapin nadi		
(8)		Balan nadi		
A			Koria nadi	
B			Siswari k.	
C			Kuti k.	
D			Rae nadi	
(9)		Sapahi nadi		
(10)		Kalyandehi		
(11)		Gobarjal		
XIV	Kosi			
XIV-1		Bhote Kosi		
(1)			Chakhu Khola	
(2)			Bhairavkund k.	
(3)			Libing k.	
(4)			Jum k.	
XIV-2		Tama Kosi		
(1)			Bhatauli k.	
(2)			Milti k.	
(3)			Khimti k.	
(4)			Bhote Kosi	
a				Chyadu k.
b				Zom k.
c				Rolwaling k.
d				Tamba Kosi
e				Sonung k.
f				Khahari k.
g				Suri k.
h				Gumbu k.
i				Dolti k.
j				Charnawati k.
XIV-3		Dudh Kosi		
(1)			Thotne k.	
(2)			Rawa k.	
a				Lising k.
b				Tap k.

LIST OF RIVER IN NEPAL (13/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(3)			Solu k.	
(4)			Inkhu k.	
(5)			Hingu k.	
(6)			Lumading k.	
(7)			Kyanghar k.	
(8)			Imja k.	
(9)			Lagmoche k.	
(10)			Thami k.	
(11)			Bhote Kosi	
(12)			Dhuh Kosi	
(13)			Cholaku k.	
XIV-4		Arun		
(1)			Dhanre k.	
(2)			Pikhwa k.	
a				Siktei k.
b				Madhuwa k.
c				Kawa k.
d				Akhuwa k.
(3)			Munga k.	
(4)			Mangma k.	
(5)			Leguwa k.	
(6)			Chhintalung k.	
(7)			Piluwa k.	
(8)			Hinwa k.	
(9)			Sabhaya k.	
(10)			Chirkhuwa k.	
(11)			Irkhuwa k.	
(12)			Sinwa k.	
a				Apsuwa k.
(13)			Sankhuwa k.	
(14)			Chhoyang k.	
(15)			Iswa k.	
(16)			Kusuwa k.	
(17)			Maghang k.	
(18)			Wabak k.	
(19)			Barun k.	
(20)			Dima k.	
(21)			Chhong k.	
(22)			Bagang k.	
a				Sumjung k.
b				Lhese k.
(23)			Tiju k.	
(24)			Wakang k.	
a				Pilung k.
(25)			Karmachu k. (C)	
(26)			Phungchu k. (C)	
(27)			Naktangchu k. (C)	
XIV-5		Tamur/Tamar		
(1)			Kabeli Khola	
a				Pha Khola
b				Tawa Khola
c				Inwa Khola
d				Soma Khola
(2)			Mewa Khola	
(3)			Kosini k.	
(4)			Sisni k.	
(5)			Telis k.	
(6)			Nabhu k.	
(7)			Sanwan k.	
(8)			Khorang k.	
(9)			Koya k.	

LIST OF RIVER IN NEPAL (14/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(10)			Nibhu k.	
(11)			Hima/Phemi k.	
(12)			Maewa k.	
(13)			Mewa k.	
a				Siswa k.
b				Saju k.
c				Mewa k.
d				Soma k.
e				Palung k.
(14)			Tamur k.	
a				Simbhuwa k.
b				Thapabu k.
c				Yagma k.
(15)			Phesua k.	
(16)			Dhobi k.	
a				Raguwa k.
(17)			Phongsuwa k.	
(18)			Leoti k.	
a				Sisne k.
b				Makhmupa k.
c				Simsua k.
d				Sunsuwa k.
e				Khokula k.
(19)			Dhankuta k.	
a				Ruduwa k.
b				Chuchi k.
c				Bange k.
(20)			Tankhuwa k.	
a				Nibuwa k.
(21)			Raghuwa k.	
(22)			Chharuwa k.	
a				Jaruwa k.
b				Bhote k.
c				Lugima k.
d				Chharwa k.
XIV-6		Sun Kosi Main (Others)		
(1)			Sun Kosi	
a				Sarong k.
b				Yari k.
c				Rankua k.
d				Laikhu k.
e				Chhalang k.
f				Dinkhuwa k.
g				Sawan k.
(2)			Balephi k.	
a				Jhikhu k.
b				Nosem k.
c				Duskoi k.
d				Risama k.
(3)			Indrawari k.	
a				Chunari k.
b				Khani k.
c				Malemchi k.
d				Sindhu k.
(4)			Rosi k.	
(5)			Likhu k.	
XV	Southern B. No.7			
(1)		Lodhiya nadi		
(2)		Aruwa nadi		
(3)		Ratuwa nadi		
(4)		Krishni nadi		

LIST OF RIVER IN NEPAL (15/15)

Basin No.	River System	River Name (1)	River Name (2)	River Name (3)
(5)		Gewria nadi		
(6)		Bakra nadi		
A			Napa nadi	
B			Saphewa k.	
C			Bakra k.	
D			Teli nadi	
E			Dani nadi	
F			Kair k.	
(7)		Lohandro nadi		
(8)		Singhai nadi		
A			Madhu k.	
B			Kesai nadi	
(9)		Rasal nadi		
(10)		Bodi nadi		
A			Buri nadi	
B			Sehra nadi	
C			Sunsari nadi	
XVI	Kankai			
(1)		Deomai		
(2)		Pua k.		
(3)		Jogmai nadi		
XVII	Southern B. No.8			
(1)		Mechi r.		
(2)		Nanda nadi		
(3)		Phulbesi nadi		
(4)		Handiya nadi		
(5)		Deonia nadi		
(6)		Jamuna nadi		
(7)		Bearing nadi		
(8)		Koklati nadi		
(9)		Tangting nadi		
(10)		Rate nadi		
(11)		Baluwa nadi		
(12)		Khuskuse nadi		
(13)		Kawai nadi		

APPENDIX-2

TYPICAL/REPRESENTATIVE FLOOD PROBLEMS IN TERAI PLAIN

TYPICAL/REPRESENTATIVE FLOOD PROBLEM
IN TERAI PLAIN (1/5)

Item No. 1

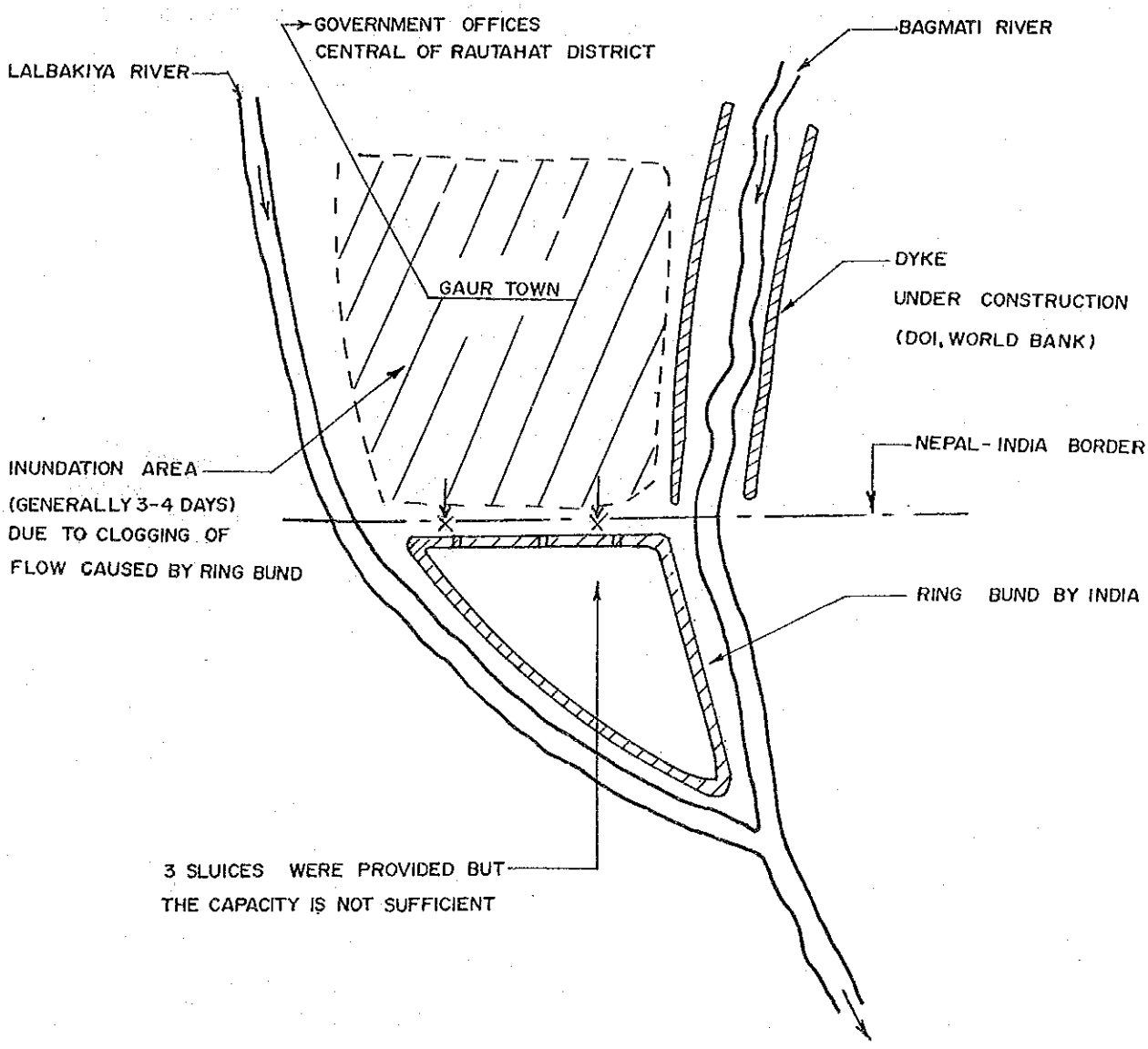
Location:

Central Development Region
Gaur Bazaar, Gaur Village Panchayat and areas in between Bagmati and Lal Bakaiya in Rautahat District.

Cause of Inundation:

Flooding of the areas due to construction of ring bund by India along Nepal-India border.

Sketch (for easy understanding) of Situation:



TYPICAL/REPRESENTATIVE FLOOD PROBLEM
IN TERAI PLAIN (2/5)

Item No. 2

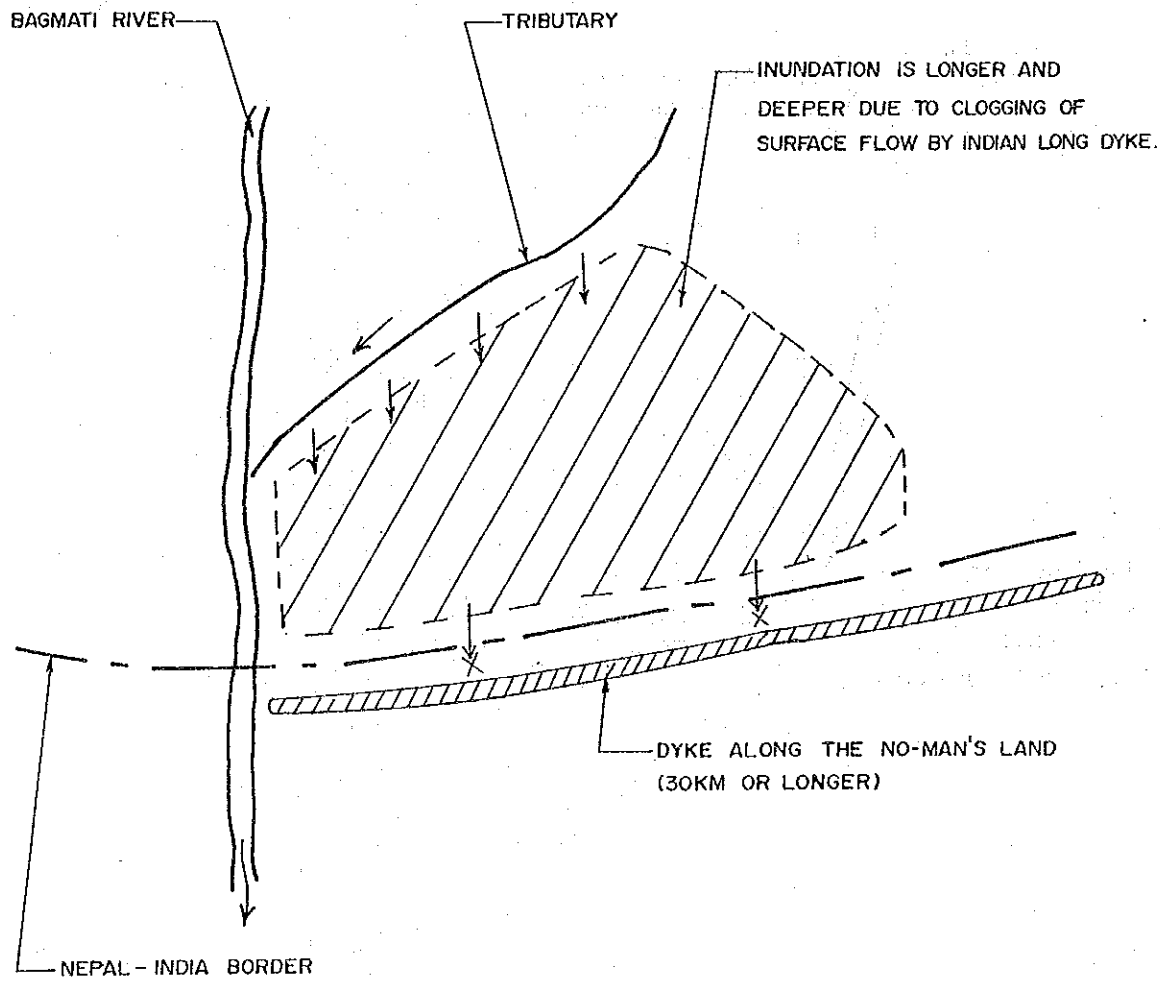
Location:

Central Development Region
Raghunathpur Village, Balra and Hathiyol Village of Sarlahi District and Southern part of Mahottari District.

Cause of Inundation:

Due to construction of embankment and spurs within the no-man's land along the border by the Indian side.

Sketch of Situation:



TYPICAL/REPRESENTATIVE FLOOD PROBLEM
IN TERAI PLAIN (3/5)

Item No. 5 & 6

Location:

Eastern Development Region

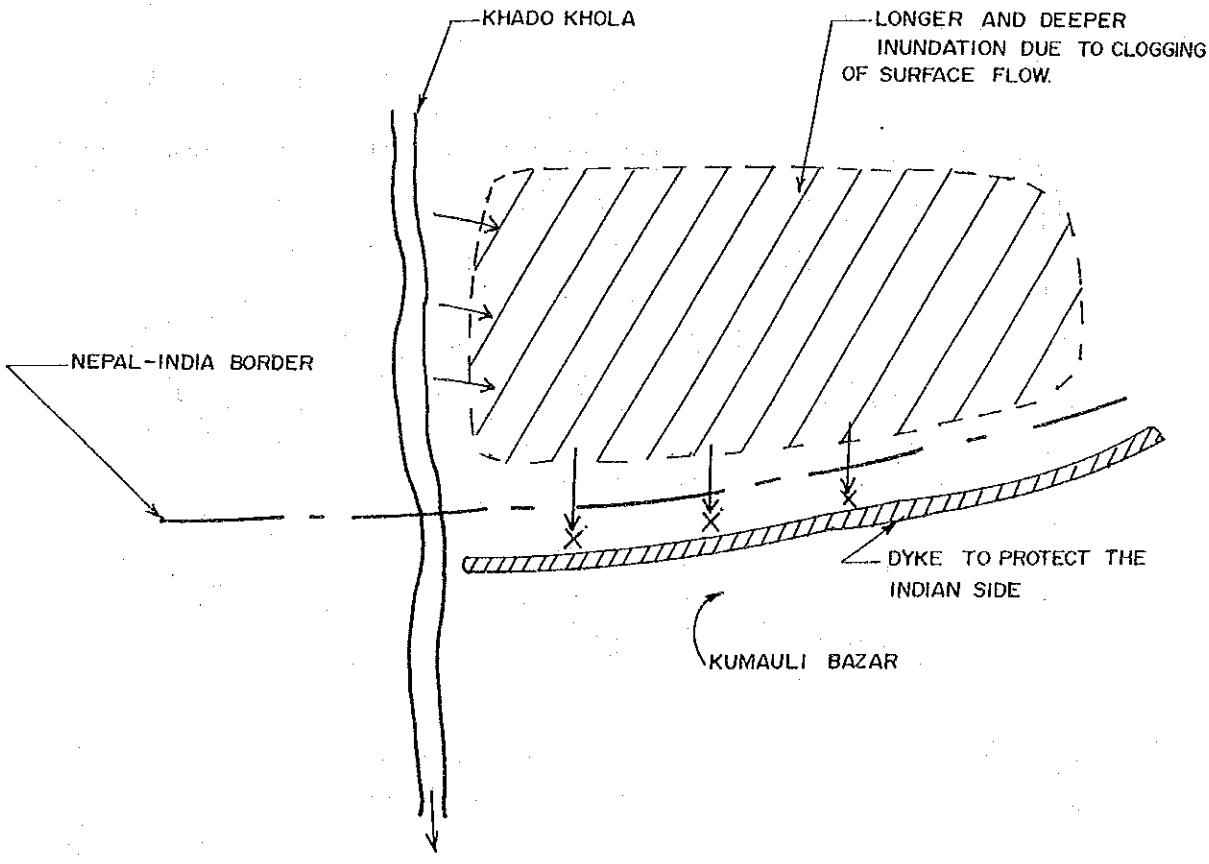
Item No. 5: Govindpur, Lalpatti Villages and the surrounding area of surrounding area of Lalpatti Village in Saptari District.

Item No. 6: Tilathi Village and surrounding area including customs area in Saptari District.

Cause of Inundation:

Due to the construction of natural flow during flood season of Khando river by construction of an embankment in Indian side of border. Due to construction of parallel embankment along the border (to protect their Kunauli Bazaar) there by restricting the flow.

Sketch of Situation:



TYPICAL/REPRESENTATIVE FLOOD PROBLEM
IN TERAI PLAIN (4/5)

Item No. 11

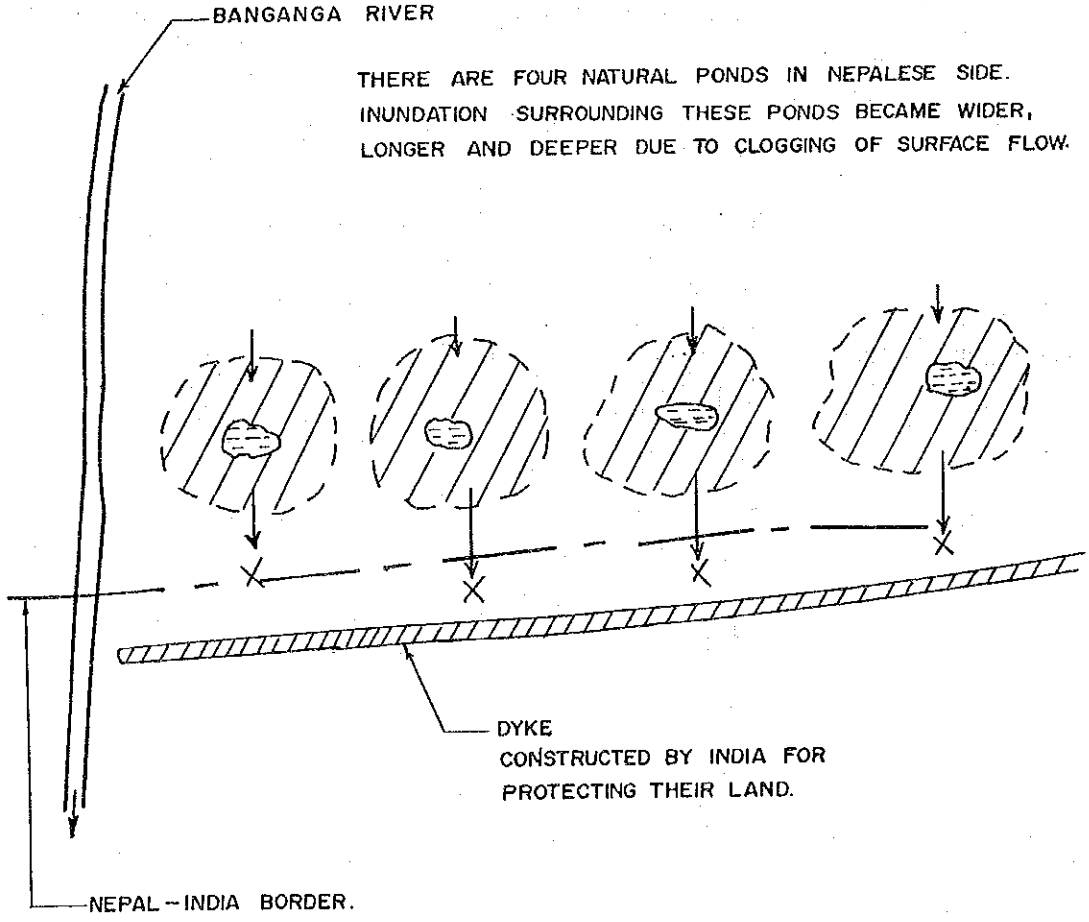
Location:

Western Development Region
Submergence of areas around Rangpur Village, Tulsipur Village and Bijuwa Village.

Cause of Inundation:

Due to construction of dyke near the border at Siswa Sagar, Bajha Sagar, Marthi Sagar and Mahuli Sagar by the Indian side.

Sketch of Situation:



TYPICAL/REPRESENTATIVE FLOOD PROBLEM
IN TERAI PLAIN (5/5)

Item No. 21

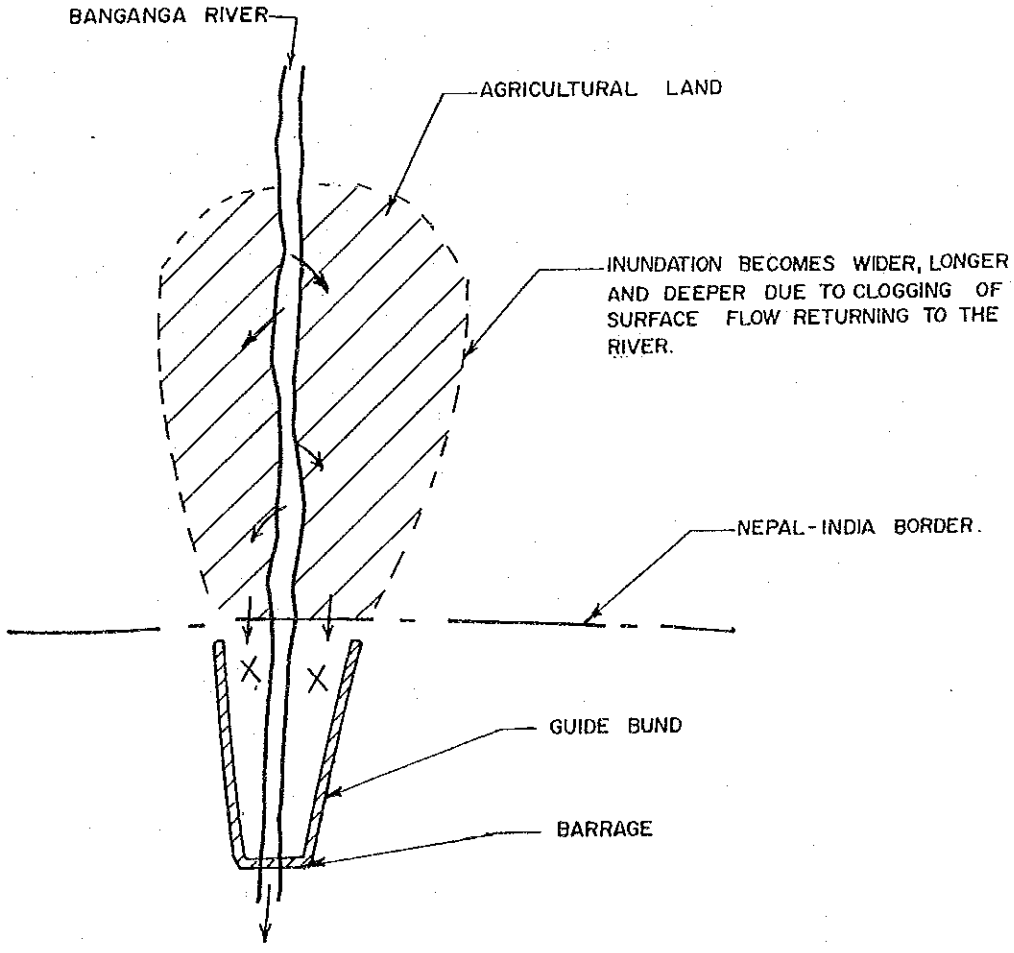
Location:

Western Development Region
Karaulia, Heradawa, Singhahawa, Semari, Itahawa Village and areas of Suthaula and Rajahua Villages in Kapilvastu District.

Cause of Inundation:

Due to closure of gates on the Banganga barrage in Indian side and construction of guide bunds on both banks of the Banganga river upto border causing flooding and submergence of the Nepalese territory.

Sketch of Situation:



ANNEX D

WATER RESOURCES DEVELOPMENT

NATIONWIDE HYDRO-METEOROLOGICAL DATA MANAGEMENT PROJECT

ANNEX D WATER RESOURCES DEVELOPMENT

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1. INTRODUCTION

The objectives of the study on water resources development in this project are to obtain informations and data on the existing water resources development projects and plans and their priorities which will be one of the basis for formulating the Long Term and Immediate Programmes to improve and expand the current nationwide hydro-meteorological observation network system and data management system.

Especially, the priority projects in the next five year plan in Nepal may require the further meteorological and hydrological data to decide the development scale of the project. Therefore, this national plan will be duly reflected in planning the system and its implementation programme.

The study concentrated on the data collection mentioned above and based on which the inventory of the existing projects have been produced. The 8th 5-year development plan is under preparation by the Government as of July 1991.

2. WATER RESOURCES DEVELOPMENT PROJECTS IDENTIFIED BY THE PREVIOUS STUDIES AND INVESTIGATIONS

2.1 Hydropower Development

It is said that Nepal has about 83 million kW of theoretical hydropower potential and some 19 million kW of economically viable potential which is estimated as follows:

River Basin	Hydropower Potential (kW)
Kosi	6,777,500
Gandaki	5,130,000
Karnali	6,765,000
Southern Rivers	365,240
Total	19,028,740

Source : Water and Energy Resources of the Himalayan Block, C.K. Sharma

As of 1988, the following hydropower projects were implemented and/or are on-going, and about 239 MW of electricity, which corresponds to 1.3% of the economically viable hydropower potential, is developed in Nepal.

Existing Hydropower	River Basin Station	Installed Capacity (kW)
Panauti	Sun Kosi in Kosi	2,400
Trisuli	Trisuli in Gandaki	21,000
Sunkosi	Sun Kosi in Kosi	10,050
Gandaki	Narayani	15,000
Kulekhani No.1	Kulekhani in Bagmati	60,000
Devighat	Trisuli in Gandakit	14,100
Kulekhani No.2	East Rapti	32,000
Marsyangdi	Marsyangdi in Gandaki	69,000
Adhikhola	Adhikhola in Gandaki	5,100
Small Hydro		
- Existing		6,164
- Under construction		3,805
Total	238,619	

Source : Nepal, Power Development, WECS, 1988

While, power demand in Nepal including potential export to India was estimated as follows:

Year	Energy (GWh)	Peak Load (MW)
1990/1991	1049.5	238.6
1991/1992	1167.8	264.5
1992/1993	1299.4	293.1
1993/1994	1445.6	324.2
1994/1995	1608.0	359.2
1995/1996	1768.0	97.1
1996/1997	1987.4	439.7
1997/1998	2208.1	486.6
1998/1999	2452.0	537.2
1999/2000	2721.2	594.0
2000/2001	018.2	655.0
2001/2002	3345.5	723.3

Source: 1983 Electric Load Forecast for Period 1983-2001
Report No. 3/3/080883/1/6, Electricity Department

Comparing the current installed capacity with the above load forecast, electricity deficit in Nepal is obviously predicted to occur within a few years and will reach about 416 MW in 2001 which will be about 1.7 times the current capacity.

To cope with this predicted defect, Nepal Government has made efforts to identify the hydropower development projects and investigations, studies and design works have been made to realize these as early as possible. Fig. 2.1 shows the locations of the identified hydropower projects and their main features are listed in Table 2.1.

Among the listed projects, more than 60 in numbers, the following are considered to be more prospective projects in the next decade according to the informations from NEA, the result of "A Relative Ranking of Potential Hydroelectric Projects for Nepal" in 1984 and the progress of the each project's study and design:

Project	River Basin	Stage	Type	Installed Capacity (MW)
Arun No.3	Arun in Kosi	D/D	Run-of-river	402
Sapt Gandaki	Gandaki	F/S	Run-of-river	225
Kali Gandaki A	Kali Gandaki in Gandaki	F/S	Run-of-river	90
Upper Arun	Arun in Kosi	F/S	Run-of-river	300-350
Karnali (Chisapani)	Karnali	F/S	Reservoir	3,600
Sapt Kosi High Dam	Kosi	M/P	Reservoir	3,489
Lakharpata	Bheri in Karnali	P/S	Reservoir	1,200
Upper Karnali	Karnali	pre F/S	Run-of-river	230-500
Kali Gandaki No.2	Kali Gandaki	Pre F/S	Reservoir	660
Adhikhola No.1	Adhikhola in Gandaki	M/P	Reservoir	180

2.2 Irrigation Development

Agricultural sector occupies a large part of Gross Regional Domestic Product (GRDP) and its occupancy rate reaches about 50% at present. Also,a great majority of the working population belong to this sector. Main food crops are paddy, maize, wheat, barley, millet, pulses and potato, and their production volumes are as follows:

Major Crops	Cropped Area (1000 ha)	Production Volume (1000 tonnes)
Paddy	1,423	2,982
Maize	674	902
Wheat	597	744
Barley	29	24
Millet	165	150
Potato	80	566
Pulses	265	139
Total	3,233	5,507

Source: Master Plan for Irrigation Development in Nepal, Main Report

Nepal was a exporter of food grains until the middle of 1980's, however, food demand has exceeded production in recent years and self sufficiency in food production is estimated to be 80% to 90%. Among the above cropped area, irrigated area is 933 thousand ha (net) and others are rainfed areas. In Nepal, irrigable area of 1,245 thousand ha (refer to the following table) are remained and the Government have made an effort to cultivate the remaining areas with irrigation water supply so as to increase food production volumes.

District	Total Irrigable Area (Net ha)	Irrigated Area (Net ha)	Total Remaining Irrigable Area (Net ha)
Terai	1,744,000	725,000	1,019,000
Hill	373,000	179,000	194,000
Mountain	61,000	29,000	32,000
Total	2,178,000	933,000	1,245,000

Source : Master Plan for Irrigation Development in Nepal, Main Report

In the remaining areas, many projects have been identified by the Department of Irrigation, Ministry of Water Resources. Among these, location of the projects with irrigation area more than 1,000 ha are illustrated in Fig. 2.2 and their main features are indicated in Table 2.2.

In the Master Plan for Irrigation Development, food requirement in 2001 is estimated as follows:

Major Crops	Present Production Volume (1000 tonnes)	Food Requirement in 2001 (1000 tonnes)
Paddy	2,982	5,135
Maize	902	1,891
Wheat	744	1,189
Barley	24	43
Millet	150	251
Potato	566	775
Pulses	139	416
Total	5,507	9,700

Source : Master Plan for Irrigation Development in Nepal, Main Report

To achieve the target above, the master plan proposed the followings regarding large scale projects in Fig. 2.2 and DOI will reflect these proposal in the next 5-year plan:

(1) implementation of Mahakali II, East Rapti and Babai projects committed for construction by DOI;

(2) implementation of the most viable project, Bhairawa-Lumbini III DTW and eastern Terai projects;

(3) completion of the studies for Karnali Multipurpose, Bheri-Babai diversion and Sun Kosi-Kamala diversion projects;

(4) refinement of the study for Kankai multipurpose project; and

(5) examination of options for the use of Narayani river waters in Chitwan, Nawalparasi and Rupandehi districts

2.3 Water Supply

The population of Nepal in 1986 is about 17 million and is projected to increase at the rate of 2.66% per annum to 25 million by 2001 according to Water Supply and Sanitation Sector Study executed by UNDP/World Bank. Urban population of 1.1 million within Town Panchayats is also projected to grow at 7.9% per annum, and to yield 3.5 million in 2001.

Water supply in urban and rural areas is carried out mainly by the Department of Water Supply and Sewerage (DWSS), the Water Supply and Sewerage Corporation (WSSC), both under the Ministry of Housing and Physical Planning. Population served by these bodies in 1985 are as follows:

Water Supply Bodies	Population Served (1000 persons) by 1985				
	Urban by piped system	Rural			Total
		by Piped system	by Shallow Tube Well	Total Rural	
MOWR					
- WSSC	727	-	-	-	727
- DWSS	144	862	788	1,650	1,794
Sub-total	871	862	788	1,650	2,521
MPLD	-	695	79	774	774
MPLD 8 IRDP	-	325	4	329	329
NGO	-	131	99	230	230
Total	871	2,013	970	2,983	3,854

Source : Water Supply and Sanitation Sector Study, 1986

To supply safety water to the increasing urban and rural population mentioned above, water supply requirement and project cost are estimated by the mentioned sector study as follows:

Water Supply Bodies	Population Served (1000 persons)			Project Cost (mil.NRs.)
	by 2001	1986	Incremental	
Urban water supply for 29 Town Panchayat in Table 3	3,579	1,177	2,402	3,717.6
Rural water supply				
- Shallow tube well	8,169	970	7,199	118.8
- Piped system	11,107	2,192	8,916	3,262.0
Total	22,855	4,339	18,517	7,098.4

Source : Water Supply and Sanitation Sector Study, 1986

In the sector study, coverage target in 2001 for urban and rural water supply was set at 100% for urban area and 89% for rural area (refer to the following table). The lower coverage target in the rural area was based on the present conditions of the existence of the scattered isolated dwellings and individual dwellings and small settlement located above any available water sources in the Hill area.

Period	Percentage of Population served				
	Urban	Rural Piped System	Rural Shallow Tube	Total of Rural Well	Total
1985	84	13	6	19	23
1990	89	20	11	31	36
1995	95	31	19	50	54
2000	100	47	34	81	83
2001	100	51	38	89	91

Source : Water Supply and Sanitation Sector Study, 1986

To achieve the target, the following investments were proposed:

(Unit : million NRS)

Period	Urban	Rural Piped System	Rural Shallow Tube Well	Rehabili-tation	Total
1985-1990	909	552	15	70	1,546
1990-1995	1,360	934	30	140	2,464
1995-2000	2,041	1,578	58	6	3,683
2000-2001	517	428	17	0	962
Total	4,827	3,492	120	216	8,655

Source : Water Supply and Sanitation Sector Study, 1986.
Note : The above values include O & M costs

2.4 Natural Disaster Prevention Works

2.4.1 Historical Water Induced Natural Disaster Records and Damages

In Nepal, natural disasters due to heavy rainfall are classified into three types: i) flooding in the Terai plain; ii) glacial lake burst; and iii) landslide and soil erosion in the mountainous areas.

Table 2.4 shows the historical natural disaster records of floods, glacial lake bursts and landslides due to heavy rainfall. Such disasters mainly occurred in the Central and Eastern Regions which belong to the Gandaki and Kosi river basins and are comparatively developed areas in Nepal.

The damages of the natural hazards listed by the Home Ministry in 1985/1986 are shown in Table 2.5 and summarized as follows for the different river basin systems.

No.	River Basin	Damage						
		Human Death (Person) (nos.)	Human Injury (Person)	Live-stock (nos.)	Houses (nos.)	Crops (ha)	Loss of Property (US$)	Bridges
1.	Mahakali	1	4	0	13	0	2,918	2
2.	Karnali	9	8	11	48	850	34,683	1
3.	S.B. No.1	0	0	88	47	0	3,238	0
4.	Babai	7	5	2	15	0	5,354	0
5.	S.B. No.2	0	0	0	0	0	0	0
6.	West Rapti	1	0	12	44	0	48,250	0
7.	S.B. No.3	0	0	0	0	0	0	0
8.	Gandaki	107	68	390	1,006	9,602	1,311,344	1
9.	S.B. No.4	6	0	532	2,003	42,371	1,531,875	0
10.	Bagmati	5	4	31	43	0	8,405	0
11.	S.B. No.5	0	0	164	33	0	4,048	0
12.	Kamala	7	1	0	0	0	0	0
13.	S.B. No.6	0	0	0	0	0	0	0
14.	Kosi	169	30	620	91	6,437	1,012,041	14
15.	S.B. No.7	0	2	3	229	90	0	0
16.	Kankai	0	0	0	2	0	0	0
17.	S.B.No.8	1	0	0	0	0	0	0
Total		313	122	1,853	3,574	59,350	3,962,156	18

Source: Home Ministry HMG, Nepal, record of 1985/1986
Note : S.B. means rivers in the Southern Border River Group.

As seen in the above table, natural disasters caused severe damages in the Terai between Gandaki and Kosi rivers in 1985/1986.

2.4.2 Natural Disaster Prevention Works

(1) Flood Control

Flood control works have been carried out by River Training Division, Department of Irrigation (DOI) which mainly implements such minor river training works as small dyke construction, river bank protection by gabion mattress, etc. so as to protect the irrigation areas from the floods. DOI has also carried out the drainage works within the irrigation areas (refer to section 2.2) and has further plan to implement river training works in the lower reaches of Kamala and Bagmati irrigation areas. Also, the multipurpose projects of

Kosi High Dam and Karnali schemes include the flood mitigation effect in the project purposes. However, detailed damage and inundation surveys will be required to be carried out for establishing a certain flood control plan because those data are not available at present in DOI.

The Nepal Government has also made efforts to solve flood control problems under cooperation of foreign countries as follows:

a) The Standing Committee between Nepal and India on Inundation Problems was organized so as to; i) identify the problem areas in Terai plain; ii) itemize the actions to be taken; and iii) suggest the solution of the problems. The meeting has already been held six times and is scheduled to be continued.

b) Nepal-India Flood Forecasting Project, which plans to provide 20 water level and 45 rainfall gauges with wireless communication facility (SSB) in Nepal by the equipment supply of the Indian Government, is going on at present. The planned locations and equipments to be supplied are shown in Fig. 2.4 and Table 2.6, respectively. Among these gauges, 4 rainfall and water level gauging stations in the Kankai, Arun, Sun Kosi, and Bagmati river basins are scheduled to start their operation in fiscal year 1991/1992 and implementation schedule for other stations is not yet decided. Data and informations for floods collected through SSB to DHM in Kathmandu will be sent to Delhi in India by using this communication system. The meteorological data at 7 stations with SSB (Bhairahawa, Pokhara, Simra, Okhaldhung, Taplejung, Dhankuta and Kathmandu) operated by DHM are also sent to India.

c) The Nepal-Bangladesh joint study was carried out for flood mitigation and multipurpose use of water resources in 1989. This study made the following recommendations:

   1) Flood mitigation

      - development of flood forecasting and warning system by wireless communication for transmission of water levels and flow discharges between Nepal and Bangladesh.
      - initiation of catchment management, afforestation programme aimed at soil conservation
      - coordination of development activities aiming at getting away from drainage congestion

   2) Harnessing of water resources of the region

      - creation of reservoirs at upstream reaches for optimal and multipurpose use of water resources to reduce the flood peak discharges

3) Study, research and investigation

- Study, research and investigation programme on appropriate catchment management to reduce the adversities such as top soil erosion, land slides and consequential influx of sediment into the rivers, and glacial and snow melt phenomenon

d) The Water Induced Disaster Prevention Technical Centre is establishing to heighten technical capability of Nepalese engineer through research on disaster prevention works due to heavy rainfall including hydrological study under technical and financial assistance of the Japanese Government.

(2) Glacial lake burst

Glacial lakes are distributed above the snowline of about EL. 4,300 m in the Eastern and Central regions. Glacial lakes identified in the Arun and Bhote-Sun Kosi river basins are summarized as follows:

River Basin	Nos. of Lake	Total Surface Area (km^2)	Total Water Volume (million m^3)
Arun	229	46.7	1,231
Bhote-Sun Kosi	45	12.3	388

Source: Report on First Expedition to Glaciers and Glacier Lakes in the Arun and Bhote-Sun Kosi River Basins, Tibet, China, Sino-Nepalese Investigation of Glacier Lake Outburst Floods in the Himalayas, NEA, WECS, and Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Science.

Glacial lake burst caused the damage on the upstream bridges, houses, existing power houses as listed in Table 2.4 and 2.5 Countermeasures to the burst are under study by WECS including mechanism of burst, etc.

(3) Watershed Management

Watershed management works were initiated by the Department of Soil Conservation and Watershed Management (DSCWM) under the financial and technical assistance of UNDP/FAO from 1967 to 1970. Afterwards, the following projects were implemented between 1975 and 1980:

No.	Project Year	Starting	Main Activity
1.	Bagmati Catchment	1974	- Gully control - Afforestation - Horticulture - Grass establishment
2.	Daxinkali Pilot	1975	- Multidisciplinary, suited to specific problems in the area
3.	Phewa-Tal	1976	- Integrated watershed management including agriculture and livestock programmes
4.	Lothar Catchment	1975	- Forest protection - Improvement of agricultural practices
5.	Bering Catchment	1975	- Food control by afforestation
6.	Surket, Khorke, Itram Catchment	1974	- Afforestation - Gully control - Grass establishment - Horticulture
7.	River Control Project in Mahakali	1975/1976	- River control
8.	Integrated Watershed Management, Torrent Control and Landuse Development	1975/1976	- Institutional development - Preparing inventory - Planning - Training
9.	Rasuwa-Nuwakot Rural	1976/1977	- Integrated rural development

Source: A long-Term Programme for the Department of Soil Conservation and Watershed Management

Following the above works in 1980's, DSCWM implemented the projects under several donors' assistance:

Project	Donor	Project	Donor
Bagmati	EEC	Rapti	USAID
K-Bird	CIDA	Agricultural Resources Inventory	USAID
Mahakali	IBRD	Sagarmata	ADB
Phewa Tal	UNDP/FAO	Tinau	SATA/FGR
Kulekhani	UNDP/FAO	Shivapuri	NORWAY
Rasuwa-Nuwakot	IBRD	Environmental Impact Study	NONE
Daraundi	USAID	Remote Sensing Centre	USAID
Myagdi	USAID	Begnas and Rupa	CARE
INTERNATIONAL Mustang	USAID	Dhankuta	INDIA

Source: A Long-Term Programme for the Department of Soil Conservation and Watershed Management

A long-term programme on soil conservation and watershed management until 2001 was established in 1987 by the studies under the technical assistance of UNDP/FAO. This programme was based on the field reconnaissance covering all the districts and analyses on the classification of watershed conditions as shown in Fig. 2.5, and proposed the following works and their costs to sustain the water resources development and natural disaster prevention works:

Work Item	Required Budget (US$)
On farm conservation	6,125,000
Plantation	83,520,000
Terrace improvement	2,650,000
Grassland establishment	225,000
Water harvesting	3,120,000
Landuse change	1,170,000
Agroforestry	210,000
Fodder production	470,000
Promote stall feeding of cattle	1,710,000
Establish demonstration	187,500
Land rehabilitation	426,750
Trail improvement	660,000
Torrent/gully control	5,060,000
Channel improvement	254,000
Road erosion control	3,075,000
Total	108,863,250

Source: A Long-Term Programme for the Department of Soil Conservation and Watershed Management

3. DEVELOPMENT TARGETS IN 1980'S

3.1 Electric Power Sector

In early 1980's, electric peak power demand at the end of this decade was estimated at about 300 MW in Nepal and to meet this demand, Devighat (14 MW), Kulekhani No.1 (60 MW), Marsyangdi (60 MW), Sapt Gandaki (150 MW) capacity at the end of 1990 would be insufficient even if the above power stations were planned to be completed by the end of 1990. Then, an additional power of a storage type with installed capacity of 200 to 300 MW was required to be constructed the early 1990's because the total installed capacity at the end of 1990 would be insufficient even if the above power stations were constructed. As possibilities for the storage type schemes, West Rapti, Bagmati, Gandaki, and Kosi multipurpose schemes were considered to be prospective. Run-of-river schemes in the Gandaki and Kosi river basins or a combination with small scale storage projects of the Kankai and Mulghat were also planned as alternatives for further studies.

Review study on electric power demand was made in the middle of 1980's and the estimated power demand was revised at about 70% against the original one. Whilst, the construction of electric power stations planned were completed except the Sapt Gandaki scheme.

3.2 Irrigation Sector

The following irrigation development was planned to be implemented by DOI in the 1980's:

Year	Target Irrigation Area (ha)	Rehabilitation of Existing Area (ha)
end of 1980	180,000	
end of 1985 (6th plan)	155,000	115,000
end of 1990 (7th plan)	145,000	65,000
Total	490,000	

At present, irrigated area of 933,000 ha (DOI:265,000 ha, Farmer Schemes: 668,000 ha) was developed in Nepal though all the areas are not always year-round irrigated areas.

3.3 Water Supply Sector

In the water supply sector, during the decade, rural water supply was emphasized to make drinking water available for about 70% of the rural population (11 million) by 1990 providing piped water with standpipes and shallow tube wells against the population coverage of 6.4% in 1980.

Target for urban water supply was continuous supply of water of 90 l/day/capita to 112 l/day/capita to 93% of urban population (1.25 million) by improving and expanding the existing supply system against supply capacity of 40 l/day/capita to 50 l/day/capita for 83% of urban population (0.69 million)and discontinuous supply hours of 4 to 5 hours in 1980.

In 1986, population served by rural and urban water supply system was about 3.1 million and 1.2 million respectively.