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JAPAN INTERNATIONAL COOPERATION AGENCY

DEPARTMENT OF IRRIGATION
MINISTRY OF WATER RESOURCES
THE KINGDOM OF NEPAL

THE STUDY
ON
FLOOD MITIGATION PLAN
FOR
SELECTED RIVERS IN THE TERAI PLAIN
IN
THE KINGDOM OF NEPAL

FINAL REPORT

VOLUME III (6/9)

SUPPORTING REPORT

(A6: FMP/WEST RAPTI RIVER)

MAY 1999

NIKKEN Consultants, Inc.
NIPPON KOEI CO., LTD.

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A6. FLOOD MITIGATION PLAN:

WEST RAPTI RIVER BASIN

SUPPORTING REPORT
A6. FLOOD MITIGATION PLAN: WEST RAPTI RIVER BASIN

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1. EXISTING CONDITIONS

1.1 Topography and Geology

The topography and geology of Nepal can be divided into the following zones (Fig. A1.1):

1) Inner Himalayan valleys
2) Higher Himalayan zone
3) Lesser Himalayan zone
   - Midland range
   - Mahabharat range
4) Siwalik (Churia) hills
5) Dun valleys
6) Terai plain

The West Rapti river basin falls under the topographical and geological zones of Midland and Mahabharat ranges, Siwalik hills, Dun Valleys and Terai plain. Principal features of these zones are presented below.

(1) Lesser Himalayan Zone

Lesser Himalayan zone occupies the central part of the Himalayan Mountains. It consists of a series of mountain ranges rising abruptly above its low rolling hills.

The Lesser Himalayan zone is divided into two sub-ranges, namely the Midland and Mahabharat ranges from north.

<u>Midland Range</u>

The Midland range consists of low hills, river and tectonic valleys. The slope ranges from 100 to 400 m/km. In this range, generally the rocks consist of fissile phyllite and schist. The dip of the bed in this part is generally towards the north. In the areas where rivers have east-west course, landslides are seen on the southern bank of the river. Since the phyllite is a soft rock, the exposed bed in the bottom section of hill is found to be crushed in most places, indicating that the load is beyond its bearing capacity.

The Midland range is composed of soft rocks (phyllite, slate and dolomite) and thick

soil covers this area, hence it is heavily populated. Because soft rocks weather easily, the Midland range forms low and mild slope hills. Nearly all the hill slopes are found to be formed from the talus of landslide and rock fall. Generally the hill slope appears to be stable for a period of 8 to 10 years after the slide till the talus is washed away by under-cutting of the river, and at the same time, this causes the development of gullies and erosion throughout valleys. Slowly the topography changes from flat to steeper terrain and sliding occurs again.

Mahabharat Range

The Mahabharat range consists of comparatively harder rock than the midland range. The number of slides is found to be less even though the topography is steep. The topography is steeper on the southern slope comparing to the northern one of about 100 to 200 m/km. Slides take place on the northern slope and rock falls on the southern slope. The steep of the topography can be attributed to the Main Boundary Fault (MBF) which lies mostly at the southern foot of the ranges.

The Mahabharat range is the first set of high mountains facing the Terai plain, and affects much to the climate of Nepal during the monsoon.

(2) Siwalik (Churia) Hills

The Siwalik (Churia) hills are the lowest hills bordering the Indo-Gangetic plain in the north. Mostly it consists of rocks of alternating beds of clay, sandstone, sand and pebble. The rocks generally dip northwards. Alternately loose and hard rock beds have produced the escarpment feature. In many places rugged land with numerous gullies and mound of talus are found. The topographic slope varies from 200 to 400 m/km on the average. The Siwalik hills are divided into three layers, i.e., upper, middle and lower Siwaliks.

Upper Siwalik

The upper Siwalik is mainly conglomerate with pebbles and boulders of pale schistose quartzite, purple and white quartzite; dark phyllites; purple and dark pebbly quartzite and silt brown sandstone. The depth of upper Siwalik is about 2000 to 3000 meters.

Middle Siwalik

The layer of middle Siwalik is found in the form of thick deposits of sandstone. These are characterized by their feldspar and mica content. Apparently the sandstone has been derived from granite rocks. Calcareous concretions and seams of coal are found in the basal part. In many sections, the sandstone forms vertical cliffs. The depth of middle Siwalik is about 2000 to 2500 meters.

Lower Siwalik

The lower Siwalik is alteration of brown, weathered sandstone and chocolate colored clays. The alternation of beds are not thick as the sandstone. Beds of impure limestone also occur within the lower Siwalik. The depth of lower Siwalik is about 1200 to 1500 meters. All pebbles except those found in the brown sandstone are derived from rocks of Pre-tertiary age.

(3) Dun Valleys

The Siwalik hills make separate ranges from east to west except in some places where it merges with Mahabharat range. The separate ranges form Dun Valleys as seen in Trijunga, East Rapti-Nawalpur, Deokhuri (West Rapti), Dang Valley, Surkhet Valley, etc. The Dun Valleys are fertile and are similar to the Terai plain in nature. Hence they are sometimes classified as a part of the Terai plain.

(4) Terai Plain

The Terai plain is the continuation of Indo-Gangetic plain having an elevation from 50 to 300 m,MSL. Its width varies between 10 to 30 km with one exception at Koilabash narrow, and extends from east to west Nepal for about 900 km.

The Terai slopes toward south with steeper slope at the foot hill region and nearly flat at the southern end.

In the Terai plain the changes of river stream are often seen in places by the lateral erosion incorporated by much sediment from the mountainous area. On such rivers, artificial structure works such as bridge, roads and irrigation facilities have to be given careful consideration.

The Terai plain is divided into three zones, i.e., (1) Bhabhar zone (foot of hill), (2) Marshy area (spring line), and (3) Southern Terai (Indian border).

Bhabhar Zone

The Bhabhar zone lies at the foot of Siwalik hills and is about 12 km wide (Charkose Jhadi). It is composed of boulder, pebble, cobble and sand of Siwalik hills or Mahabharat range deposited by the present rivers. In most cases the rocks are sandstone, quartz or charty dolomite. The foot of hills is covered with evergreen forest.

Soils are mainly alluvium consisting of sand, silt, clay looms and silty clay. In the dry season almost all rivers in this zone have no flow on the surface and water flow underground only.

Marshy Area

The marshy area is found in the south of Bhabhar zone where two lithological units having different porosity and permeability meet or inter finger along with the change of elevation mainly resulting in spring lines, ponds, lakes, etc. The lithology is mostly composed of pebbles and sandy bed with a few clay partings. The lithology of the pebbles is similar to the boulder zone and sand beds are loose, brownish to greenish with black and red shale fragments. The clay is mostly blackish gray where a thick sequence is found, but yellow one is also observed at some places where there was a temporary hiatus in its deposition or because of a flood at that time. This is particularly true in Lumbini zone.

Southern Terai

This nearly flat and not well-drained area is found between middle Terai and the Indo-Nepal border. The area is composed of sand, clay and silt with less pebble.

(5) West Rapti River Basin

The West Rapti river basin originates in the Mahabharat ranges. In the upper basin, the river is forced to bend its course by Main Boundary Thrust (MBT) and other faults. The channel is forced to flow to the northwest direction due to the Siwalik hills before it reaches to the Terai plain. Geological map of the West Rapti river basin is shown in Fig. A1.2.

1.2 Meteorology and Hydrology

1.2.1 Meteo-Hydrological Observation

Responsibilities for meteo-hydrological data collection and analysis in Nepal have been born mainly by the Department of Hydrology and Meteorology (DHM), the Ministry of Science and Technology. Other authorities such as the Department of Irrigation (DOI), Nepal Electricity Authority (NEA), International Center for Integrated Mountain Development (ICIMOD) also conduct meteo-hydrological observations. In principle, all of these data observed by other authorities are also sent to the DHM. The DHM publishes data in yearbooks after basic checking has been completed.

The Meteorology Section of DHM is responsible for compilation and analysis of meteorological observation records such as precipitation, temperature, humidity, vapor pressure, sunshine, wind, evaporation and soil temperature. And the Hydrology Section of DHM is responsible for compilation and analysis of hydrological observation records such as water level and sediment.

Based on the DHM's data, a list of meteorological and hydro-metric stations in the Mid Western Development Region is shown in Tables A1.1 and A1.2, and their locations in Figs. A1.3 and A1.4.

In order to supplement the existing observatory, new recording rain gauge was installed by the Study Team at Banke District Irrigation Office in Nepalganj (1 site) for the lower West Rapti and Babai river basins. This office is under the direct control of DOI. An ordinary rain gauge (sta. No.0416 under DHM) is installed here.

River basin	Caretaker	Serial Number
West Rapti/Babai	Banke District Irrigation Office (Nepalganj)	Gauge: 232717 Recorder: 244189

1.2.2 Meteo-Hydrological Features of Basin

Climate of the West Rapti river basin falls under monsoon subtropical zone (Terai plain and Siwalik hills) and temperate zone (lesser Himalayan zone). The dry season (from October to May) and rainy season (from June to September) are clear. The dry and rainy seasons due to monsoon are the major cause of climatic contrasts in the West Rapti river basin. Figure A1.5 shows the meteo-hydrological features of the basin based

on the monthly average data at Nepalganj (sta. code: 0416).

(1) Temperature

Altitude affects much the temperature. The annual average temperature is 25.0℃, ranging from 15.4℃ in the coldest month to 31.6℃ in the hottest month. The coldest month is in January and the hottest falls in between May and August. The temperature rises from March to June-July while it decreases from October to January.

(2) Relative Humidity

According to Fig. A1.5, annual average relative humidity is 82.3%, ranging from 62.0% in May to 93.3% in January.

(3) Rainfall

The study area receives the southeast monsoon during the months from June to September. The monsoon air-stream is forced to rise as it meets the Himalayas and causes heavy rainfall on the south facing slopes (Fig. A1.6).

According to Fig. A1.5, annual rainfall at Nepalganj is 1,370mm on average ranging from 869 to 1,911mm depending on the year. The maximum rainfall is 1911mm in 1988. The 85% of annual rainfall is concentrated in rainy season from June to September.

(4) Runoff

Figure A1.7 shows the monthly average flow of the West Rapti river at Jalkundi station (No.360).

According to Fig. A1.7, The runoff increases from May to August while it decreases from August to November and the most of runoff is concentrated in rainy season from June to September. The annual average runoff at Jalkundi station is approximately 130m^3/s. The maximum monthly average flow is approximately 420m^3/s in August. The monthly average flow exceeds the annual average during the period from July to October.

1.3 Environment

1.3.1 Environmental Organizations and Institutions

The Environmental Division of the Ministry of Population and Environment has overall responsibility for environmental matters in Nepal. In June of 1997, Environmental Conservation Rules were issued under section 24 of the 1997 Environmental Conservation Act. These rules lay down procedure to be followed when new projects are proposed or existing projects extended.

1.3.2 Environmental Overview

The West Rapti river is a class-II river of about 230 km. rising in the lesser Mahabharat ranges. Once it reaches the Terai plains it first travels west about 110 km. before turning south to the Indian border. From this point, its length to the border with India is about 53 km.. Its total basin area is 6,418 km^2 (641,800 ha.) of which 618 km^2 (61,800 ha.) are in the Terai.

According to the Inventory of Wetlands in the Terai, (IUCN 1996), the wetlands along the West Rapti river have still to be fully determined. However, the West Rapti river floodplain occupies an area of 37,500 ha and crosses three districts, - Arghakhanchi, Dang and Banke. An estimated 40% of the land is farmed and 10% is classified as settlements, thus half of this floodplain has been modified already by human activity.

Dalbergia sissoo, Acacia catechu, Ficus glomerata, Engenia jambolana, Bombax ceiba, Terminalia tomentosa and *Shorea robusta* characterize the floodplain. It is a staging and foraging ground for migratory waterfowl such as *Egretta alba, Alcedo atthis, Pavo cristatus, Bubo nipalensis* and *Dendrocygna javanica.* The marsh crocodile *(Crocodilus palustris)* and the smooth otter *(Lutrogale perspicillata)* occur here.

While the wetlands and accompanying forest areas are important in the West Rapti basin of the Terai, over half the land has been converted to agriculture and with people migrating from other parts of Nepal, the forests and wetlands in this basin and the surrounding watershed are under threat. This can only be mitigated by increasing agricultural productivity and flood prevention measures are a key component of this. The existing land use and population of the West Rapti river basin is shown below.

(Land Area, Land Use and Population: 1998)

Items	Agri-culture	Forest	Barren/ sand	Other	Total	Population
Area (ha)	35,140	25,130	1,290	240	61,800	(173,400)*
Ratio (%)	56.8	40.7	2.1	0.4	100	(2.8)**

(Note)*: Population (persons), **: Population density (per/ha)

Every year, sand, silt and/or floodwater on average covers on average about 2,700 hectares of which about 500 ha. are covered with sand and soil. Some of this soil cover is a result of human activity, especially in the Chure hills. In addition, nearly 2% of the land is barren or covered with sand, principally due to flooding and inundation.

With appropriate flood mitigation measures, such land could be reclaimed and soil/sand inundation should be reduced. Also, farmers knowing their land is safe from flooding and inundation, could invest in irrigation and increase their productivity. This may relieve the pressure on the remaining forestlands, curtail deforestation and boost grain production. This is why flood mitigation measures, including wetland protection and watershed activities are essential to protect the environment.

1.4 Socio Economy

(1) Economic Activities

Land Use: The West Rapti river flows in Banke and Dang districts. According to the district data, agricultural and forestland makes up most of the total plain area in the two districts (85.7%/nearly 100% respectively).

unit: hectare

District	Agriculture	Forest	Sand/Gravel /Boulder	Others
BANKE	55,785 48.0%	55,430 47.7%	4,670 4.0%	331 0.3%
DANG	71,871 66.4%	36,400 33.6%	0 0.0%	0 0.0%
10 Districts (where M/P rivers flow)	800,591 64.1%	352,508 28.2%	43095 3.5%	52,449 4.2%

Source: Land Resources Mapping Project 1986, Department of Survey
Forest Survey 1993, Department of Forest

Economically Active Population (10 Years of Age and Over) by Major Occupation: A ratio of 67.3%/80.0% of the labor force is engaged in agriculture, as opposed to 7.1%/5.0% in manufacturing and 17.2%/10.4% in service sectors.

District	Agriculture Worker	Service Worker	Production Worker	Sales Worker and Others
BANKE	62,613 67.3%	16,030 17.2%	6,599 7.1%	7810 8.4%
DANG	101,353 80.0%	13,246 10.4%	6,320 5.0%	5752 4.6%
10 Districts (where M/P rivers flow)	1,123,328 73.9%	215,393 14.2%	73,937 4.9%	107522 7%

Source: Population Census 1991, Central Bureau of Statistics

Crop Area and Productively of Agriculture Crop: Banke and Dang districts produce a wide range of crops, with major crops of paddy, maize, wheat, and pulse. These major crops but wheat and pulse are grown during the monsoon. Although there are also winter paddy and maize, most of the paddy and maize are grown in summer.

unit: hectare. (metric ton/ha.)

District	Paddy	Maize	Wheat	Pulses	Oilseeds	Sugarcane	Vegetables
BANKE	32,350 (2.48)	7,500 (1.17)	12,899 (1.58)	9,450 ()1.09	8,488 (0.97)	---	3,535 (12.55)
DANG	33,500 (3.20)	23,200 2.09	14,100 (2.50)	24,150 (1.03)	18,450 (0.72)	---	1,323 (12.27)
10 Districts (where M/P rivers flow)	537671 (27.79)	145489 (18.14)	174589 (19)	98536 (4.9)	102720 (7.92)	17331 (233.06)	11930 (52.58)

Source: Annual Agricultural Development Programme 1995/96, District

(2) Land Holding

Land Ownership & Holding: In Banke/Dang districts, the average land holding size has declined in recent years like other districts in the Terai plain. The average size is far below the 16.4-hectare ceiling imposed by the 1964 Lands Act. Nearly 90 % of the agricultural land is under owner-cultivation. With regard to the agricultural land under "formal" tenancy, the most dominant form is sharecropping.

District	Owner-Cultivated (%)		Average Holding Size (ha.)	
	1981/82	1991/92	1981/82	1991/92
BANKE	88.5	86.2	1.47	1.37
DANG	80.4	80.9	1.57	1.17
Terai	91.8	87.6	1.47	1.22

Tenure Arrangements: However, that since informal arrangements of land tenancy are not recorded in the official census, the above figure of owner-cultivation should be treated with caution. Underlying the sharecropping category is a commonly known phenomenon of "dual ownership". To undertake flood mitigation works for land under "dual ownership", it will be imperative to involve both land owners and tenants, both of

whom are entitled to certain shares of the proceeds of the land.

District	Tenure Arrangement -- 1991/92 (%)		
	Fixed Rent	Share Crop	Others
BANKE	2.7	94.9	2.4
DANG	7.5	89.8	1.7
Terai	30.6	62.7	6.7

Source: Nepal Sample Census of Agriculture 1991/92, Department of Agriculture

(3) Population

From nation-wide viewpoint, in-migration in the east is approaching to zero, as new lands available for cultivation are being closed. On the other hand, the western districts continue to exhibit high population growth, since the land frontiers are relatively open. In a similar vein, the original inhabitants of the Terai constitute nearly or more than half the population towards the west, while the proportion of indigenous groups makes up less than half in most of the eastern districts.

Population of Banke and Dang districts is 286,000 and 354,000 as of 1991 with population growth rates of 3.3% and 2.8% (1981-1991) respectively. The population growth ratios were lower than the national average during 1970s, but the current pace of population growth rates are slightly higher than the national average, i.e., 2.3% (1981-1991).

Demographic Records Of Flood-Prone VDCs: The following table shows the population trends of the VDCs affected by West Rapti floods. The 1981-91 population growth rate of the affected VDCs is 6.7%. This indicates that the population pressure is higher in the flood-risk VDCs, than other localities in Banke/Dang districts.

District	VDC	1971	1981	1991	1996
Dang	Gobardiya	4,183	8,075	19,755	12,377
	Gangaparaspur	3,106	6,969	8,042	9,255
	Gadawa	-	8,181	7,877	9,065
	Rajpur	-	-	8,811	10,140
	Lalmetiya	7,196	8,619	12,048	13,866
	Sisahaniya	6,736	11,289	11,972	13,778
	Sonpur	4,775	6,376	8,650	9,955
	Chaulahi	5,585	7,333	10,800	12,429
	Satbariya	3,323	6,415	8,829	10,161

Banke	Bejapur	2,954	-	7,745	9,110
	Betahani	3,396	-	5,195	6,111
	Binavna	2,959	-	4,839	5,692
	Holiya	3,071	-	4,588	5,361
	Kamdi	2,465	3,783	6,391	7,517
	Kanchanpur	-	-	5,470	6,434
	Khaskusma	2,347	4,232	3,839	4,516
	Phatepur	4,713	6,593	10,793	12,695
	Gangapur	2,097	-	3,837	4,513
Total		58,906	77,865	149,481	162,975

Source: Population Census 1991, Central Bureau of Statistics
Nepal District Profile 1997, National search Associates

(4) Human Development Index (HDI)

In terms of the Human Development Index (which is a development indicator based on life expectancy, adult literacy, and GDP), the districts in eastern areas of the country receive, in general, higher performance, and become lower toward the west. Accordingly, the HDIs of Banke and Dang districts are ranked among the lower strata (46th and 53th among all 75 districts).

1.5 River and Basin Conditions

1.5.1 Principal Basin Features

The West Rapti river basin extends from 27°45′N to 28°30′N and from 81°45′E to 83°15′E. The West Rapti river originates in Midland range and is classified as a class II river. Administratively it is located in Dang district (watershed basin) and Banke district (plain basin) both in Mid-Western Development Region.

Basin area of the West Rapti river is 6,418 km^2 in total, consisting of 5,800 km^2 of mountainous basin and 618 km^2 of plain area. Boundaries of the river basin and sub-basins were drawn on the basin map. Basin boundary in the Terai plain was delineated in consideration of existing drainage channels, irrigation canals, road networks and other ground objects.

General basin maps of the West Rapti river is shown in Fig. A1.8. Topographic maps of 1/25,000 for the western part of Nepal are under preparation in Department of Survey and not yet available. Topographic maps of 1/50,000 were used to prepare overall basin maps of the West Rapti river. Lower basin of the West Rapti river was prepared based

on the draft topographic maps of 1/25,000. Aerial photos of approximately 1/50,000 also were used to supplement the topographic maps.

Notable features of the West Rapti river basin are as follows:

1) The West Rapti river can be divided into upper and lower reaches by the narrow reaches upstream from Sikta.
2) The upper reaches of the West Rapti river forms a valley surrounded by the northern slope of the Siwalik hill, southern slope of the Mahabharat ranges, and narrow gorge in the lower end.
3) The lower reaches of the West Rapti river have wide channel of mild slope. Bank erosion and river course shifting are active.
4) Any works in the gorge sections to improve drainage in the upper basin would affect the flood flow conditions in the lower reaches.
5) Sikta Irrigation Project was studied in 1980. The project, however, was not put into implementation due to failure of coordination with India.
6) A barrage was being constructed by India crossing the West Rapti river near the border. The works are said suspended now.

1.5.2 Characteristics of River Channel

Channel slope and width of the existing river are shown in Fig. A1.9 for the plain stretch. These were prepared based on the topographic map of scale 1/25,000, since river survey results were not available. In order to obtain the river profile, spot elevation data on the topographic map were used and the river width was measured on the map at the intervals of 1 km along the river. The river width includes perennial river sections and sandbars of the meandering and braided river section.

According to the figure, principal features of the existing river in the Terai plain are summarized below.

River	Class	Length(km)	Slope	Width(m)
W. Rapti R.	II	53.0(163.5)	1/540～1920	200～1700

Note: River length in ( ) indicates that downstream from E-W Highway

1.5.3 River Course Shifting

It is generally said that rivers in the Terai plain have tendency to shift westwards. If it is

true the existing talweg might take closer to west or right side bank as a whole. To confirm this hypothesis, the location of talweg in the river section was measured at every 1 km and shown in the Fig. A1.9. The clear tendency of westward shifting was not seen.

In order to look into the actual shifting of river course in the past, topographic maps prepared in 1953/54 (scale: 1/50,000) and those in 1996 (scale: 1/25,000) were superimposed and shown in Fig. A1.10.

As for the West Rapti river, only the lower reaches from Sikta was studied, since the shifting of river course upstream were considered to be limited within the meander belt of the existing river being sandwiched by the Mahabharat ranges and the Siwalik hill.

According to the figure showing river course change during the past 42 years, the following features are considered:

1) Meander of the West Rapti river in the upper reaches of the Jhijhari river junction is not severe and the shifting of river course remains within the meandering belt.
2) In the lower reaches of the junction, scale of the meandering gets larger and shifting of river courses is remarkable.

1.5.4 Riverbed Materials

The Study Team investigated riverbed materials along the plain reaches of the river. The investigation includes the following outdoor and indoor works:

1) Sampling of river bed materials at site
2) Grain size analysis at site field and in laboratory
3) Specific gravity test in laboratory

Bed materials of the West Rapti river were sampled at 23 sites (Fig. A1.11) among which outdoor analyses were carried out at 12 sites.

Results of riverbed material tests are shown in Table A1.3 and the grading curves in Fig.A1.12.

Principal features of the riverbed materials are summarized below. In the descriptions

below, UI denotes uniformity index defined as a ratio of d_{84} to d_{16}, SG stands for specific gravity, and classification of grain size is principally based on classification by AGU.

1) Samples: Samples are from the main course of the West Rapti river except for the following:
   - Tributaries from Mahabharat: WR-8. WR-9, WR-11, WR-13 WR-18
   - Other tributaries: WR-6, WR-23
2) Grain size: It is note worthy that the grading curves of the West Rapti river are clearly classified into two types.
   - d_{60} = 0.17 to 0.54 mm (fine to coarse sand):Main river downstream from WR-5 site
   - d_{60} = 23.56 to 33.09 mm (coarse grovel): Main river downstream from WR-12 site
   - d_{60} = 0.18 to 0.34 mm (fine to medium sand): Main river downstream from WR-17 site
   - d_{60} = 22.17 to 46.69 mm (coarse to very coarse gravel): Main river upstream from WR-19 site
   - d_{60} = 0.18 to 0.59 mm (fine to coarse sand): Tributary samples of WR-6 ,WR-8, WR-9
   - d_{60} = 52.86 to 65.48 mm (very coarse gravel): Tributary samples of WR-11, WR-13, WR-18, WR-23
3) Uniformity index: Riverbed materials are well sorted and uniform in the reaches from WR-1 to WR-5 and WR-14 to WR-16
   - UI = 2.1 to 3.0: Main river downstream from WR-5 site
   - UI = 64 to 117: Main river downstream from WR-12 site
   - UI = 2.2 to 5.0 Main river downstream from WR-16 site
   - UI = 40 to 168: Main river upstream from WR-17 site
   - UI = 2.1 to 2.5: Tributary samples of WR-6, WR-8, WR-9
   - UI = 14 to 63: Tributary samples of WR-11, WR-13, WR-18, WR-23
4) Specific gravity
   - SG = 2.64 g/cc on average ranging from 2.58 to 2.69 g/cc
5) Longitudinal distribution: Significant changes in grain sizes are seen at three sections between (1) WR-5 and WR-7 sites, (2) WR-12 and WR-14 sites, and (3) WR-17 and WR-19 sites.

Based on the investigation result, grain size distribution along the river is shown in the Fig. A1.9.

1.5.5 Land Use

Land utilization map and land capability map (scale: 1/50,000) are available. These maps have been prepared by Topographic Survey Section of Survey Department under the Canadian assistance program.

Mapping details are based on aerial photos taken in 1978 and 1979 and extensive field truthing and sampling during the year 1980 and 1981. The maps were published in 1982.

Existing land use of the plain area is shown in Fig. A1.13 based on the land utilization map. These maps were prepared rearranging the classifications into five categories, i.e., (1) rice field, (2) diversified cropland, (3) grazing land, (4) forest, and (5) settlement.

Land capability map is also available, which shows the land capability for agricultural development mainly based on the land system such as topography, land slope, soil and drainage conditions. Future land use would be prospected from the land capability.

1.5.6 Existing Basin Development Projects and Plans

Sikta Irrigation Project

Introduction: The project area proposed to be irrigated under this scheme lies in the Banke District of the Mid Western Development Region of Nepal. In the west project area extends right down to the India border. In the project area Nepalganj is the main town that is the district as well as zonal headquarter of Bheri Zone.

Scheme: In this project (Fig. A1.14), a Head-works (Barrage) shall be constructed on Rapti river near village Agaiya to irrigate net 36070 ha. of land by constructing canals on both the banks. The Head-works site is nearby 60 km east of Nepalganj and is easily approachable by an all weather road (Mahendra Raj Marg). Before reaching the main irrigable area, 36 km of the right bank main canal will have to pass through a forest. The area to be irrigated by the right canal system is 34,270 ha between Mand and Dundwa rivers. The right main canal shall be lined for 36 km and its design capacity is 34 m^3/s. Irrigation area on the left and is 1,800 ha (net). The left bank canal will be 12.4 km in length with design capacity of in 2 m^3/s.

Back Ground: The pre-feasibility study of the project was conducted from January 1975 to June 1978. German Consultant Lahmeyer International (Gmbh) conducted its feasibility study from November 1978 to August 1980 and feasibility of this project with run-of-river diversion alone was established. On the basis of these studies, Department of Irrigation, Hydrology and Meteorology of HMGN (DIHM) established its full-fledged office in Nepalganj in November 1981 for a detailed investigation, planning, design, and execution of the project.

Construction Schedule: The construction schedule of this project has been shown in Appendix II. This schedule has been prepared on the assumption that construction work will start in full fledged way from the fiscal year 2040-41 (1983-84). In this condition, the project would be completed in 10 years i.e. in fiscal year 1992-93.
(Source: Sikta Irrigation Project, Brief Report; Mid-Western Development Region)

1.6 Vegetation in Watershed Area

General features of vegetation in the watershed area are presented here. Sediment yield from the watershed was not estimated for the West Rapti river, since the watershed area is large and the sediment yield in the watershed does not directly affect the sediment flows in the plain area. Most of the sediments in the plain area are secondary or tertiary sediment deposit transported by river flows.

Watershed of the West Rapti river is classified as the climate and vegetation divisions of Middle Mountain and Terai and Outer Himalaya.

(1) Terai and Outer Himalaya

The Terai plain is composed of an alluvial fan and an alluvial plain of elevation ranging from 50 m to 300 m,MSL extending from the foot of Siwalik hills to the Indian border. The climate of this area belongs to the monsoon subtropical zone, and the dry season is from October to May with the rainy season from June to September. The Terai plain was covered widely by Sal forests (*Shorea robusta*). But, recently farmers from Middle Mountains cleared the forests rapidly for agricultural land and villages.

The Siwalik hills were formed by upheaval of sediment bed carried from Himalaya. Forests are left in the Siwalik hills, because of too steep inclination for settlement and farming. But, clearing forest takes place recently even in the Siwalik hills.

(2) Middle Mountain

The Middle Mountain is the area of 1000 to 2500 m,MSL between the Mahabharat and High Himalaya mountain. The Middle Mountain is the central place of Himalayan mountain residents. In the eastern and central part of the Middle Mountain, population is large and forest changed to cultivated lands and residential areas.

Large forest area shall remain in the western part of the country where population is sparse. Generally the forests are left in the areas such as (1) steep slope area which is hard to approach, (2) community forest managed by village, (3) forest with small shrine of native belief, and (4) north slope which is not suitable for agriculture.

Vegetation changes according to the changes of elevation. Sal forest continues from the Terai plain up to 1000 to 1200 m,MSL, followed by laurel forest from 1000 to 2500 m,MSL. These vegetation zones are recognized throughout the Middle Mountain, and forest species changes from humid type in eastern part to dry type in western part.

1.7 Past Flood and Sediment Disasters

The Study Team investigated conditions of past flood and sediment disasters in January 1998. On the basis of the information obtained from the District Irrigation offices and District Development Committee offices, a total of 14 VDC/Municipality offices were selected for the investigation. Furthermore, a total of 228 residents in the flood prone areas were selected for the interview using questionnaire form.

Questionnaires to the residents are summarized and shown in Table A1.4. In recent ten years, the biggest flood occurred in 1997, followed by 1996 and 1993. Floods in 1961 and 1969 were more destructive than the above.

Bank erosion, flooding over farmland and sedimentation are the major types of disasters. According to the data and information obtained from DDC and DIO of Dang and Banke districts, areas suffering from bank erosion and flooding are summarized as shown below.

(Areas Suffering from Bank Erosion and Flooding)

VDC	Bank	Ward No.
Khaskusma	Right and left	No.9
Kachanapur	Right	No.1, 8
Baijapur	Left	No.2, 6
Binauna	Left	No.3, 8
Kamdi	Right	No.1
Fatehpur	Left	No.1, 2, 8, 9
Betahani	Right and left	No.4, 5, 6, 7, 8
Holiya	Right	No.2, 3, 4, 5, 6, 7
Lalmatiya	Right	No.1, 2, 3, 4
Sishaniya	Right	No. 2, 3, 9
Sonpur	Right	No. 2, 4,7
Chailahi	Right	No. 2, 4, 5, 6, 7
Satbariya	Right	No. 2, 3, 4
Gobardiya	Left	No. 1, 8, 9
Gangaparaspur	Left	No. 2, 3, 4, 7, 9
Gadwa	Left	No.6, 7, 8, 9
Rajpur	Left	No.1, 8, 9

Loss of life and damage to properties are shown in Table A1.5, mainly based on data during 1997-flood. According to the field investigation and interviews of residents in the flood-suffering areas during the 1997-flood are shown in Fig. A1.15.

1.8 Flood Mitigation Activities

1.8.1 Existing River Facilities

According to the result of investigation conducted by the Study Team in January 1998, major river facilities of the Lakhandei river are as follows:

1) Embankment: none
2) Spur : 81 sites
3) Revetment : 15 sites
4) Head work : 1 site
5) Bridge : 3 sites

Location of these facilities is shown in Fig. A1.16. As seen in the above, spur (groin) works share by far the majority of the facilities followed by revetment works. Almost all the spur and revetment works are made of gabion by boulder and galvanized iron (G.I.) wire net.

The existing facilities are located sporadically along the river course. Some of these spur and revetment works are damaged already probably due to inappropriate foot protection. In some sites single spur was seen, though the spur works can function effectively, in general, when they are installed as a series. The types of existing spur or bank protection works are monotonous. Variety of works should be introduced taking account the river condition and availability of materials. Photos of typical river facilities are shown in Fig. A1.17.

1.8.2 Policy Framework

There are various laws and policies governing and orientating the flood mitigation activities. The followings are the major ones, among others:

1) Approach to the Ninth Plan (1997-2002)
2) National Action Plan on Disaster Management
3) Draft Flood Mitigation Policy
4) Watershed Development Policy

1.8.3 Organizations Involved in Flood Mitigation

The Department of Irrigation (DOI) is responsible for flood mitigation in the downstream areas. At the same time, there are other agencies that can make significant contributions to the implementation of flood mitigation project, both within and outside the central Government.

The Water-induced Disaster Prevention Technical Center (DPTC) has developed technologies and methodologies which can be applied to the project.

The Department of Soil Conservation and Watershed Management (DOSCWM), with an increasing number of branch offices in the Terai plain, also contributes to the project implementation through soil conservation which is also a crucial factor in promoting flood mitigation in the target areas.

As indicated by the experience of the efforts for small-scale infrastructure development by the Ministry of Local Development (MLD), the local governing institutions (LGIs) can play a significant role in facilitating community mobilization and also in coordinating different organizations operating in their own jurisdictions. There exists an NGO-led disaster preparedness network (DPNET), an association of organizations

concerned with community-based disaster management can participate in implementing community development components of the flood mitigation project.

Table A1.1

LIST OF METEOROLOGICAL STATIONS

Station No.	Station Name	Type of Station	Reg.	Latitude			Longitude			Elevation (m)	Start of Record	Remarks
				°	'	"	°	'	"			
0301	Mugu	Precipitation	MW	29	45	00	82	33	00	3,803	06-1958	
0302	Thirpu	Precipitation	MW	29	19	00	81	46	00	1,006	12-1956	
0303	Jumla	Synoptic	MW	29	17	00	82	10	00	2,300	12-1956	
0304	Guti Chaur	Precipitation	MW	29	17	00	82	19	00	3,080	06-1976	
0305	Sheri Ghat	Precipitation	MW	29	08	00	81	36	00	1,210	02-1966	
0306	Gam Shree Nagar	Precipitation	MW	29	33	00	82	09	00	2,133	10-1970	
0307	Rara	Climatology	MW	29	33	00	82	07	00	3,048	10-1970	
0308	Nagma	Precipitation	MW	29	12	00	81	54	00	1,905	10-1970	
0309	Bijayapur (Raskot)	Precipitation	MW	29	14	00	81	38	00	1,814	12-1956	
0310	Dipayal Gaun	Climatology	MW	29	16	00	82	13	00	2,310	06-1974	
0311	Simikot	Climatology	MW	29	58	00	81	50	00	2,800	05-1976	
0312	Dunai	Climatology	MW	28	56	00	82	55	00	2,058	06-1958	
0313	Darma	Precipitation	MW	29	44	00	82	06	00	1,950	09-1979	
0401	Pusma Camp	Climatology	MW	28	53	00	81	15	00	950	03-1963	
0402	Dailekh	Climatology	MW	28	51	00	81	43	00	1,402	01-1957	
0403	Jamu (Tikuwa Kuna)	Precipitation	MW	28	47	00	81	20	00	260	05-1963	
0404	Jajarkot	Precipitation	MW	28	42	00	82	12	00	1,231	12-1956	
0405	Chisapani (Karnali)	Climatology	MW	28	39	00	81	16	00	225	01-1963	
0406	Surkhet (Birendra Nagar)	Synoptic	MW	28	36	00	81	37	00	720	01-1957	
0407	Kusum	Precipitation	MW	28	01	00	82	07	00	235	11-1956	West Rapti
0408	Gulariya	Precipitation	MW	28	10	00	81	21	00	215	01-1957	Babai
0409	Khajura (Nepalgunj)	Agrometeology	MW	28	06	00	81	34	00	190	01-1968	West Rapti
0410	Bale Budha	Precipitation	MW	28	47	00	81	45	00	610	05-1965	
0411	Rajapur	Precipitation	MW	28	26	00	81	06	00	129	02-1971	
0412	Naubasta	Precipitation	MW	28	16	00	81	43	00	135	02-1971	West Rapti
0413	Shyalo Shree	Precipitation	MW	28	27	00	81	35	00	302	02-1971	Babai
0414	Baijapur	Precipitation	MW	28	03	00	81	54	00	226	02-1971	West Rapti
0415	Bargadaha	Precipitation	MW	28	26	00	81	21	00	200	11-1967	Babai
0416	Nepalgunj (Reg Off.)	Climatology	MW	28	04	00	81	37	00	144	02-1973	West Rapti
0417	Rani Jaruwa Nursery	Climatology	MW	28	23	00	81	21	00	200	12-1975	Babai
0418	Maina Gaun (D.bas)	Precipitation	MW	28	59	00	82	17	00	2,000	05-1975	
0419	Sikta	Agrometeology	MW	28	02	00	81	47	00	195	05-1978	West Rapti
0501	Rukumkot	Precipitation	MW	28	36	00	82	38	00	1,560	07-1957	
0502	Shera Gaun	Precipitation	MW	28	35	00	82	49	00	2,150	07-1957	
0504	Libang Gaun	Precipitation	MW	28	18	00	82	38	00	1,270	07-1957	West Rapti
0505	Bijuwar Tar	Precipitation	MW	28	06	00	82	52	00	823	08-1957	West Rapti
0507	Nayabasti (Dang)	Precipitation	MW	28	13	00	82	07	00	698	12-1970	Babai
0508	Tulsipur	Climatology	MW	28	08	00	82	18	00	725	12-1970	Babai
0509	Ghorahi (Masina)	Precipitation	MW	28	03	00	82	30	00	725	12-1970	Babai
0510	Lotlabas	Precipitation	MW	27	42	00	82	32	00	320	02-1971	
0511	Salyan Bazar	Climatology	MW	28	23	00	82	20	00	1,457	11-1956	Babai
0512	Luwamjula Bazar	Precipitation	MW	28	18	00	82	17	00	885	11-1971	Babai
0513	Chaur Jhari Tar	Climatology	MW	28	32	00	82	01	00	910	06-1975	
0514	Musikot (Rukumkot)	Climatology	MW	28	38	00	82	29	00	2,100	07-1973	
0515	Ghorai	Synoptic	MW	28	03	00	82	30	00	725	*	

(Note) Reg. MW: Mid Western Region (All the stations of this region are listed.)

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude	Longitude	Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			° ' "	° ' "								
120.	Chamelia	Karkale Gaon	29 40 20	80 33 30	-	1,150				01/01/65		
150.	Mahakali	Pancheshwor	29 26 45	80 15 30	-	12,236	C	R		01/01/62		
169.8	Sumagad	Gujar Gaon	29 31 00	80 35 00	-	(66)	C			-		
170.	Sumagad	Patan near Baitadi	29 27 30	80 33 10	1,110	118	C			01/01/66	01/04/88	
190.5	Kandr Khola	Amsara	28 36 00	80 56 00	-	(313)				-		
190.8	Khutiya Khola	Boladevi Gaon	28 53 00	80 44 00	-	-				-		Khutiya
205.	Kharpu Khola	Kharpu	29 57 00	81 52 00	-	1,310				14/05/78		
206.	Humla Karnali	Bihi Chhara	29 38 00	81 52 00	-	(8,447)				17/06/79		
208.	Mugu Karnali	Surkhet	29 37 00	81 52 00	-	5,300	C			13/06/79		
209.	Kawadi Khola	Kawadi Ghat	29 36 16	81 45 28	-	795				17/01/89		
210.	Rara Daha	Nizal	29 31 00	82 04 00	-	1,150				08/11/65		
215.	Humla Karnali	Thuldada	29 09 00	81 36 00	-	15,200	C			06/02/66		
220.	Tila Nala	Nagina	29 12 00	81 55 00	-	1,870	C			19/03/64		
225.	Sinja Khola	Diware	29 12 00	81 55 00	-	824	C			17/03/64		
230.	Tila Nadi	Seti Ghat	29 08 00	81 36 00	-	3,470	C			08/03/64		
240.	Karnali	Asara Ghat	28 57 10	81 26 30	629	19,260	C	R	S	01/01/61		
241.	Lohare Khola	Tallo Dungeswat	28 41 00	81 36 00	-	1,060	C			24/05/65		
245.	Chhamghat Khola	Gitachaur	28 56 00	81 41 30	-	(108)	C			20/03/78		
250.	Karnali	Benighat	28 57 40	81 07 10	320	21,240	C	R		01/02/63		
251.	Seit	Chainpur	29 33 30	80 12 40	-	2,040	C			-		
255.	Bhdhi Ganga	Kakarsant	29 11 00	81 13 00	-	1,340	C			28/04/78		
259.2	Seit	Gopaghat Gaon	29 18 00	80 46 30	-	4,420	C			-		
260.	Seit	Banga near Belgaon	28 58 40	81 08 40	328	7,460	C	R	S	06/02/63		
262.	Tuli Gad	Khanayatal	28 56 00	80 54 00	314	896	C	R		17/06/65		
265.	Thulo Bheri	Rimna	28 42 30	82 17 30	-	6,720	C			18/06/72		
267.	Sano Bheri	Simli Ghat	28 39 30	82 21 30	-	2,620	C			18/06/76		
269.5	Bheri Nadi	Samaiji Ghar			-	-	C	PR		16/12/89		
270.	Bheri	Jamu	28 45 20	81 21 00	246	12,290	C	R	S	23/01/63		
280.	Karnali	Chisapani	28 38 40	81 17 30	191	42,890	C	R	S	01/01/62		

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude	Longitude	Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			° ' "	° ' "								
284.	Sarda Khola	Shyalpani-Sita Pall	28 22 30	82 11 45	-	295				17/06/77		Babai
285.	Mohana	Kalakunta	28 27 00	81 00 30	-	(623)				22/04/76		
286.	Sarada Khola	Daradhunga	28 17 58	82 01 30	-	816	C	R	S	01/01/72		Babai
287.	Kauriala Karnali	Sattar Farm	28 24 30	81 05 00	-	-				17/03/80		
288.	Geruwa Karnali	Kothiya Ghat	28 22 30	81 12 00	-	(14,853)				18/03/80		
289.	Babai River	Gangate Gaon	28 15 00	81 57 00						06/01/72		
289.5	Gohar Khola	Sirchaur Gaon	28 09 15	82 22 45	-	-	C			21/06/77		Babai
289.9	Babai Nadi	Gangata			-	-				-		Babai
289.95	Babai Nadi	Chepang			-	-	C	R		01/10/89		Babai
290.	Babai	Bargadha	28 25 20	81 22 10	192	3,000	C	R		16/07/66	13/04/89	Babai
291.	Babai Nadi	Bhada			-	-				-		Babai
327.	Lungri Khola	Khungree Gaon	28 13 30	82 42 30	-	467	C			26/12/76		West Rapti
330.	Mari Khola	Nayagaon	28 04 20	82 48 00	536	1,980	C			01/01/64		West Rapti
333.	Arun Khola	Devistan	28 02 00	82 45 30	-	136	C			--/--/68		West Rapti
339.5	Jhimruk Khola	Tigra Gaon	28 03 00	82 49 40	-	683	C			22/05/71		West Rapti
340.	Jhimruk Khola	Kalimati Ghat	28 02 10	82 53 00	692	696	C			01/01/65	21/05/71	
350.	Rapti	Bagasoti Gaon	27 54 00	82 51 00	381	3,380	C	R	S	08/05/75		West Rapti
350.5	Rangsing Khola	Tinkhanne Gaon	27 47 30	82 49 00	-	(92)	C			03/01/83		West Rapti
360.	Rapri	Jalkundi	27 56 50	82 13 30	218	5,150	C	R	S	08/04/64		West Rapti
380.	Rapti River	Sindhania	28 01 00	81 44 45						06/03/83		
385.2	Rapti River	Farinda			-	-				-		West Rapti
387.4	Dumre Khola	Kalimati	27 47 47	83 32 09	595	90	C			18/06/80		Tinau
387.5	Madi Tinau	Charchare	27 47 29	83 33 08	570	103	C	R		17/06/80		Tinau
387.8	Jhumsa Khola	Dumahi Bari	27 45 00	83 30 46	335	99	C			15/02/85		Tinau
390.	Tinau Khola	Butwal	27 42 10	83 27 50	184	554	C			09/12/63		Tinau
403.	Kali Gandaki	Jomsom	28 47 30	83 45 00	-	(3,060)				07/06/69		Narayani
403.5	Kali Gandaki	Tatopani	28 29 00	83 39 00	1,239	-		R		--/03/92		
404.6	Kali Gandaki	Kalipul Beni	28 21 30	83 34 30	-	(4,581)				05/04/71		Narayani
404.7	Myagdi Khola	Mangla Ghat	28 21 30	83 32 00	-	(1,112)	C			19/05/75		Narayani

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude	Longitude	Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			° ' "	° ' "								
406.	Kali Gandaki	Modi Beni	28 12 00	83 42 00	667	-		R		--/03/92		
406.5	Modi Khola	Nayapul	28 13 30	83 42 15	-	(635)	C			25/05/75		Narayani
409.5	Seti Khola	Seti Beni	28 00 40	83 37 10	-	(138)				22/02/76		Narayani
410.	Kali Gandaki	Seti Beni	28 00 30	83 36 10	546	6,630	C	R	S	21/02/64		Narayani
413.2	Danab Khola				-	-	C			27/05/90		
414.1	Dararun Khola	Arjun Chaupari			-	-				01/01/90		
415.	Andhi Khola	Dumrichaur Andhimuhan	27 58 20	83 35 20	543	476	C			06/04/89		Narayani
416.2	Daram Khola	Wamitaksar	28 11 45	83 18 15	-	(239)	C			18/12/78		Narayani
417.	Badigad Khola	Rudrabeni Gulmi	27 58 20	83 28 10	-	1,990	C			24/05/67		Narayani
419.1	Kali Gandaki	Ansigh-AndhiGhat			-	-	C			13/04/89		Narayani
420.	Kali Gandaki	Kotagaon Shringe	27 45 00	84 20 50	198	11,400	C	R		15/04/64		Narayani
428.	Mardi Khola	Lahachok	28 18 30	83 55 30	-	160	C			07/06/70		Narayani
430.	Seti Khola	Phoolbari	28 14 00	84 00 00	830	582	C			01/01/89		Narayani
438.	Madi	Shisa Ghat	28 06 00	84 14 00	-	858	C			08/02/73		Narayani
439.3	Khudi Khola	Khudi Bazar	28 17 15	84 21 45	-	(151)	C			04/07/81		Narayani
439.4	Dordi Khola	Amote Bazar-Sera Besi	28 10 45	84 27 30	-	(341)	C			09/02/76		Narayani
439.7	Marsyangdi	Bimal Nagar	27 57 00	84 25 48	354	(4,088)	C	R	S	31/03/87		Narayani
439.8	Marsyangdi	Gopling Ghat	27 55 35	84 29 42	320	3,850	C	R	S	01/06/73	21/05/88	
440.	Chepe Khola	Garam Besi	28 03 41	84 29 23	442	308	C	PR		20/11/63		Narayani
441.	Daraundi Khola	Nayasanghu Gorkha	28 01 00	84 35 15	-	386	C			13/10/67		Narayani
441.5	Daraundi Khola	Ramdi								26/12/86		
445.	Burhi Gandaki	Arughat	28 02 37	84 48 59	485	4,270	C	R	S	28/11/63		Narayani
445.3	Ankhu Khola	Ankhu Bridge	27 58 20	84 49 10	-	768	C			--/--/67		Narayani
446.15	Lirung Khola	Kyangjin								-		
446.2	Langtang Khola	Shyaprubesi	28 09 30	85 20 45	-	(540)	C			-		Narayani
446.25	Bhote Kosi	Syaprubesi			-	-				-		
446.3	Trisuli Khola	Dhunche	28 07 10	85 17 40	-	49	C	R		--/--/63		Narayani
446.8	Phalankhu Khola	Betrawati	27 58 25	85 11 15	630	162				24/04/69		Narayani
447.	Trisuli	Betrawati	27 58 08	85 11 00	600	4,110	C	R	S	01/04/67		Narayani

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude	Longitude	Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			° ' "	° ' "								
447.4	Tadi Khola	Rautar Nuwakot	27 55 00	85 17 10	-	254				-		Narayani
447.9	Likhu Khola	Pattawari Nuwakot	27 53 30	85 14 45	-	(145)				-		Narayani
448.	Tadi Khola	Tadipul Belkot	27 51 35	85 08 18	475	653				14/06/68		Narayani
449.9	Trisuli	Mugling	27 51 00	84 34 30	-	-				-		Narayani
449.91	Trishuli	-			-	-				-		
449.95	Trisuli	Bhorletar	27 49 00	84 26 45	-	(14,500)	C			26/02/82		Narayani
450.	Narayani	Narayan Ghat	27 42 30	84 25 50	180	31,100	C	R	S	10/02/62		Narayani
460.	Rapti	Rajaiya	27 26 30	84 58 15	332	579	C			01/01/63		Narayani
465.	Manahari Khola	Manahari	27 33 00	84 48 10	305	427	C	R		13/06/63		Narayani
470.	Lothar Khola	Lothar	27 35 40	84 43 00	336	169	C			30/11/63		Narayani
505.	Bagmati	Sundarijal	27 46 30	85 25 40	1,600	17	C	R		07/12/62		
507.	Nagmati	Sundarijal	27 46 20	85 26 10	1,660	13				00/11/63		
510.	Sialmati	Syamdado	27 46 10	85 25 10	1,660	3				00/11/63		
511.	Dhakal Khola	Gagalgau	27 44 45	85 26 15	-	-				-		
520.	Bagmati River	Gokarna	27 43 45	85 23 30		56				-		
525.5	Manahara River	Shakyu Salmutar			-	-				04/03/00		
530.	Bagmati	Gauri Ghat	27 42 30	85 21 00	1,300	68				15/11/64		
536.2	Bishnumati Khola	Budhanilkantha	27 46 49	85 21 32	1,454	4				27/05/68	27/08/98	
540.	Nakhu Khola	Tika Bhairab	27 34 30	85 18 50	1,400	43				23/11/62		
548.	Nakhu Khola	Nakhu Jail Near Patan	27 39 40	85 18 30	-	56				01/01/87		
550.	Bagmati River	Chovar	27 39 40	85 17 50	1,280	585	C	R	S	01/07/62	--/--/80	
550.05	Bagmati	Khokana	27 16 00	85 13 00	1,255	607		PR		01/06/91		
550.1	Bagmati River	Sampkhel	27 33 30	85 15 45	-	-	C	R	S	15/06/85		
565.	Kulekhani Khola	Lamichaur	27 36 13	85 09 39	1,514	122	C	R		01/07/75	09/12/78	
570.	Kulekhani Khola	Kulekhani	27 35 10	85 09 30	1,480	126	C	R	S	01/12/62	15/11/77	
586.	Bagmati	Rai Gaon			-	-				01/02/88		
589.	Bagmati	Pandhera Dobhan	27 06 20	85 28 30	180	2,700	C	R	S	28/01/79		
590.	Bagmati	Karmaiya - Mangalpur	27 06 20	85 28 30	177	2,720		R	S	21/06/64	17/10/84	
592.	Bagmati	Bramhapuri	26 45 30	85 20 00	-	(13,790)				-		

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude	Longitude	Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			° ' "	° ' "								
595.	Jamuni	Chyutaha	26 57 00	85 20 00	-	-				19/03/92		
598.	Kamala	Chisapani	26 55 15	86 10 30	-	(1,595)				-		
599.	Kamala	Inarawa	26 36 45	86 09 00	-	-				-		
600.05	Barun Khola	Seksila Hatiya	27 41 00	87 21 00	1,500	352				22/12/86		
600.1	Arun	Uwa Gaon	27 36 00	87 20 06	1,294	26,750	C	R	S	11/05/72		
601.8	Pangtha Khola	Kurle Besi	27 24 00	87 13 30	-	(26)				01/09/98		
601.9	Pangma Khola	Kurle Besi	27 24 00	87 12 45	-	(38)				01/09/98		
602.	Sabhaya Khola	Tumlingtar	27 18 20	87 13 15	-	375	C	R		02/01/74		
602.5	Hinwa Khola	Pipletar	27 17 45	87 13 30	-	110	C			-		
604.	Arun	Leguwa Ghat	27 09 00	87 16 30	-	(4,183)				01/06/68		
604.5	Arun	Turkeghat	27 20 00	87 11 30	414	28,200	C	R		23/05/75		
605.	Pikhuwa Khola	Parapani Phedi	27 05 00	87 07 00		337				0/0/64		
606.	Arun	Simle	26 55 30	87 09 30	-	30,380	Br			-		
610.	Bhote Kosi	Barabise	27 47 10	85 53 20	840	2,410				17/02/65		
612.	Sun Kosi	Barabise	27 46 30	85 54 30	-	(84)				-		
620.	Balephi Khola	Jalbire	27 48 20	85 46 10	793	629	C			25/12/63		
625.	Sun Kosi	Dolalghat	27 38 30	85 43 00	-	(1,375)	C			-		
627.5	Melamchi Khola	Helambu	28 02 30	85 32 00	-	-				-		
627.55	Melamchi Khola	Sajhaya			-	-				-		
629.1	Indrawati	Dolalghat	27 38 20	85 42 30	-	1,225	C			17/09/72		
630.	Sunkosi	Pachuwar Ghat	27 33 30	85 45 10	589	4,920	C			26/03/64		
640.	Rosi Khola	Panauti	27 34 50	85 30 50	1,480	87				17/10/63		
641.	Rosi Khola	Lold Khola			-	-				-		
647.	Tamakosi	Busti	27 38 05	86 05 12	849	2,753	C	R		14/01/70		
650.	Khimti Khola	Rasnalu Village	27 34 30	86 11 50	1,520	313	C			06/04/64		
652.	Sunkosi	Khurkot	27 20 00	86 00 00	455	10,000	C			01/07/67		
660.	Likhu Khola	Sanghu Khola	27 20 10	86 13 10	543	823	C			24/03/64		
665.	Sun Kosi	Ahrkapur (Tokselghat)	27 10 30	86 22 00	-	(8,736)	C			20/02/86		
668.4	Taktor Khola	Beni	27 31 45	86 33 30	2,350	(87)	Br			-		

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude	Longitude	Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			° ' "	° ' "								
668.5	Solua Khola	Salme	27 30 30	86 33 15	1,800	(324)	Br			-		
669.5	Rawa Khola	Gaikhure	27 16 00	86 40 30						-		
670.	Dudh Kosi	Rabuwa Bazar	27 16 00	86 39 50	460	4,100	C	R	S	10/03/64		
680.	Sun Kosi	Kampughat	26 52 30	86 49 20	200	17,600				28/06/65		
681.	Sun Kosi	Hampuachuwar	26 55 15	87 08 45	-	-	C			-		
684.	Tamur	Majhitar	27 09 30	87 42 45	-	-	C			-		
685.3	Maiwa Khola	Maiwa Dovan	27 22 10	87 36 50		194				-		
685.9	Hima Khola	Thapatar (Phidim)	27 09 45	87 46 15						0/0/74		
688.5	Madhu Khola	Dhankuta	26 59 30	87 22 15						-		
688.6	Banchare Khola	Dhankuta	26 59 00	87 22 30		13				-		
688.7	Nibuwa Khola	Dhankuta	26 59 00	87 23 15	-	(28)				-		
689.	Tankhuwa Khola	Biretar Near Dhankuta	26 58 30	87 22 15	-	51				--/--/64		
690.	Tamur	Mulghat	26 55 50	87 19 45	276	5,640	Br	PR	S	11/03/65		
691.	Tamur	Tribeni	26 55 00	87 10 00	-	(6,146)	C			-		
695.	Sapta Koshi	Chatara-Kothu	26 52 00	87 09 30	140	54,100	C		S	01/01/77		
698.	Sardu Khola	Mathilo Sardu-Dharan	26 51 00	87 18 05		7				0/0/71		
715.	Mai Khola	Mai Beni	26 53 25	87 57 20		210				0/0/71		
720.	Jog Mai Khola	Mai Beni	27 53 40	87 59 20		140				0/0/67		
728.	Mai Khola	Rajdwail	26 52 45	87 55 45	-	377	C		S	01/01/83		
730.	Puwa Khola	Sajbote (Ilam)	26 55 00	87 54 40	802	107	C			18/01/65		
738.	Deo Mai Khola	Angdang	26 54 00	87 46 15	-	(199)	C			-		Ratuwa ?
795.	Kankai Mai	Mainachuli	26 41 12	87 52 44	125	1,148	C	R		01/05/71		
799.	Kankai	Kumarkhod-Jhapa			-	-				30/10/87		
848.4	Siddhi Khola	Kajeni	26 51 15	88 07 00	-	-				-		

Note:

C: Cable way for discharge measurement

Br: Bridge available for discharge measurement

R: Recording gauge for water level observation

PR: Pressure type gauge for water level observation

GRAIDING OF RIVERBED MATERIALS

Sample code	Cumulative percentage of passing materials (%)														
	<0.075 (mm)	<0.106 (mm)	<0.25 (mm)	<0.425 (mm)	<0.85 (mm)	<2 (mm)	<4.75 (mm)	<9.5 (mm)	<19 (mm)	<26.5 (mm)	<37.5 (mm)	<53 (mm)	<100 (mm)	<200 (mm)	<400 (mm)
	0.075	0.106	0.250	0.425	0.850	2.00	4.75	9.50	19.0	26.5	37.5	53.0	100.0	200.0	400.0
West Rapti River															
WR-1	2.7	7.9	72.6	96.5	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-2	5.9	16.2	97.5	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-3	0.6	3.1	45.5	99.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-4	3.3	7.8	64.4	93.1	96.8	97.1	97.6	98.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-5	0.0	0.1	5.2	39.0	98.7	99.3	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-6	3.3	8.6	88.1	98.2	98.9	99.3	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-7	0.7	1.2	4.3	11.0	15.2	17.4	22.6	31.2	45.7	54.4	63.1	73.1	91.0	100.0	100.0
WR-8	0.0	0.1	4.0	27.4	97.5	99.3	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-9	1.3	4.9	27.2	90.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-10	0.1	0.4	3.8	10.1	15.4	18.9	25.1	35.3	48.5	57.4	67.0	77.5	100.0	100.0	100.0
WR-11	0.5	1.0	4.4	8.1	12.3	16.4	20.7	24.8	34.5	40.9	48.9	57.8	79.5	100.0	100.0
WR-12	0.3	0.6	7.8	15.7	19.7	21.7	25.8	35.6	52.8	63.9	75.5	84.5	100.0	100.0	100.0
WR-13	0.4	0.9	5.1	9.3	12.4	15.1	19.2	24.7	32.5	37.5	44.2	54.1	77.8	100.0	100.0
WR-14	0.8	2.2	41.3	92.4	99.0	99.3	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-15	1.9	6.2	41.5	72.0	89.9	93.3	95.9	98.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-16	5.3	12.8	89.3	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-17	4.4	9.1	54.7	68.2	71.5	72.3	74.3	81.0	86.4	89.8	93.4	96.0	100.0	100.0	100.0
WR-18	0.1	0.2	1.1	3.3	7.3	11.7	14.7	17.5	29.6	37.6	48.5	60.1	88.9	100.0	100.0
WR-19	3.7	6.1	10.1	12.9	17.3	21.6	27.9	35.5	54.4	66.5	79.8	90.6	100.0	100.0	100.0
WR-20	1.3	2.7	11.9	20.9	24.8	27.1	31.0	38.0	55.3	63.9	73.3	83.7	100.0	100.0	100.0
WR-21	1.3	2.4	6.4	6.4	13.9	17.2	22.8	30.0	48.6	59.2	71.4	80.7	100.0	100.0	100.0
WR-22	3.1	4.7	8.2	11.0	14.0	17.0	20.8	26.9	38.3	45.0	54.6	63.1	79.7	100.0	100.0
WR-23	0.4	0.8	3.1	4.8	6.4	11.4	18.2	24.7	34.4	39.0	46.4	52.9	74.3	100.0	100.0

REPRESENTATIVE GRAIN SIZES AND SPECIFIC GRAVITY

Sample code	Representative grain size					Specific gravity(g/cc)		
	16 (%)	60 (%)	65 (%)	84 (%)	d84/d16	S.G.1 (g/cc)	S.G.2 (g/cc)	S.Gave (g/cc)
West Rapti River								
WR-1	0.12	0.21	0.23	0.32	2.73	2.67	2.69	2.68
WR-2	0.11	0.17	0.18	0.22	2.06	2.56	2.60	2.58
WR-3	0.14	0.29	0.30	0.37	2.65	2.66	2.60	2.63
WR-4	0.12	0.23	0.25	0.36	2.99	2.59	2.60	2.60
WR-5	0.30	0.54	0.57	0.72	2.42	2.56	2.60	2.58
WR-6	0.11	0.18	0.19	0.24	2.08	2.66	2.63	2.65
WR-7	1.17	33.09	39.99	77.97	66.38	2.65	2.68	2.67
WR-8	0.33	0.59	0.62	0.74	2.27	2.63	2.66	2.65
WR-9	0.16	0.33	0.34	0.40	2.47	2.59	2.60	2.60
WR-10	0.99	29.15	34.94	63.62	64.16	2.68	2.70	2.69
WR-11	1.84	56.53	65.43	116.43	63.32	2.59	2.63	2.61
WR-12	0.45	23.56	27.35	51.89	116.57	2.66	2.68	2.67
WR-13	2.43	62.10	71.00	121.36	49.86	2.64	2.61	2.63
WR-14	0.14	0.30	0.32	0.39	2.71	2.67	2.68	2.68
WR-15	0.13	0.34	0.38	0.68	5.03	2.63	2.67	2.65
WR-16	0.11	0.18	0.19	0.24	2.15	2.65	2.63	2.64
WR-17	0.12	0.31	0.38	13.95	115.59	2.65	2.67	2.66
WR-18	6.50	52.86	59.06	89.77	13.80	2.67	2.63	2.65
WR-19	0.69	22.17	25.42	42.90	61.82	2.60	2.59	2.60
WR-20	0.32	22.82	27.64	53.59	168.32	2.66	2.69	2.68
WR-21	1.47	27.09	31.25	59.10	40.29	2.67	2.70	2.69
WR-22	1.49	46.69	56.91	115.82	77.62	2.60	2.63	2.62
WR-23	3.58	65.48	75.93	129.90	36.26	2.63	2.67	2.65
							Average	2.61

SUMMARY OF QUESTIONNAIRES BY RIVER

Name of river: **WEST RAPTI RIVER(1/2)**

No.	Questions/items	Summary of answers
1. FLOOD EVENTS		
1.1	Year of most severe flood in past 10 years (nop)	1997(144), 1993(12), 1996(12), 1995(3)
1.2	Floods in a year (times)	Average(7) ranging(4 to 12)
1.3	Severe floods in past 10 years (times)	Average(5) ranging(2 to 12)
1.4	(Cancelled)	(Cancelled)
1.5	Cause of flood (nop)	• Too much rain(150) • Sediment flow(37) • Bank erosion(69) • Others(13)
2. EFFECT DUE TO SEVERE FLOOD IN PAST		
2.1	Loss of human life (nop)	0 (excluding those due to epidemic disease)
2.2	Loss of livestock/husbandry (nos)	• Cow(88) • Buffalo(30) • Sheep/Goat(15) • Poultry(0)
2.3	Damage to farm land (ha)	• Irrigated land: Average(0.0) ranging(0) • Non-irrigated land: Average(1.7) ranging(0.7 to 2.7)
2.4	Extent of damage to farm land	• Simple inundation (nop): 0 • Loss of crops (nop): Paddy(79), Sugarcane(0), Maize(4), Others(1) • Total washout (ha): Average(1.6) ranging(0 to 16.0)
2.5	Extent of damage to dwelling and asset	• Flooding duration (days): Average(2.3) ranging(1 to 7) • Flooding depth in (m): Average(1.5) ranging(0.75 to 2.0) • Damage to house (nop): Severe(32), Moderate(6), Ordinary(22) • Loss of cash (Rs): (No answer) • Loss of food grains (kg): Paddy: Average(250) ranging(0 to 460) • Clothing (nos): Average(0) ranging(0) • Other valuables: Average(0) ranging(0)
2.6	Problems during flood (nop)	• Erosion of river bank(82) • Sediment in the river(15) • Sediment in irrigation canal(8) • Drinking water problem(48) • Sanitary problem(2) • Salinity(0) • Flooding over farm land(43) • Others(9)
2.7	Epidemic disease after flood? (nop)	• Yes(28) • No(13)
2.8	If yes, kind of epidemic disease (nop)	• Cholera(11) • Dysentery(10) • Typhoid(0) • Others(7)
2.9	Fatal causality? (nop)	• Yes(0) • No(43)
2.10	Reason of flood(nop)	• Too much rain(31) • Lack of flood protection works(75) • Weak river training works(5) • Sediment load in the flood water(3) • Flood from adjoining rivers(7)
2.11	Total amount of damage (Rs)	Average(211,000) ranging(0 to 1,500,000)

(Remarks) nop: Number of persons who answer to the item.

SUMMARY OF QUESTIONNAIRES BY RIVER

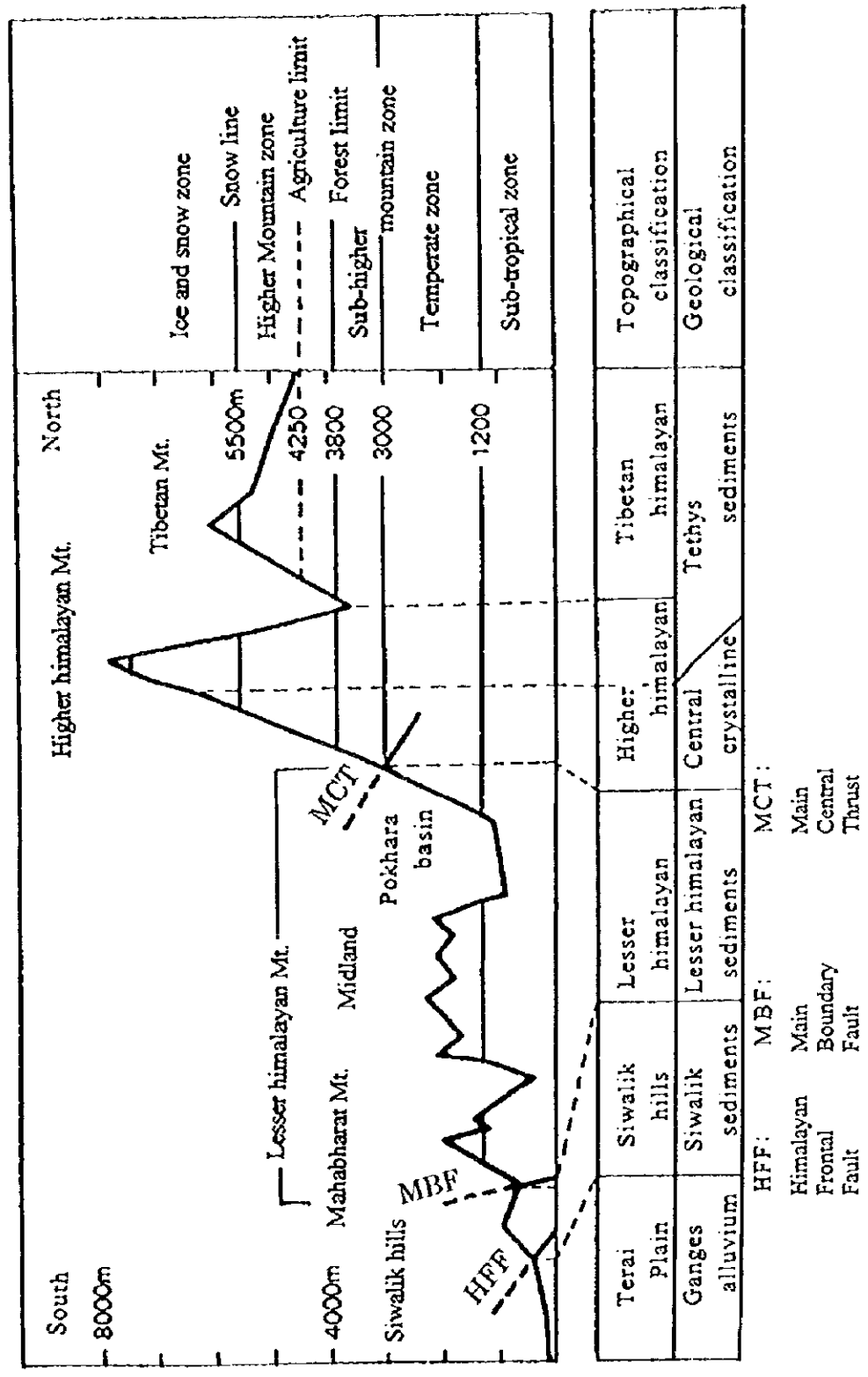
Name of river: **WEST RAPTI RIVER(2/2)**

No.	Questions/items	Summary of answers
3. FLOOD WARNING SYSTEM		
3.1	(Cancelled)	(Cancelled)
3.2	Self warning (nop)	• Heavy rain/High flood level(100) • Bank erosion(4) • Smelled mud(0) • Unusual sound(16) • Others(2)
3.3	Warning by others (nop)	• Neighbors(0) • Institutions(0) • Others(0)
4. FLOOD RELIEF MEASURES		
4.1	Evacuation experience? (nop)	• Yes(52) • No(127)
4.2	If yes, place of evacuation (nop)	• High ground(10) • Public building(0) • Others houses(5) • Other sites(33)
4.3	Being relieved? (nop)	• Yes(4) • No(169)
4.4	If yes, how?(nop)	• In cash(3) • Kind(1)
4.5	Organization/individual giving relief (nop)	• Central government(3) • DDC(0) • VDC(4) • Other institutions(0) • NGO(0) • Individuals(0)
4.6	(Cancelled)	(Cancelled)
5. PREVENTIVE MEASURES AGAINST FLOOD		
5.1a	Current preparedness/ measures (nop)	• Warning(0) • Evacuation(12) • Settlement(21)
5.1b	Proposed preparedness/ measures (nop)	• Warning(5) • Evacuation(3) • Settlement(26)
5.2a	Current non-structural measures (nop)	• Seed storage(0) • Cash pools(0) • Informal insurance(0) • Others(0)
5.2b	Proposed non-structural measures (nop)	• Seed storage(4) • Cash pools(5) • Informal insurance(4) • Others(1)
5.3a	Current structural measures (nop)	• Embankment(0) • Spur(0) • Simple gabion(0) • Plantation(0) • Others(1)
5.3b	Proposed structural measures(nop)	• Embankment(125) • Spur(63) • Simple gabion(30) • Plantation(16) • Others(2)
6. PARTICIPATION ACTIVITIES		
6.1	Experience of Participation in activities? (nop)	• Yes(49) • No(137)
6.2	If yes, type (nop)	• Cash(2) • Labor(48) • Kind(0) • Care taker(2) • Others(2)
6.3	If no, reason (nop)	• Being affected badly(4) • Financially weak(0) • Being out of the area(1) • No willingness(1) • Others(135)
6.4	Willing to participate in future? (nop)	• Yes(159) • No(23)
6.5	If yes, type (nop)	• Cash(19) • Labor(163) • Kind(5) • Care taker(26) • Others(2)
6.6	If no, reasons (nop)	• No time(4) • No benefit(21) • No Willingness(0) • Not known how to participate(0) • Others(0)

(Remarks) nop: Number of persons who answer to the item.

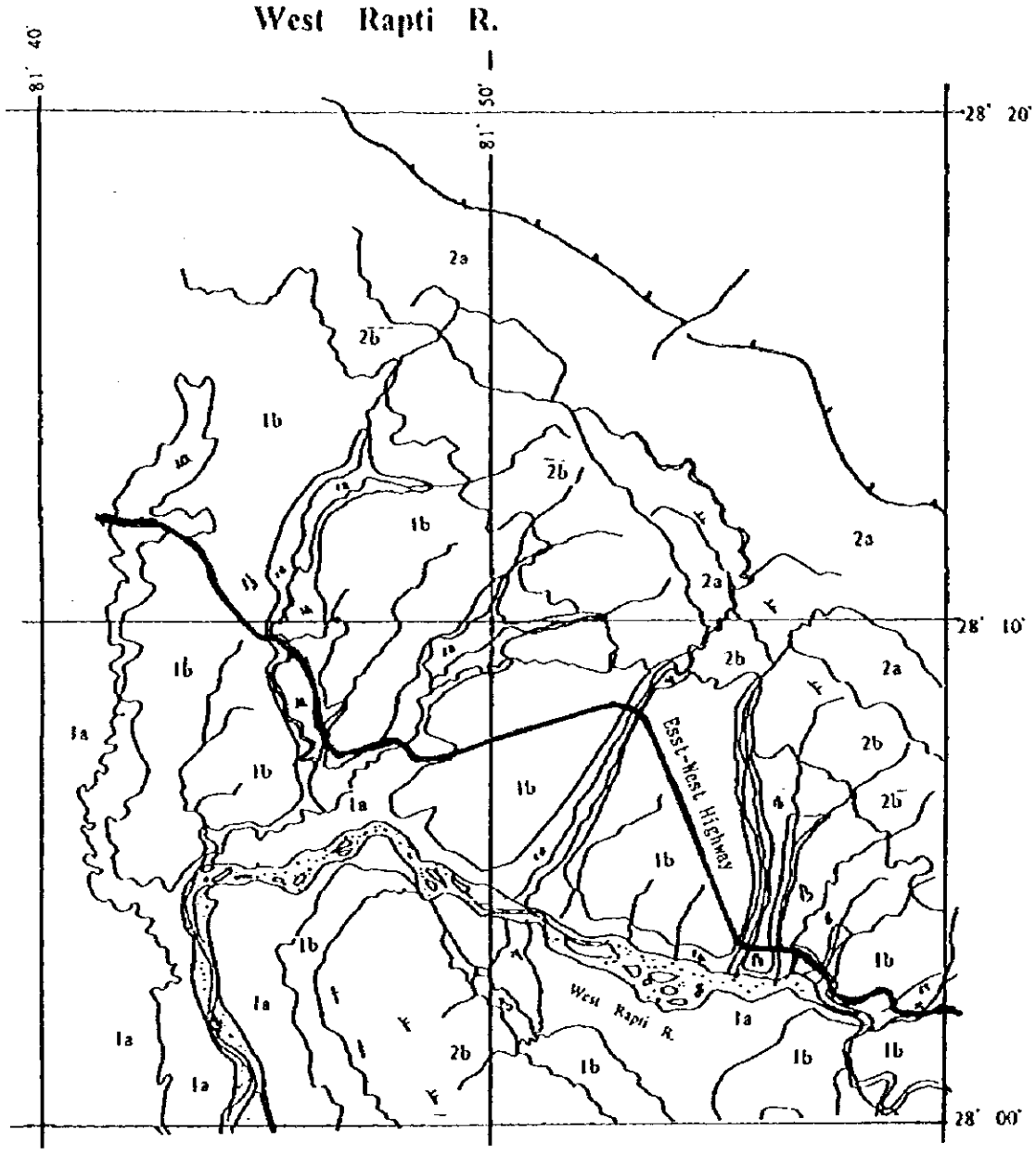
LOSS OF LIFE AND DAMAGE TO PROPERTIES (WEST RAPTI RIVER)
(1997-FLOOD)

VDC/Municipality	Loss of				Damage of						Remarks
	Human Life (nos.)	Cattle (nos.)	Land (hac)	House (nos.)	Crop (ton)	Land (hac)	House (nos.)	Public Facility			
								Road (m)	Channel (m)	Others	
Kanchapur	8	3	17	-	-	-	-	-	-	-	at Agahiya
Khaskusum	-	-	-	-	-	30	-	-	-	-	near Rapti
Barijapur	-	5	10	-	-	30	-	-	-	-	Bridge
Bihauna	-	-	15	25	8	-	-	-	-	-	BANKEY
Kamdi	3	13	67	25	92	-	30	-	-	-	DISTRICT
Fatehpur	-	35	157	5	-	-	-	-	-	-	
Betahani	2	45	50	5	210	-	30	-	-	-	
Holiya	22	37	242	25	81	95	160	-	-	-	Ferry
Gangapur	-	40	75	25	-	-	-	-	-	-	Accident
Lalmatiya	-	-	121	-	-	-	-	-	-	-	
Sonpur	-	-	28	-	-	4	22	-	-	-	DANG
Sishaniya	-	22	6	-	-	-	4	33	-	-	DISTRICT
Chailahi	-	-	29	-	-	3	-	-	-	-	
Satbariya	-	-	85	-	-	13	-	-	-	-	
Gobardiha	-	-	9	13	-	-	-	-	-	-	
Gangaparaspur	-	-	78	-	-	-	-	-	-	-	
Gadwa	-	-	22	-	-	-	-	38	-	-	
Rajpur	-	-	21	-	-	-	-	-	-	-	
Total	35	200	1.032	123	391	175	246	71	0	0	



TOPOGRAPHICAL AND GEOLOGICAL CLASSIFICATION(N-S PROFILE)

His Majesty's Government of Nepal Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



Legend

1. Unconsolidated sediments, chiefly in the Terai plain
   - 1a. alluvium, deposited or reworked by water
   - 1b. alluvial fans, talus, colluvium
2. Siwalik sedimentary system
   - 2a Upper formation-generally coarser clastics
   - 2b. Lower formation-generally finer clastics

GEOLOGICAL MAP(WEST RAPTI R.)

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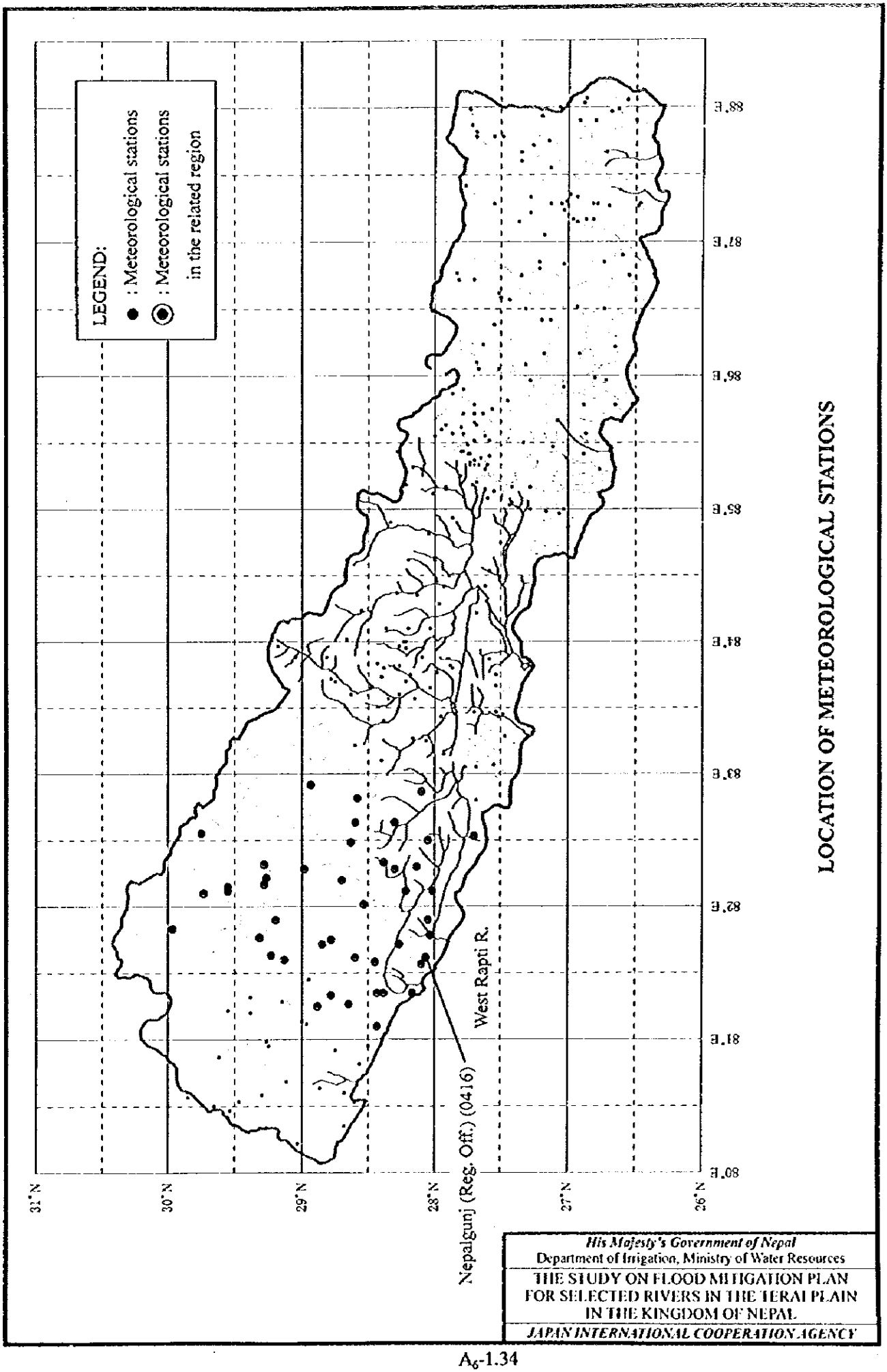
Fig. A1.3



LOCATION OF METEOROLOGICAL STATIONS

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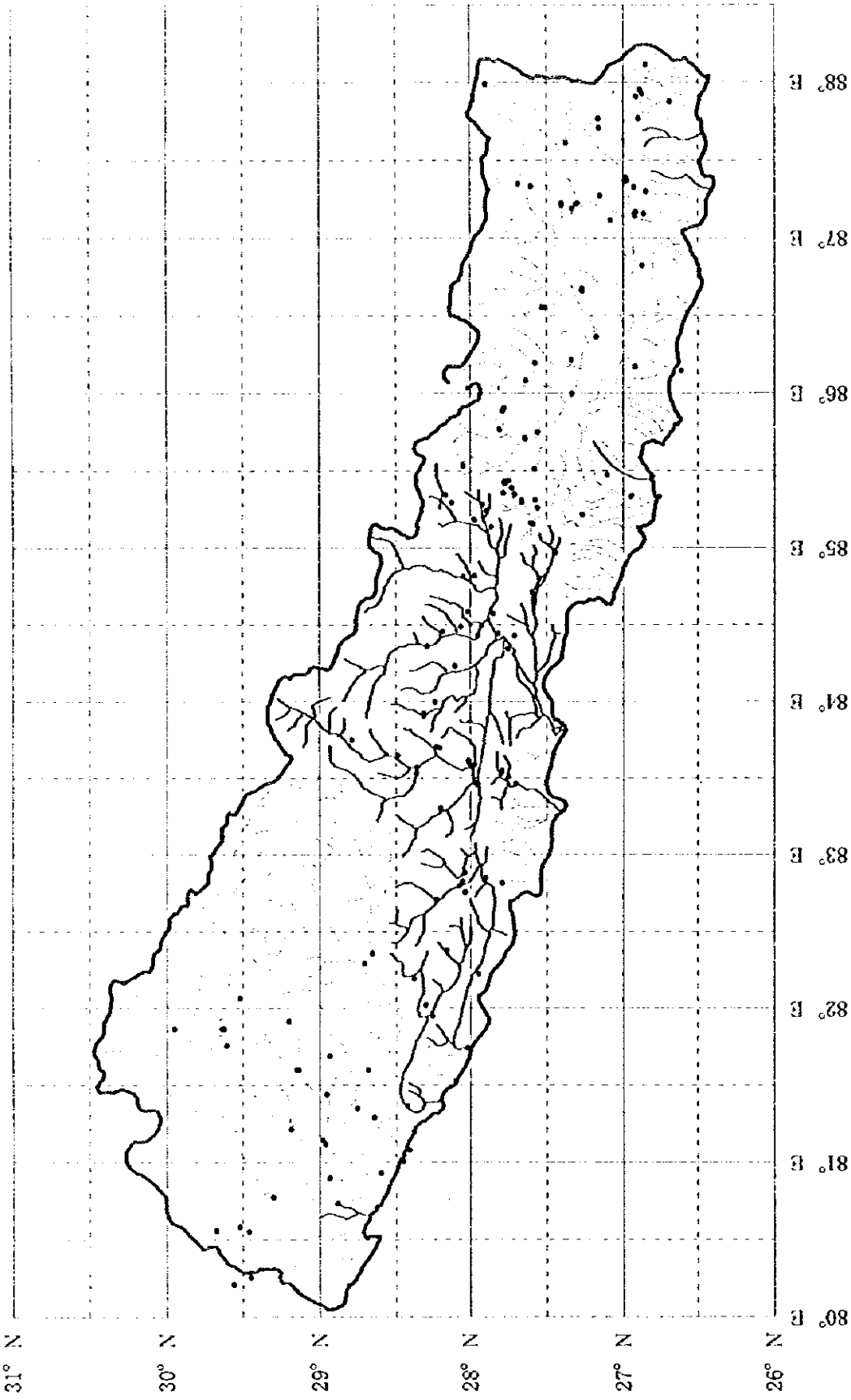
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



LOCATION OF HYDROMETRIC STATIONS

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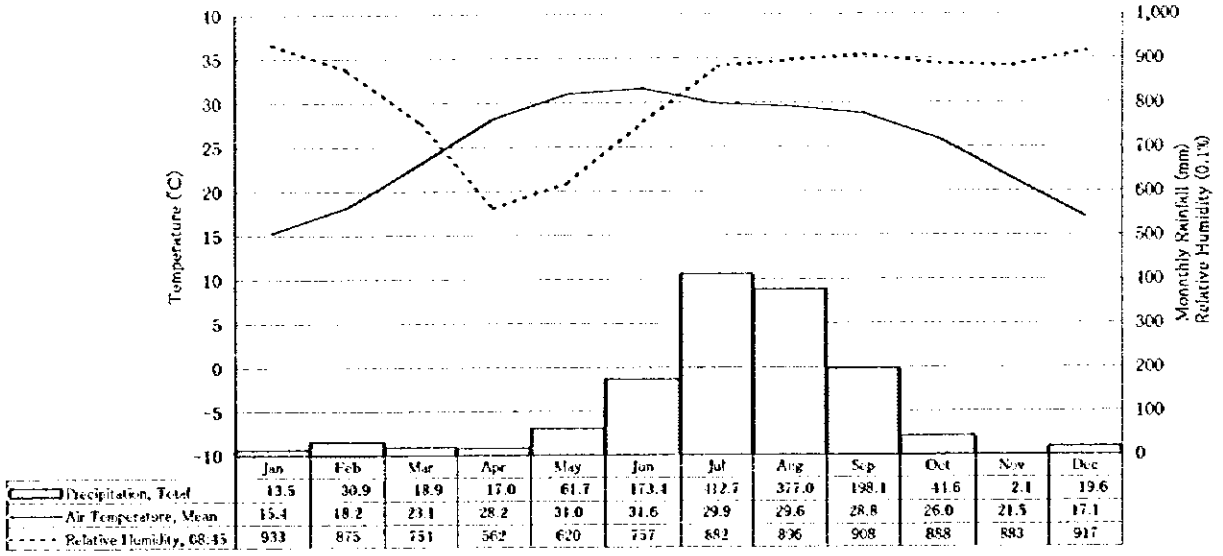
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY

Code: 0416
Station: Nepalgunj (Reg.Off.)

Latitude: 28°04'
Longitude: 81°37'
Elevation: 144 m

Nepalgunj (Reg.Off.) (0416)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation, Total	13.5	30.9	18.9	17.0	61.7	173.4	412.7	377.0	198.1	41.6	2.1	19.6
Air Temperature, Mean	15.4	18.2	23.1	28.2	31.0	31.6	29.9	29.6	28.8	26.0	21.5	17.1
Relative Humidity, 08:45	933	875	751	562	620	737	882	896	908	888	893	917

Air Temperature, Mean (Unit: °C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	15.8	17.9	24.6	29.5	32.0	31.6	29.1	29.7	28.1	25.3	21.1	17.3	25.2
1986	15.8	18.2	23.5	28.0	29.6	31.6	29.5	29.9	28.7	25.5	22.1	17.5	25.0
1987	16.5	20.8	24.3	28.4	30.0	33.7	29.6	29.6	29.3	26.2	21.2	17.1	25.5
1988	16.0	19.2	22.8	29.0	31.7	31.1	29.5	29.0	29.2	26.1	22.0	-	-
1989	14.4	16.6	22.5	27.5	31.6	29.9	29.4	29.4	28.6	26.4	21.2	17.1	24.5
1990	15.4	17.7	21.7	27.4	29.3	31.2	29.0	29.9	29.0	25.4	21.6	17.3	24.5
1991	14.8	19.0	23.6	28.0	32.5	31.6	30.8	29.5	28.8	26.1	19.8	16.3	25.0
1992	15.0	16.1	23.2	29.1	30.8	32.1	32.0	29.7	28.9	26.2	21.7	16.5	25.1
1993	14.0	19.4	21.4	27.5	30.5	31.1	30.1	29.6	28.5	26.8	22.7	18.0	25.0
1994	16.3	17.8	23.9	28.1	32.5	32.4	30.6	29.5	29.1	25.9	21.5	17.1	25.4
Ave.	15.4	18.2	23.1	28.2	31.0	31.6	29.9	29.6	28.8	26.0	21.5	17.1	25.0

Relative Humidity, 08:45 (Unit: %)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	92	84	65	49	54	72	87	87	90	89	87	92	79.0
1986	91	91	73	52	53	69	86	86	86	87	87	94	79.6
1987	92	86	72	55	57	65	89	87	87	88	88	91	79.8
1988	94	83	70	52	63	75	89	91	91	89	85	92	81.2
1989	93	84	78	48	55	82	89	90	94	93	91	92	82.4
1990	96	93	82	60	77	84	91	89	93	88	88	90	85.9
1991	93	84	78	60	62	77	85	91	92	86	90	92	82.5
1992	94	92	77	62	63	71	88	90	94	91	91	94	83.9
1993	95	89	77	67	77	84	92	94	92	90	92	91	86.7
1994	93	89	82	57	59	78	86	91	89	87	88	89	82.0
Ave.	93.3	87.5	75.4	56.2	62.0	75.7	88.2	89.6	90.8	88.8	88.3	91.7	82.3

Precipitation, Total (Unit: mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	5	2	0	4	37	218	295	481	447	157	0	11	1,657
1986	3	46	6	24	46	96	212	274	190	53	3	56	1,009
1987	4	24	0	31	102	58	684	139	196	48	0	8	1,294
1988	15	10	20	22	63	157	834	629	106	23	0	32	1,911
1989	45	20	27	0	47	133	613	269	268	58	12	19	1,511
1990	0	100	95	0	146	293	510	210	158	19	0	34	1,565
1991	13	26	10	25	29	112	174	453	132	0	0	36	1,010
1992	9	12	0	8	20	125	201	432	230	88	6	0	1,131
1993	8	4	31	56	90	427	369	557	196	0	0	0	1,738
1994	33	65	0	0	37	115	235	326	58	0	0	0	869
Ave.	13.5	30.9	18.9	17.0	61.7	173.4	412.7	377.0	198.1	41.6	2.1	19.6	1,370

METEOROLOGICAL CONDITIONS

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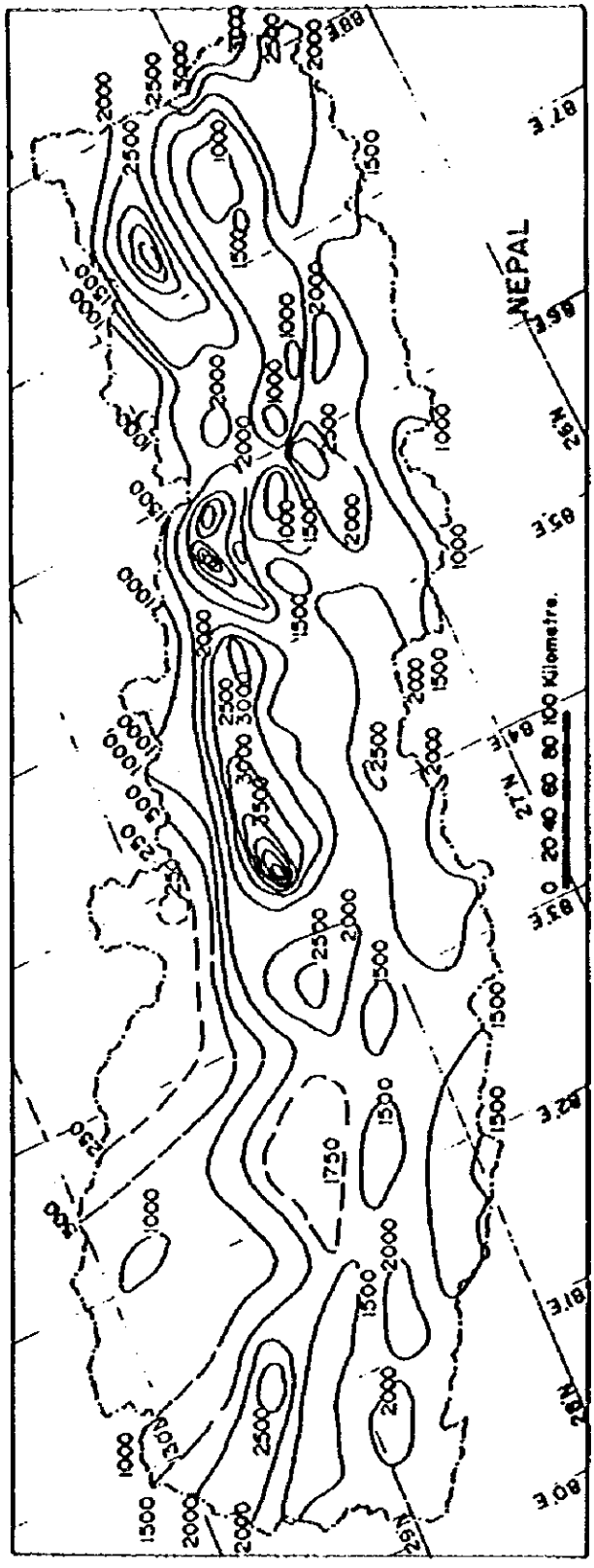
MEAN ANNUAL PRECIPITATION (mm) 1971-1985



Source: Natural Hazards and Man Made Impacts in The Nepal Himalaya, C.K.Sharman, 1988

ANNUAL RAINFALL
DISTRIBUTION OF NEPAL

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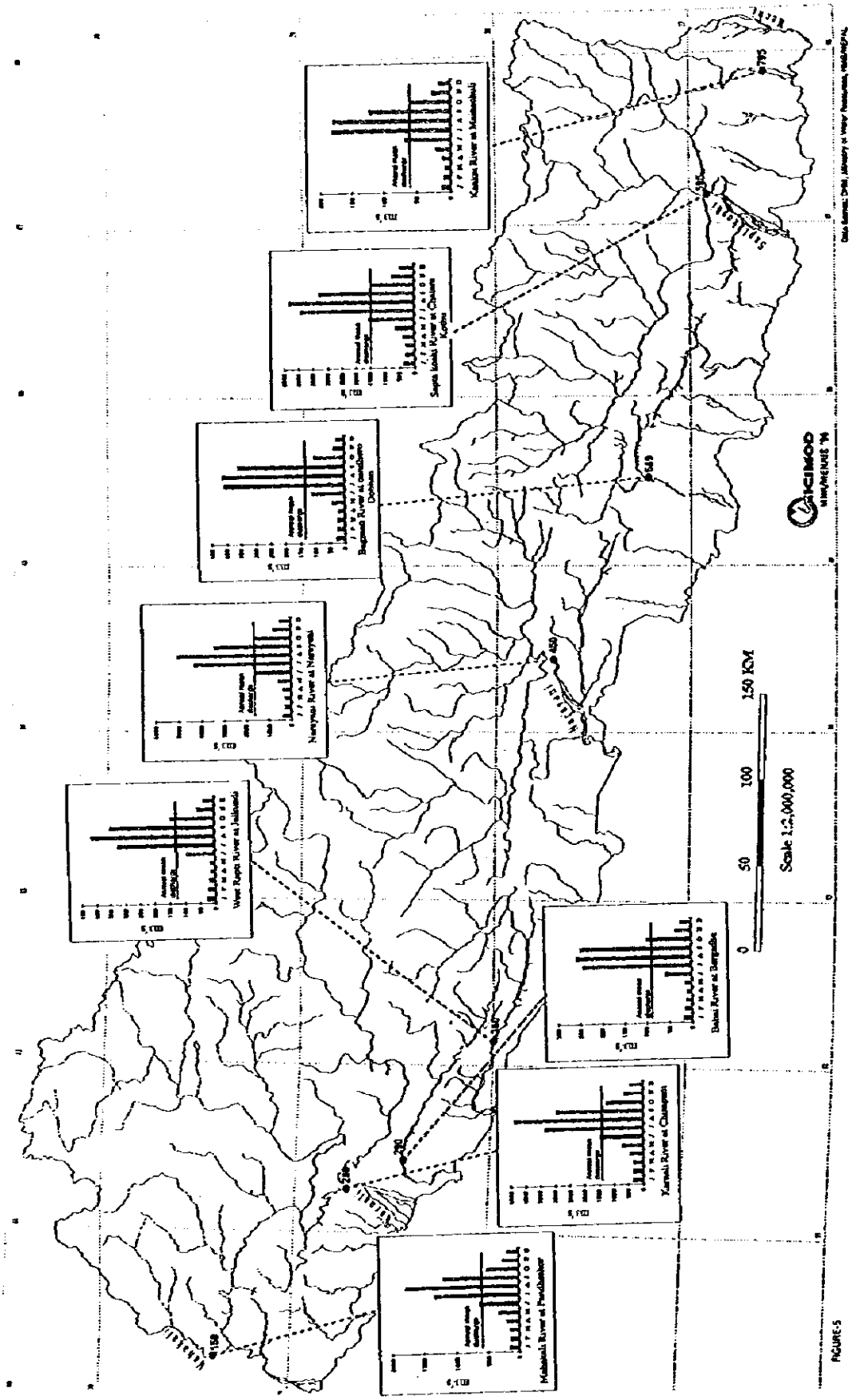

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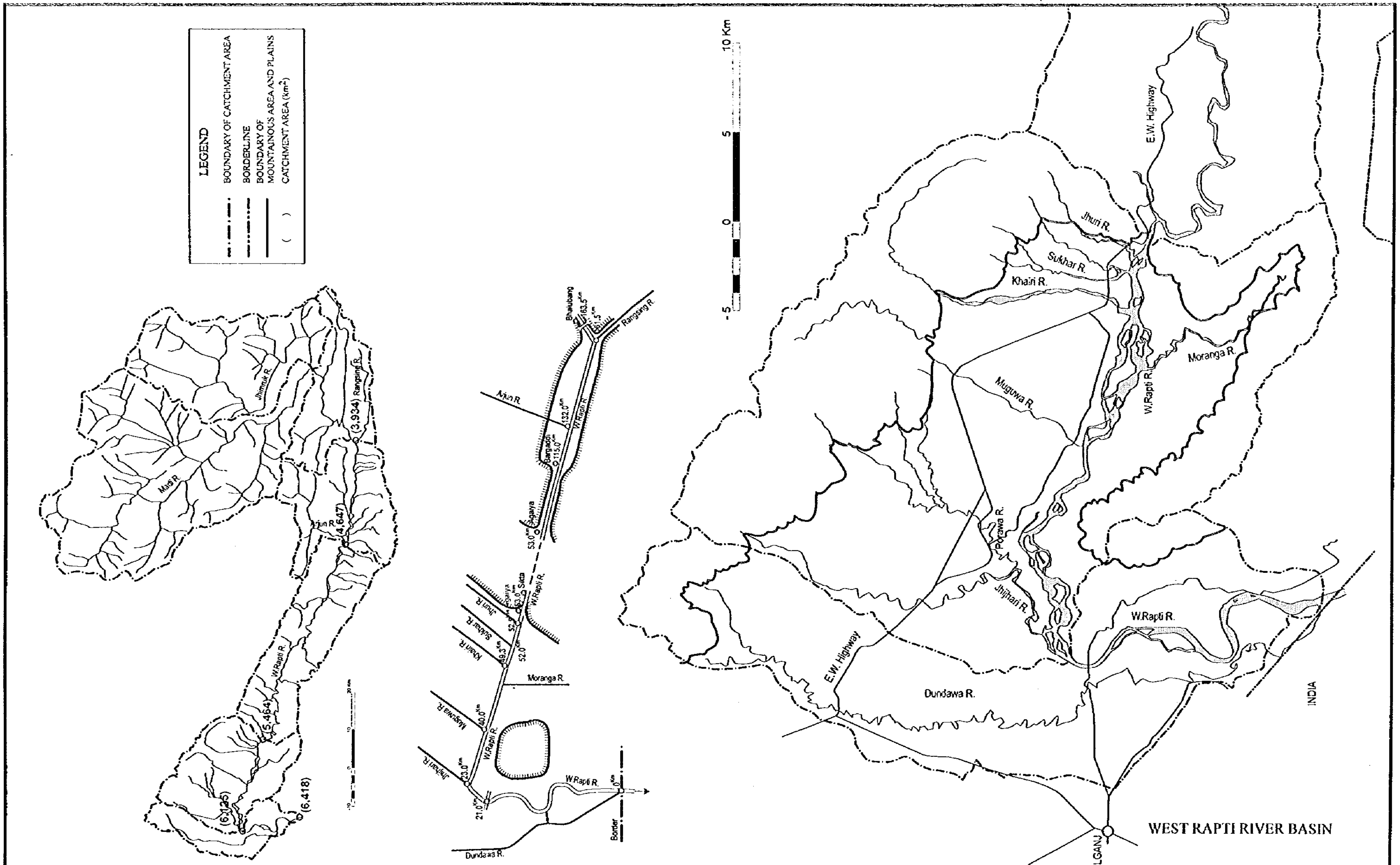
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



WEST RAPTI RIVER BASIN

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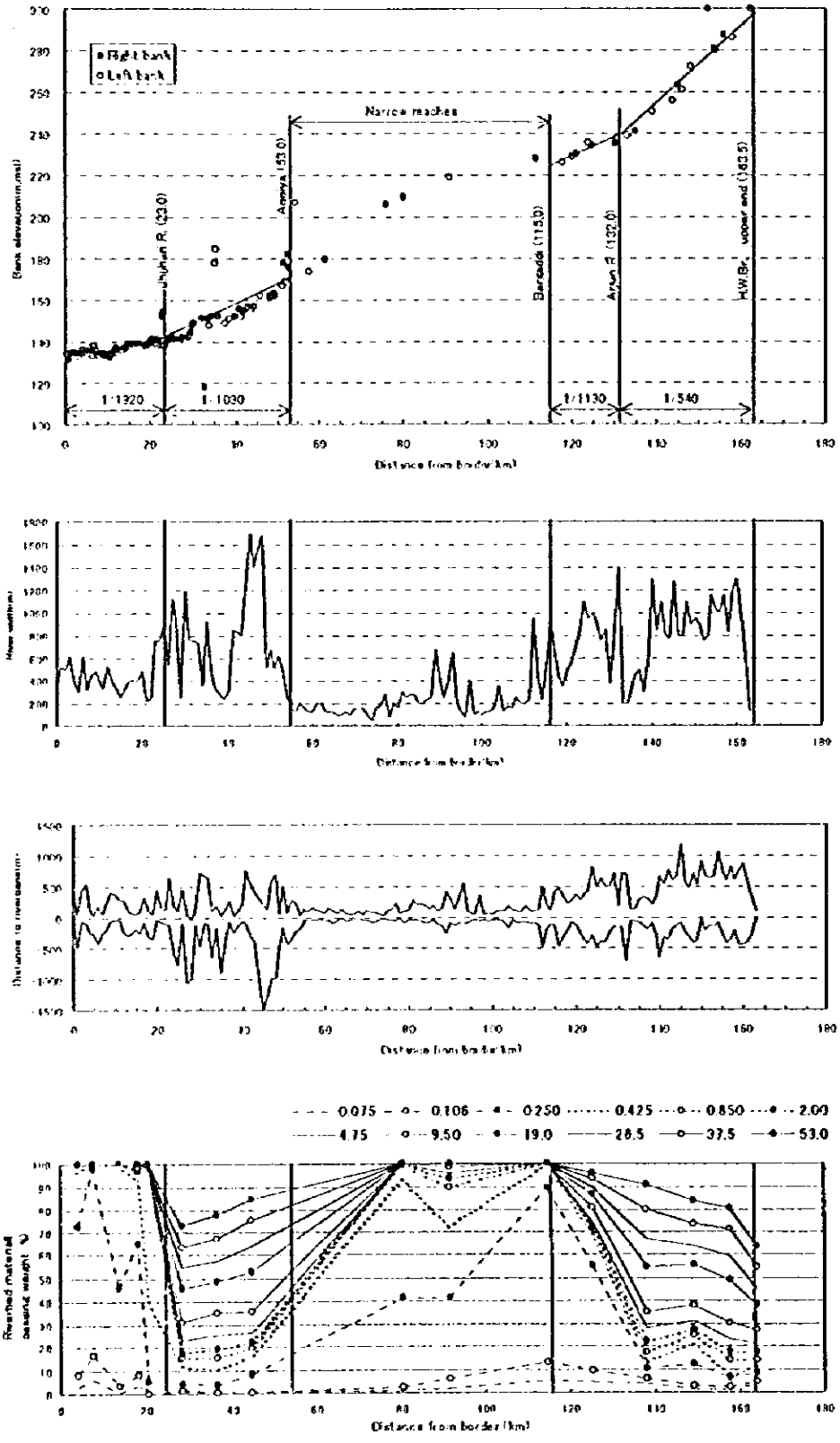
WEST RAPTI RIVER



0.075 — 0.106 — 0.250 ····· 0.425 — 0.850 — 2.00
4.75 — 9.50 — 19.0 — 26.5 — 37.5 — 53.0

CHARACTERISTICS OF EXISTING CHANNEL

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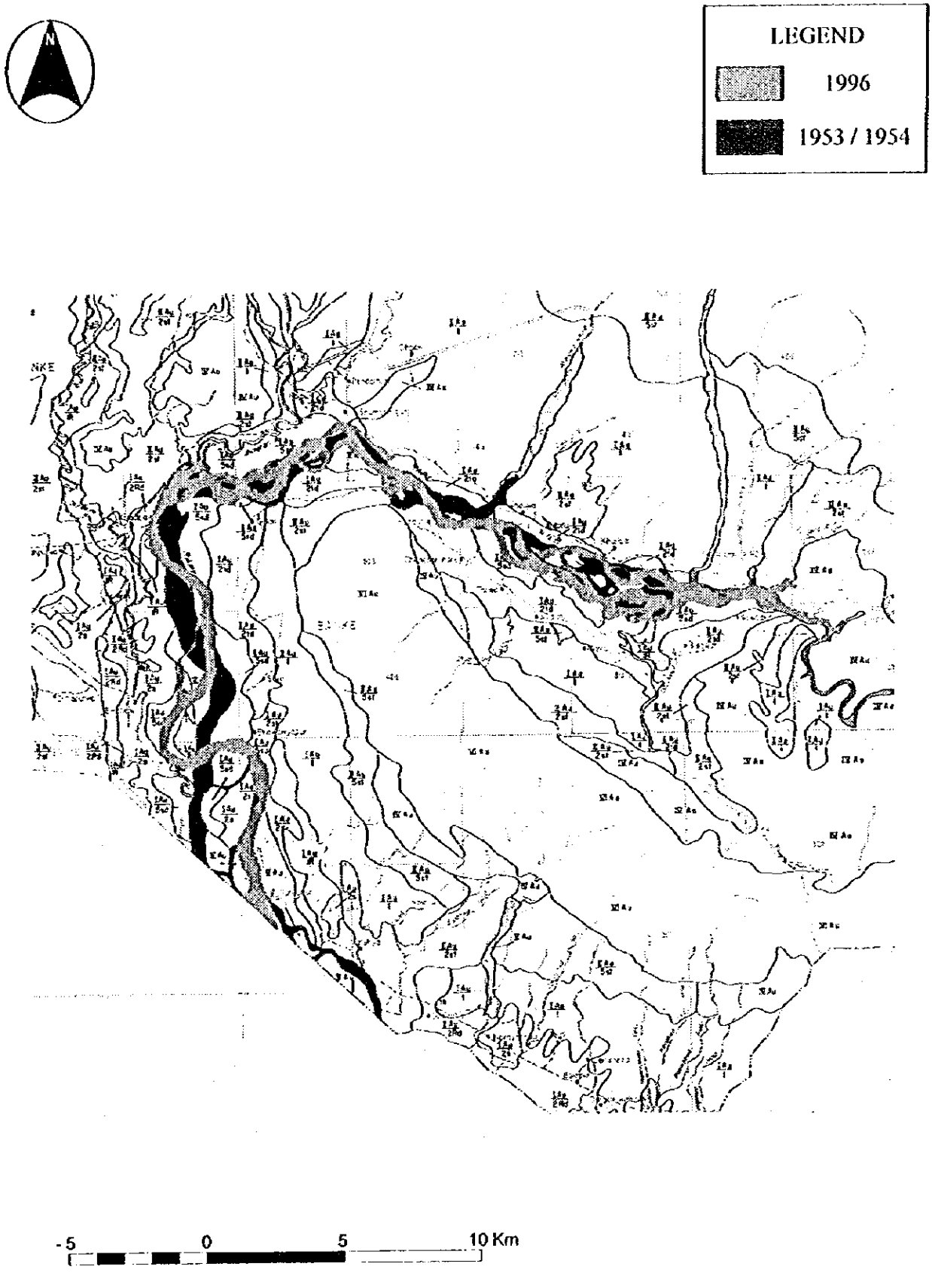
JAPAN INTERNATIONAL COOPERATION AGENCY



CHANGE OF WEST RAPTI RIVER COURSE

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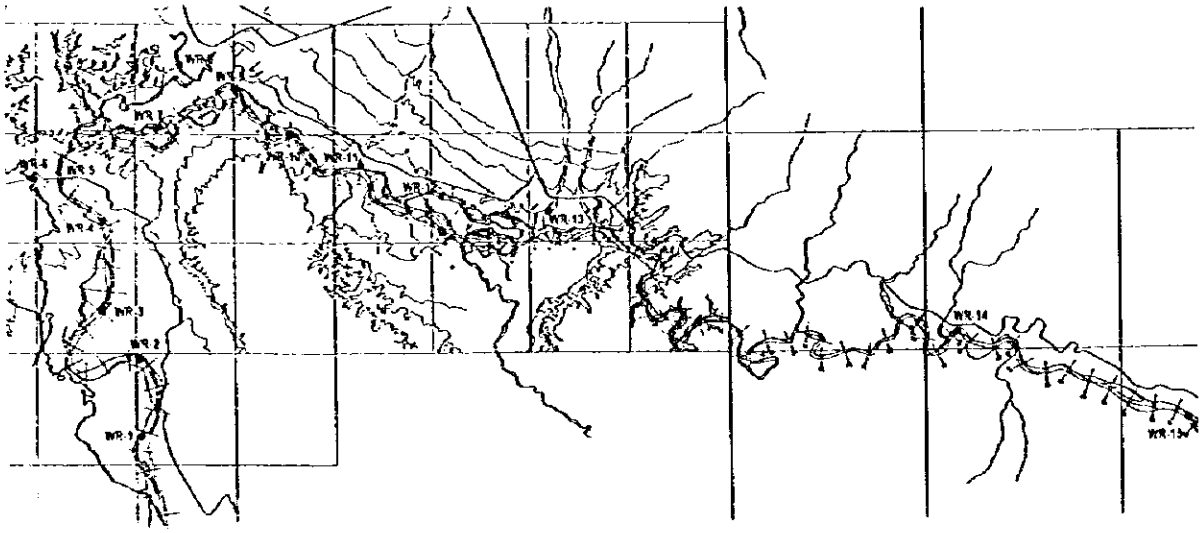
JAPAN INTERNATIONAL COOPERATION AGENCY



SN	Sample code	Soil classification by eye	Description of sampling place	GPS Reading N	GPS Reading E	FGA (Y/N)
1	WR-1	Fine sand		27°58.593'	81°43.786'	N
2	WR-2	Fine sand with silt		28°00.278'	81°43.284'	N
3	WR-3	Fine sand with silt		28°01.125'	81°43.548'	N
4	WR-4	Fine sand with silt		28°02.974'	81°44.172'	N
5	WR-5	Fine Silt		28°03.777'	81°43.171'	N
6	WR-6	Silty sand		28°04.019'	81°42.329'	N
7	WR-7	Mixed gravel		28°05.269'	81°45.811	Y
8	WR-8	Fine to medium sand		28°06.711'	81°46.023'	N
9	WR-9	Fine sand		28°06.175'	81°47.510'	N
10	WR-10	Mixed gravel		28°04.947'	81°49.110'	Y
11	WR-11	Mixed gravel(Large size)		28°04.733'	81°51.026'	Y
12	WR-12	Mixed gravel(Medium size)		28°03.496'	81°52.900'	Y
13	WR-13	Mixed gravel(Large size)		28°03.328'	81°55.593'	Y
14	WR-14	Fine sand		28°00.480'	82°05.914'	N
15	WR-15	Medium to fine sand		27°58.510'	82°11.866'	N
16	WR-16	Fine sand and silt		27°53.537'	82°21.447'	N
17	WR-17	Mixed gravel		27°51.824'	82°26.679'	Y
18	WR-18	Mixed gravel		27°53.041'	82°30.540'	Y
19	WR-19	Mixed gravel(Medium sand)		27°50.501'	82°32.105'	Y
20	WR-20	Mixed gravel with loosed medium sand		27°49.440'	82°38.256'	Y
21	WR_21	Mixed gravel(Medium)size		27°49.506'	82°43.059'	Y
22	WR-22	Mixed gravel with sand (Large size)		27°50.420'	82°46.157'	Y
23	WR-23			27°48.657'	82°45.881'	Y

SAMPLING SITES OF RIVERBED MATERIALS (WEST RAPTI RIVER)

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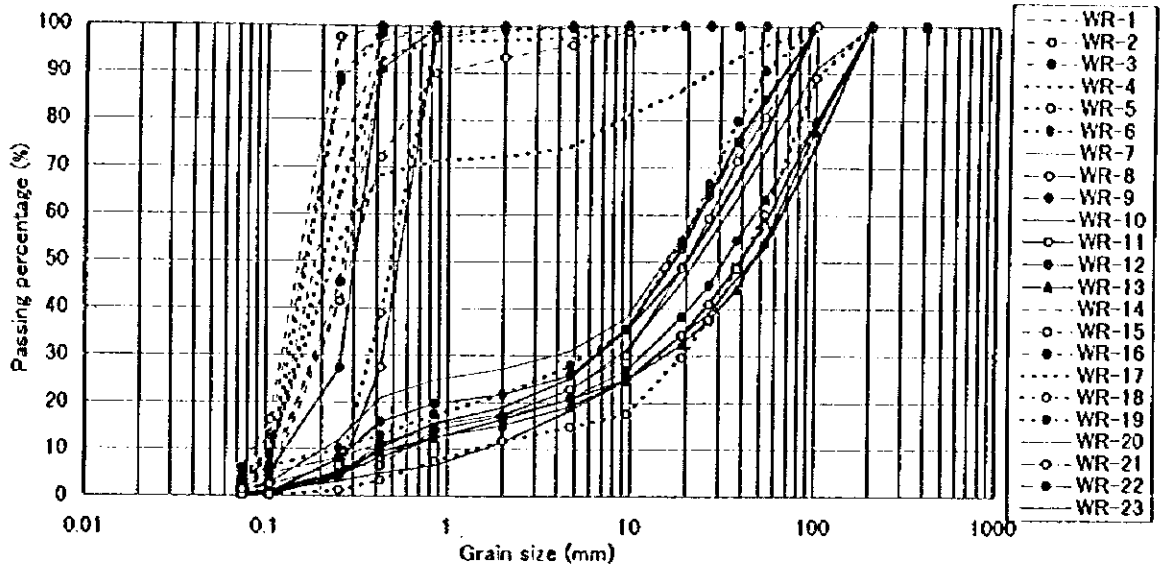

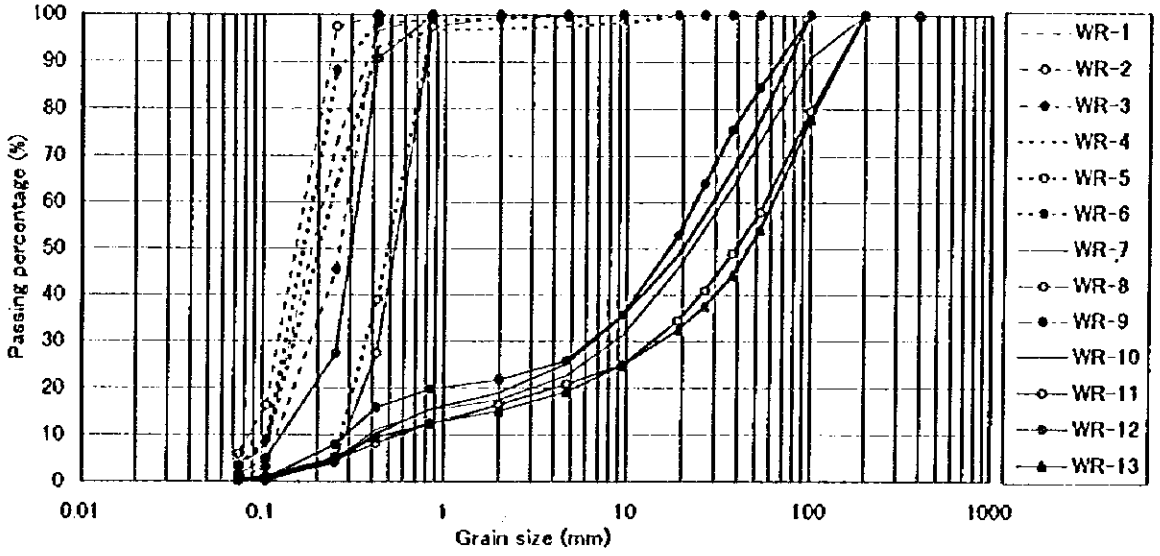

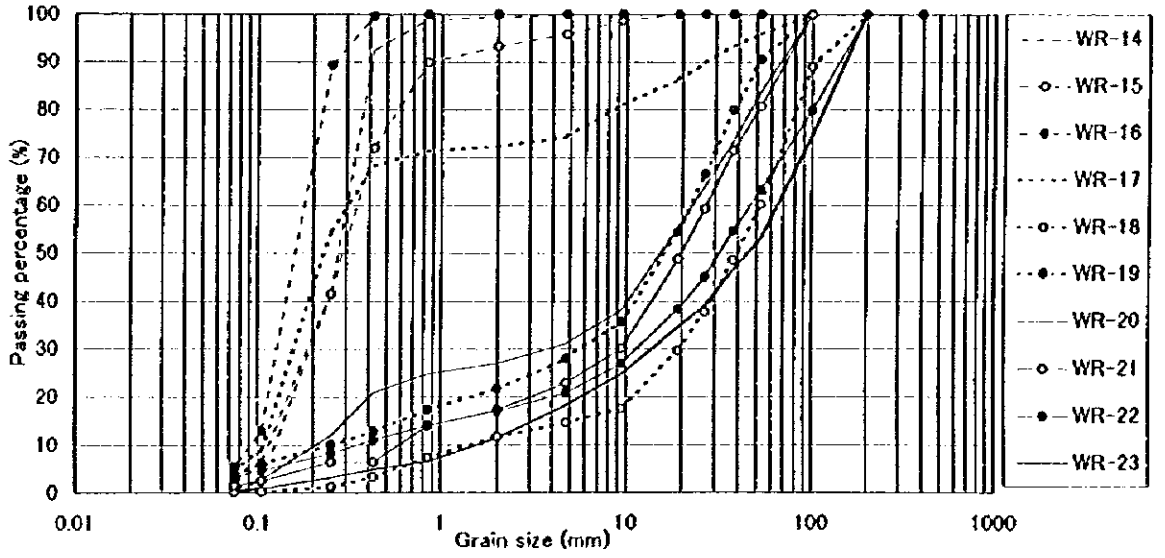

GRADING CURVES OF RIVERBED MATERIALS (WEST RAPTI R.)

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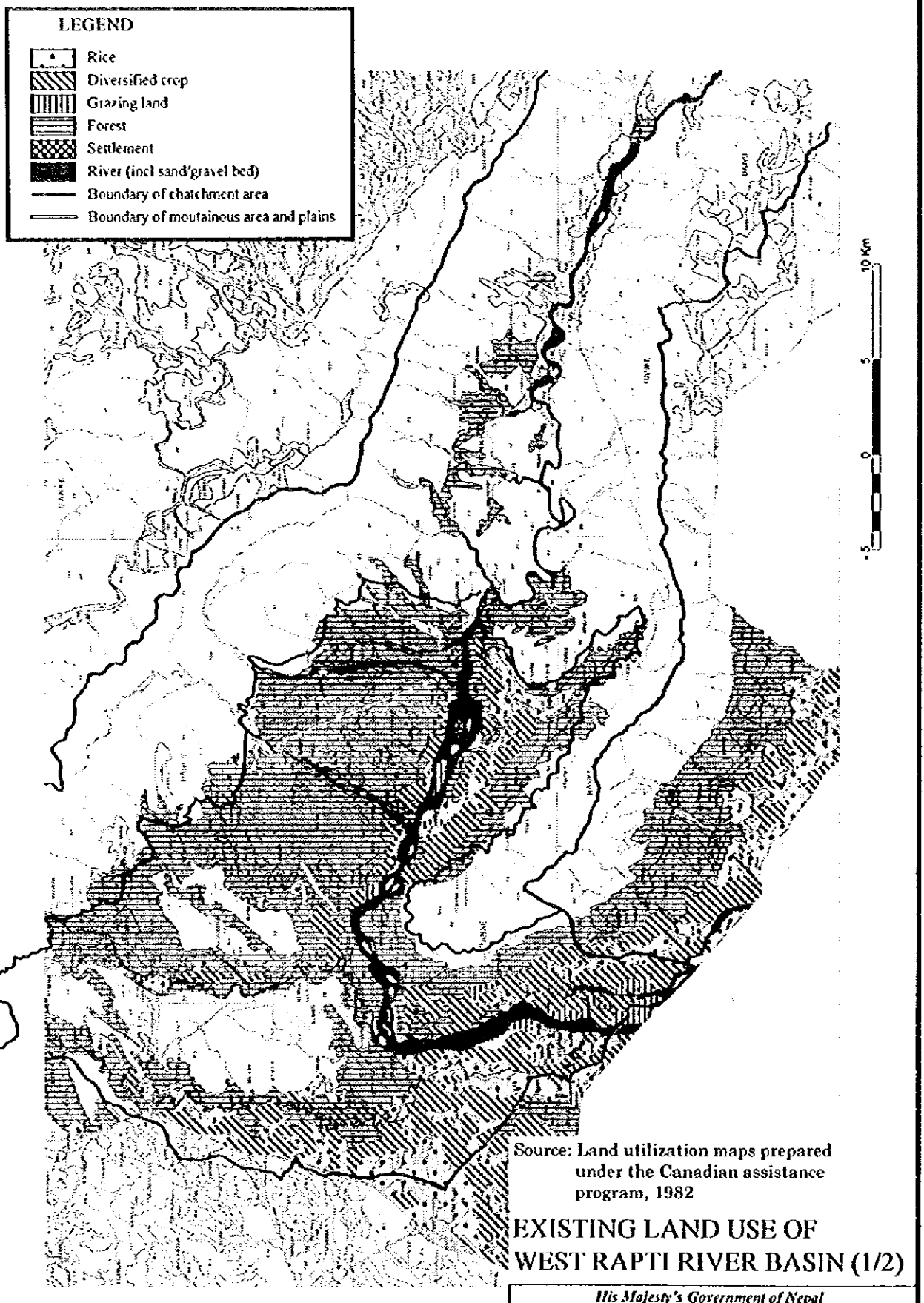

Source: Land utilization maps prepared under the Canadian assistance program, 1982

EXISTING LAND USE OF WEST RAPTI RIVER BASIN (1/2)

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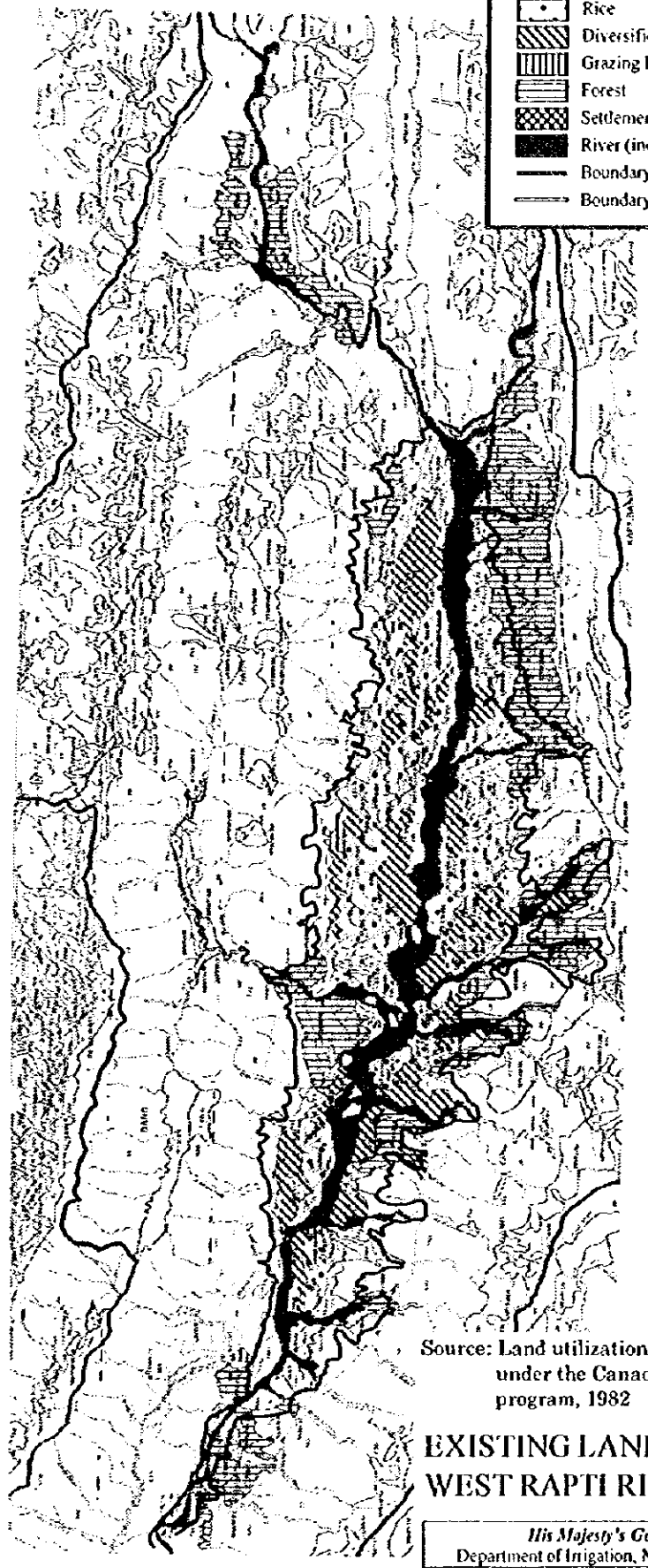

Source: Land utilization maps prepared under the Canadian assistance program, 1982

EXISTING LAND USE OF WEST RAPTI RIVER BASIN (2/2)

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THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

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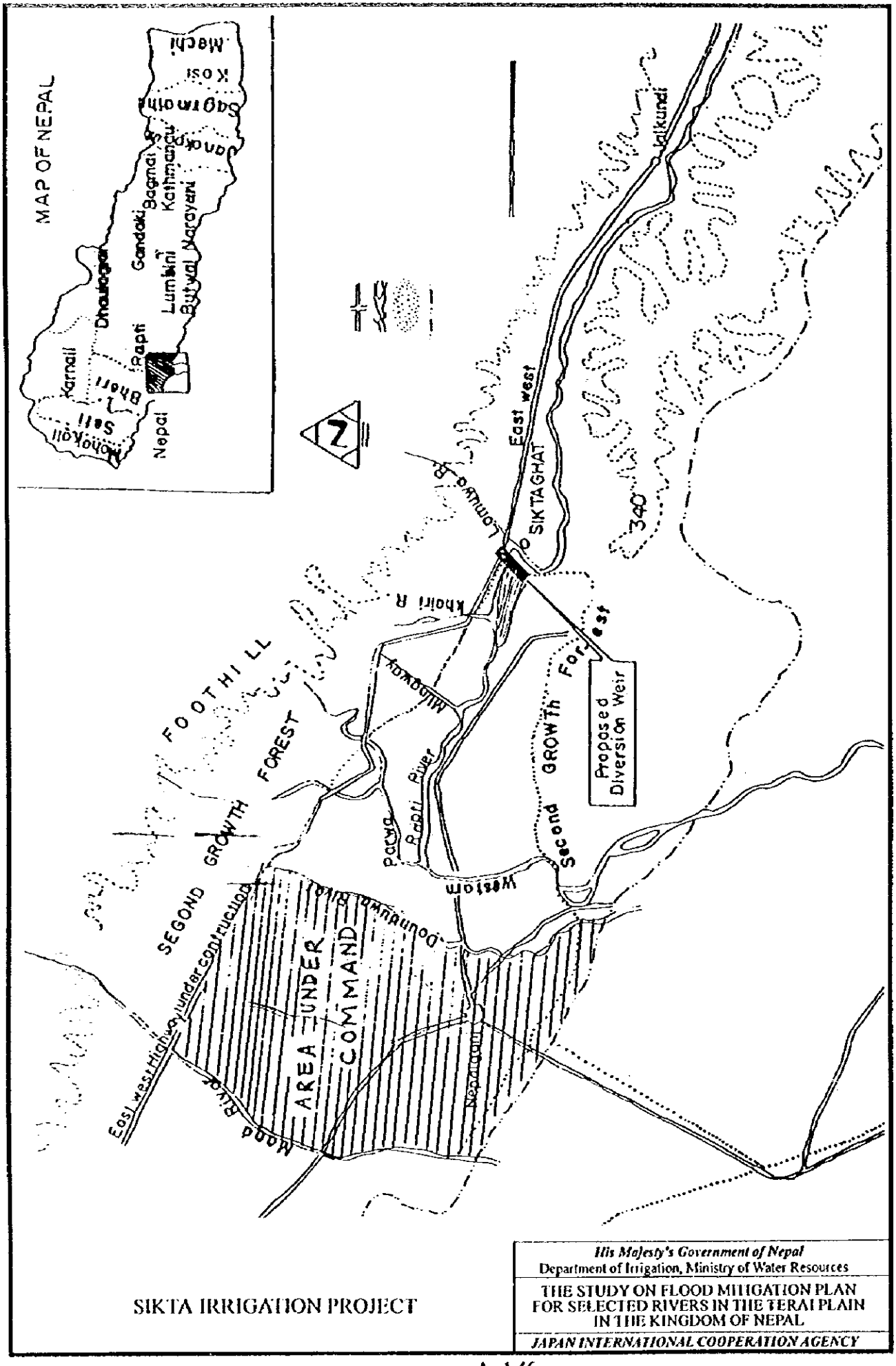
Fig. A1.14



SIKTA IRRIGATION PROJECT

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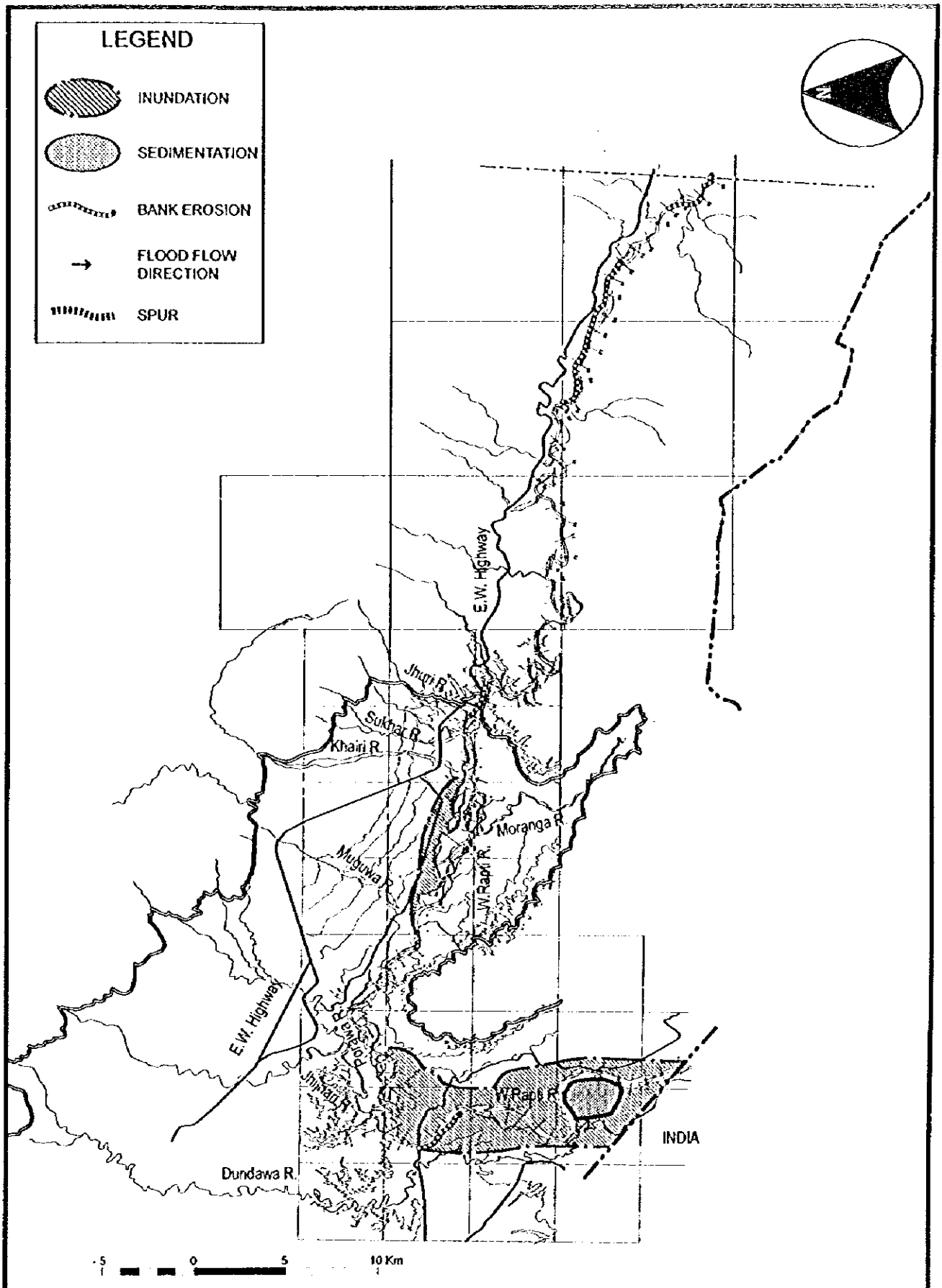
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



FLOOD SUFFERING AREA
(WEST RAPTI RIVER 1/2,1995)

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THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

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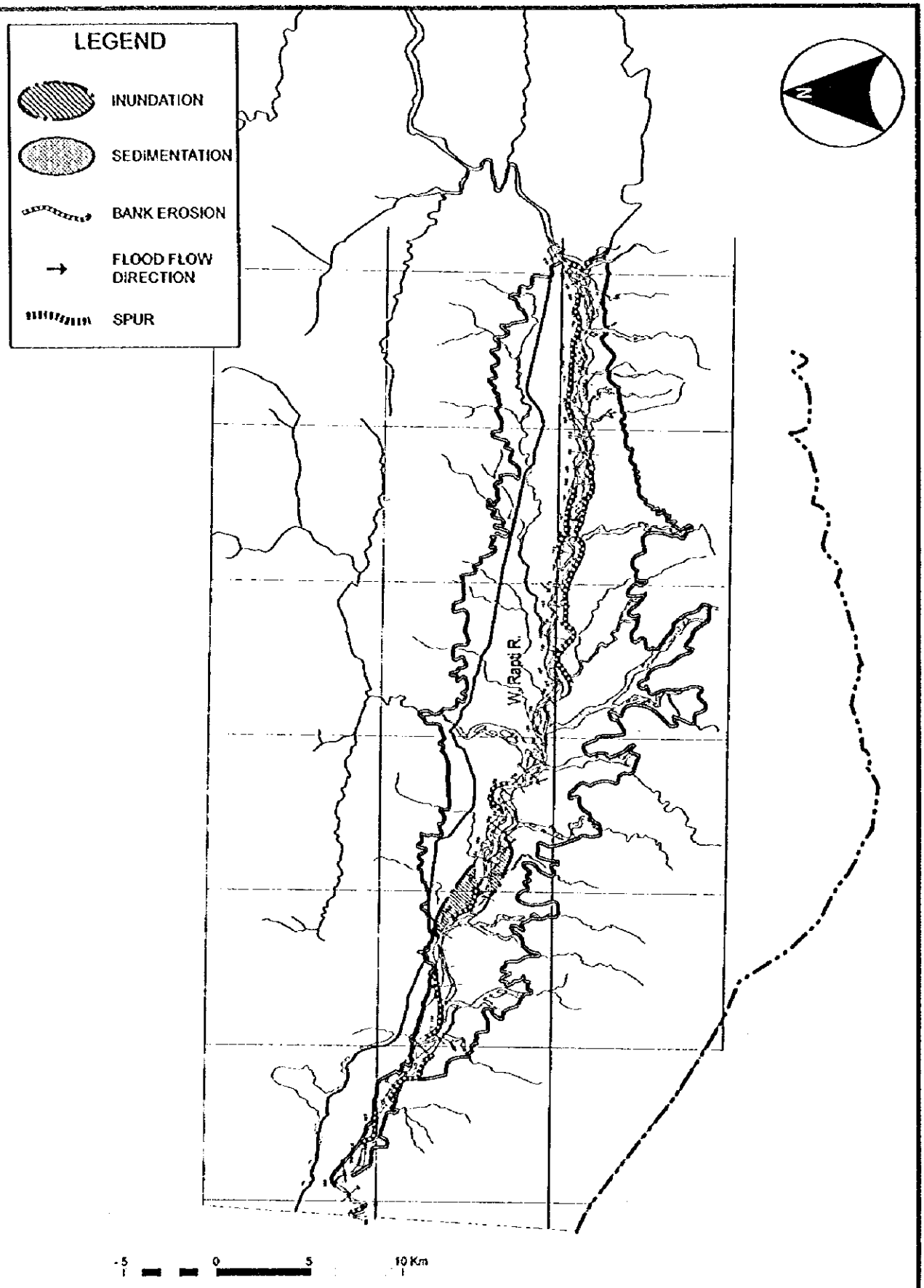

FLOOD SUFFERING AREA
(WEST RAPTI RIVER 2/2,1995)

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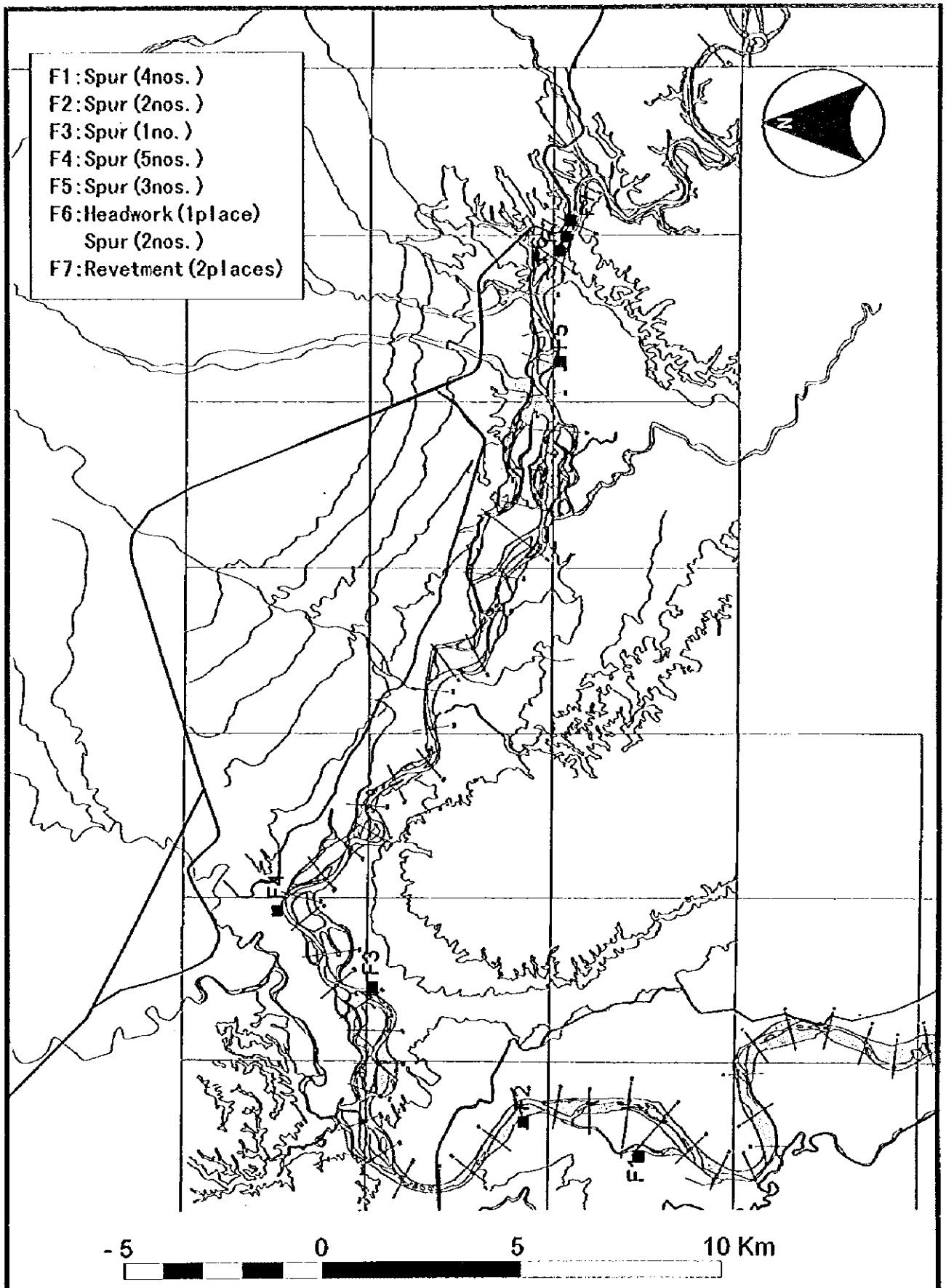

LOCATIONS OF RIVER FACILITIES

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THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

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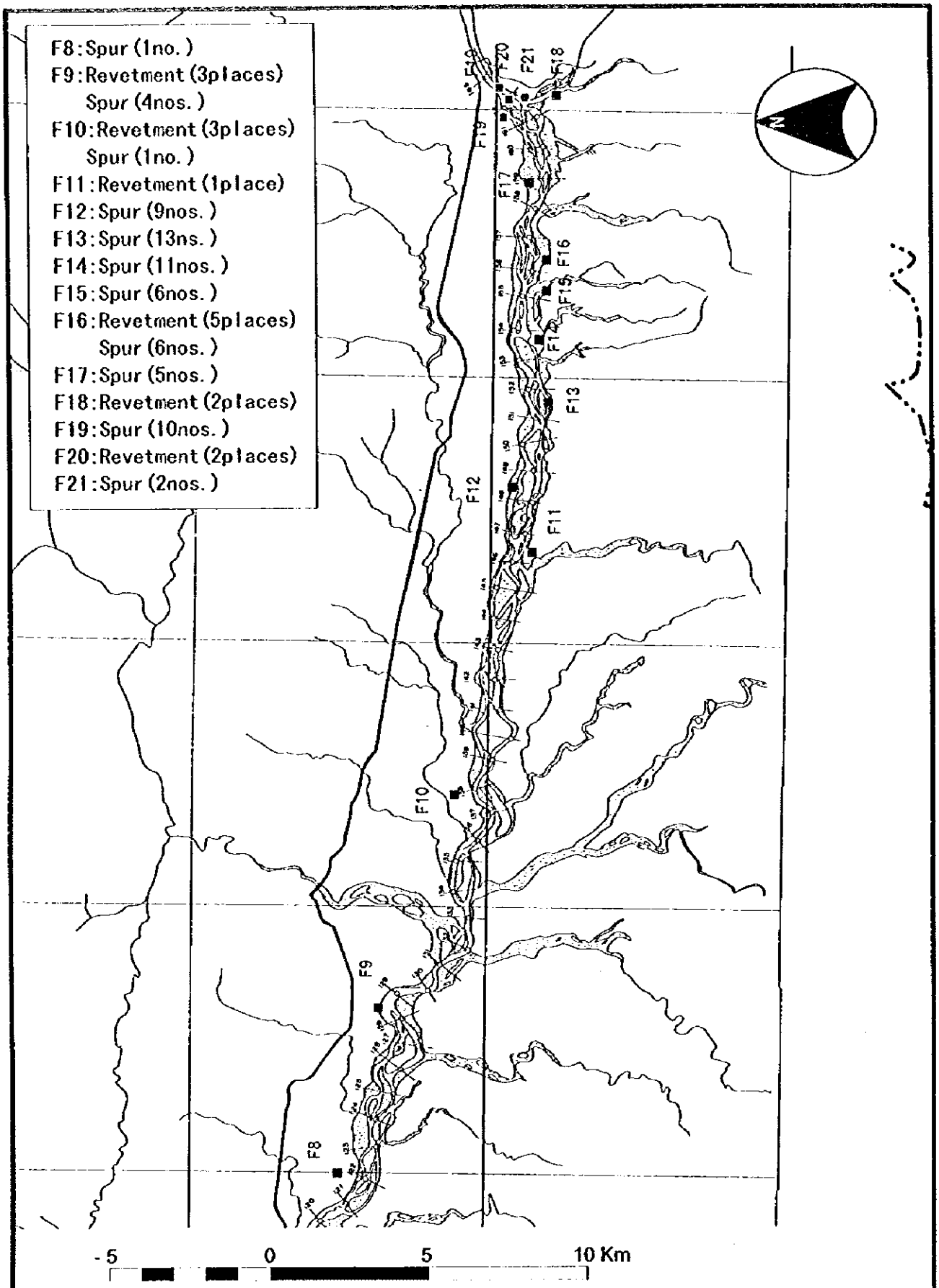

LOCATIONS OF RIVER FACILITIES

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TYPICAL RIVER FACILITIES

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