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 (5/9)

SUPPORTING REPORT

(A5: FMP/TINAU RIVER)

MAY 1999

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

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FINAL REPORT

VOLUME I : EXECUTIVE SUMMARY

VOLUME II : MAIN REPORT

VOLUME III : SUPPORTING REPORT

- A1: FLOOD MITIGATION PLAN/RATUWA RIVER
- A2: FLOOD MITIGATION PLAN/LOHANDRA RIVER
- A3: FLOOD MITIGATION PLAN/LAKHANDEI RIVER
- A4: FLOOD MITIGATION PLAN/NARAYANI RIVER
- A5: FLOOD MITIGATION PLAN/TINAU RIVER
- A6: FLOOD MITIGATION PLAN/WEST RAPTI RIVER
- A7: FLOOD MITIGATION PLAN/BABAI RIVER
- A8: FLOOD MITIGATION PLAN/KHUTIYA RIVER
- B : OVERALL DESCRIPTION OF STUDY AREA
- C : BASIC INVESTIGATIONS AND STUDIES
- D : OTHER DOCUMENTS

VOLUME IV : DATA BOOK

The costs are estimated based on the price and average exchange rate in October 1998.

The average exchange rate is as follows:

US$ 1.00=NRs.67.93

¥ 1.00 =NRs.0.59

A5. FLOOD MITIGATION PLAN:

TINAU RIVER BASIN

SUPPORTING REPORT
A5. FLOOD MITIGATION PLAN: TINAU RIVER BASIN

TABLE OF CONTENTS

(page)

LIST OF TABLES

(page)

LIST OF FIGURES

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 Tinau river basin falls under the topographical and geological zones of Mahabharat range, Siwalik hills and Terai plain. Principal features of these zones are presented below.

(1) Mahabharat Range

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.

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 is 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) 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.

(4) Tinau River Basin

The Tinau river flows into the Terai plain across the Siwalik hills. The Tinau river originates near Tansen where the main boundary thrust is located. This area is formed with boulder conglomerate and unconsolidated sediments including cobble, pebble and sand. Hence debris flow often occurs in this area after the heavy rain and deposits much boulder and cobble in the valley. Much cobble, pebble and coarse sand are found on the riverbed near Butwal which is located at the outlet from the mountainous area. The Dano river, a major tributary of the Tinau, receives sediment from the Siwalik hills.

Geological map of the Tinau 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 in 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 hydrometric stations in the Western Development Region is shown in Tables A1.1 and A1.2, and their locations in Figs. A1.3 and A1.4.

1.2.2 Meteo-Hydrological Features of Basin

Climate of Tinau river basin falls under monsoon subtropical zone (Terai plain and Siwalik hills) and temperate zone (Mahabharat range). 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 Tinau river basin. Figure A1.5 shows the meteo-hydrological features of the basin based on the monthly average data at Bhairhawa airport (sta. code: 0705).

(1) Temperature

Altitude affects much the temperature. The annual average temperature is 24.7℃, ranging from 15.5℃ in the coldest month to 30.5℃ 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 79.6%, ranging from 50.7% in April to 95.5% 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 Bhairhawa airport is 1,602mm on average ranging from 1,182 to 2,129mm depending on the year. The maximum rainfall is 2,129mm in 1988. The 84% of annual rainfall is concentrated in rainy season from June to September.

(4) Runoff

There exist a hydrometric station in the Tinau river. However the data are not made public.

Although the hydro-metric records such as water level and discharge are not available for this river basin, the following runoff characteristics are presumed from the rainfall and topographic features of the basin:

1) Runoff concentrates in monsoon season. The discharge in the driest months is

low but perennial throughout the year.

2) Flood hydrograph would be very sharp with high peak discharge, since several tributaries of similar sizes join near the outlet from the mountainous basin. The runoff duration would be one or two days.
3) The main Tinau river drain rainwater from Mahabharat range and the Dano river, a tributary of the Tinau, receives runoff from the Siwalik hills.

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 Tinau is a class-II river rising in the lesser Himalayan mountain range with a length of 230 km. Once it reaches the Terai plains its length to the border with India is about 60 km. Close to the border, the Dano river joins the Tinau. In the upper reaches of the Terai the Kanchan river joins the Dano. It has a basin area of some 1,081 km^2, (108,100 hectares) of which 412 km^2 (41,200 ha.) are in the Terai.

According to the Inventory of Wetlands in the Terai, (IUCN 1996), there are three wetlands in the vicinity of the Tinau and Dano rivers. These are the Tinau floodplain, (No. 89 in the IUCN book), the Dano floodplain (No. 90 in the IUCN book) and the Gaindhawa tal [lake] (No. 97 in the IUCN book).

The Tinau floodplain extends over 5,700 ha. Its major tree flora is *Dalbergia sissoo, Terminalia tomentosa, Acacia catechu, Ficus glomerata* and *Bombax ceiba*. The principal ground species are *Clenodendrum visuasum, Cynodon dactydon, Ipomoea fistulosa* and *Saccharum spontaneum*. This wetland is an important feeding and breeding ground for several aquatic birds including *Grus antigon*, (sarus crane), *Egretta alba, Ciconia nigra, Ibidorhyncha struthensii, Sterna albifrons*, and *Nettapus coromandelianus*.

The Dano floodplain covers 2,800 ha. with a similar tree flora to the Tinau floodplain. The embankment to the floodplain consists of *Xanthium stumarium, Calotropis gigantea, Clerochordrum viscesus, Tridax procumbens* and *Croton sparailorus.* It is an important breeding ground for the sarus crane. In addition to the aquatic birds mentioned above, there are the following birds, *Hydrophasianus chirurgus, Alcedo atthis, Gallinula chloropus, Bubo nipalensis, Dendrocygna javanica* and *Ardea cicenea.*

Gaindhawa is a small lake of about 50 ha. The water is covered with *Lemma spp., Nymphaea stellata* and *Azolla imricata,* with the margins growing *Ipomoea fistulosa, Saccharum spontaneum* and *Imperata cylindrica.* This wetland is an important winter ground for several waterfowl species. Rare species such as *Sarkidiornis melanotos, Myceteria leucocephala and Platalea leucorodia* have been recorded on this lake. Ten species of fish occur in this lake.

Agriculture is the main land use system accounting for an estimated 80% of the area, with tree cover a further 17%. The river flows through 15 village development committee areas (VDC) of Rupandehi district. The estimated population is about 166,000, (30,000 households). The existing land use and population density of the Tinau river basin in the Terai is shown below.

(Land Area, Land Use and Population:1998)

Items	Agri-culture	Forest	Barren/ sand	Other	Total	Population
Area (ha)	33,170	7,120	690	220	41,200	(166,000)*
Ratio (%)	80.5	17.3	1.7	0.5	100	(4.0)**

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

Every year, sand, silt and/or floodwater on average covers on average about 3,000 hectares of which about 580 ha. are covered with sand and soil. Some of this soil cover is a result of human activity, especially in the Siwalik 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 Tinau river flows in Rupandei district. According to the district data, agricultural and forestland makes up 87.3% of the total plain area.

unit: hectare

District	Agriculture	Forest	Sand/Gravel /Boulder	Others
RUPANDEI	97,456 80.5%	20,926 17.3%	2024 1.7%	660 0.5%
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 76.7% of the labor force is engaged in agriculture, as opposed to 4.9% in manufacturing and 11.5% in service sectors.

District	Agriculture Worker	Service Worker	Production Worker	Sales Worker and Others
RUPANDEI	130,583 76.7%	19,549 11.5%	8,385 4.9%	11716 6.5%
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: Rupandei district produces a wide range of crops, with major crops of paddy, wheat, pulses, and oilseed. These major crops 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
RUPANDEI	68,000 (1.72)	1,050 (1.72)	20,300 (2.00)	7,400 (0.69)	5,000 (0.69)	3,000 (32.0)	980 (11.31)
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 Rupandei district, 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. More than 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
RUPANDEI	99.3	86.4	1.59	1.08
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
RUPANDEI	11.9	78.7	9.6
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 Rupandei district is 522,000 as of 1991 with population growth rate of 3.2% (1981-1991). The population growth ratio was high during 1970s and, since then, it has gradually declined, just as the growth rate of many other Teri districts subsided.

The following table shows the population trends of the VDCs affected by Tinau floods. The 1981-91 population growth rate of the affected VDCs is 7.0%. This indicates that the population pressure is higher in the flood-risk VDCs, than other localities in Rupandei district.

Demographic Records of Flood-Prone VDCs:

District	VDC	1971	1981	1991	1996
Rupndehi	Shankar Nagar	-	-	9,466	11,081
	Anand Ban	6,243	10,705	6,894	8,070
	Hattibangi	-	-	5,278	6,178
	West Amuwa	3,276	7,739	6,870	8,042
	Motipur	2,805	8,489	5,601	6,556
	Harnaiya	1,525	-	3,089	3,616
	Sipawa	2,955	-	5,559	6,506
	Roinihawa	2,099	-	3,781	4,426
	Thuma-Piparhawa	2,000	-	3,181	3,724
	Bhagawappur	1,966	-	3,190	3,734
Total		22,869	26,933	52,909	68,651

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. Rupandei district (located in the Western Development Region) in the upper strata (19th among all 75 districts), compared with other nearby M/P target districts (e.g., Bardiya district ranked as 50th, and Banke district as 46th).

1.5 River and Basin Conditions

1.5.1 Principal Basin Features

The Tinau river basin extends from 27°15′N to 27°45′N and from 83°15′E to 83°45′E. The Tinau river originates in Mahabharat range and is classified as a class II river. Administratively it is located in Rupandehi district of Western Development Region.

Basin area of the Tinau river is 1081 km^2 in total, consisting of 669 km^2 of mountainous area and 412 km^2 of plain area. General basin maps of the Tinau river is shown in Fig. A1.7. The basin map was prepared based on the topographic maps of scale 1/25,000. Boundaries of the river basin and sub-basins were drawn on the basin map. Basin boundary in the irrigation canals, road networks and other ground objects.

Notable features of the Tinau river basin are as follows:

1) The Dano river diverts from the Tinau near Butwal city and joins again at about 13 km upstream from the Indian border.
2) The main Tinau river convey floodwater and sediment from the Mahabharat ranges, and the Dano river transport those from the Siwalik hill and the Tinau river.
3) The flood prone area of the Tinau river is partly covered by the service areas of the Bhairahawa Lumbini Groundwater Project.
4) Butwal city is located in the riverine area near the outlet from the mountainous basin.

1.5.2 Characteristics of River Channel

Channel slope and width of the existing river are shown in Fig. A1.8 for the plain reaches. 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)
Tinau R.	II	59.5(57.7)	1/110~3180	100~940

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. A1.8. 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 1954 (scale: 1/50,000) and those in 1993 (scale: 1/25,000) were superimposed and shown in Fig. A1.9.

According to the figure showing river course change during the past 39 years, the following features are considered:

1) Meander of the main Tinau River below the Dano junction and the Dano river are rather severe.
2) Shifting of river course seems to remain within the meander belt in general.
3) It is said that the diversion discharge to the Dano river is gradually increasing.

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 Tinau river were sampled at 13 sites (Fig. A1.10) among which outdoor analyses were carried out at 8 sites.

Results of riverbed material tests are shown in Table A1.3 and the grading curves in Fig. A1.11.

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: All samples are from the main course of the Tinau river except for Ti-3 from the Dano river.
2) Grain size:
   - d_{60} = 0.18 to 0.63 mm (fine to coarse sand): downstream from Ti-5 site and Ti-3.
   - d_{60} = 3.17 to 34.35 mm (very fine gravel to very coarse gravel): downstream from Ti-12
   - d_{60} = 80.50 mm (small cobbles): Ti-13
3) Uniformity index: Riverbed materials are well-sorted and uniform in the downstream reaches from Ti-5 site and Ti-3 site (Dano R.).

- UI = 1.9 to 4.3: downstream from Ti-5 and Ti-3
- UI = 32 to 170: upstream from Ti-6

4) Specific gravity
   - SG = 2.65 g/cc on average ranging from 2.61 to 2.68 g/cc
5) Longitudinal distribution: Significant change in grain size is observed at two sections between (1) Ti-5 and Ti-6 sites, and (2) at Ti-7 site.

Based on the investigation result, grain size distribution along the river is shown in the Fig. A1.8.

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. A1.12 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

Bhairahawa Lumbini Groundwater Project

Project Composition: The Bhairahwa Lumbini Groundwater Project (BLGWP) comprises the following stages (Fig. A1.13):

1) Stage I: Covering a target area of 7680 ha net, which was implemented during the years 1978-1983. The actual cultivated control area (CCA) is 7235 ha.
2) Stage II: Consisting of 2 Phases, covering target areas of 1850 ha and 2750 ha

for Phase 1 and Phase 2 respectively, which were implemented during the years 1983/1991. The actual CCA for Phase 1 and 2 are 1218 ha and 2755 ha respectively.

3) Stage III: Covering a target area of 8600 ha the implementation of which started in 1991 and by now is nearing its completion which is scheduled for the end of June 1998. The actual C.C.A. is 8579 ha.

Beneficiary: The number of households that will benefit from the Project according to data complied at the initiation of Stage III in 1991 was 6,600, 4,100 and 7,000 for Stage I, II and III respectively.

Progress: Up to data the following have been accomplished on the three (3) stages of the BLGWP:

1) Stage I Area: 64 irrigation systems, consisting each of tube well, pump house, distribution chamber, open distribution canals and pertinent structures, have been constructed.
2) Stage II-Phase 1 Area: 16 irrigation systems, consisting of tube well, pump house, control chamber, distribution uPVC pipelines and pertinent structures were constructed.
3) Stage II-Phase 2 Area: 22 units have been constructed in this area, 12 in the northern zone and 10 in the southern zone.
4) Stage III Area: The area with an area of 8600 ha and was designed to comprise 79 units. All 79 tube wells have been drilled and 63 irrigation systems have been completed by now.

Low Land and Drainage: A considerable part of the BLGWP area consists of low land that poses restriction of cultivation. Out of the 181 drilled tube well approximately 40% or 65 units are serving areas comprising each up to 25% of low land.
(Source: Bhairahawa Lumbini Groundwater Project, Brief Present Status of BLGWP; Jan. 1998)

1.6 Vegetation and Sediment Yield in Watershed Area

(1) Climate and Vegetation Division

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

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.

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) northern 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.

(2) Land Use in Watershed Area

The land use of the watershed area of the Tinau river are worked out using the aerial photos taken in 1990 and topographic maps of 1/25,000 as follows:

(Land Use of Watersheds)

Land use	Area (ha)	Ratio (%)
Forest	33,831	61.5
Bush	2,481	4.5
Cultivation	17,683	32.2
Cliff	565	1.0
River	329	0.6
Urban	109	0.2
Total	54,998	100.0

(Remarks) Bush: Scrub, Bush, Grass & Bamboo, Cliff: Soil cliff, Rock cliff & Out crop of rock

Watershed of the Tinau river is located in the Mahabharat range, Siwalik hills and Dun valleys, and the vegetation is Hill Sal forest and Dun Sal forest.

Cultivated land shares higher ratio of 32% and forestland relatively lower ratio of about 62%. Cultivated lands are located on the plain lands developed in the bottom of valley and on the gentle slope lands of mountain ridge and mountainside as well. Bush land is 4.5% located on the steeper slopes adjoining the cultivated land. The bush land seems to be pastureland, fallow field or abandoned field.

Ratio of cliff land is 1.0%. Cliff lands are located at the central and southern part of the watershed, and are hardly seen in the northern part. Cliff lands distribute along WNW-SSE direction because of basin's geological structure. Many cliff lands are located on the southern slope forming a large scale Cuesta.

(3) Erosive Landform of Watershed Area

The drainage system and slope of watershed of the Tinau river are shown in Fig.A1.14 and Fig. A1.15. The drainage system and slope maps allow the interpretation of erosive landform characteristics of the watershed area.

The drainage density of the Tinau river is low in the Pokharathok valley located in the north-western watershed and mountainous area in the southern part, while the density is high in other part of watershed. The cultivated lands distribute widely on the north-western hills. The steep slope lands are mainly located in the central mountainous area in an east-west zonal pattern.

(4) Estimation of Sediment Yield

The sediment yield of the Tinau river is estimated by the soil erosion rate depending on the land use. The soil erosion rate was assumed mainly referring to the data of soil erosion rates of the Ratu river.

(Estimation of Sediment Yield: Tinau River)

Land use	Area (ha)	Erosion rate(mm/yr)	Yield(m^3/yr)
Forest	33,831	2	677,000
Bush	2,481	10	348,000
Cultivation	17,683	0.4	71,000
Cliff	565	20	113,000
River	329	0	0
Urban	109	0	0
Total/average	54,998		1,108,000

According to an investigation for the soil erosion rate, sediment yield in the disaster of 1993 has been estimated at about seven (7) times of that in an ordinary year. From this, it is anticipated that the sediment yield in disastrous year may amount to some ten times of the above value estimated for the ordinary year.

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 11 VDC/Municipality offices were selected for the investigation. Furthermore, a total of 107 residents in the flood prone areas were selected for the interview using questionnaire form.

Questionnaires to the residents are totaled and shown in Table A1.4. Almost every year the Tinau river floods over and causes damage in riverine villages and farmlands.

Floods in 1996, 1995 and 1993 are the biggest three during recent 10 years. The 1996-flood is the biggest and brought about epidemic disease such as cholera, dysentery, typhoid, etc. resulting in loss of 26 lives in the whole Rupandei district.

Sedimentation, bank erosion and flooding over farmland are the major types of disasters. Bank erosion and sedimentation over the riverine farmland are more serious. According to the data and information obtained from DDC and DIO of Rupandehi district areas

suffering from bank erosion and flooding are summarized as shown below.

(Areas Suffering from Bank Erosion and Flooding)

VDC	Village/Ward
Motipur	Raniguni, Hariharpur, Dhandapur, Saureiha
Sauraha Pharsatikar	Betahani, Betahi, Bashghari, Sakhuhani
West Amawa	Pragati Tole, Belautighari, Chamkipur, Bharthapur, Kanari
Harnaiya	Sitapur, Bhaisakhadar
Mainahiya	Gadsari, Semara, Murdhahawa, Sitapur, Bhagadari
Hatti Bangai	Marchahawa, Mahuwari, Bangai, Bairihawa, Barihawa, Bairiya,Gargatti
Sankarnagar	Dingarnar, Basghari
Anandaban	Jodeni, Gorkhatwa, Harpur, Paschimpahune
Sipuwa	Chhatraoura, Padarahawa, Sipuwa, Praspura, Bagadiya, Purnihawa, Tiwaripur, Narkataha, Gchugaun
Roinihawa	Bharwaliya, Chakkidhi, Roinihawa, Dhube Tghumawa
Thumwa Piparahawa	Piparahawa
Bhagawanpur	Lamtihawa, Ardauli, Bharatpur

Loss of life and damage to properties are shown in Table A1.5, mainly based on data during 1996-flood. According to the field investigation and interview of residents, flood-suffering areas during the 1996-flood are shown in Fig. A1.16.

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 : 77 sites
3) Revetment : 19 sites
4) Head work : 3 sites
5) Bridge : 2 sites

Location of these facilities is shown in Fig. A1.17. 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. A1.18.

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
				°	'	"	°	'	"			
0601	Jomsom	Climatology	W	28	47	00	83	43	00	2,744	07-1957	Narayani
0604	Thakmarpha	Agrometeology	W	28	45	00	83	42	00	2,566	12-1966	Narayani
0605	Baglung	Climatology	W	28	16	00	83	36	00	981	05-1969	Narayani
0606	Tatopani	Precipitation	W	28	29	00	83	39	00	1,243	05-1969	Narayani
0607	Lete	Precipitation	W	28	38	00	83	36	00	2,384	05-1969	Narayani
0608	Ranipauwa (M.Nath)	Precipitation	W	28	49	00	83	53	00	3,609	05-1969	Narayani
0609	Beni Bazar	Climatology	W	28	21	00	83	34	00	835	02-1956	Narayani
0610	Ghami (Mustang)	Precipitation	W	29	03	00	83	53	00	3,465	11-1972	Narayani
0612	Mustang (Lomangtang)	Climatology	W	29	11	00	83	58	00	3,705	09-1973	Narayani
0613	Karki Neta	Precipitation	W	28	11	00	83	45	00	1,720	02-1977	Narayani
0614	Kushma	Climatology	W	28	13	00	83	42	00	891	05-1969	Narayani
0615	Bobang	Precipitation	W	28	24	00	83	06	00	2,273	12-1977	Narayani
0616	Gurja Khani	Precipitation	W	28	36	00	83	13	00	2,530	12-1978	Narayani
0619	Ghorapani	Precipitation	W	28	24	00	83	41	00	2,742	03-1975	Narayani
0620	Tribeni	Precipitation	W	28	02	00	83	39	00		"	Narayani
0621	Darbang	Precipitation	W	28	23	00	83	24	00		"	
0622	Rangkhani	Precipitation	W	28	09	00	83	34	00		"	
0701	Ridi Bazar	Precipitation	W	27	57	00	83	26	00	442	07-1956	Narayani
0702	Tansen	Climatology	W	27	52	00	83	32	00	1,067	07-1956	Tinau
0703	Butwal	Climatology	W	27	42	00	83	28	00	205	07-1956	Tinau
0704	Beluwa (Girwari)	Precipitation	W	27	41	00	83	03	00	150	02-1957	Narayani
0705	Bhairhawa Airport	Agrometeology	W	27	31	00	83	26	00	109	09-1966	Tinau
0706	Dunkauli	Agrometeology	W	27	41	00	84	13	00	154	10-1965	Narayani
0707	Bhairhawa (Agric)	Agrometeology	W	27	32	00	83	28	00	120	01-1968	Tinau
0708	Parasi	Precipitation	W	27	32	00	83	40	00	125	05-1971	
0710	Dumkibas	Precipitation	W	27	35	00	83	52	00	164	05-1970	Narayani
0715	Khanchikot	Climatology	W	27	56	00	83	09	00	1,760	11-1970	Narayani
0716	Taulihawa	Climatology	W	27	33	00	83	04	00	94	11-1970	
0721	Pattharkot (West)	Precipitation	W	27	46	00	83	03	00	200	03-1973	
0722	Musikot	Precipitation	W	28	10	00	83	16	00	1,280	06-1956	Narayani
0723	Bhagwanpur	Precipitation	W	27	41	00	82	48	00	80	01-1975	
0724	Paklihawa	Precipitation	W	27	29	00	83	27	00	100	01-1970	
0725	Tamghas	Climatology	W	28	04	00	83	15	00	1,530	11-1979	Narayani
0726	Gagarkot	Precipitation	W	27	52	00	83	48	00	500	11-1979	Narayani
0727	Lumbini	Precipitation	W	27	28	00	83	17	00	95	10-1980	Tinau
0728	Simari	Climatology	W	27	32	00	83	45	00	154	04-1981	Narayani
0801	Jagat (Setibas)	Precipitation	W	28	20	00	84	54	00	1,334	07-1957	Narayani
0802	Khudi Bazar	Climatology	W	28	17	00	84	22	00	823	07-1957	Narayani
0803	Pokhara (Hospital)	Precipitation	W	28	14	00	84	00	00	866	06-1956	Narayani
0804	Pokhara Airport	Agrometeology	W	28	13	00	84	00	00	827	10-1965	Narayani
0805	Syangja	Climatology	W	28	06	00	83	53	00	868	11-1972	Narayani
0806	Larke Sando	Precipitation	W	28	40	00	84	37	00	3,650	06-1978	Narayani
0807	Kunchha	Precipitation	W	28	08	00	84	21	00	855	06-1956	Narayani
0808	Bandipur	Precipitation	W	27	56	00	84	25	00	965	06-1956	Narayani
0809	Gorkha	Agrometeology	W	28	00	00	84	37	00	1,097	06-1956	Narayani
0810	Chapkot	Climatology	W	27	53	00	83	49	00	460	02-1957	Narayani
0811	Malepatan (Pokhara)	Agrometeology	W	28	13	00	83	57	00	856	04-1966	Narayani
0813	Bhadaure Deurali	Precipitation	W	28	16	00	83	49	00	1,600	05-1969	Narayani
0814	Lumle	Agrometeology	W	28	18	00	83	48	00	1,740	11-1969	Narayani
0815	Khairini Tar	Agrometeology	W	28	02	00	84	06	00	500	03-1969	Narayani
0816	Chame	Climatology	W	28	33	00	84	14	00	2,680	07-1974	Narayani
0817	Damauli	Precipitation	W	27	58	00	84	17	00	358	01-1974	Narayani
0818	Lamachaur	Precipitation	W	28	16	00	83	58	00	1,070	01-1972	Narayani
0820	Manang Bhot	Precipitation	W	28	40	00	84	01	00	3,420	06-1975	
0821	Ghandruk	Precipitation	W	28	23	00	83	48	00	1,960	05-1976	Narayani
0822	Khuldi	Precipitation	W	28	26	00	83	50	00	2,440	09-1973	
0823	Gharedhunga	Precipitation	W	28	12	00	84	37	00	1,120	07-1976	Narayani
0824	Siklesh	Precipitation	W	28	22	00	84	06	00	1,820	06-1977	Narayani
0825	Begnas Tal	Precipitation	W	28	12	00	84	06	00	900	07-1981	
0826	Walling	Precipitation	W	27	59	00	83	46	00	750	"	
0827	Rumjakot	Precipitation	W	27	52	00	84	08	00	660	"	

(Note) Reg. W: 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 56 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
Tinau River															
Ti-1	0.5	3.2	92.9	99.3	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ti-2	0.3	0.7	15.4	54.5	81.4	90.6	95.9	99.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ti-3	0.3	1.3	10.9	22.9	87.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ti-4	0.3	1.6	53.6	92.0	98.2	99.1	99.3	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ti-5	0.1	0.6	15.1	63.4	86.4	93.8	97.5	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ti-6	0.2	0.4	5.2	20.4	36.9	50.8	68.1	79.7	93.7	97.7	100.0	100.0	100.0	100.0	100.0
Ti-7	0.7	1.2	7.3	17.9	33.4	48.1	62.7	71.2	86.6	91.5	96.3	99.5	100.0	100.0	100.0
Ti-8	0.3	0.7	5.7	14.3	24.3	33.9	45.5	54.3	69.8	79.8	89.6	95.5	100.0	100.0	100.0
Ti-9	0.3	0.5	4.7	11.8	20.8	29.2	39.1	47.3	61.8	71.8	83.7	91.8	100.0	100.0	100.0
Ti-10	0.3	0.5	2.7	6.8	14.2	24.7	36.5	45.3	58.9	66.6	74.9	83.6	92.4	100.0	100.0
Ti-11	1.0	1.7	5.9	11.0	18.4	27.8	37.2	46.3	57.4	63.3	72.1	80.4	100.0	100.0	100.0
Ti-12	0.9	1.8	6.4	11.2	17.3	26.0	36.9	41.3	50.5	55.5	61.5	66.5	76.4	100.0	100.0
Ti-13	0.3	0.5	1.4	2.8	6.4	14.4	23.3	28.1	35.8	40.1	44.6	49.2	65.6	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)
Tinau River								
Ti-1	0.12	0.18	0.19	0.23	1.92	2.59	2.63	2.61
Ti-2	0.25	0.49	0.56	1.08	4.29	2.68	2.63	2.66
Ti-3	0.31	0.63	0.67	0.82	2.60	2.68	2.63	2.66
Ti-4	0.13	0.27	0.29	0.38	2.83	2.63	2.63	2.63
Ti-5	0.25	0.41	0.45	0.79	3.13	2.59	2.63	2.61
Ti-6	0.36	3.17	4.07	11.77	32.28	2.68	2.63	2.66
Ti-7	0.39	4.04	5.72	16.88	43.65	2.63	2.65	2.64
Ti-8	0.48	12.25	15.33	30.73	64.09	2.67	2.65	2.66
Ti-9	0.59	17.43	21.13	37.99	64.66	2.68	2.66	2.67
Ti-10	0.99	19.96	24.76	54.66	55.46	2.68	2.65	2.67
Ti-11	0.68	21.99	28.34	59.51	87.39	2.59	2.63	2.61
Ti-12	0.73	34.35	47.70	125.01	170.64	2.68	2.67	2.68
Ti-13	2.34	80.50	97.70	144.88	61.96	2.65	2.67	2.66
							Average	2.65

SUMMARY OF QUESTIONNAIRES BY RIVER

Name of river: **TINAU RIVER(1/2)**

No.	Questions/items	Summary of answers
1. FLOOD EVENTS		
1.1	Year of most severe flood in past 10 years (nop)	1996(106)
1.2	Floods in a year (times)	Average(14) ranging(14 to 15)
1.3	Severe floods in past 10 years (times)	Average(5) ranging(4 to 5)
1.4	(Cancelled)	(Cancelled)
1.5	Cause of flood (nop)	• Too much rain(97) • Sediment flow(36) • Bank erosion(106) • Others(0)
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(1) • Buffalo(0) • Sheep/Goat(0) • Poultry(0)
2.3	Damage to farm land (ha)	• Irrigated land: Average(1.1) ranging(0.05 to 10.76) • Non-irrigated land: Average(0.3) ranging(0 to 0.3)
2.4	Extent of damage to farm land	• Simple inundation (nop): 25 • Loss of crops (nop): Paddy(102), Sugarcane(3), Maize(0), Others(13) • Total washout (ha): Average(0) ranging(0)
2.5	Extent of damage to dwelling and asset	• Flooding duration (days): Average(3.3) ranging(1 to 5) • Flooding depth in (m): Average(1.1) ranging(0.2 to 1.6) • Damage to house (nop): Severe(16), Moderate(6), Ordinary(6) • Loss of cash (Rs): Average(850) ranging(0 to 1,500) • Loss of food grains (kg): Paddy: Average(335) ranging(0 to 590) • Clothing (nos): Average(1) ranging(0 to 1) • Other valuables: Average(1) ranging(0 to 1)
2.6	Problems during flood (nop)	• Erosion of river bank(106) • Sediment in the river(68) • Sediment in irrigation canal(99) • Drinking water problem(97) • Sanitary problem(57) • Salinity(87) • Flooding over farm land(27) • Others(2)
2.7	Epidemic disease after flood? (nop)	• Yes(74) • No(25)
2.8	If yes, kind of epidemic disease (nop)	• Cholera(0) • Dysentery(63) • Typhoid(74) • Others(1)
2.9	Fatal causality? (nop)	• Yes(1) • No(40)
2.10	Reason of flood(nop)	• Too much rain(106) • Lack of flood protection works(105) • Weak river training works(101) • Sediment load in the flood water(79) • Flood from adjoining rivers(9)
2.11	Total amount of damage (Rs)	Average(150,000) ranging(0 to 500,000)

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

SUMMARY OF QUESTIONNAIRES BY RIVER

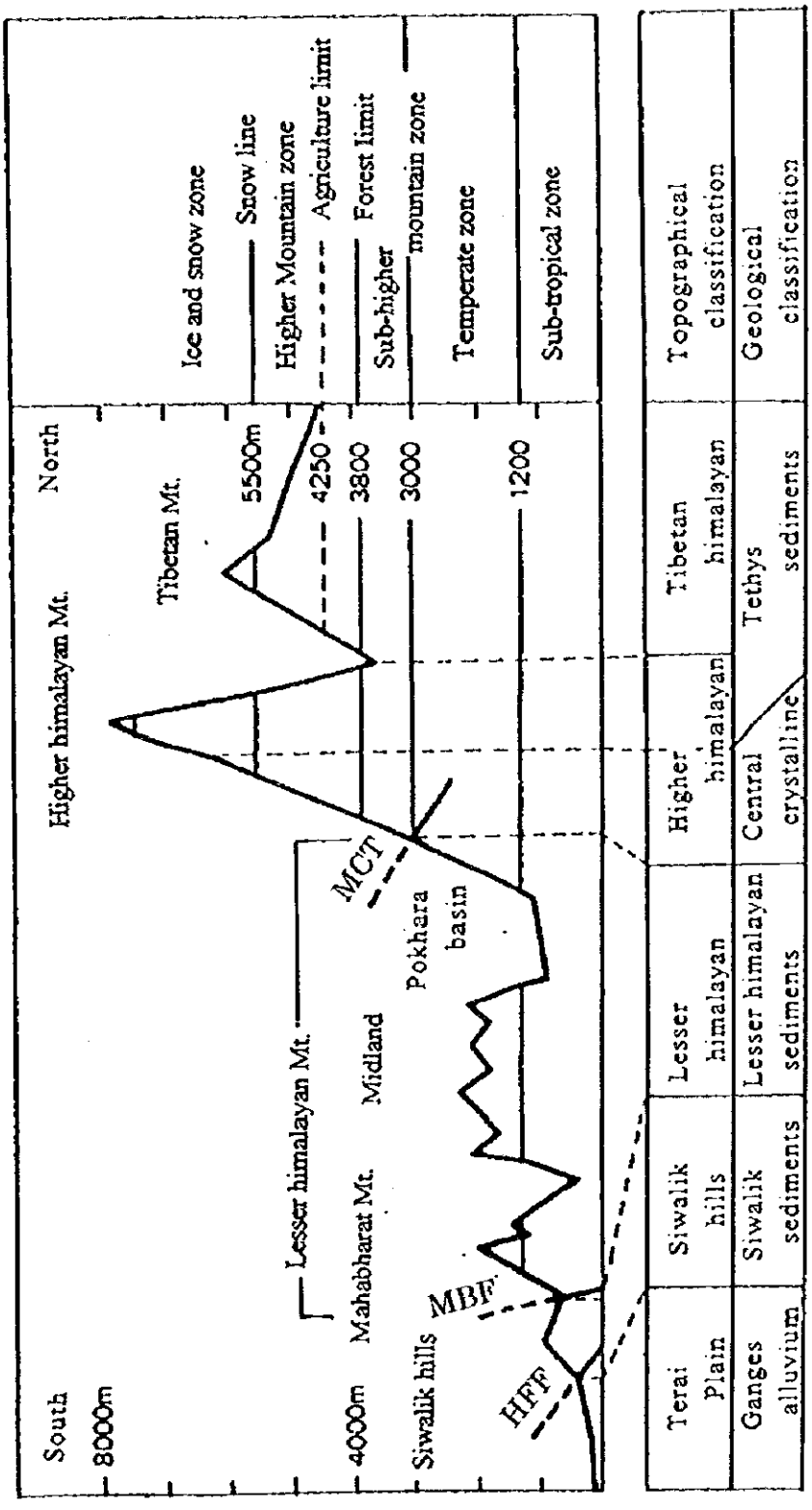
Name of river: TINAU RIVER(2/2)

No.	Questions/items	Summary of answers
3. FLOOD WARNING SYSTEM		
3.1	(Cancelled)	(Cancelled)
3.2	Self warning (nop)	• Heavy rain/High flood level(2) • Bank erosion(2) • Smelled mud(0) • Unusual sound(0) • Others(0)
3.3	Warning by others (nop)	• Neighbors(0) • Institutions(0) • Others(0)
4. FLOOD RELIEF MEASURES		
4.1	Evacuation experience? (nop)	• Yes(72) • No(29)
4.2	If yes, place of evacuation (nop)	• High ground(10) • Public building(4) • Others houses(6) • Other sites(0)
4.3	Being relieved? (nop)	• Yes(5) • No(102)
4.4	If yes, how?(nop)	• In cash(4) • Kind(1)
4.5	Organization/individual giving relief (nop)	• Central government(0) • DDC(0) • VDC(4) • Other institutions(1) • NGO(0) • Individuals(0)
4.6	(Cancelled)	(Cancelled)
5. PREVENTIVE MEASURES AGAINST FLOOD		
5.1a	Current preparedness/ measures (nop)	• Warning(0) • Evacuation(2) • Settlement(0)
5.1b	Proposed preparedness/ measures (nop)	• Warning(104) • Evacuation(0) • Settlement(1)
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(0) • Cash pools(0) • Informal insurance(0) • Others(0)
5.3a	Current structural measures (nop)	• Embankment(9) • Spur(78) • Simple gabion(82) • Plantation(0) • Others(0)
5.3b	Proposed structural measures(nop)	• Embankment(105) • Spur(107) • Simple gabion(105) • Plantation(102) • Others(0)
6. PARTICIPATION ACTIVITIES		
6.1	Experience of Participation in activities? (nop)	• Yes(106) • No(1)
6.2	If yes, type (nop)	• Cash(2) • Labor(102) • Kind(0) • Care taker(0) • Others(0)
6.3	If no, reason (nop)	• Being affected badly(0) • Financially weak(0) • Being out of the area(0) • No willingness(0) • Others(0)
6.4	Willing to participate in future? (nop)	• Yes(105) • No(0)
6.5	If yes, type (nop)	• Cash(21) • Labor(104) • Kind(0) • Care taker(0) • Others(0)
6.6	If no, reasons (nop)	• No time(0) • No benefit(0) • 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 (TINAU RIVER)
(1996-FLOOD)

VDC/Municipality	Loss of					Damage of							Remarks
									Public Facilities				
	Life (nos.)	Cattle (nos.)	Crops (ton)	Land (hac)	Houses (nos.)	Cross (ton)	Land (hac)	Houses (nos.)	Road (m)	Culvert (nos.)	School (nos.)	Irrigation Channel	
Motipur	1	-	76	20	-	-	-	-	5	-	-	v	Drinking water
Sauraha-Pharsatikar	-	10	268	67	-	-	-	-	-	-	-	v	System damaged
West-Amuwa	-	-	67	15	17	-	-	-	2	-	-	v	
Mainahiya	-	-	52	16	-	-	-	30	20	1	-	v	
Shankar Nagar	-	-	-	-	-	1	21	-	3	-	-	v	Barren land
Anand Van	-	-	50	20	-	-	-	5	30	-	-	v	
Sipuwa	-	4	1,250	-	-	-	66	150	20	1	-	v	
Roinihawa	2	16	1,000	-	-	-	400	60	10	-	-	v	Masjid
Ihuma-Piparahawa	-	-	1,165	466	-	-	-	14	1	-	-	v	
Bhagwanpur	7	18	138	-	-	-	86	44	2	-	1	v	
Hatti Bangai	-	20	747	-	-	-	166	100	3	-	-	v	
Harnaiya	2	-	103	-	-	2	23	11	5	-	-	v	
Total	12	68	4,916	604	17	3	762	414	101	2	1		

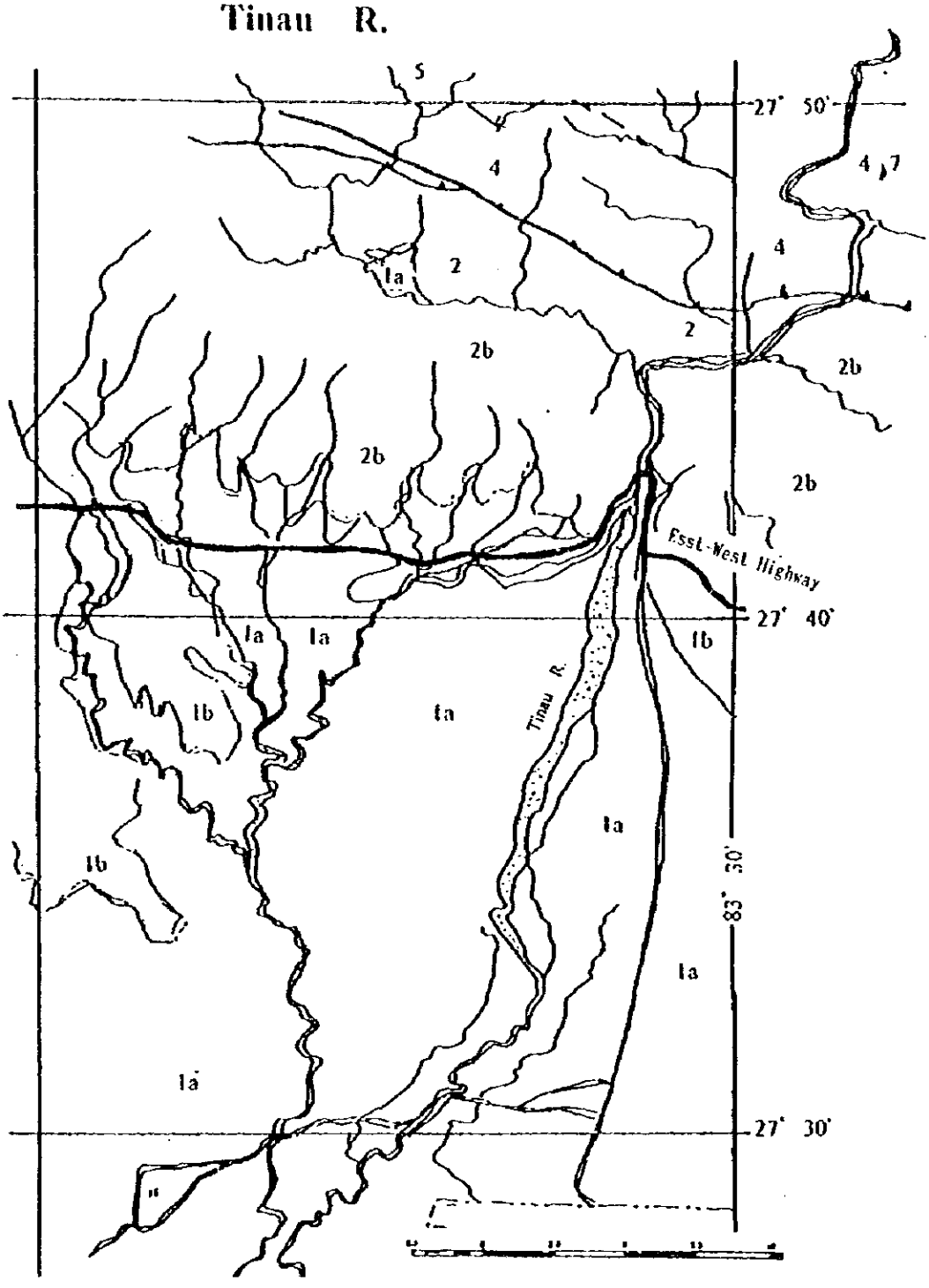


TOPOGRAPHICAL AND GEOLOGICAL CLASSIFICATION(N-S PROFILE)

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
4. Shale and limestone (Eocene)
5. Conglomerate, quartzite, schist
7. Midland sediments group

GEOLOGICAL MAP(TINAU R.)

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
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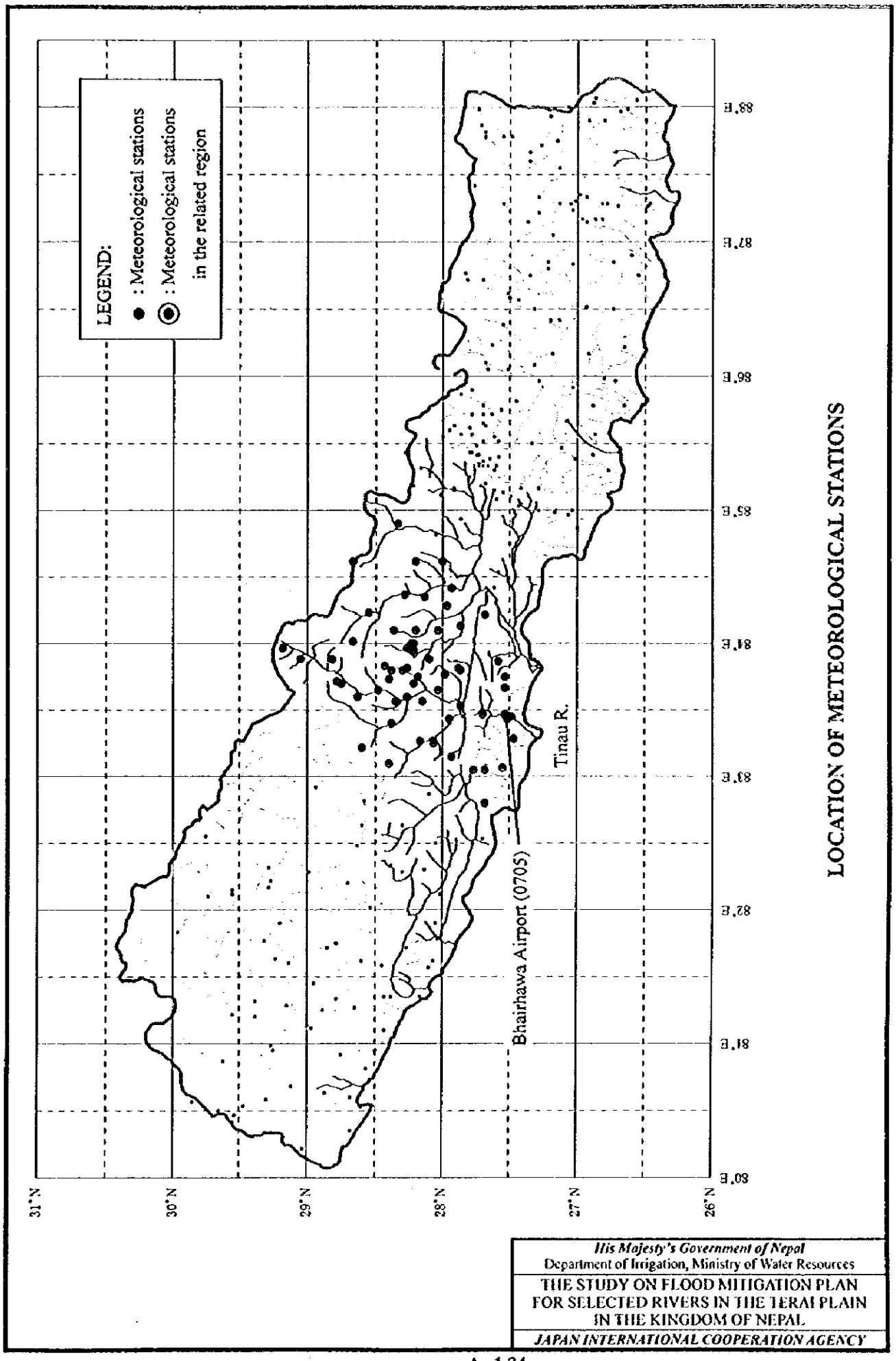
Fig. A1.3



LOCATION OF METEOROLOGICAL STATIONS

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FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL
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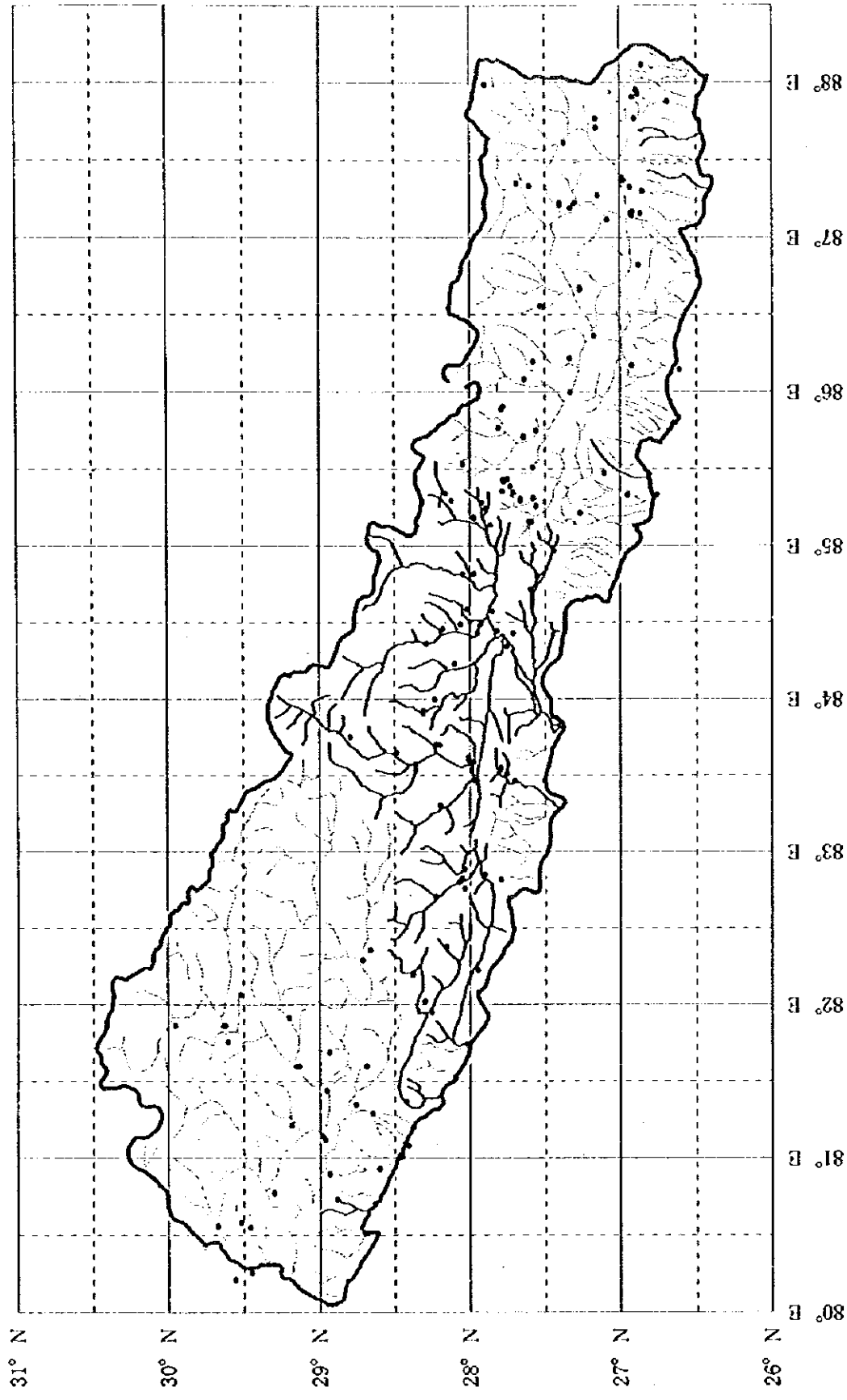
Fig. A1.4



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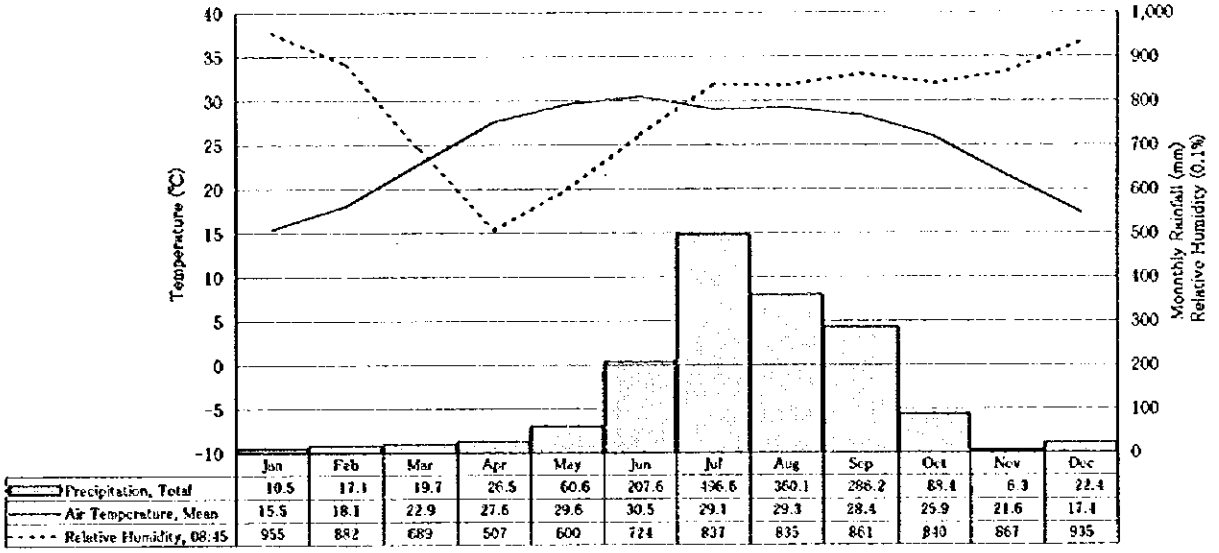
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

Code: 0705
Station: Bhairhawa Airport

Latitude: 27°31'
Longitude: 83°26'
Elevation: 109 m

Bhairhawa Airport (0705)



Air Temperature, Mean (Unit: ℃)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	16.0	17.8	24.8	29.1	30.2	30.8	28.6	30.2	28.3	26.2	21.5	17.9	25.1
1986	16.0	18.1	23.4	27.6	28.6	31.5	29.4	30.0	28.3	25.6	22.3	17.9	24.9
1987	16.3	20.0	23.7	27.7	29.7	31.8	28.3	28.5	28.3	26.0	21.9	17.7	25.0
1988	16.2	19.3	22.3	27.6	29.8	29.5	28.7	28.4	28.9	26.4	21.6	18.2	24.7
1989	14.6	16.7	22.2	27.4	30.2	29.8	28.1	29.5	-	26.5	21.0	16.3	-
1990	15.2	17.8	21.8	26.7	28.6	30.2	28.7	29.8	28.7	25.3	22.3	17.6	24.4
1991	14.9	18.9	23.3	27.6	30.4	29.9	29.8	29.1	28.9	26.0	20.1	16.5	24.6
1992	15.4	16.2	23.0	28.7	29.2	30.8	29.1	28.8	28.7	25.8	21.9	17.0	24.5
1993	13.7	19.0	20.9	26.6	29.4	30.3	30.2	28.9	27.7	26.4	22.1	18.0	24.4
1994	16.4	17.3	23.7	27.7	30.7	30.7	30.1	29.7	28.3	25.4	21.1	17.1	24.8
Ave.	15.5	18.1	22.9	27.6	29.6	30.5	29.1	29.3	28.4	25.9	21.6	17.4	24.7

Relative Humidity, 08:45 (Unit: %)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	95	87	64	50	60	72	86	82	84	85	86	92	78.6
1986	95	88	67	53	60	68	84	84	88	86	87	91	79.3
1987	94	86	73	52	49	64	85	81	85	82	84	96	77.6
1988	97	85	69	56	64	73	85	87	85	81	79	91	79.3
1989	95	86	70	38	54	75	88	80	-	84	87	92	-
1990	96	89	69	55	67	77	84	81	84	83	84	93	80.2
1991	94	87	72	50	63	75	82	84	88	84	90	93	80.2
1992	96	92	64	41	59	66	79	82	86	88	89	97	78.3
1993	97	90	69	60	68	75	82	88	88	84	92	95	82.3
1994	96	92	72	52	56	79	82	86	87	83	89	95	80.8
Ave.	95.5	88.2	68.9	50.7	60.0	72.4	83.7	83.5	86.1	84.0	86.7	93.5	79.6

Precipitation, Total (Unit: mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	12	5	0	14	51	148	389	234	468	182	0	37	1,540
1986	1	21	0	87	53	309	416	323	419	131	27	62	1,849
1987	1	2	4	41	20	73	599	344	193	124	0	8	1,409
1988	0	9	21	64	37	210	894	703	99	35	28	49	2,129
1989	34	10	40	0	63	263	1,072	207	312	4	2	18	2,025
1990	0	63	15	10	125	237	655	295	169	263	0	3	1,835
1991	27	10	33	11	64	200	215	445	314	0	1	42	1,362
1992	6	13	0	4	69	142	350	270	163	160	5	0	1,182
1993	3	1	84	28	90	246	130	444	447	5	0	0	1,478
1994	21	37	0	6	34	248	246	336	278	0	0	5	1,211
Ave.	10.5	17.1	19.7	26.5	60.6	207.6	496.6	360.1	286.2	88.4	6.3	22.4	1,602

METEOROLOGICAL CONDITIONS

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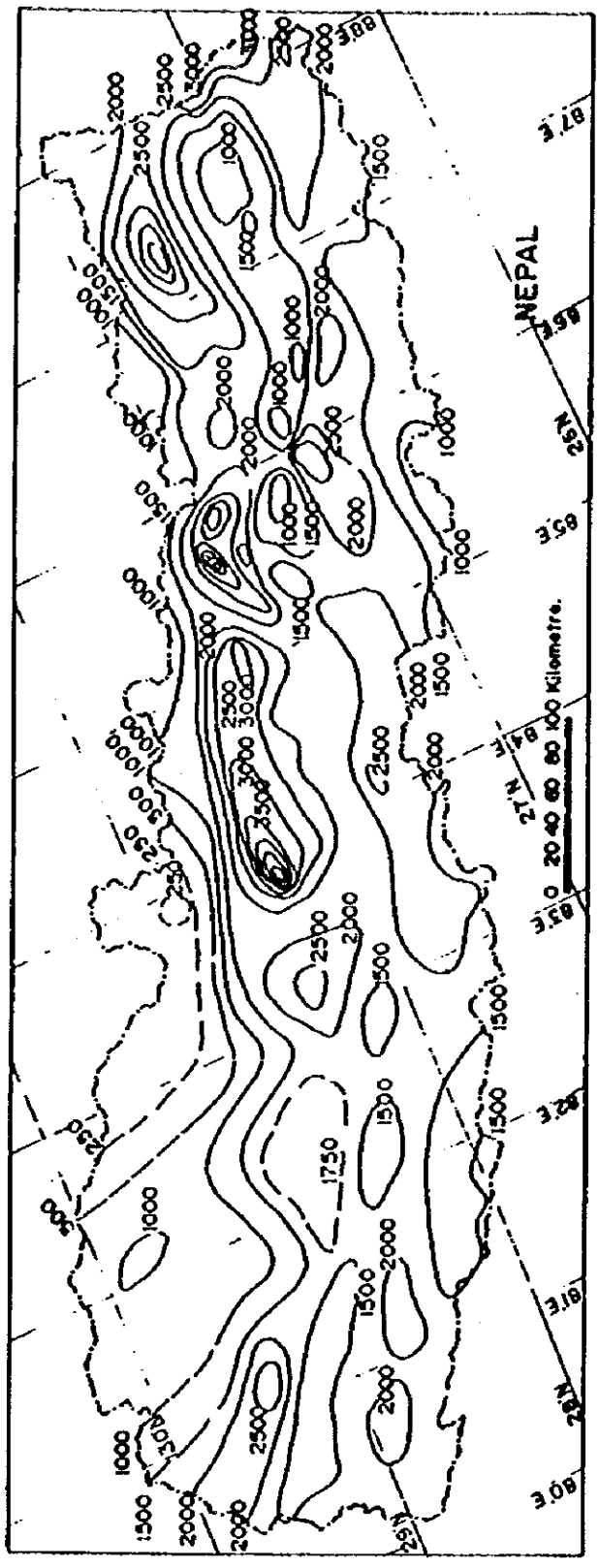
MEAN ANNUAL PRECIPITATION (mm) 1971-1985



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

ANNUAL RAINFALL DISTRIBUTION OF NEPAL

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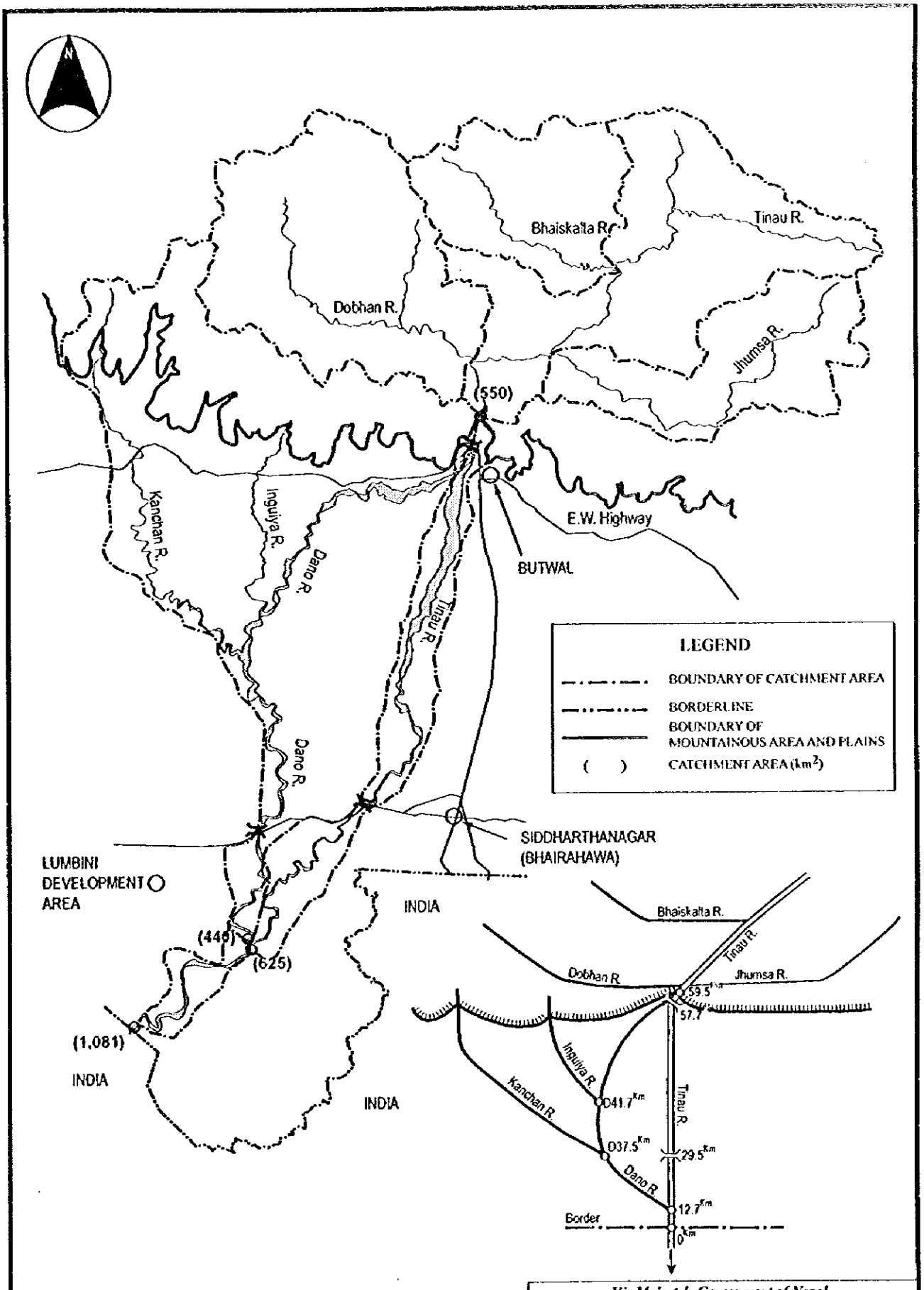

TINAU RIVER BASIN

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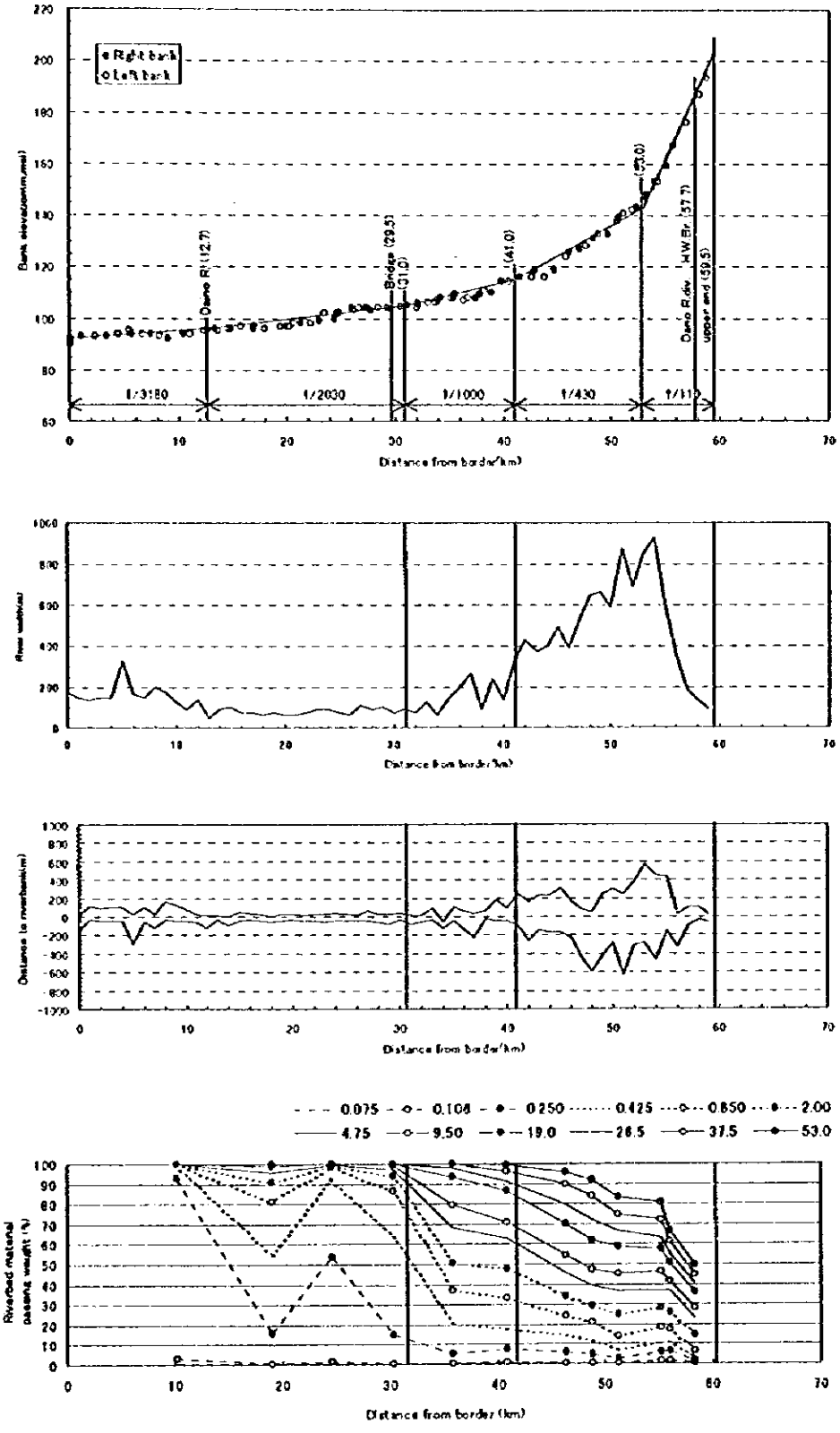
TINAU RIVER



CHARACTERISTICS OF EXISTING CHANNEL

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CHANGE OF TINAU RIVER COURSE

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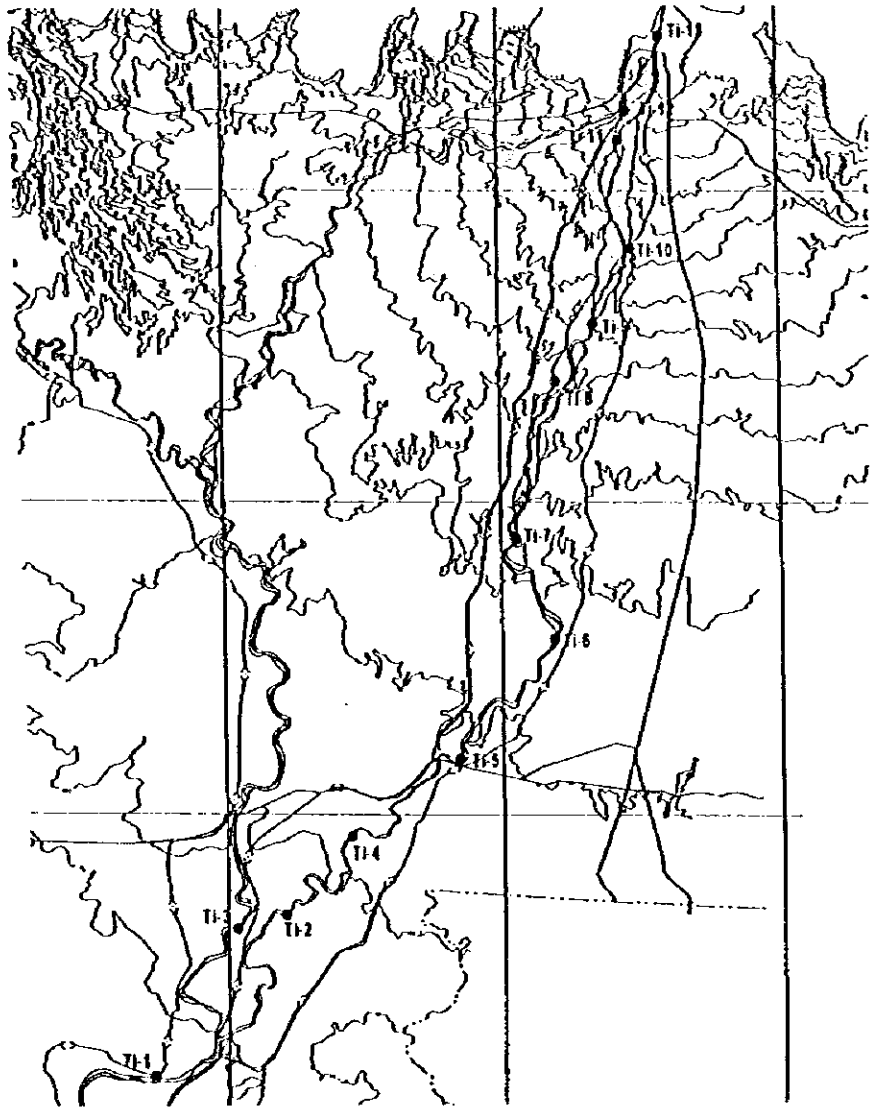

SN	Sample code	Soil classification by eye	Description of sampling place	GPS Reading		FGA (Y/N)
				N	E	
1	Ti-1	Silt		27°42.413′	83°27.762′	N
2	Ti-2	Medium sand		27°28.377′	83°20.735′	N
3	Ti-3	Silty sand		27°28.088′	83°19.987′	N
4	Ti-4	Fine sand		27°29.452′	83°22.082′	N
5	Ti-5	Coarse to medium sand		27°30.856′	83°24.047′	N
6	Ti-6	Gravel mixed gravel		27°32.599′	83°25.746′	Y
7	Ti-7	Mixed gravel		27°34.341′	83°25.125′	Y
8	Ti-8	Mixed gravel		27°36.618′	83°25.897′	Y
9	Ti-9	Mixed gravel		27°37.876′	83°26.602′	Y
10	Ti-10	Mixed gravel		27°41.058′	83°27.165′	Y
11	Ti-11	Mixed gravel		27°41.058′	83°27.165′	Y
12	Ti-12	Mixed gravel		27°41.534′	83°27.223′	Y
13	Ti-13	Coarse Aggregate		27°42.467′	83°27.824′	Y

SAMPLING SITES OF RIVERBED MATERIALS (TINAU RIVER)

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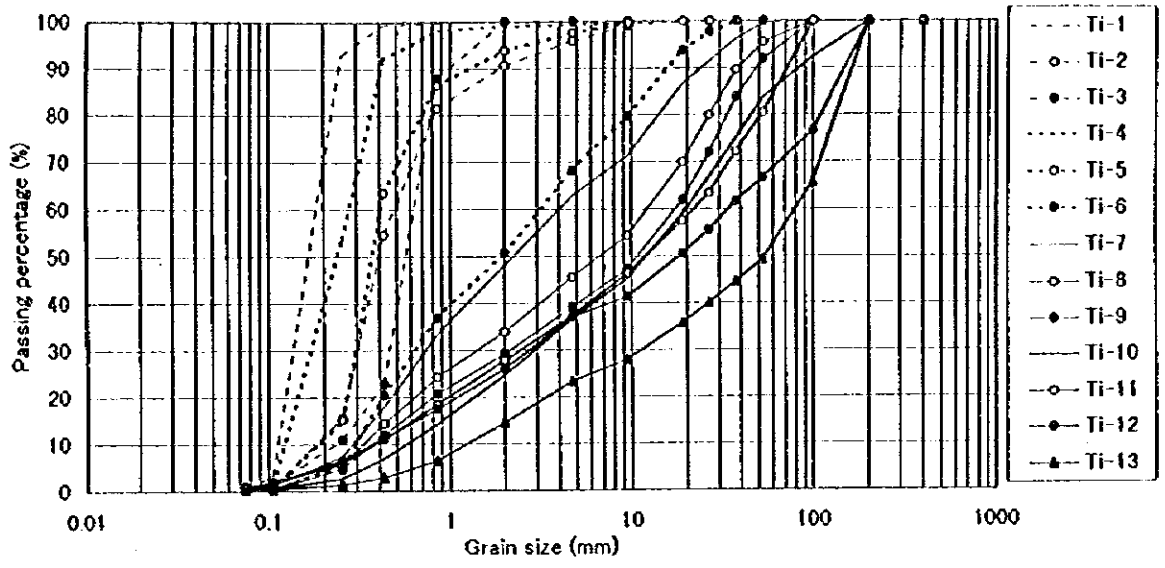

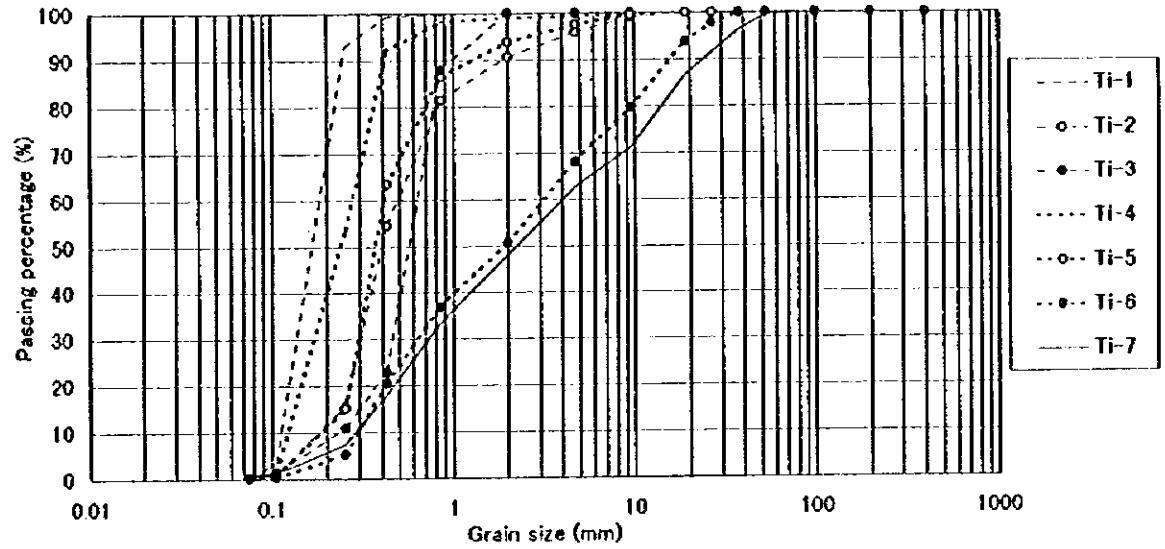

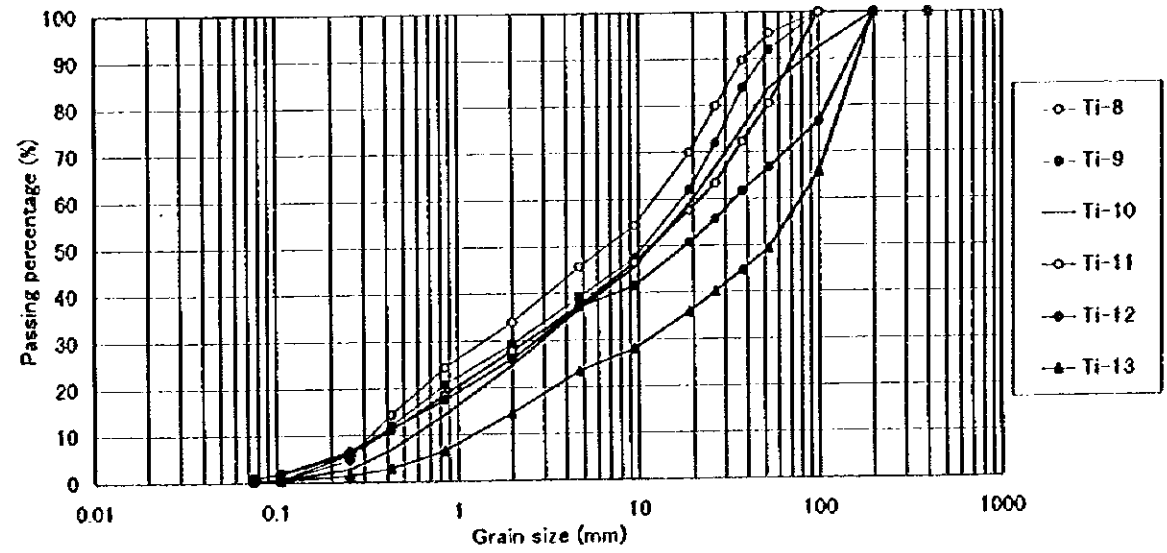

GRADING CURVES OF RIVERBED MATERIALS (TINAU R.)

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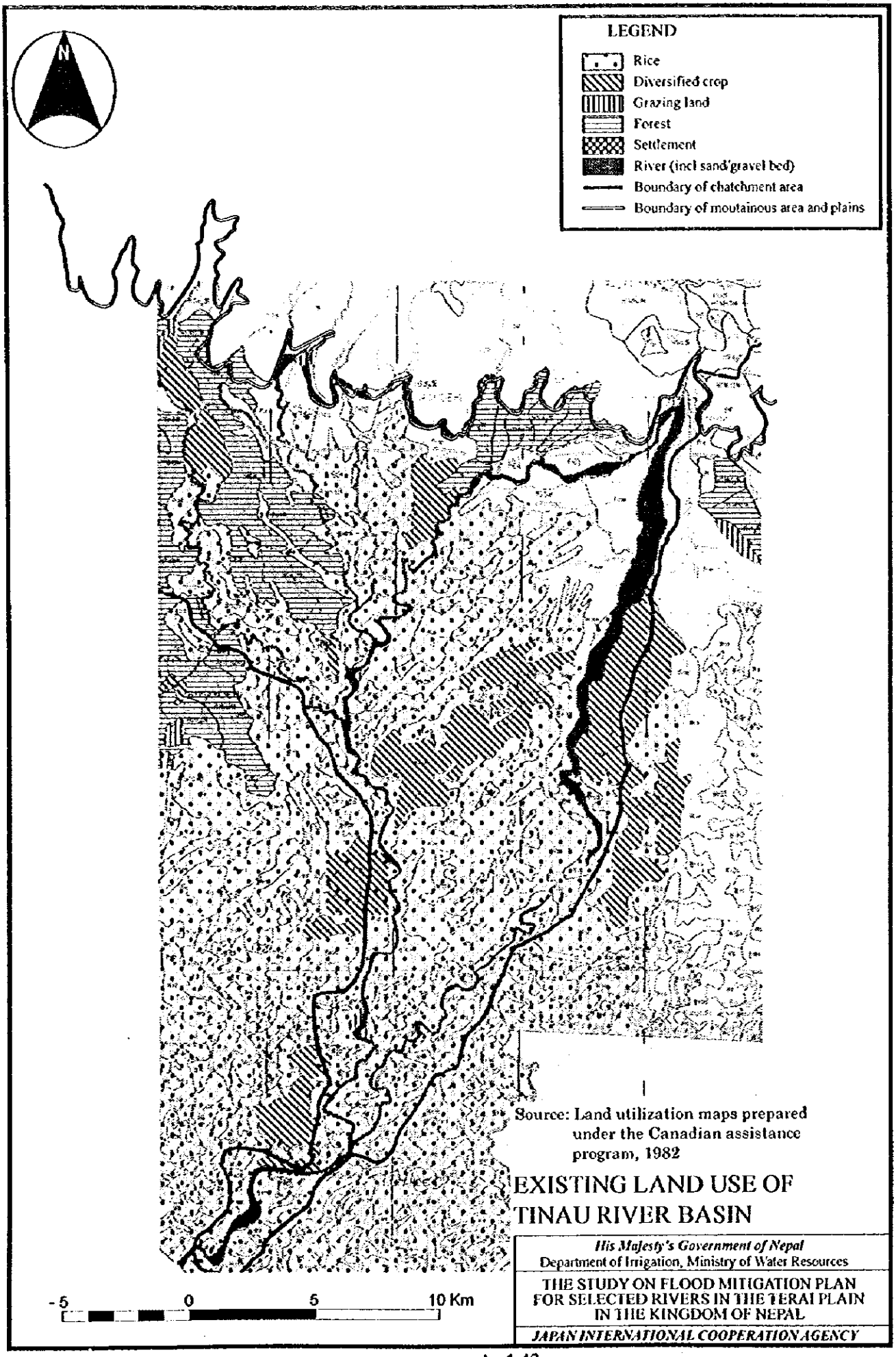
Fig. A1.12



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

EXISTING LAND USE OF TINAU RIVER BASIN

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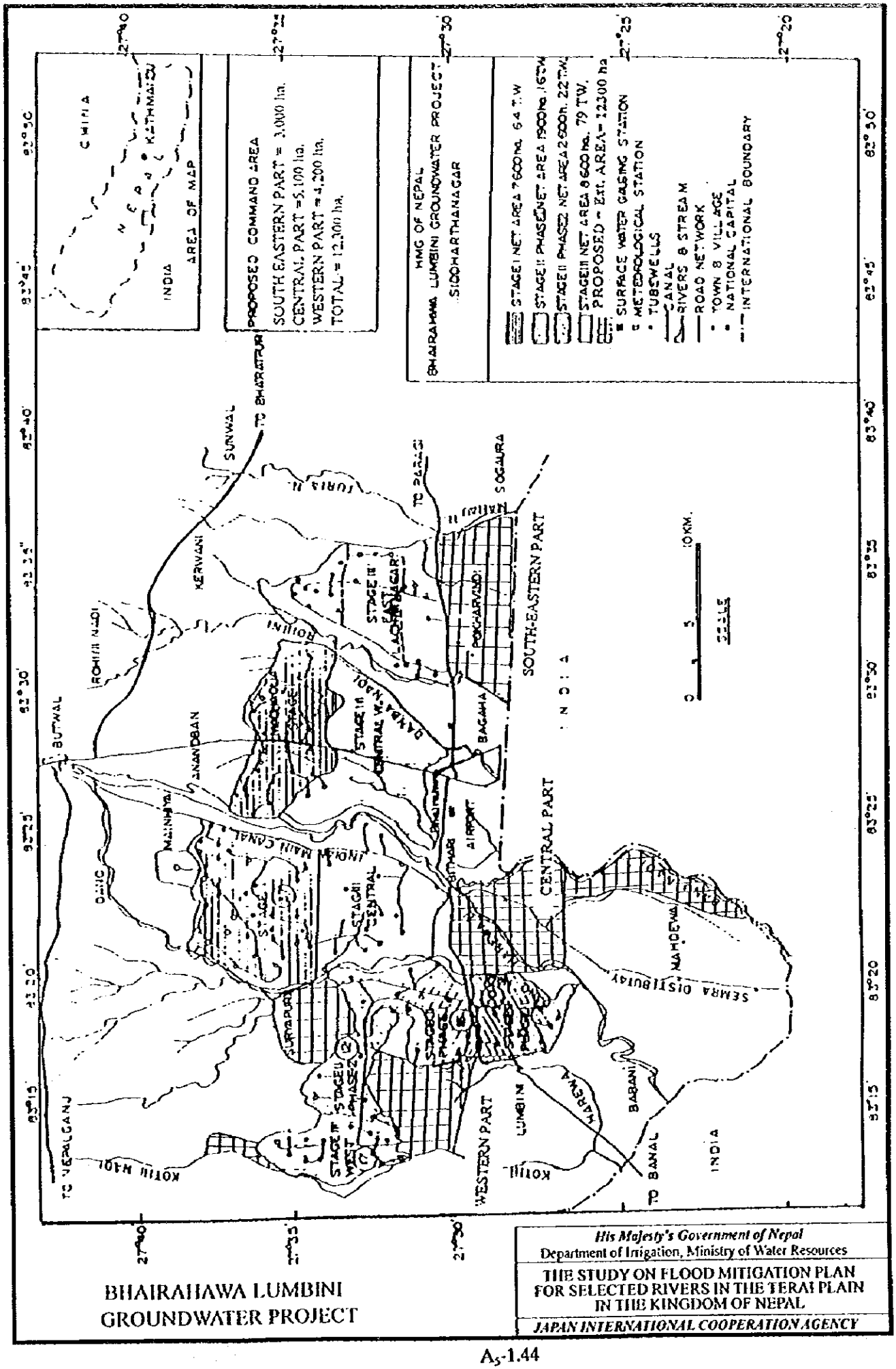
AREA OF MAP
CHINA
INDIA
PROPOSED COMMAND AREA
SOUTH EASTERN PART = 3,000 ha.
CENTRAL PART = 5,100 ha.
WESTERN PART = 4,200 ha.
TOTAL = 12,300 ha.
HMG OF NEPAL
BHAIRAHAWA LUMBINI GROUNDWATER PROJECT
SIDDHARTHANAGAR
STAGE I NET AREA 7600ha. 64 T.W.
STAGE II PHASE-I NET AREA 1900ha. 16 T.W.
STAGE II PHASE-II NET AREA 2600h. 22 T.W.
STAGE III NET AREA 8600 ha. 79 T.W.
PROPOSED - Ext. AREA - 12300 ha
SURFACE WATER GAUGING STATION
METEOROLOGICAL STATION
TUBEWELLS
CANAL
RIVERS & STREAM
ROAD NETWORK
TOWN & VILLAGE
NATIONAL CAPITAL
INTERNATIONAL BOUNDARY
TO BHAIRAHAWA
TO PARASI
SUNWAL
KERWANI
ROHINI NADI
BUTWAL
ANANDBAN
MAINHIYA
OMIC
MAIN CANAL
MAIN FRONT
STAGE I
STAGE I CENTRAL
STAGE II
STAGE II PHASE-I
STAGE II PHASE-II
STAGE III WEST
STAGE III EAST
STAGE III CENTRAL
SOGAURA
POKHARVARI
BAGAHA
BITHARI
AIRPORT
SOUTH-EASTERN PART
CENTRAL PART
WESTERN PART
MAHDEWA
SEMRA DISTRIBUTARY
LUMBINI
KOTIHI
KOTIHI MAIN
TO DEVADANGANJ
BABANI
BANAL
INDIA
0 5 10KM.
SCALE
BHAIRAHAWA LUMBINI GROUNDWATER PROJECT
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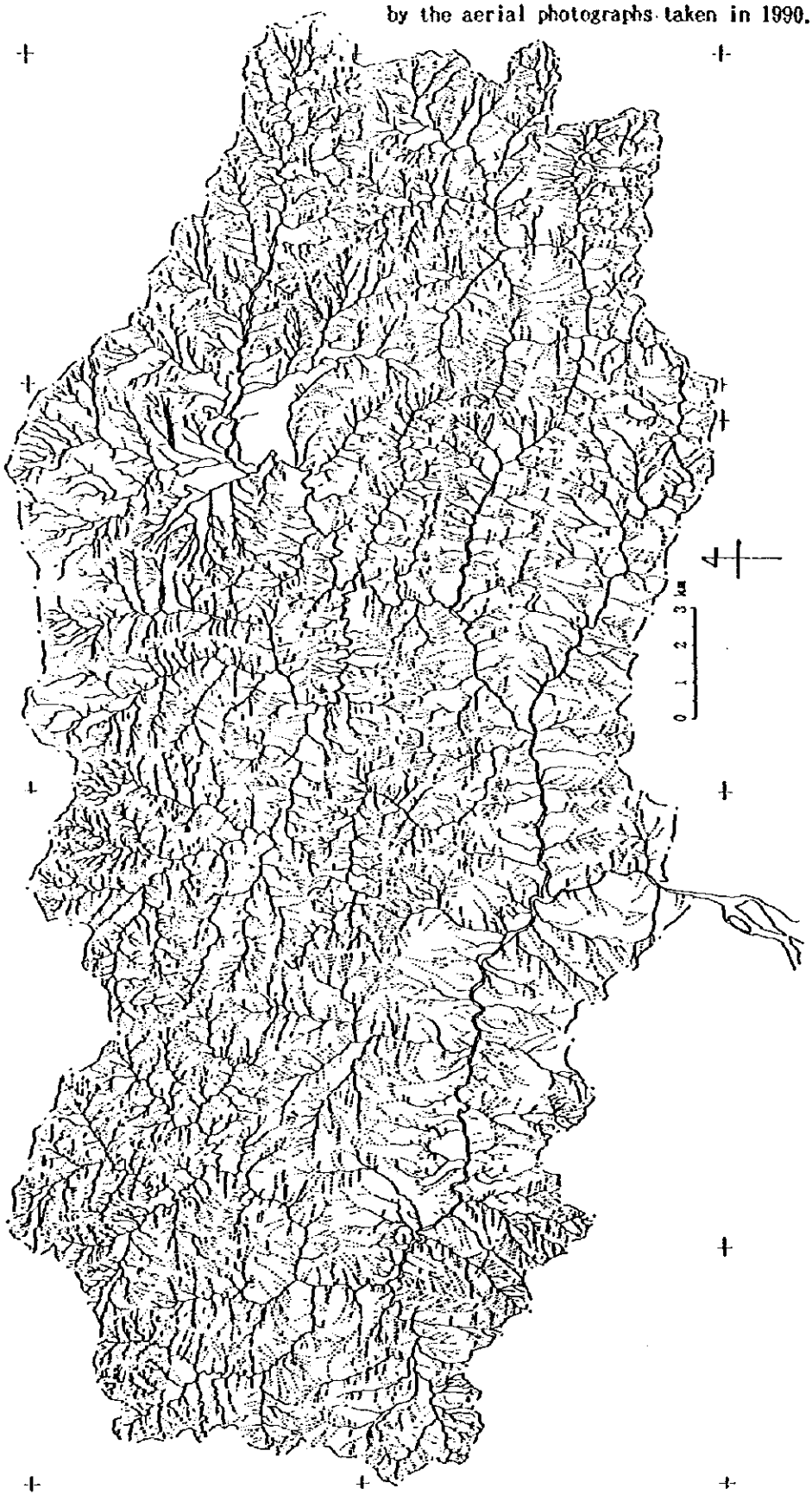
The drainage system map compiled from 1:25,000 scale map by the aerial photographs taken in 1990.



DRAINAGE SYTEM OF
THE TINAU WATERSHED

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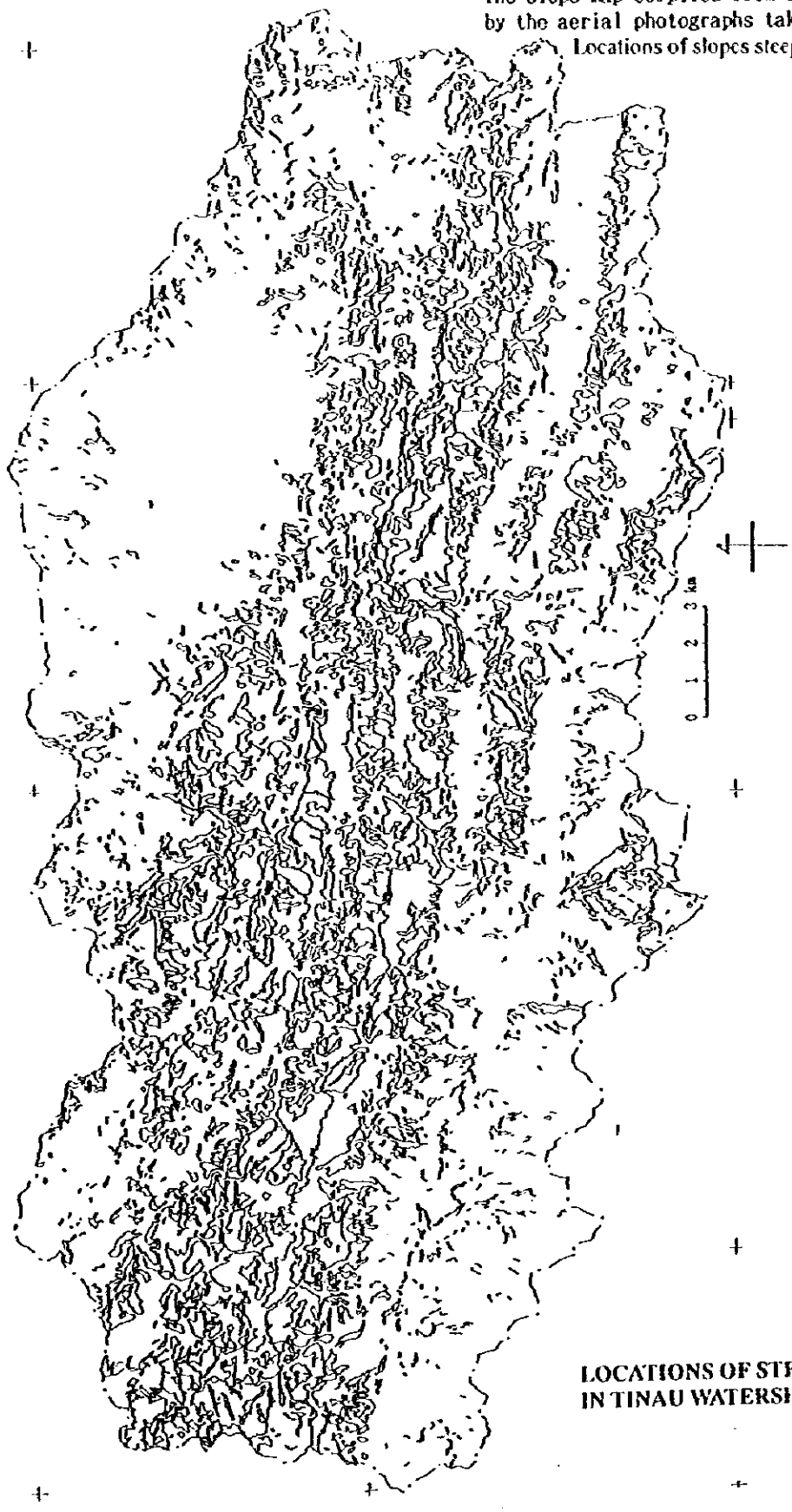
The slope map compiled from 1:25,000 scale map by the aerial photographs taken in 1990.
Locations of slopes steeper than 40°are shown



LOCATIONS OF STEEP SLOPE IN TINAU WATERSHED

SLOPE MAP MORE THAN 40° OF THE TINAU RIVER

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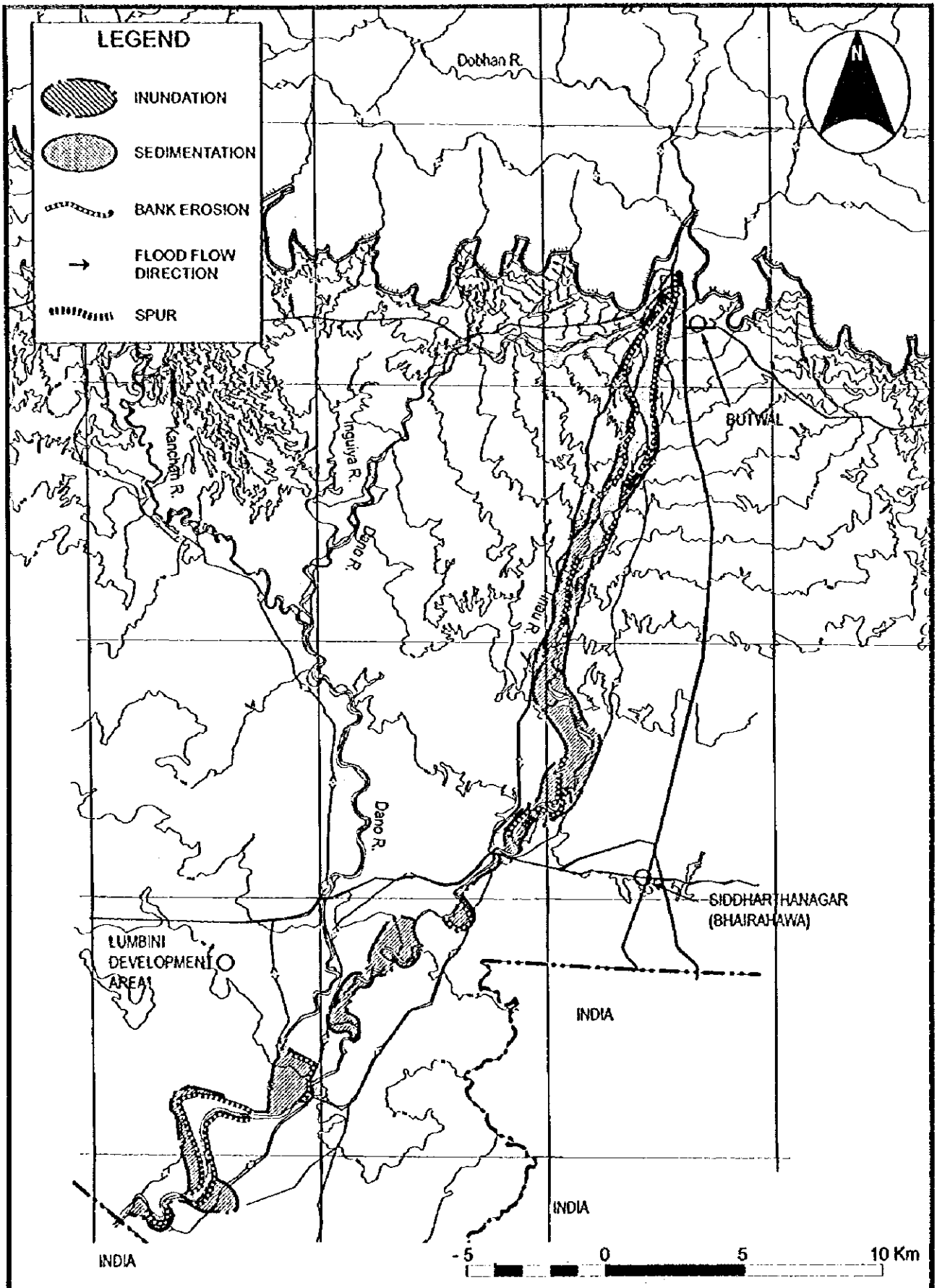
Fig. A1.16



FLOOD SUFFERING AREA (TINAU RIVER,1995)

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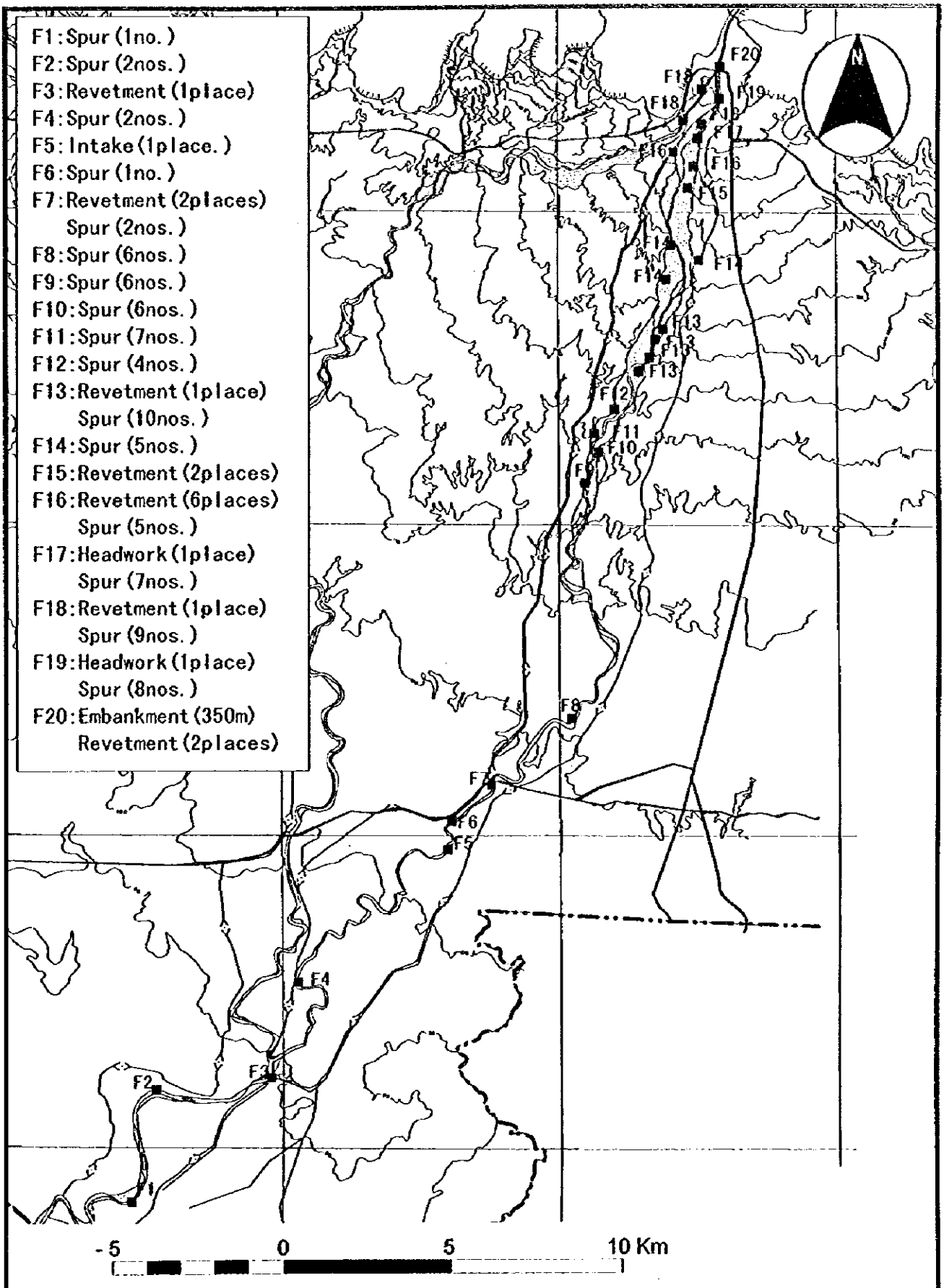

LOCATIONS OF RIVER FACILITIES

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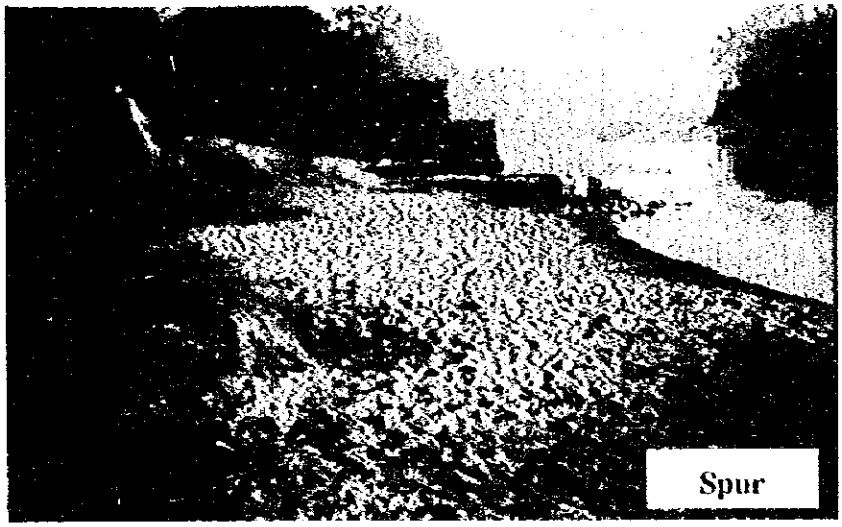

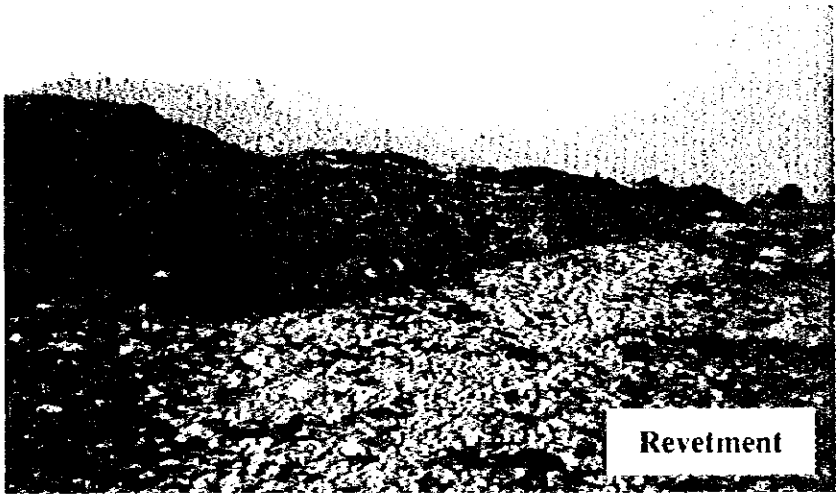

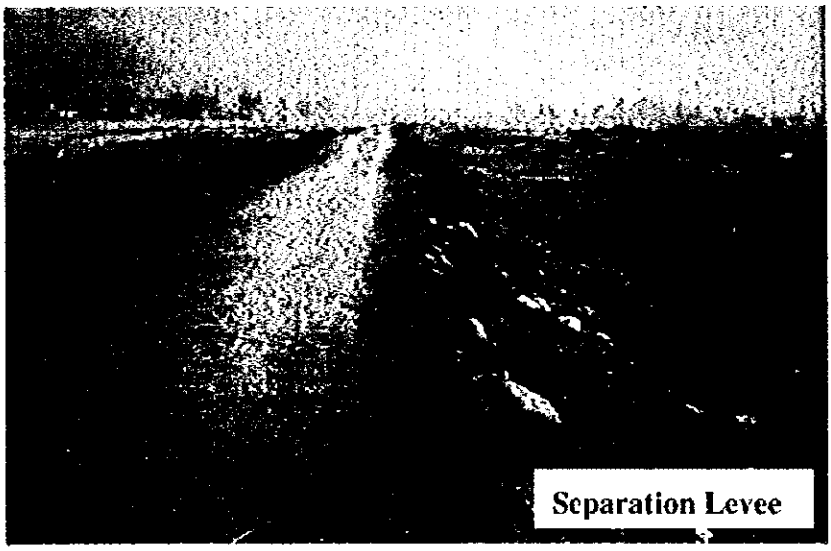

TYPICAL RIVER FACILITIES

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