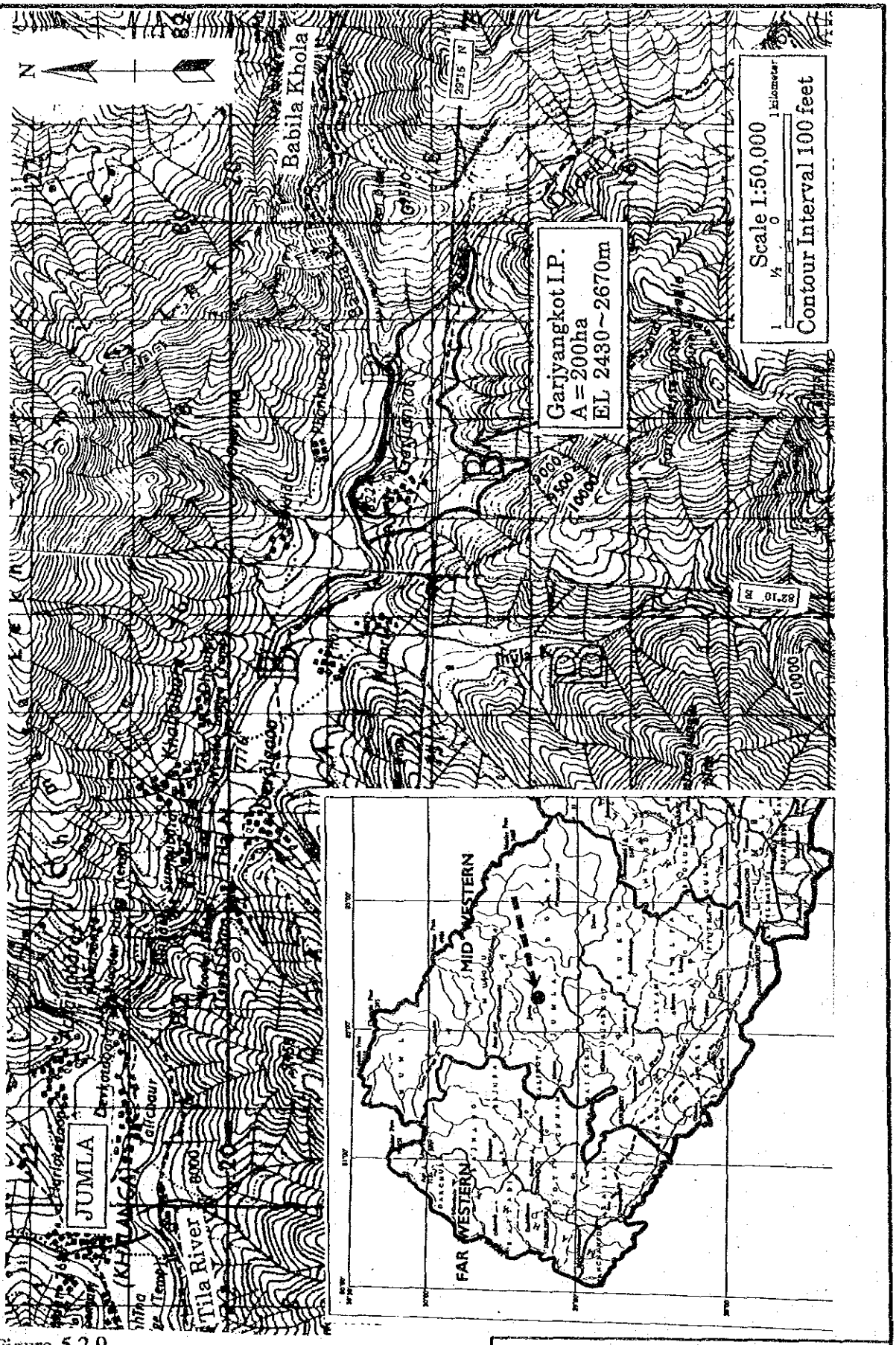


Figure 5.2.9
Garjyangkot Potential Scheme Site in Jumla District

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

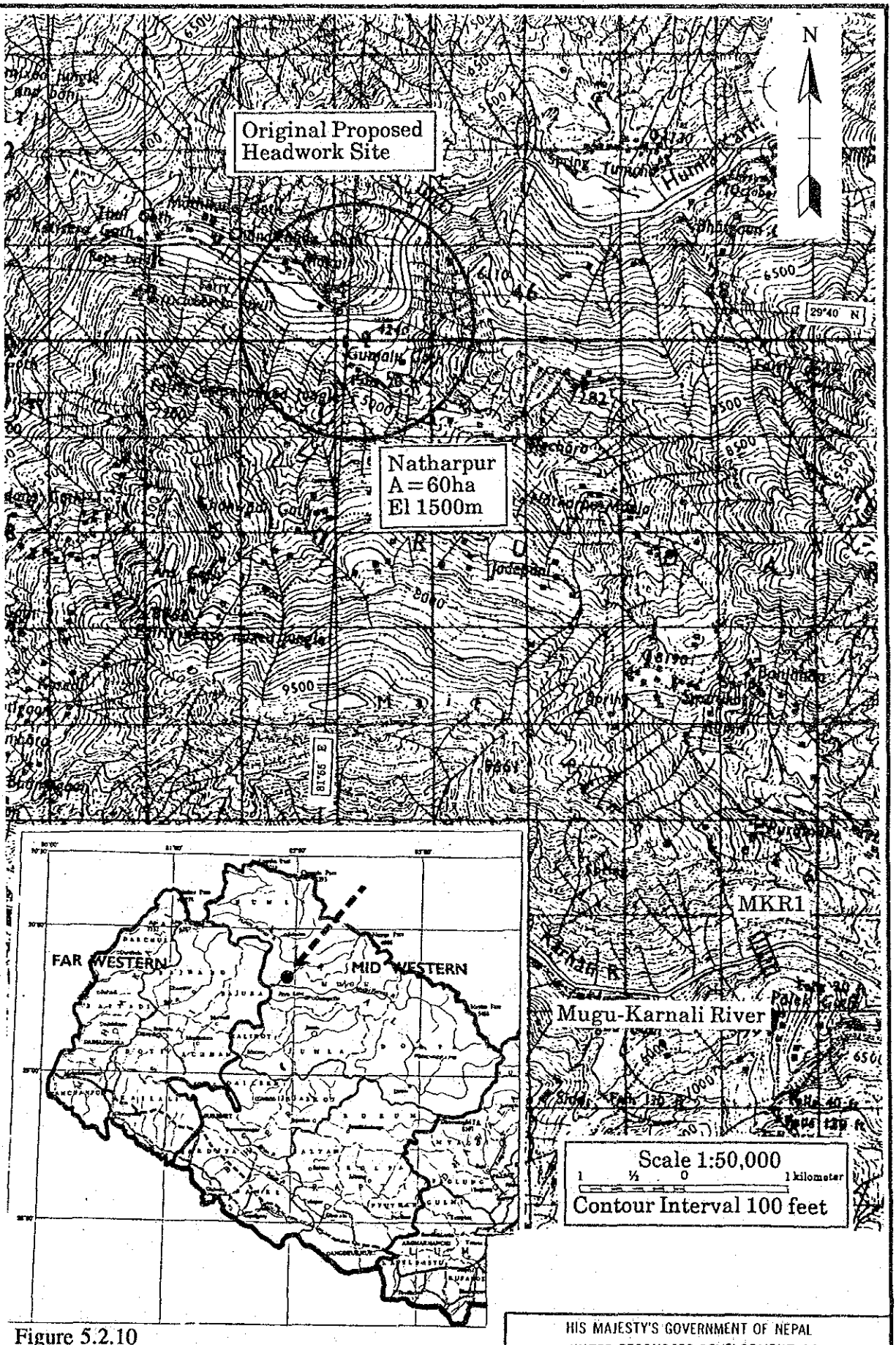


Figure 5.2.10
Natharpur Potential Scheme Site in Mugu District

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

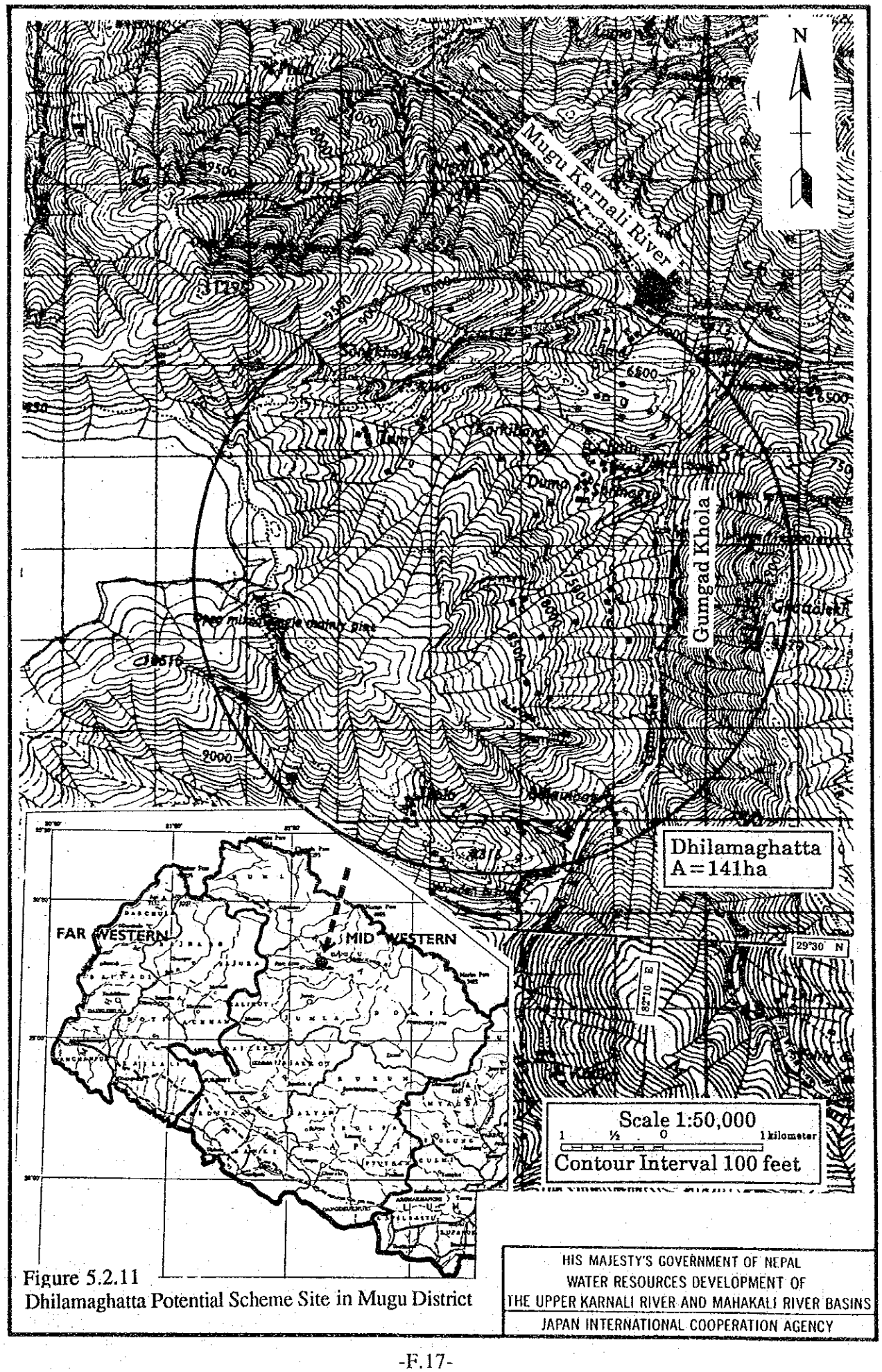


Figure 5.2.11
Dhilamaghatta Potential Scheme Site in Mugu District

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

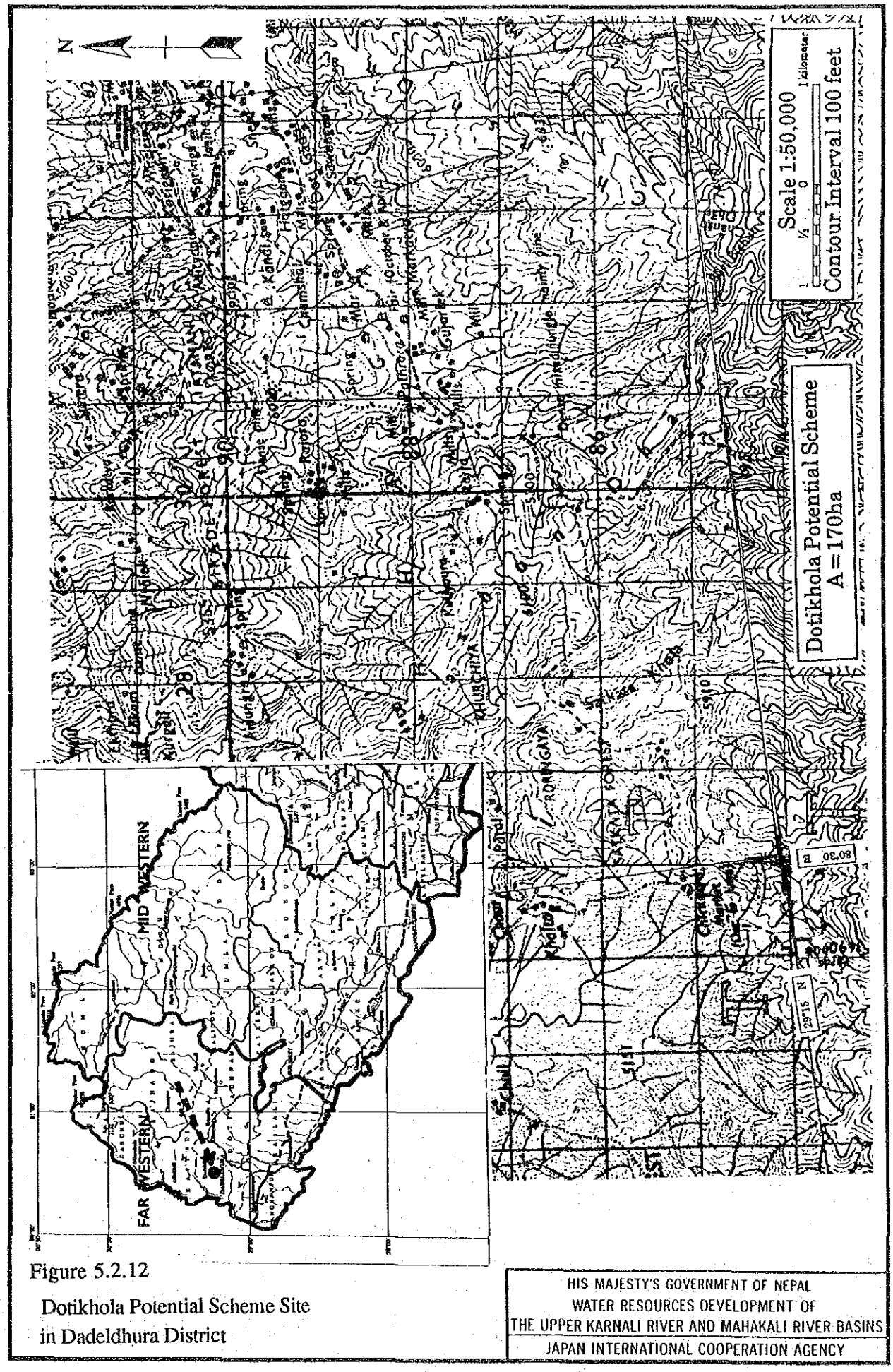


Figure 5.2.12

Dotikhola Potential Scheme Site
in Dadeldhura District

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 5.2.13

Kakari-Melghat Scheme in Baitadi District

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

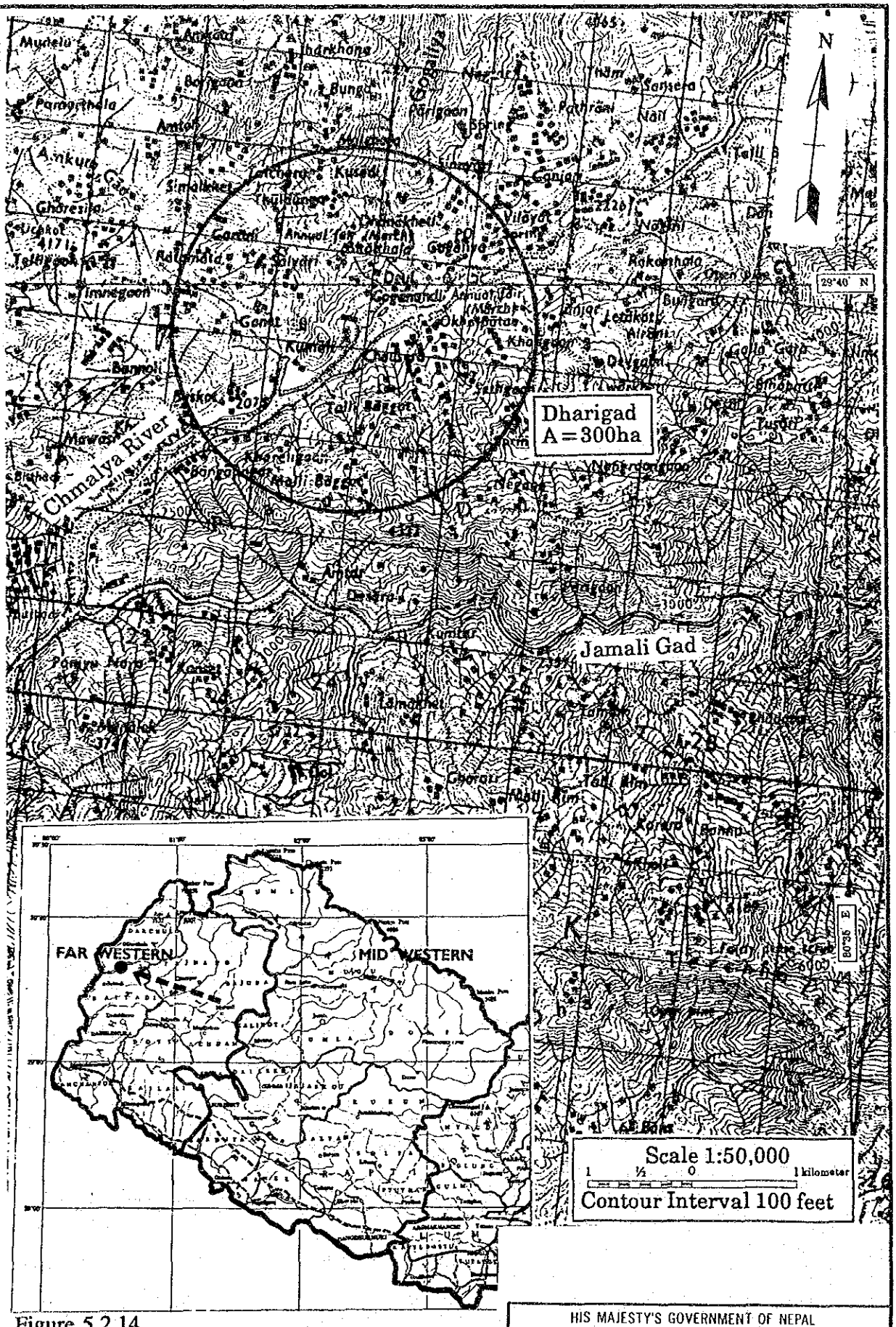


Figure 5.2.14

Dharigad Potential Scheme Site in Darchula District

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

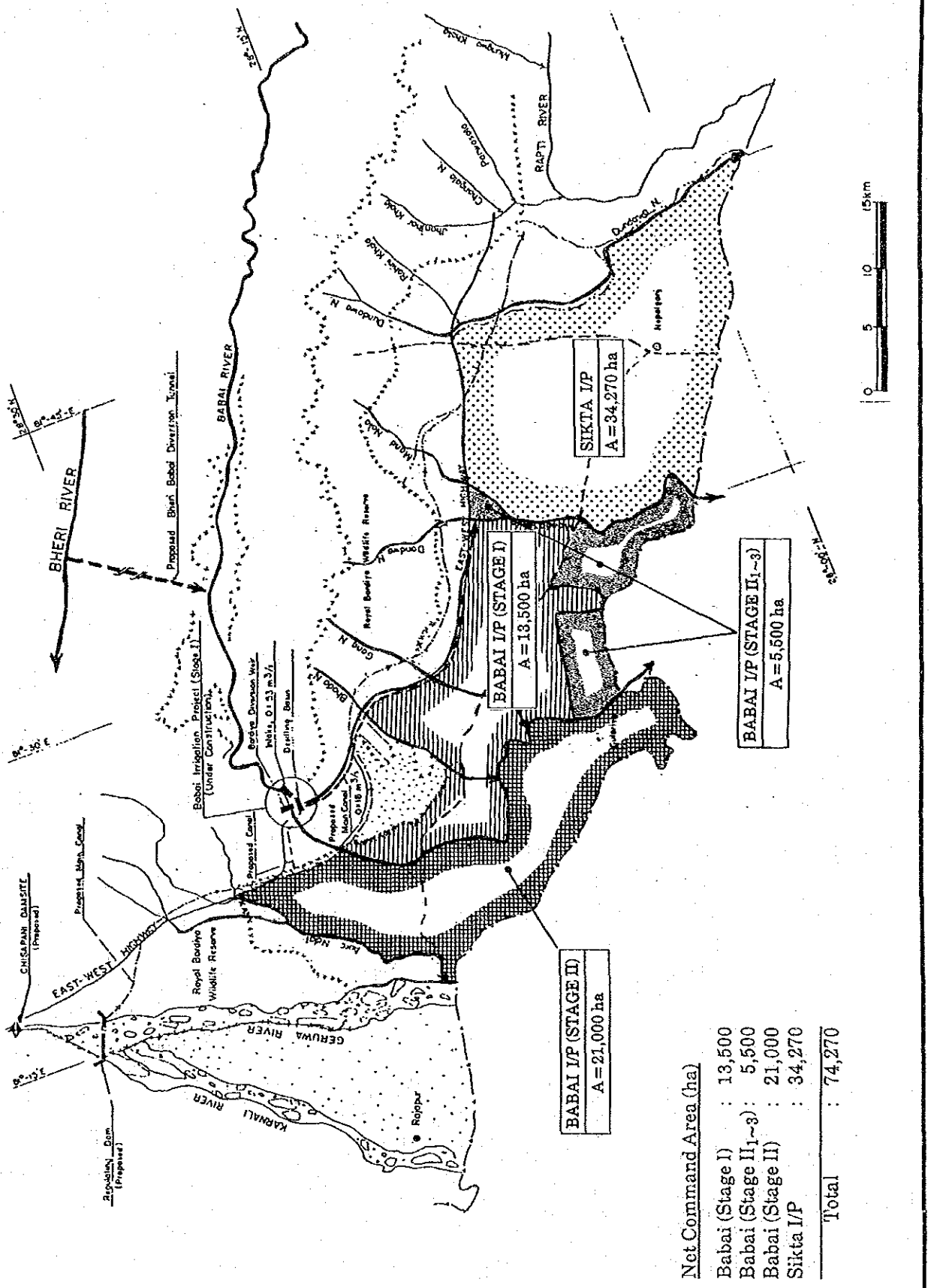


Figure 7.1.1 Bheri-Babai Irrigation Scheme

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

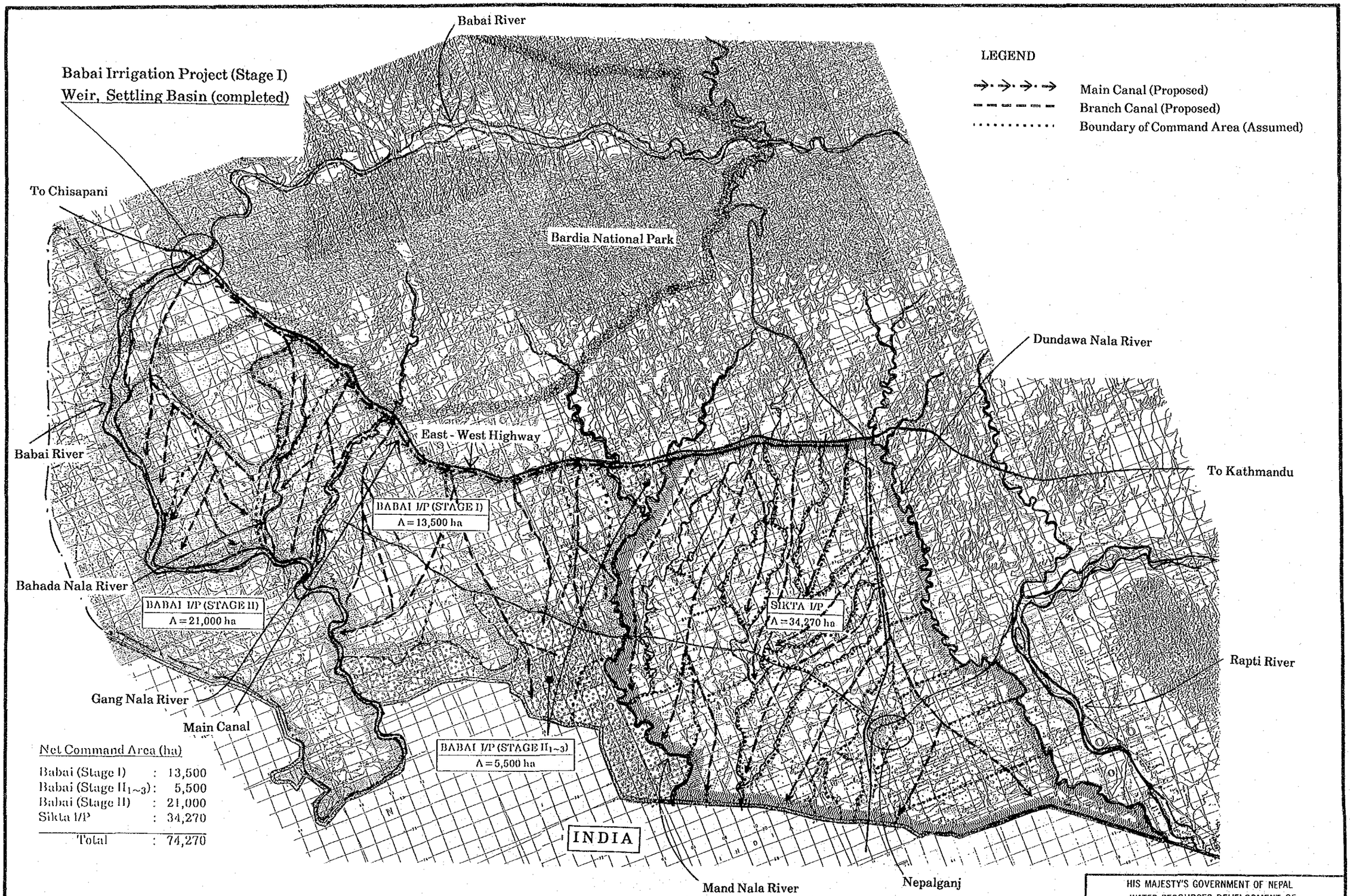
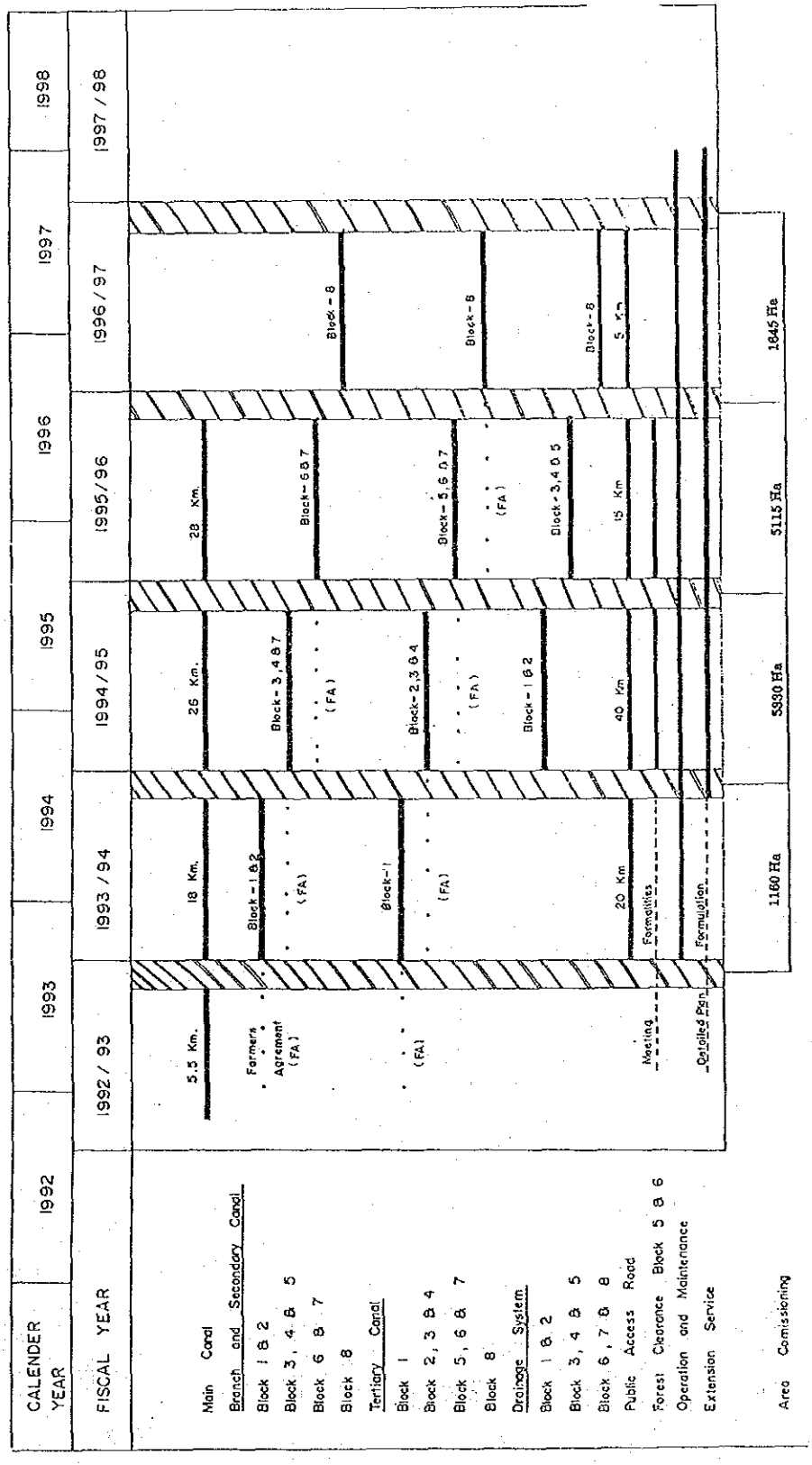


Figure 7.1.2 **Irrigation and Drainage System for Bheri-Babai Irrigation Scheme**

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY



Source : Babai Irrigation Project Report (Oct, 1992)

Figure 7.1.3 Babai Irrigation Project (Stage I) Implementation Schedule

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

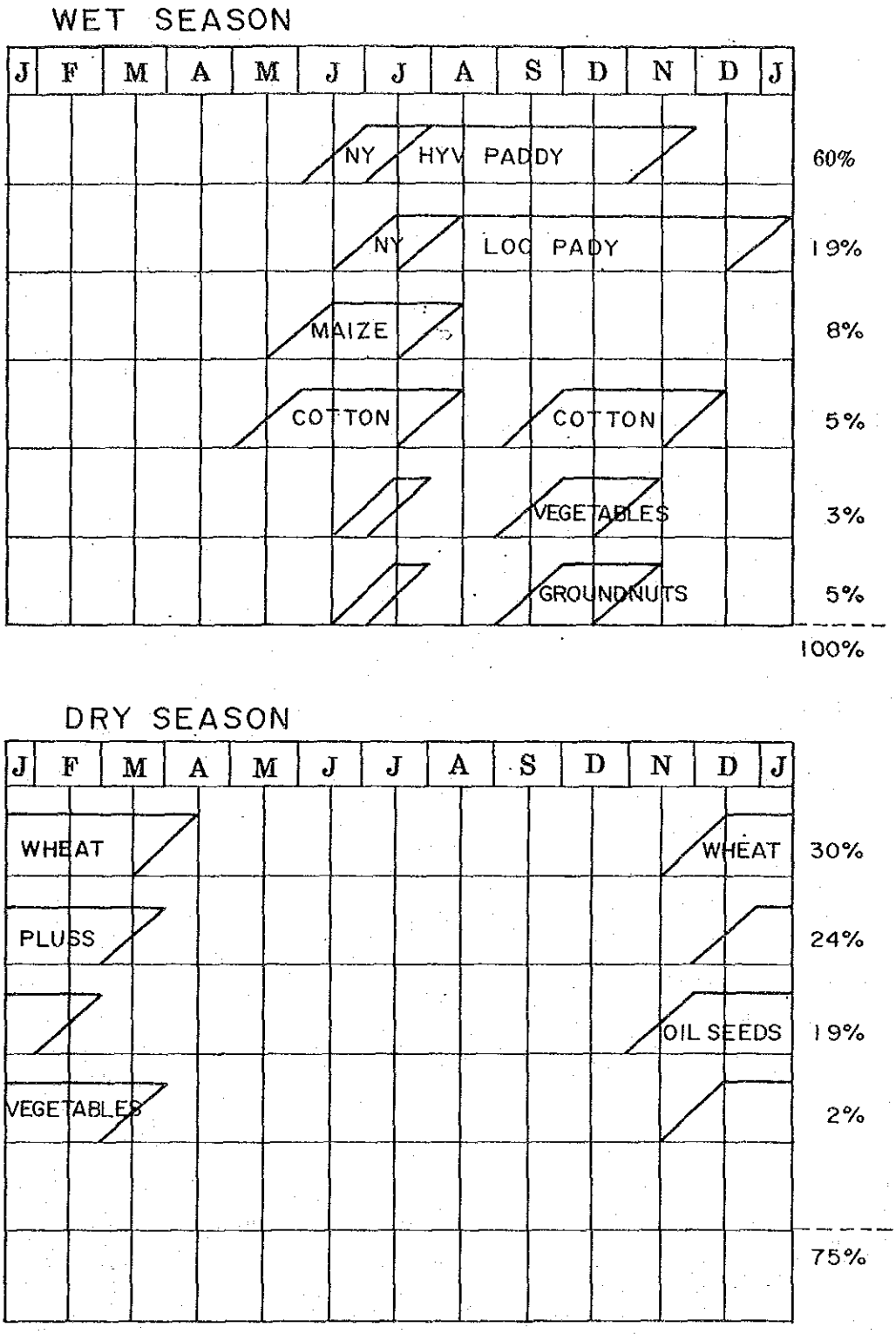


Figure 7.1.4 Proposed Cropping Pattern for Babai Irrigation Scheme (Stage I)

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

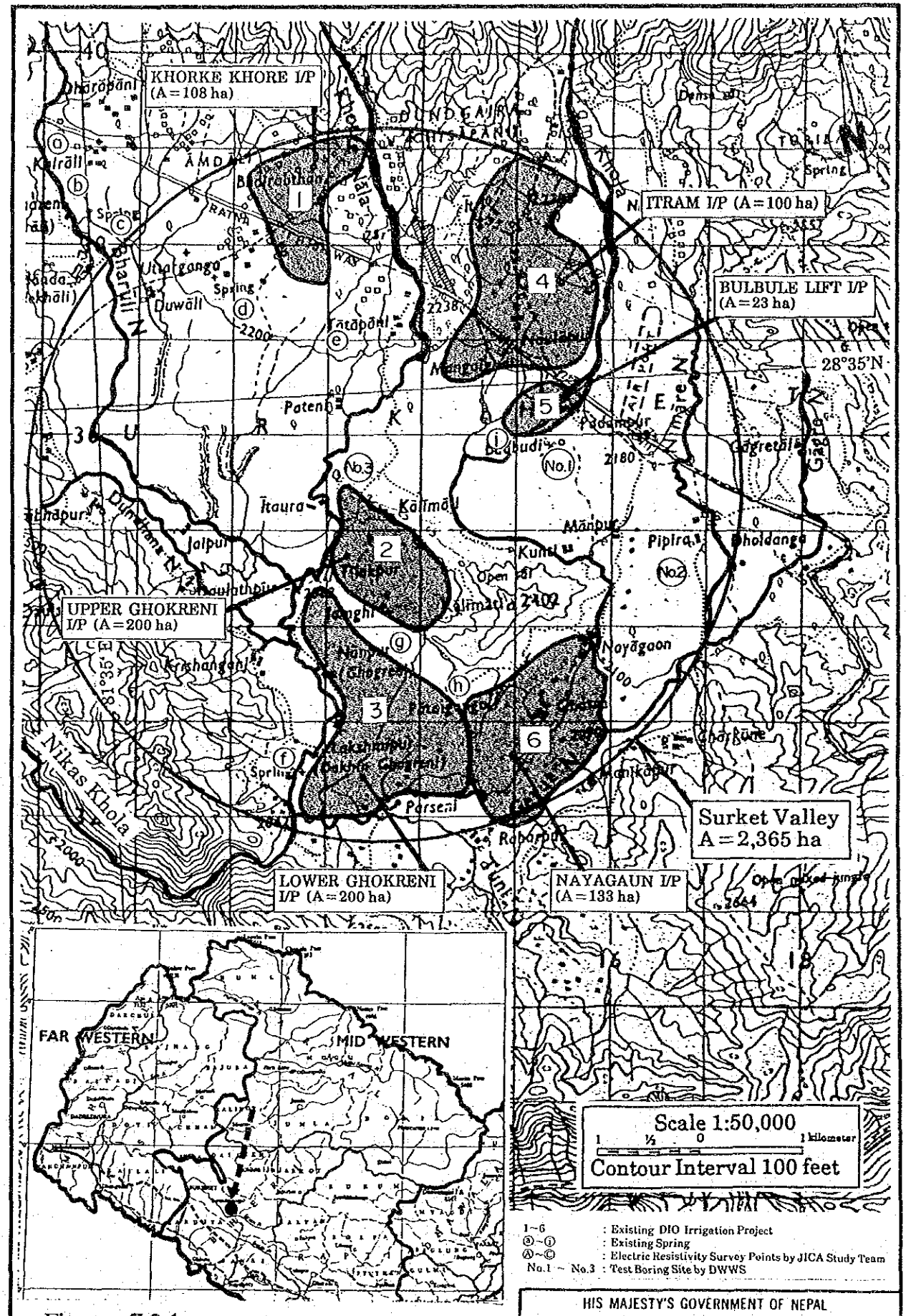


Figure 7.2.1
Surkhet Valley Irrigation Scheme

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

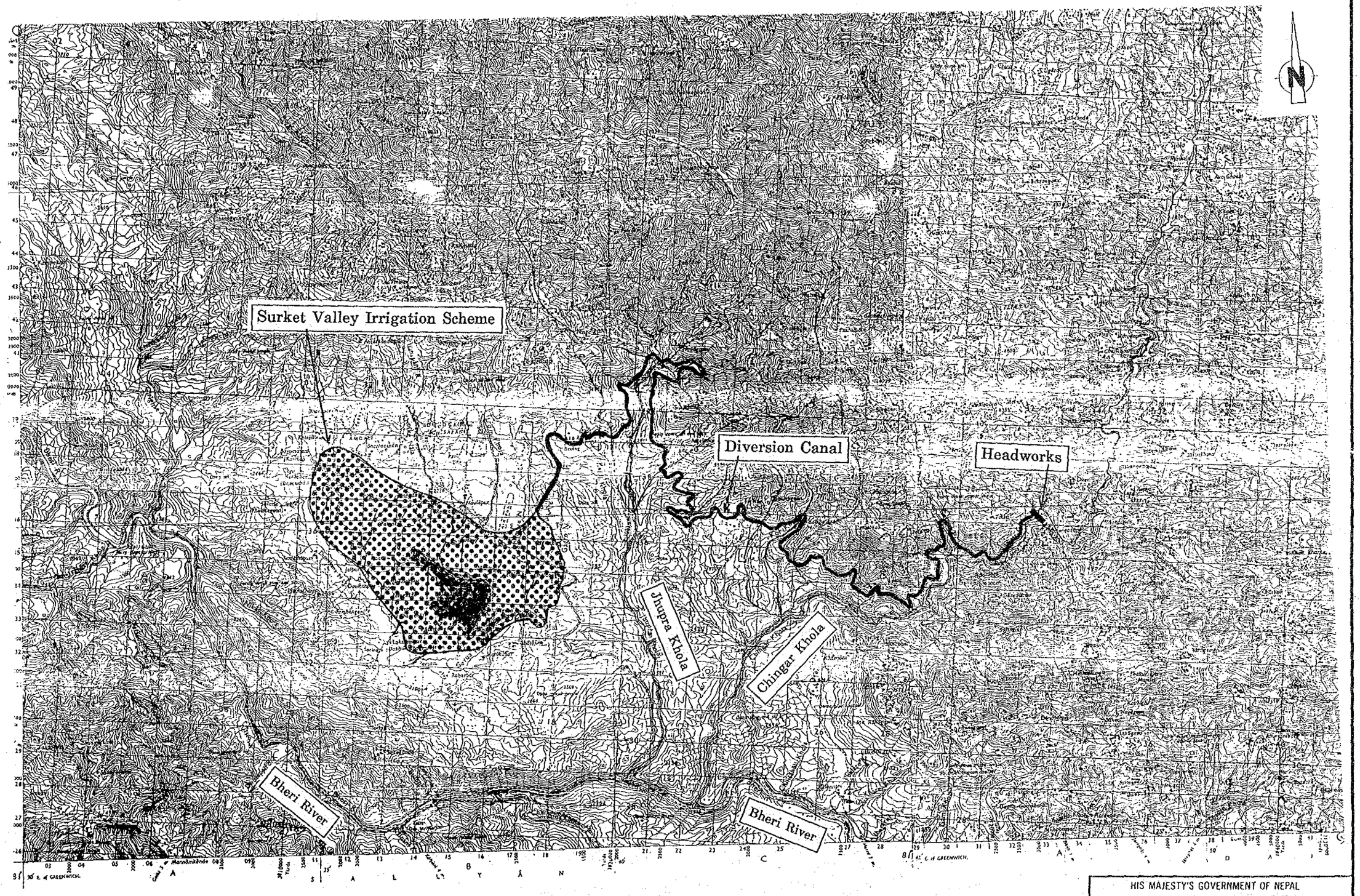
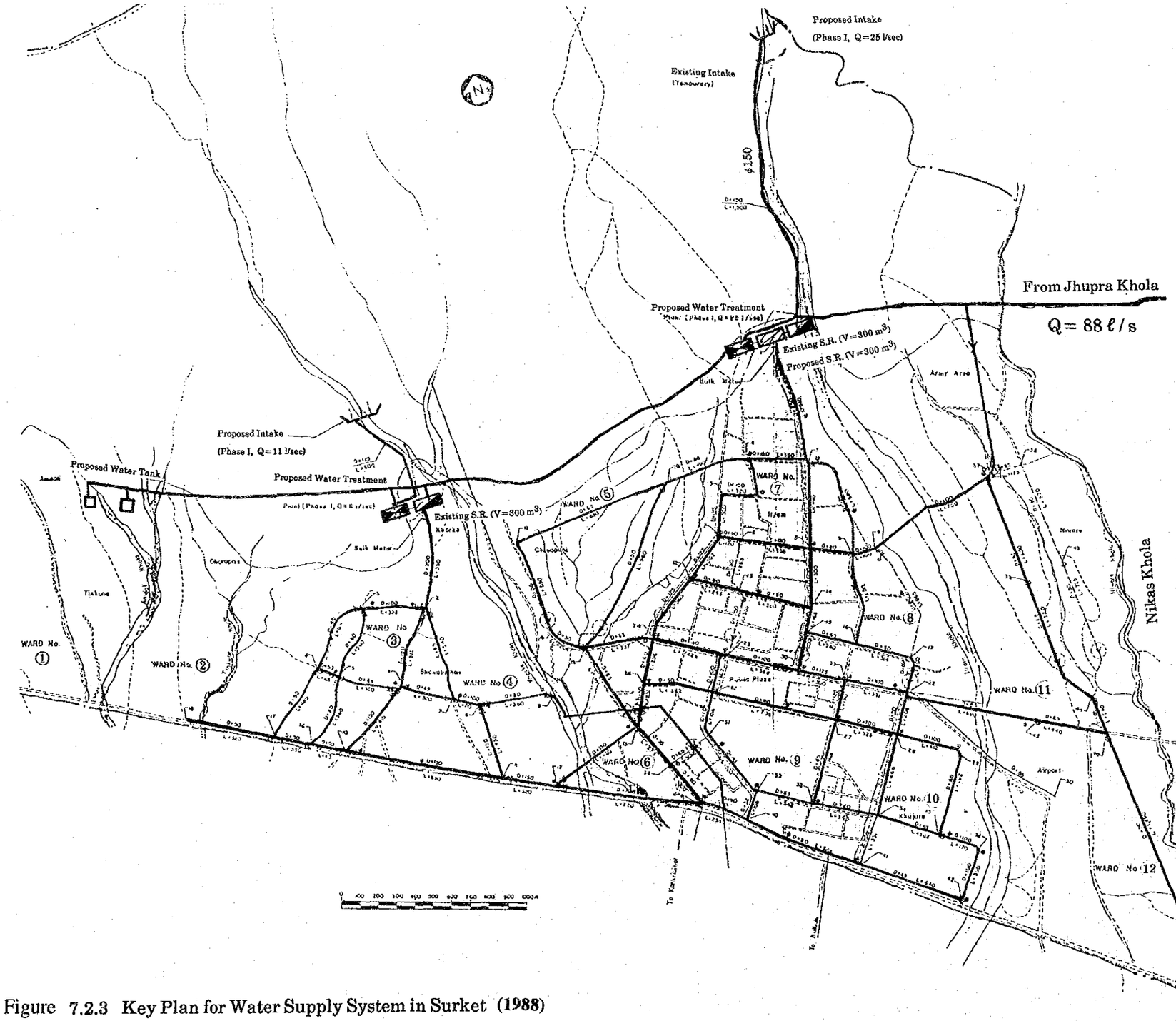


Figure 7.2.2 Surket Valley Irrigation Scheme (water source from Chingar Khola)

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

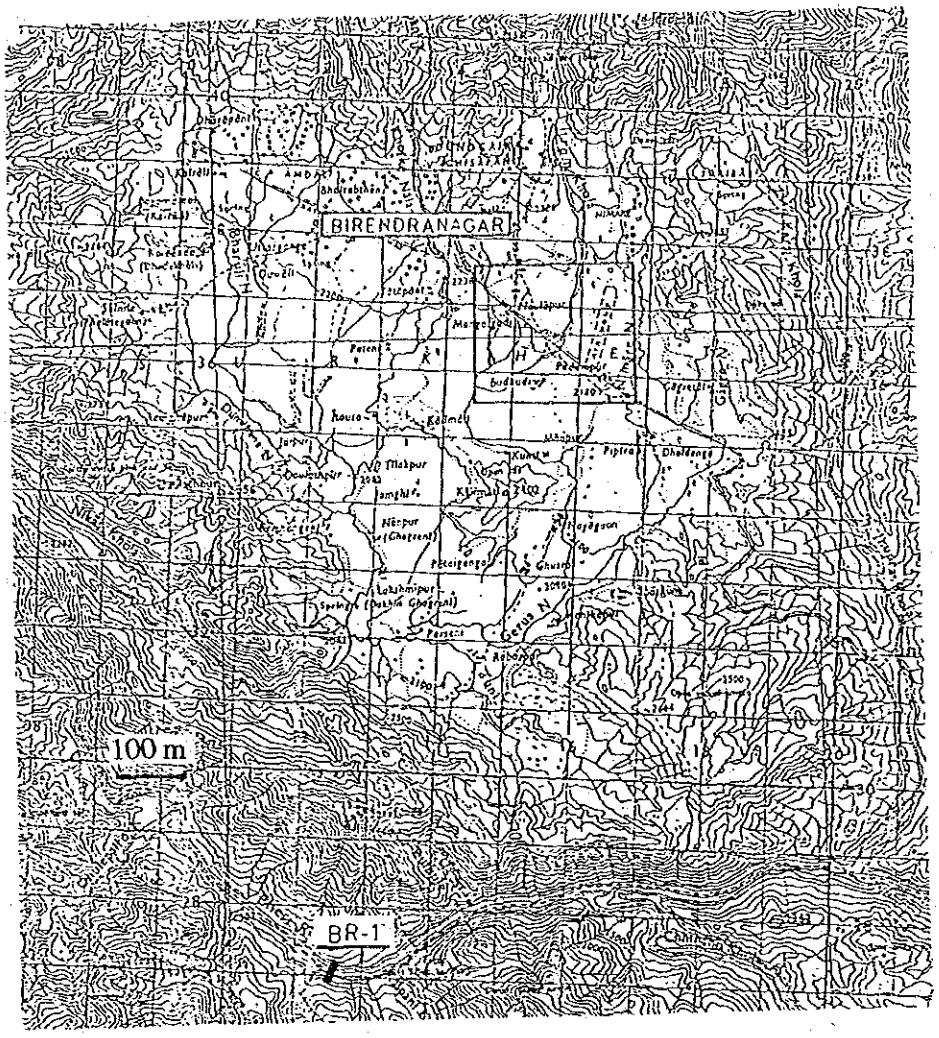


LEGEND

SYMBOL		DESCRIPTION
EXISTING	PHASE I	
1989	1998	Target Year
	1990 - 1998	Construction Period
		Intake (Surface Water)
		Deep Well (Ground Water)
		Water Treatment Plant
		Service Reservoir
		Booster Pumping Station
		Transmission and Distribution Pipeline
		Nagar Panchayat Boundary
		Ward Boundary
		Ward Number
		Khola and Stream
		Metalled Road
		Track
		Water Supply System Division Line
		Junction Number

Figure 7.2.3 Key Plan for Water Supply System in Surket (1988)

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY



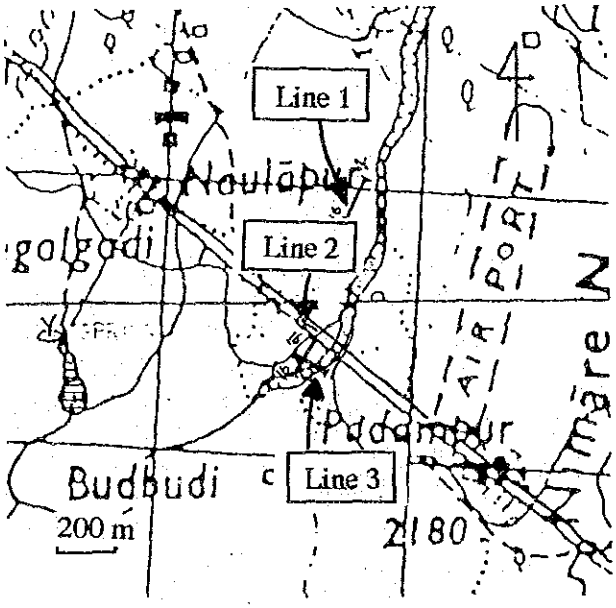


Figure 7.2.4 Index Map of Electric Survey in Surkhet Valley

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

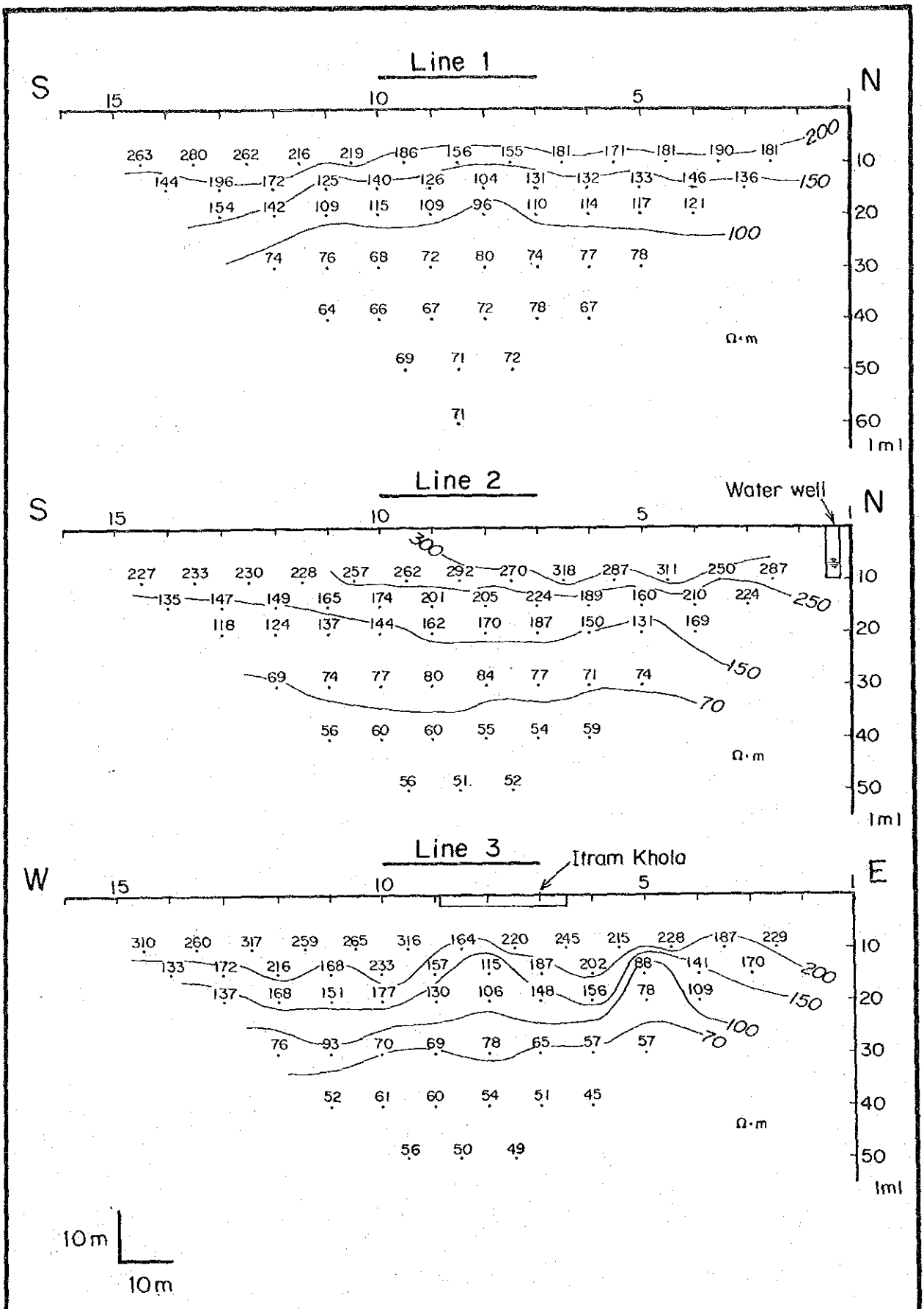
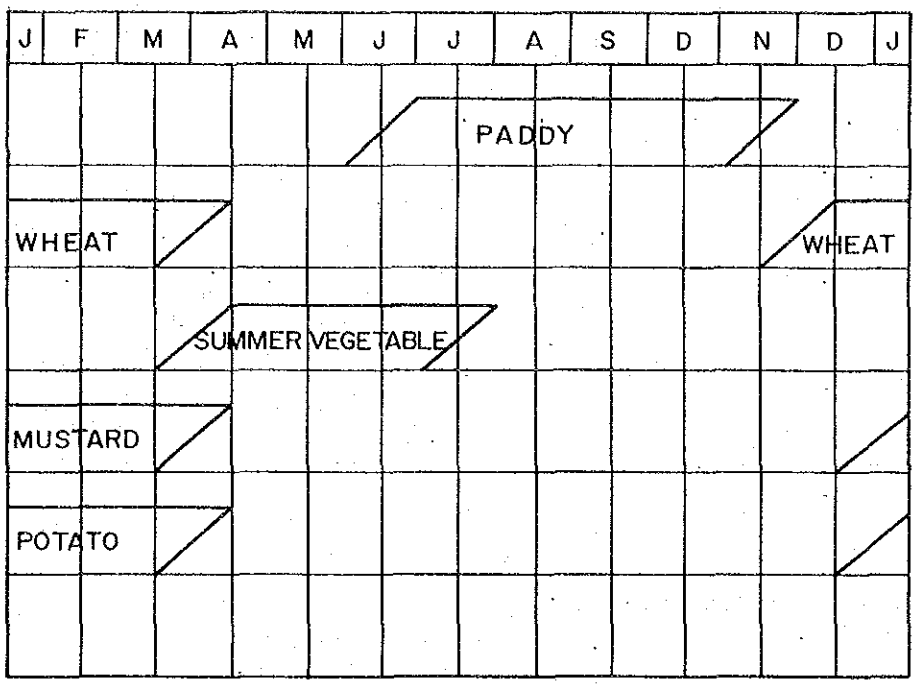
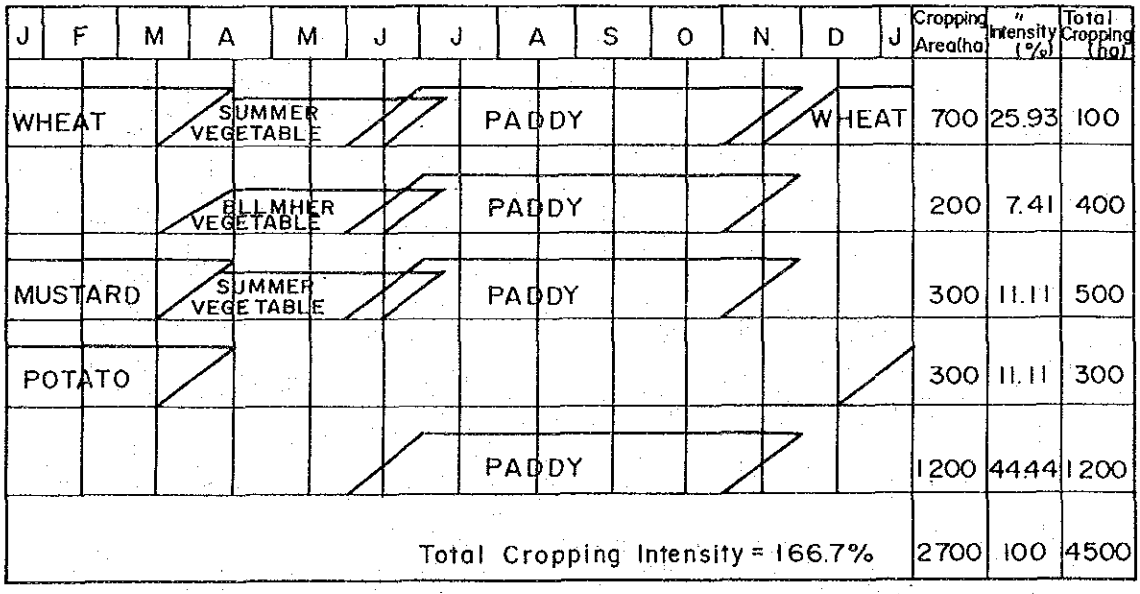


Figure 7.2.5
Resistivity Profile by Dipole- Dipole Configuration in Surkhet Valley

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY



CROPPING INTENSITY 166%



Cropping Area(ha)	" Intensity (%)	Total Cropping (ha)
700	25.93	100
200	7.41	400
300	11.11	500
300	11.11	300
1200	4444	1200
2700	100	4500

GCA : 3000 ha
NCA : 2700 ha

Figure 7.2.6 Proposed Cropping Pattern for Surkhet Valley Irrigation Scheme

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

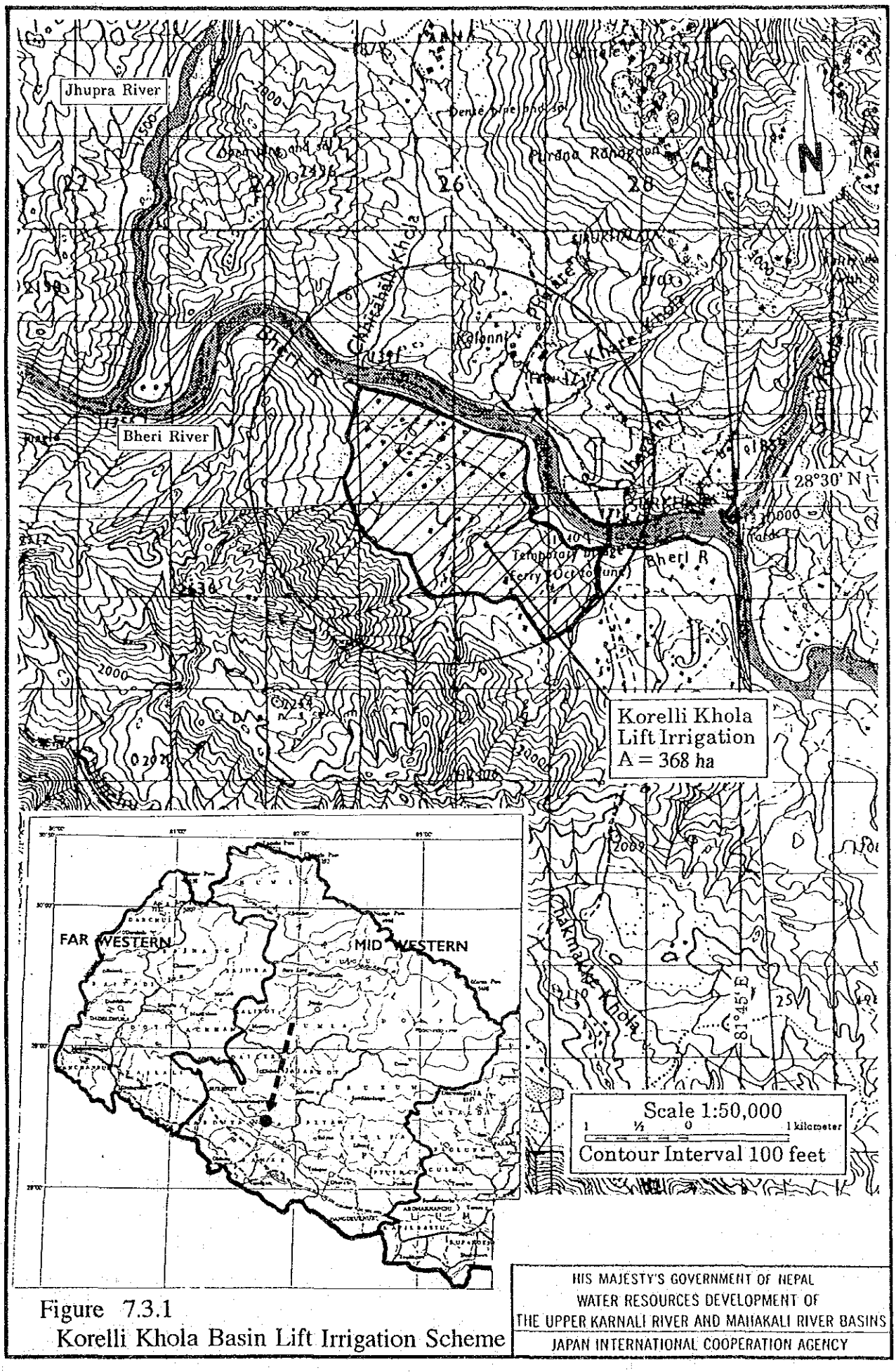


Figure 7.3.1
Korelli Khola Basin Lift Irrigation Scheme

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

Monthly Cropping Pattern Project Requirement

Month	Volume for 1,000 ha (Mm3)		Rate per ha (l/s/ha)	
	Diversion	Consumption	Diversion	Consumption
Jan	1.424	0.712	0.53	0.27
Feb	1.541	0.771	0.64	0.32
Mar	2.231	0.821	0.83	0.31
Apr	1.613	0.472	0.62	0.18
May	0.573	0.121	0.21	0.05
Jun	3.557	0.614	1.37	0.24
Jul	5.699	0.887	2.13	0.33
Aug	6.048	1.082	2.26	0.40
Sep	5.014	0.913	1.93	0.35
Oct	6.215	1.053	2.32	0.39
Nov	4.070	0.652	1.57	0.25
Dec	0.560	0.280	0.21	0.10
Tot	38.545	8.378	1.22	0.27

Source : Cropping Pattern No.11 : HMV/W/YR/C (MPID 2)

Note: CET = Crop Evapotranspiration; FIR = Field Irrigation Requirement; DIR = Diversion Irrigation Requirement

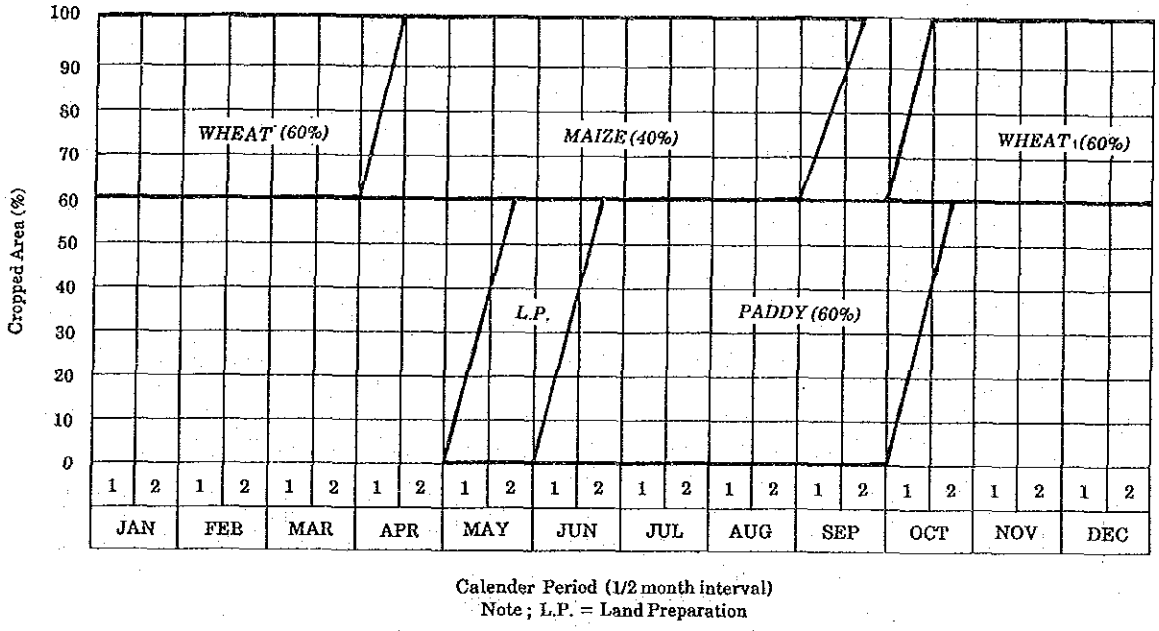


Figure 7.3.2

Proposed Cropping Pattern for Korelli Khola Basin Lift Irrigation Scheme

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

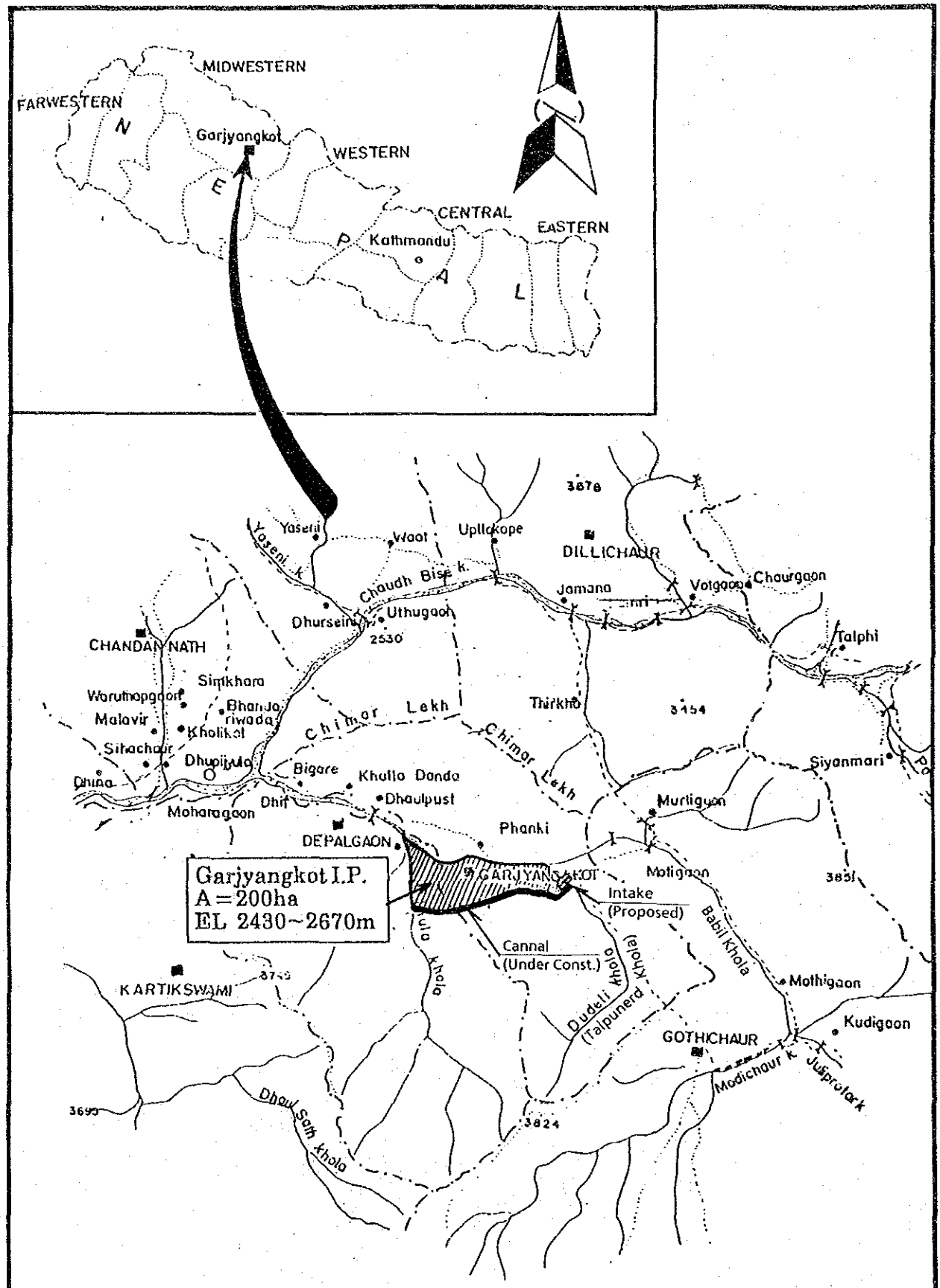
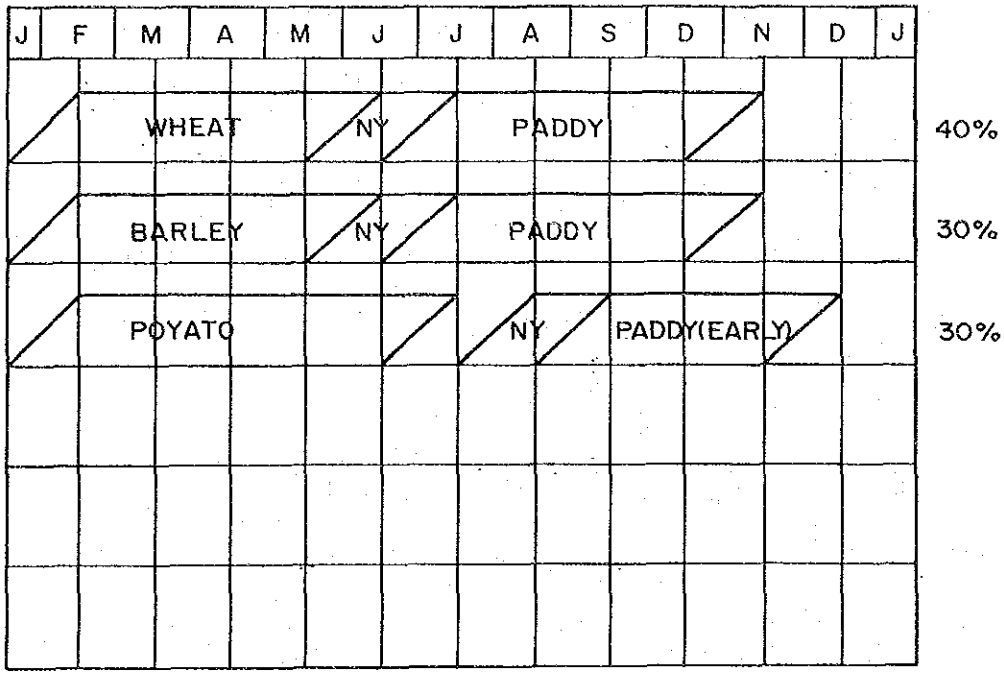


Figure 7.4.1 **Garjyangkot Irrigation Scheme**

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY



TOTAL COMMAND AREA — 200 ha
CROPPING INTENSITY — 200 %

AREA COVERED BY EACH CROP
PADDY 100% 200 ha
WHEAT 40% 80 ha
BARLEY 30% 60 ha
POTATO 30% ...60 ha

Figure 7.4.2

Proposed Cropping Pattern for Garjyangkot Irrigation Scheme

HIS MAJESTY'S GOVERNMENT OF NEPAL
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY

APPENDIX VII

FLOOD MITIGATION

APPENDIX VII

FLOOD MITIGATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The objectives of the flood mitigation study are (a) to clarify the present situations of river problems in the Study Area, (b) to identify a priority flood mitigation scheme out of potential ones, and (c) to prepare recommendations on the needs for the flood mitigation works to be done in the future. The Study Area consists of the area of the upper Karnali River basin upstream of the full supply level of the Karnali Multipurpose Project and the Mahakali River basin within the territory of Nepal.

The flood mitigation study during Phase I, between November 1991 and January 1992, mainly comprised data collection and field reconnaissance. It was found that no particular systematic inventory study of river problems or flood mitigation schemes was available in the Study Area at the central level. Therefore, the field investigation of Phase II, between March and April 1992, aimed to clarify present situations of river problems in the hill area by inquiring them at the Regional Irrigation Directorates, District Irrigation Offices and other agencies concerned. In addition to the above, river problems of the downstream area of the Karnali and Mahakali rivers in the Terai area and other rivers lying between them were also surveyed to compare those in the hill area. During the succeeding home office work, between May and August 1992, a preliminary river training work plan in the hill area was presented. In addition, river training works for the Dodhara and Chandani areas were selected as a flood mitigation priority scheme. During the field investigation of Phase III, between February and March 1993, a field survey was carried out in the Dodhara and Chandani areas regarding (a) the present situation and (b) the present agricultural situation including irrigation system in order to confirm the importance of the development of these areas. Besides the above, the existing river training works were surveyed, and the construction cost for the required river training works was reviewed. This appendix includes all the findings obtained and the study results analyzed during the Study.

2. OVERVIEW OF RIVER PROBLEMS AND RIVER TRAINING WORKS IN NEPAL

2.1 Rivers

2.1.1 River Basins

According to " Erosion and Sedimentation in the Nepal Himalaya " published by the Water and Energy Commission Secretariat (WECS) in 1987 (Ref. VII-1), all the rivers in Nepal are divided into ten river basins as listed below :

No.	Name of river basins	Catchment area : km^2	
1.	Mahakali	15,260	(5,317)
2.	Karnali	43,700	(43,227)
3.	Babai	3,270	(3,252)
4.	Rapti	6,500	(6,215)
5.	Gandaki	34,960	(31,726)
6.	Bagmati	11,610	(3,681)
7.	Kamala	2,160	(1,786)
8.	Kosi	60,400	(27,863)
9.	Kankai	1,575	(1,317)
10.	Southern border river groups	19,572	(22,797)
	Total	199,007	(147,181)

Note : The above catchment areas include those in India and/or China territory and figures between parentheses are those in the Nepal territory.

2.1.2 Classification of Rivers

F. Zollinger, author of "Analysis of River Problems and Strategy for Flood Control in the Nepalese Terai" (Ref.VII-2), suggested in his report that the rivers in Nepal are broadly divided into three classes in terms of the catchment type as summarized below :

Class I rivers : Four major rivers flowing from the Himalayas and Tibet such as the Mahakali, Karnali, Gandaki and Sapta Kosi rivers with a

catchment area more than 15,000 km^2. The Karnali, Gandaki and Sapta Kosi rivers originate from the Tibetan plateau and cross Himalayas.

Class II rivers : Middle size rivers originating in the midlands such as the Babai, West Rapti, Tinau, Bagmati, Kamala and Kankai rivers with a catchment area between 500 and 15,000 km^2. These rivers originate below the snow line.

Class III rivers : Remaining numerous small rivers coming from the southern slopes of the Siwaliks with a catchment area less than 500 km^2.

2.1.3 General Characteristics of Rivers

Most of major rivers in Nepal, before entering the Terai area, flow in narrow gorges with a gradient steep enough to enable them to transport bed load. In the Terai, they spread out with a decrease in their gradient and flow capacity. Other rivers originating from the southern slope of the Siwaliks are characterized by drying up of river channels in the dry season and flash floods in the monsoon season.

General characteristics of rivers in Nepal are briefly summarized below based on the results of the field investigation and hydrological data :

- Melting of snow and ice on the above-mentioned Class I contribute to the constant base flow.

- The absence of snow and glacier melt in the dry season on the Class II rivers results in much higher flow fluctuation than flow fluctuation on the Class I rivers.

- Numerous small rivers belonging to the Class III are characterized by high flood peaks in the monsoon season and low flow in the dry season.

- Rivers running in high mountain regions usually form narrow and deep gorges. At wider river sections, the gradient of river bed is relatively gentle, and alluvial plain or terraces are formed.

- Rivers running in the middle mountains form alluvial plains and fans.

- After flowing into the Terai area, rivers generally meander without forming fixed river channels in the flat area. Observed are a lot of sand bars or islands in the river course, which are sediment deposit transported by tractive force of floods.

2.2 River Problems

2.2.1 Classification of River Problems

Primary problems of rivers in Nepal are classified as listed below and briefly reviewed in the succeeding sub-sections :

- Loss or damage of habitants, lands and houses caused by inundation, riverbank erosion, or washout at floods,
- Devastating damage caused by floods resulted from outburst of glacier lakes,
- Substantial bed rise in the plains including formation of meandering and multiple channels,
- Flood inundation problems in some areas located close to the border between Nepal and India, and
- River water utilization of large rivers under formal water agreements between Nepal and India.

2.2.2 Flood Damage Record

Damage records of such disasters as fires and epidemics are collected by each district office through an interview survey and transferred to the Ministry of Home. Damages induced by floods and landslides are included in the records, having relatively large portion of the total damages. The damage records in Nepal for the eight-year period from 1983 to 1990 were prepared by District Disaster Relief Committee as shown in Table 2.2.1, and the records in the recent 1987-1990 period are summarized below:

Fiscal year	Dead	Injured	Houses	Family affected	Livestock lost
1987					
Flood/Landslides	391	162	33,721	96,151	1,431
Total disaster damage	881	162	36,220	97,036	1,852
1988					
Flood/Landslides	328	198	2,396	4,113	539
Total disaster damage	1,584	12,543	108,801	70,197	2,789
1989					
Flood/Landslides	680	0	6,024	N.A.	1,512
Total disaster damage	1,716	3,014	18,974	N.A.	4,210
1990					
Flood/Landslides	307	26	3,060	5,165	314
Total disaster damage	913	196	6,352	8,461	867

Note : N.A. means that data is not available.

It is noted that downpour occurred in July 1993 in the Central Development Region between the Mahabharat ranges and the Siwaliks hills, causing severe damage in the Terai areas of the Bagmati, Kamala and East Rapti rivers. On the other hand, torrential rainfall occurred in September 1993 in the Mahakali River basin, damaging its downstream reaches lying the Terai.

2.2.3 Glacier Lake Outburst Flood

Most of the major perennial rivers of Nepal originate from the High Himalaya, where a number of glacier lakes embanked by glacier ice, moraine or ice-cored moraine are found. These lakes are essentially consolidated and sometimes burst to flooding by such causes as piping under ice or overtopping by upper glacier calving, flood types of which are called Glacier Lake Outburst Flood (GLOF). Glacier lake outburst floods incur debris torrents downstream within a short time to damage roads, bridges and villages as well as loss of human life and to generate severe riverbank erosion followed by high sediment concentration. In planning the development of a water resources project, the possibility of GLOF in an objective area is subject to a careful scrutiny.

Comprehensive studies on GLOFs are available in Nepal. Of them, representatives are " Preliminary Study of Glacier Lake Outburst Floods in the Nepal Himalaya, Phase 1 - Interim

Report" (Ref.VII-3) and " Preliminary Work Report on Glacier Lake Outburst Flood in the Nepal Himalaya" (Ref.VII-4). These reports describe the glacier lake inventory in Eastern, Central and Western Development Regions and the recent hazards of GLOFs affecting Nepal recorded on the Tamur Khola, Arun, Dudh Koshi and Sun Koshi rivers in the Sapta Koshi drainage system and the Trisuli and Seti rivers in the Narayani drainage system. A recent instance of a catastrophic flood is reported on the Bhote/Dudh Kosh rivers on August 4, 1985. A glacier lake named Dig Cho overtopped a terminal moraine with a volume of six to ten million m^3 of water, and the flood wave lasted about four hours.

No systematic studies in the Mid Western and Far Western Development Regions have been done so far. Some glaciers exist in the upper Mahakali River basis as shown in Figure 2.2.1 and two glaciers, i.e.Nal Kankal and Sakhimohar, lie in the upper Karnali River basin as shown in Figure 2.2.2. It is found, however, that (a) no record of GLOFs was reported in the Study Area, (b) glacier lakes are said to be much more developed in East Nepal than West Nepal, and (c) no glacier lakes are identified in the Mahakali River basin on the satellite image on a scale of 1: 250,000 as studied during the Pancheshwar Field Investigation. A further visual field investigation will be required to confirm for making the risk of GLOFs less during the feasibility study stage of water resources development in the Study Area.

2.2.4 Inundation Problems between Nepal and India

It is reported that the Terai in the Nepal territory near the Nepal-India international borders was artificially inundated by such river structures as barrages and river training works built in India. Upon the recognition of the Indian government for the situation, both the governments agreed to establish a Standing Committee in 1986, which aims (a) to identify problem areas, (b) to itemize actions to be taken, and (c) to suggest solutions of the problems.

After the first meeting held in July 1986, a total of 31 problem areas was identified in the Nepal territory as shown in Table 2.2.2 and plotted in Figure 2.2.3. A total of 15 inundation problems has been dropped as both the parties agreed that these are not so serious or the problems with less priority, but remaining 16 problem areas are under discussion or in process of taking countermeasures.

In the Karnali and Mahakali drainage basins, five inundation problems have been identified as listed below, which are under discussion between Nepal and India (refer to Table 2.2.3.).

- Item No. 14 : Darchula District headquarters in Darchula area in the Mahakali River

- Item No. 31 : Jogbure area in Kanchanpur District in the Mahakali River

- Item No. 26 : Chaugurdi village and border area of Dhansingh village of Kailali District in the Karnali River

- Item No. 27 & 29 : Rajapur village and Gulariya village in Bardiya District in the Karnali and Babai rivers.

2.2.5 River Water Utilization between Nepal and India

Nepal and India have made formal water agreements on the water use of three large rivers: i.e. the agreement related to the Sarda Project on the Mahakali River, the agreement on the Gandaki Irrigation and Power Project, and the Kosi Project Agreement on the Kosi River. Every agreement was reached between two countries aiming at (a) the construction of a barrage by India and (b) supply of irrigation water and hydropower energy to Nepal. Recently an agreement related to the Tanakpur Hydroelectric Project was reached. In this Appendix VII, the agreements related to the Sarda Project and Tanakpur Hydroelectric Project are mentioned hereunder.

The Sarda Project Agreement was completed in 1920. The construction of Sarda Barrage by India necessitated the exchange of land of 4,093.88 acres in the barrage area, initially having belonged to Nepal, for an equivalent area of land from India. India has provided irrigation water for the Mahakali Irrigation Project in Nepal for the period listed below:

- In the wet season (May 15 to October 15) 400 cusec at minimum to 1,000 cusec at maximum, and

- in the dry season (October 16 to May 14) 150 cusec at minimum.

The Tanakpur Barrage is almost completed in early 1993 by providing the land for the construction of the left afflux bund about 577m in length. In exchange of land, the following clarification was agreed upon in the Joint Communiqué in October 1992 between both countries: