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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF WATER RESOURCES
HIS MAJESTY'S GOVERNMENT OF NEPAL

MASTER PLAN STUDY FOR WATER RESOURCES DEVELOPMENT OF THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS

FINAL REPORT

VOLUME I

EXECUTIVE SUMMARY

OCTOBER 1993

NIPPON KOEI CO., LTD., TOKYO JAPAN
CHUO KAIHATSU CORPORATION, TOKYO JAPAN

This Report consists of

Volume I	Executive Summary	
Volume II	Main Report of Part I (General Study of the Master Plan)	
Volume III	Main Report of Part II (Detailed Analysis of Priority Schemes)	
Volume IV	Supporting Report	
	Appendix I	Topography and Geology
	Appendix II	Meteorology and Hydrology
	Appendix III	Land Use, Environment and Watershed
Volume V	Supporting Report	
	Appendix IV	Hydroelectric Power Generation
	Appendix V	Domestic Water Supply
Volume VI	Supporting Report	
	Appendix VI	Irrigation
	Appendix VII	Flood Mitigation
Volume VII	Data on Geological Investigation and Cost Breakdown of Hydropower Potential Schemes	

The cost estimate was based on the March 1993 price level and expressed in US Dollar according to the exchange rate of US$ 1.00 = Nepal Rupees 46.65 = Japanese Yen 116.30 as of March 31, 1993.

PREFACE

In response to a request from the Government of the Kingdom of Nepal, the Government of Japan decided to conduct a Master Plan Study for Water Resources Development of the Upper Karnali River and Mahakali River Basins in Nepal and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Nepal a study team headed by Mr. Ichiro Kuno, Nippon Koei Co., Ltd., and composed of members from Nippon Koei Co., Ltd. and Chuo Kaihatsu Corpoation, five times between November 1991 and August 1993.

The team held discussions with the officials concerned of the Government of Nepal, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Nepal for their close cooperation extended to the team.

October 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

October 1993

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

Letter of Transmittal

We are pleased to submit herewith the Final Report of Master Plan Study for Water Resources Development of the Upper Karnali River and Mahakali River Basins. This Report deals with the formulation of master plan for water resources development in the Karnali River basin upstream of the full supply level of the Karnali Multipurpose Project and the Mahakali River basin within the territory of Nepal. Studies were further extended to the nine priority schemes selected in this master plan study taking into consideration not only economic viability but also contribution to the regional development and spatial distribution.

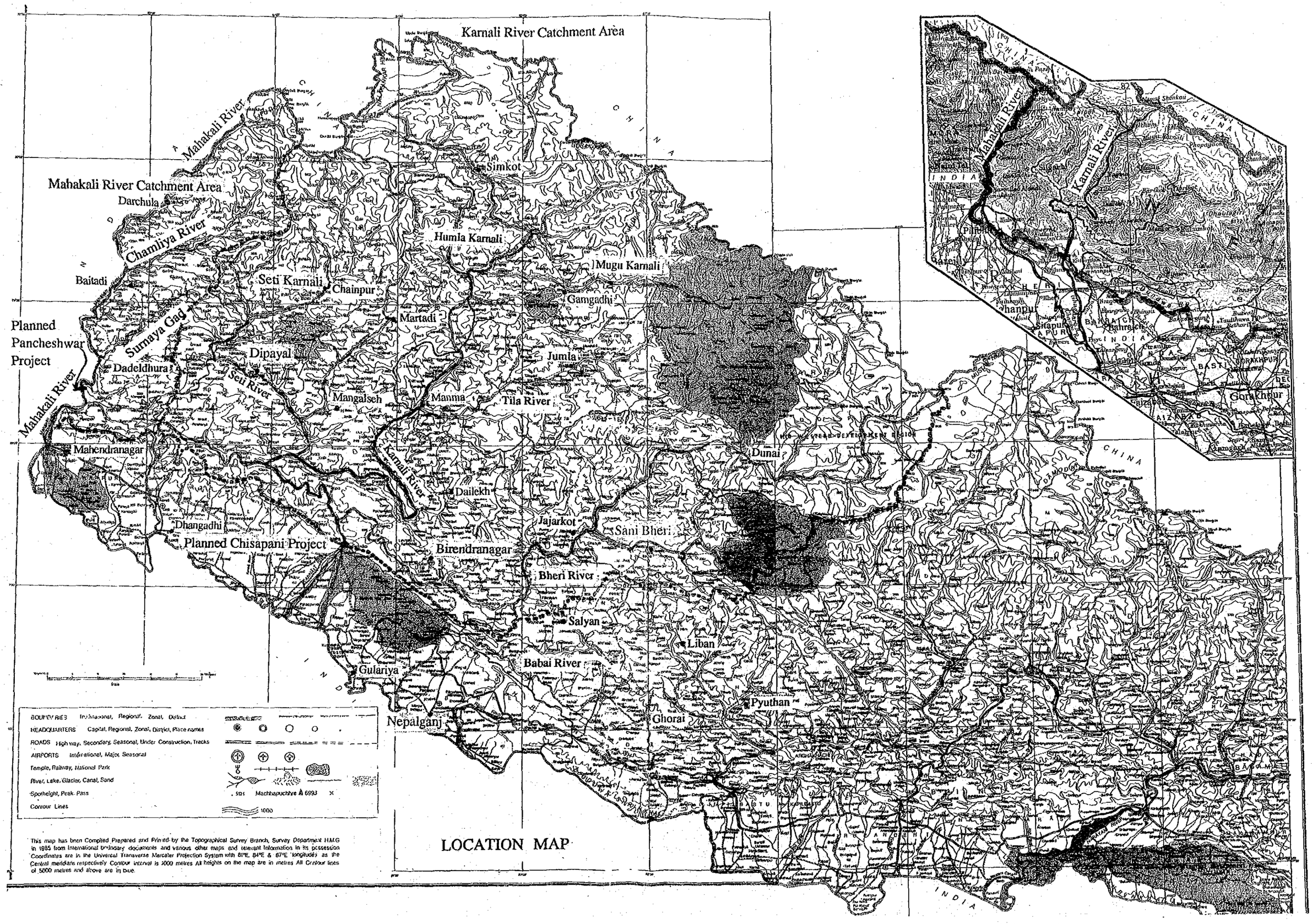
The Report consists of seven volumes, Executive Summary, Main Report of Part I, Main Report of Part II, three Supporting Reports and Data Book. Main outputs of this study are presented in Executive Summary. Main Report of Part I deals with the general study of the master plan, whilst Main Report of Part II gives detailed analysis of the priority schemes selected in this study. Three Supporting Reports give in-depth discussions for respective study items. Data Book compiles the results of geological investigation carried out in this study and cost breakdown of hydropower potential schemes.

We would like to express our grateful acknowledgment to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Nepal, and also to officials and individuals of the Government of Nepal for their assistance and advice extended to the Study Team. We sincerely hope that the results of this study would contribute to the regional development of the Study Area.

Yours sincerely,

Ichiro Kuno
Team Leader
Master Plan Study for
Water Resources Development of
the Upper Karnali River and Mahakali River Basins

LOCATION MAP



This map has been Compiled Prepared and Printed by the Topographical Survey Branch, Survey Department HMG in 1985 from International boundary documents and various other maps and relevant information in its possession Coordinates are in the Universal Transverse Mercator Projection System with 81°E, 84°E & 87°E longitudes as the Central meridians respectively Contour interval is 1000 metres All heights on the map are in metres All Contour lines of 5000 metres and above are in bue.

MASTER PLAN STUDY FOR
WATER RESOURCES DEVELOPMENT OF
THE UPPER KARNALI RIVER AND MAHAKALI RIVER BASINS
OUTLINE OF STUDY

1. Objectives of the Study

The objectives of the captioned Study were to formulate a master plan for water resources development of the Study Area, which 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, but the plan may include some schemes which will affect some area of the lower Karnali River basin and its vicinity, and to transfer technology to Nepalese counterpart personnel in the course of the Study.

2. Study Period and Cooperation

The Study was carried out over the period November 1991 to October 1993 by the Study Team of Japan International Cooperation Agency (JICA) in collaboration with counterpart personnel of the Ministry of Water Resources (MWR) of His Majesty's Government of Nepal (HMG/N).

3. Water Resources Development Potential in the Study Area

Investigation to identify the water resources development potential in the Study Area was carried out for hydropower, irrigation, domestic water supply, flood mitigation and watershed management. Main outcomes of the investigation are summarized as follows:

(1) Hydropower

A total of 23 hydropower potential schemes was identified in the Karnali River and Mahakali River basins including the Karnali (Chisapani) and Pancheshwar projects by the past studies. This Study newly added 15 schemes, and thus 38 hydropower potential schemes were identified in the Study Area. After the computation of power and energy outputs and the cost estimate for those identified schemes, six reservoir type and ten run-of-river type schemes besides the schemes, which are under the feasibility and pre-feasibility study level, were assessed to be viable for the implementation in economic terms.

(2) Irrigation

In irrigation, seven large scale potential schemes were identified; three run-of-river schemes including Sikta, Babai, Khutiya II and Mahakali II, and three multipurpose schemes including West Rapti, Karnali and Bheri-Babai. On the other hand, small potential schemes identified are 82 including 11 schemes in the Terai Ecological Belt, 38 schemes in the Hill Ecological Belt and 33 schemes in the Mountain Ecological Belt.

Vol. I Executive Summary

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EXECUTIVE SUMMARY

1. INTRODUCTION

A Master Plan Study for Water Resources Development of the Upper Karnali River and Mahakali River Basins in the Kingdom of Nepal (the Study) was carried out over the period November 1991 to October 1993 by the Study Team of Japan International Cooperation Agency (JICA) in collaboration with counterpart personnel of the Ministry of Water Resources (MWR) of His Majesty's Government of Nepal (HMG/N). The objectives of the Study were to formulate a master plan for water resources development of the Study Area (refer to Location Map and Figure 1), which 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, but the plan may include some schemes which will affect some area of the lower Karnali River basin and its vicinity, and to transfer technology to Nepalese counterpart personnel in the course of the Study. This Final Report was prepared by summarizing all the results achieved through the course of the study, highlighting the formulation of the master plan for water resources development in the Study Area and the further detailed studies for the priority schemes selected from among the identified potential schemes.

2. COMPOSITION OF THE REPORT

This Final Report of the master plan study is composed of seven volumes. Volume I is the executive summary, which deals with the main outcomes of the Study. Volume II is the main report of Part I to discuss the general study of the master plan for water resources development of the Study Area, whilst Volume III is the main report of Part II to deal with the further studies of the selected priority schemes. Volumes IV to VI are the supporting reports to discuss by study item, and Volume VII is a data book, which contains results of geological investigation and detailed breakdown of construction costs for hydropower potential schemes.

PART I: GENERAL STUDY OF THE MASTER PLAN

3. OVERVIEW OF NEPAL

The Kingdom of Nepal has a land area of 147,000 km^2, which is extending from the Himalaya range in the north to Terai plain in the south. The climate varies from arctic in the north to subtropical in the south. The land is classified into agricultural land of 27%, forest land of 38%, shrub of 5%, grazing land of 12% and other lands of 18%. According to the 1991 census, total population is 18,462,081. The annual population growth rate is estimated at 2.08% over the period 1981 to 1991. Gross Domestic Product (GDP) at the current market price in year 1989/90 was Rs. 88,711 million, corresponding to US$ 160 per capita. The balance of external trade was in deficit of Rs. 13,183 million in year 1989/90. Agriculture sector accounted for 53.4% of GDP with labour force of more than 90% engaged in this sector.

Total cultivated area is 2.6 million ha. Major crops are food grains, of which total production volume was 4.9 million tons in year 1987. Improved seeds and chemical fertilizers are little used. Inadequate water is available even on the most irrigated farms. In consequence, crop yields are generally low and largely fluctuate depending on climate. Nepal has been shifted from a net exporter to a net importer of food since mid-1980's. Food self-sufficiency stays at a level of 80 to 90% at present.

The total length of roads was 7,007 km in year 1989, more than half being gravel or earthen roads. There are 43 airports/air strips in the country for international and domestic air services. The communications system is underdeveloped mainly due to mountainous terrain. There are 260 MW of electric power generation facilities, among which hydropower is dominant. HMG/N is implementing mini hydroelectric power projects in isolated places.

The Eighth Plan (1992/93 to 1996/97) is the first economic development plan which was promulgated under the new Constitution (1990). The Plan is prepared for the objectives of sustainable economic growth, poverty alleviation, and rural development and regional balance, being guided by a philosophy of the assurance of a minimum standard of living for the poor, people's participation in planning and development and maximum privatization of productive activities.

4. GENERAL DESCRIPTION OF THE STUDY AREA

The Study Area is identified with the entirety of the Mid Western Development Region (MWDR) and the Far Western Development Region (FWDR). According to grouping of districts into ecological belts, the total area of 61,917 km^2 consists of 8,927 km^2 of Terai Ecological Belt, 26,029 km^2 of Hill Ecological Belt and 26,961 km^2 of Mountain Ecological Belt. The relief of the Study Area is characterized by west northwest-east southeast running ranges, i.e. the Himalaya, Mahabharat, Churia and Dundwa ranges. The ranges are cut by deep river valleys. The Karnali and Mahakali rivers originating from the Himalaya range drain most Mountain and Hill Ecological Belts with a catchment area of 43,679 km^2 at the proposed Karnali Multipurpose Project site of the Karnali River and 12,600 km^2 at the Pancheshwar Hydroelectric Project site of the Mahakali River. The Bheri and Seti rivers, which are main tributaries of the Karnali River and originate from Hill Ecological Belt, are major rivers draining the Terai Ecological Belt.

Geology of Himalaya is divided into three zones, i.e. Siwalik (Sub-Himalaya), Midland (Lesser-Himalaya) and Higher Himalaya (Greater-Himalaya) from south to north based on the litho-structural condition (refer to Figure 2). The Siwalik is young sedimentary molasse deposits of Tertiary age. In Midland, widely distributed are low grade metamorphic rocks such as phyllites, quartzites and limestones. The Higher Himalaya consists of crystalline rocks at the base and sedimentary rock succession at the top.

The climate of Nepal is in general classified into two seasons; one is a rainy season lasting for a period of June to September and the other is a dry season prevailing in winters. Average annual rainfall of the Study Area is estimated at 1,262 mm from the isohyetal map prepared on basis of 1963 to 1989 records observed at the rain gauges in and around the basins (refer to Figure 3). Rainfall brought by the southeast monsoon accounts for more than 75% of annual rainfall.

There are 15 stream gauges in the Study Area and four stations in the Indian territory of the Mahakali River basin (refer to Figure 1). According to the records observed in the period of 1963 to 1989, mean annual runoff in terms of specific discharge falls in the range of 0.038 to 0.057 $m^3/sec/km^2$ for the Mahakali River basin and 0.026 to 0.039 $m^3/sec/km^2$ for the Karnali River basin. Sediment yield is estimated at 2,322 $m^3/km^2/year$ for the Karnali River and 3,060 $m^3/km^2/year$ for the Mahakali River in terms of specific yield.

The Terai area is generally covered with fine to medium textured alluvial soils of deep horizon and high water holding capacity. Siwaliks soils are fine loamy to sandy often containing pebbles. They are generally shallow and acidic, having low water holding capacity.

Soils in the mountain areas are generally sandy to gravely with light to medium texture. They are acidic, less fertile and highly erodible. High agricultural potential area is estimated at 666,724 ha, accounting for only 10.7% of the Study Area.

Flora in Nepal is rich and there are a number of forest types because of wide variety of climate. Land Resource Mapping Project (LRMP) estimated that 62% of Terai tropical hardwood forest had been cleared for agriculture. The forests in other areas are also degraded rapidly. The proportional extents of land use in the Study Area are calculated to be 17.5% of cultivated land, 15.2% of grazing land, 42.4% of forest land, 2.2% of shrub and 22.8% of other lands based on LRMP data. An observation indicates that the Study Area is characterized by small cultivated area and large forest relative to the national average.

There are five categories of protected areas such as the National Park, Wildlife Reserve, Strict Nature Reserve, Hunting Reserve and Conservation Area in Nepal according to the National Parks and Wildlife Conservation (NPWC) Act 1973, totalling an area of 15,933 km^2. Of this, 5,366 km^2 or one-third is located in the Study Area. Many kinds of animals are found in the protected areas of the Study Area due to the variety of climate as mentioned earlier. Of them, some faunas are protected by NPWC Act; 27 Mammalia, 3 Reptilia and 9 Aves, but not flora. As many as 18 different species of fish are observed in the Karnali River.

Water quality tests were conducted in the Karnali and Mahakali rivers by the Study Team. According to the test results, contents of calcium, which causes coagulation of surface soil, stay at an intermediate level. Thus, water in the Study Area can be used for irrigated farming, but appropriate treatment is required for drinking water. Water-borne diseases prevalent in the Study Area are many digestive tract diseases, hepatitis A, entozoon, Japanese encephalitis and malaria.

5. SOCIO-ECONOMIC CONDITIONS IN THE STUDY AREA

The Study Area administratively lies in the Mid Western and Far Western Development Regions as mentioned earlier. The former region includes three zones and 15 districts, whilst the latter is composed of two zones and nine districts (refer to Figure 4). Population in the Study Area is 4,079,548 in year 1991, and its annual growth rate between 1981 and 1991 is 2.2% on an average. A dominant ethnic group living in the Study Area is the Chhetri, followed by the Thakuri and the Brahman. Minor groups such as the Bhotiya and the Magar are inhabited in the high Himal areas. The Tharu, which is dominant in the Terai, lives in the Surkhet Valley.

Major food crops produced in the Study Area are paddy, maize, millet, wheat and barley, totalling 1.1 million tons in 1988/1989 including 558,460 tons of paddy, 257,300 tons of maize, 30,790 tons of millet, 249,840 tons of wheat and 15,980 tons of barley. The production of 1.1 million is translated into the per capita consumption of 279 kg.

The East-West highway in the Study Area will be completed by 1992/93 (refer to Figure 5). A North-South highway each in the Mid Western Development Region and the Far Western Development Region is being developed and partly in service. Literacy ratio in the Study Area is as low as 13% to 20% in year 1988. The gross enrollment ratio in the primary school in year 1989 is only 50% against national average of 73%. Each district has at least one hospital, but no doctor is reported in eight district hospitals. There are many historical and cultural heritages distributed in the Study Area. Among them, Tripura Sundari and the Pancheshwar Mahader temple particularly receive visits of devotees and holy men.

6. WATER RESOURCES DEVELOPMENT POTENTIAL

(1) Hydroelectric Power Generation

The installed and effective capacities of generating facilities are 283.3 and 253.4 MW as of December 1991 in the national power supply system, respectively. By type, hydropower dominates by accounting for 82% in installed capacity and 83% in effective capacity. On the other hand, power demand was projected by JICA using the latest power data (Master Plan and Feasibility Study on Extenstion and Reinforcement of Power Transmission and Distribution System in Kathmandu Valley in Nepal, Final Report, December 1991). The balance between the demand projected by the said JICA study and the supply capacity shows power deficits in year 1994 onward (refer to Figure 6). To meet growing power and energy demands, most promising schemes are Arun 3 (402 MW in total capacity and 201 MW for first phase development in the Aran River), Kali Gandaki A (90 MW in the Kali Gandaki), Kankai (60 MW in the Kankai River) and Khimti (60 MW in the Khimti Khola) hydro plants and fossil fuel plants among others.

The extension of power transmission lines in the Study Area, i.e. a 132 kV line to be completed between Kohalpur and Mahendranagar in year 1993 and 62 kV branch lines between Birendranagar and Dailekh and between Kanchanpur and Dipayal-Silgadhi through Dadeldhura (refer to Figure 7), will spur economic development, resulting in the increase of power demand. Future power demand in the Study Area is estimated to reach a level of 21.5 MW in year 2000/01, 32.4 MW in year 2005/06 and 48.7 MW in year 2010/11 based on the said JICA projection and the EDF result (Ten Year Transmission and Distribution Plan,

Load Forecast Study, December 1989). Thus, installation of a hydropower plant with a capacity of 50 to 100 MW is an urgent requirement for the economic development in the region including power supply to the nearby regions.

A total of 23 hydropower potential schemes was identified in the Karnali River and Mahakali River basins including the Karnali (Chisapani) and Pancheshwar projects by the past studies (refer to Figure 8). This Study newly added 15 schemes, and thus 38 hydropower potential schemes were identified in the Study Area. After the computation of power and energy outputs and the cost estimate for those identified schemes, economic evaluation was carried out to select priority schemes (Tables 1 and 2), which proceed to further study. As a consequence, five reservoir type and ten run-of-river type schemes besides the schemes, which are under feasibility and pre-feasibility study level, gained the internal rate of return (EIRR) higher than 10 %, and were thus assessed to be viable for the implementation. Among them, three run-of-river schemes of BR-1, SR-3 and CR-2 were selected as the priority schemes of hydropower. Besides, one reservoir type scheme of LR-1 was added to the list of priority schemes due to the fact that the development scale is appropriate for the power demand in the Nepal power supply system and that the reservoir type scheme much contributes to the stable power supply in winter when power supply capacity drops, even if EIRR is slightly lower than 10%.

(2) Irrigation

The balance between supply and demand for five main food grains, paddy, maize, millet, wheat and barley, was estimated by applying the food requirements of 311 kg per person to population and production of five main food grains in year 1988, showing a deficit of 21,144 ton, which is equivalent to 9.4 kg per person, in the Mid Western Development Region and 62,114 ton (39.7 kg per person) in the Far Western Development Region. Other development regions, which recorded food shortage, are only the Central Development Region of 2.8 kg per person. This result will tell the necessity of the increase of food production in the Study Area as an urgent task.

The Study Area encompasses a total cultivated area of 655,000 ha including land in the Terai Ecological Belt, of which 594,000 ha are considered irrigable. Of the irrigable cultivated area 193,000 ha have been under some kind of irrigation and the remaining 401,000 ha can be taken as potential area for future irrigation development. Except for the Terai Ecological Belt, most of the irrigable land is in river valleys and small patches on mountain slopes. In the Hill and Mountain Ecological Belts of the Mid Western Development Region, a total of 1,149

schemes has been identified, the development stage for which is from existing to planned, whilst there are 688 schemes in the same Belts of the Far Western Development Region.

The identification of irrigation potential schemes was conducted in this Study. As a result, seven large scale potential schemes were identified; four run-of-river schemes, including Sikta, Babai, Khutiya II and Mahakali II, and three multipurpose schemes, including West Rapti, Karnali and Bheri-Babai (refer to Table 3). On the other hand, small potential schemes identified are 82 including 11 schemes in the Terai Ecological Belt, 38 schemes in the Hill Ecological Belt and 33 schemes in the Mountain Ecological Belt (refer to Table 4). Valley cultivation area where high irrigation potential is assumed was identified at 18 potential sites, including six schemes in the Bheri River system, four schemes in the Karnali River system, two schemes in the Seti River system and six schemes in the Mahakali River system (refer to Figure 9).

From among the identified potential irrigation schemes, four priority schemes, which proceed to the further study stage, were selected; Bheri-Babai Diversion as a large scale scheme and Surkhet Valley, Korelli Khola Basin Lift Irrigation and Garjyang Kot as a small scale scheme.

(3) Domestic Water Supply

Systematic planning and implementation of public water supply and sewerage in Nepal date back to year 1972 when the Department of Water Supply and Sewerage, DWSS, was established to accelerate the development of public water supply and sewerage and to encourage in creating healthy manpower. By the end of year 1990, urban population of 66% could receive the public water supply, whilst this coverage was only 34% for the rural population. In the Study Area, the implementation of water supply was commenced in 1970s with a few schemes in one district, and was spurred in 1980s, but the accomplishment ratio of water supply schemes is far behind from that of national average.

The information on the present status of water supply schemes was collected by distributing questionnaires to each district office. The questionnaires show that water supply schemes in service are at present 203 and 330 in the Mid Western and Far Western Development Regions, respectively (refer to Table 5). In terms of service ratio, which is defined as the rate of the design population of existing water supply schemes to 1991 population, the Mid Western Development Region gained a ratio of 28.5%, whilst the Far Western Development Region accomplished a slightly lower ratio of 22.7%.

The future demand of domestic water supply was projected to estimate the amount of water to be developed or to be augmented in the target years. Water demand increases to a

level of 49,913,235 litre per day or 0.58 m^3/sec in year 2000 and 64,881,450 litre per day or 0.75 m^3/sec in year 2013 in the Mid Western Development Region and 51,521,760 litre per day or 0.60 m^3/sec in year 2000 and 62,711,865 litre per day or 0.73 m^3/sec in year 2013 in the Far Western Development Region (refer to Table 6). The Mid Western Development Region in the Study Area requires to develop an amount of 24,134,906 litre per day or 0.28 m^3/sec by year 2000 and 35,209,591 litre per day or 0.41 m^3/sec by year 2013, whilst total deficits of the Far Western Development Region in the Study Area are 24,327,645 litre per day or 0.28 m^3/sec by year 2000 and 33,011,858 litre per day or 0.38 m^3/sec by year 2013 (refer to Table 7).

(4) Flood Mitigation

Flood damage-prone areas totalled 48 in number were identified in the hill area (refer to Figure 10). A preliminary river training work plan was prepared to aim at giving priority to 21 river training work schemes along about 20 km long riverbank. The priority was given to such areas that flood damages were judged serious, and the past flood damage, the length of riverbank to be protected and types of river training works have been already surveyed by the District Irrigation Offices. The total construction cost was estimated at Rs. 510 million including cost of galvanized iron wire and its transportation cost. There is still need for the District Irrigation Offices of collecting information to mature the preliminary river training work plan.

The river training work scheme of the Dodhara and Chandani areas, about 5,000 ha (refer to Figure 11), was selected as a flood mitigation priority scheme taking into account the following: First of all, area losses due to the bank erosion have brought about a serious problem in spite of the fact that the agricultural production in the Dodhara and Chandani areas greatly contributes to food supply in Kanchanpur District. Secondly, field investigation and preliminary design for the work have been carried out by the Mahakali Irrigation Project Office well enough to proceed to further steps. The total project cost is estimated at Rs. 58.58 million, and its economic project cost is Rs. 49.8 million. The annual benefit values are estimated by multiplying the annual unit flood mitigation benefit, Rs. 31,620 per hectare, by the expected acreage of the farm land to be protected, which corresponds to 70 % of the total protect land. As a result of preliminary economic evaluation, the economic internal rate of return was calculated at 5.8 % and the net benefit is a negative value of Rs. 22.1 million by applying a discount rate of 10 %. Nevertheless, it is recommended that the Dodhara and Chandani areas river training work scheme be proceeded to further studies for implementation. It is also recommended that the river bank profile be monitored continuously.

(5) Watershed Management

Rivers in Nepal, all draining south to the Ganges plain, are characterized by their transportation of tremendous quantities of sediment material. A major force is the geotectonic movement caused by subduction of the Indian plate under the Himalayan mountains, resulting in the uplift and distortion of land, which form unstable steep slopes in the mountain zone. The other is the effect of human activities on forest, shrub, grazing and agricultural lands. Shrestha, B.D. et al (1983) proposed a rating method based on the idea of Nelson, D. et al (1980) to evaluate the condition of watershed. According to this, Surkhet district is classified into Class 5 (very poor) (refer to Figure 12) and requires urgent countermeasures to protect the watershed. Three districts, Dolpa, Rukum and Dailekh, are in a marginal condition, and thus the proper countermeasures should be taken.

Afforestation programmes are carried out with the objectives of soil conservation and watershed management. The districts involved in the programme in the Study Area are Darchula, Baitadi, Dadeldhura, Bujhang, Doti, Bajura and Achham in the Far Western Development Region and Jajarkot in the Mid Western Development Region as of year 1988.

(6) Studies on the Bheri-Babai Diversion Scheme

The implementation of the Karnali multipurpose project would be viable, but it will require much time, say at least 25 years, before starting the construction of the project for tackling such issues as the agreement on energy sale with India, the displacement of people in the reservoir area, financial arrangement for the implementation and so on. The delay of implementing the Karnali project implies that the project will lose the opportunities to earn the benefits originally planned by selling generated energy. The earlier implementation of the Bheri-Babai diversion scheme, which is identified as BR-1 in Figure 8 and has conflicts in water use with the Karnali project, prior to that of the Karnali would make up for a part of benefits which are gained from the Karnali project in economic terms. In this context, the possibilities of earlier implementation of the Bheri-Babai diversion scheme and the potentiality to extend the irrigation command areas lying downstream of the Babai River are discussed.

As for the earlier implementation of the Bheri-Babai diversion scheme, economic internal rate of return (EIRR) gained a value of 12.1% for the design discharge of diversion of 58.2 m^3/sec, and thus the project viability to develop as a hydropower project was verified. As for the extension of irrigation area (refer to Figure 9), paddy cropping in the monsoon season is possible for the entire irrigation area of 74,270 ha, whilst upland crops such as wheat and sugarcane can be planted for an area of 33,270 ha in the winter season.

(7) Studies of Hydropower Scheme as a Multipurpose Scheme

In planning water resources development, full attention should be given to forming multipurpose projects for the effective utilization of limited water resources so far as it is practicable. The incorporation of some single purpose schemes considered separately possibly forms one multipurpose project, which results in reduction of cost to be required if each single purpose scheme is implemented separately. A total of five irrigation schemes, Gatte Khola, Korelli Khola, Nepgad, Natharpur and Karai-Melgad, was considered to be developed together with hydropower as one scheme. As for flood mitigation, flood-prone area of Banedungrisairn located in Doti district can be managed together with the development of the proposed West Seti Hydropower Project.

7. PROPOSED WATER RESOURCES DEVELOPMENT IN THE STUDY AREA

The immediate use of water resources in large rivers by local people has been quite limited because of deep valley. On the other hand, the implementation of the Karnali Multipurpose Project and Pancheshwar Hydroelectric Project has long been considered by HMG/N and the Government of India. The development axis of Nepal has gradually expanded from Kathmandu valley to the west through Terai Ecological Belt. Now the water and land resources in the Study Area can be developed not only for the local use but for the country-wide use. Priority will be set on the development of rural infrastructure with the objective of rural development and regional balance of the Eighth Plan. Water resources will be essential for the rural infrastructure development.

The objectives of water resources development in the Study Area are set to develop mega scale hydroelectric power potential for the energy export to India, to develop medium/small scale hydroelectric power potential for domestic, agricultural and industrial uses within Nepal, to utilize large rivers for irrigation agriculture in Terai Ecological Belt, to contribute to the development of rural infrastructure in Hill and Mountain Ecological Belts, to protect flood-prone areas in the hill area from flooding and to manage the watershed in protecting land resources in Hill and Mountain Ecological Belts. Water resources development is a continuous process, and requires a systematic development based on availability of resources. Time frame for this Study is stipulated for 20 years, which correspond to the year 2012/13 (end of the Eleventh Plan Period).

Among the above objectives, energy export to India is considered as means of foreign exchange earning to the region, but no other mega scale hydroelectric power schemes than two

planned schemes, Karnali Multipurpose Project and Pancheshwar Hydroelectric Project, are assumed to be committed within the time frame of this Study. Medium/small scale hydroelectric power schemes of an appropriate size will be selected from among potential schemes in the Karnali and Mahakali river systems within the territory of Nepal. The idea of the proposed Bheri-Babai Multipurpose scheme, if feasible, will be taken up to meet country's needs before the Karnali Multipurpose Project is commissioned. Development of domestic water supply system, mini hydroelectric power scheme, irrigation system and river improvement works will be contemplated at strategic locations in Hill Ecological Belt.

The living standard of local people inhabited in the Study Area is in a subsistence level due mainly to hilly terrain and under-development of infrastructures. The strategies in this Study include the development of water resources facilities in the cores of regional development in Hill and Mountain Ecological Belts, in order to encourage urbanization of the core areas as strategic areas intending to promote socio-economic development of the Study Area as a whole. In this context, four cores called strategic area were selected taking into consideration the spatial structure as a system of development cores and transportation facilities in the Study Area, and those are Jumla, Surkhet, Dipayal-Silgadhi-Rajpur and Baitadi areas (refer to Figures 13 to 16).

8. SELECTION OF PRIORITY SCHEMES

This Study tried to identify potential schemes in the Study Area in the categories of hydropower, irrigation, domestic water supply, flood mitigation and watershed management. To mobilize the water resources available in the Study Area toward the improvement of the life of local people, the priority schemes, for which further detailed studies are undertaken, were selected from among hydropower, irrigation and flood mitigation taking into consideration not only economic viability but also spatial distribution and balanced development among sectors.

For hydropower, four schemes as mentioned earlier were selected by further considering reasonable development scale (50 to 100 MW) and less financial burden to the implementing agency besides the aspects mentioned above, and are summarized as follows (refer to Figure 17):

Scheme	Type	Installed Capacity MW	Construction Cost, million US$	EIRR, %
BR-1	Run-of-river	82.0	184.4	13.0
SR-3	"	75.2	166.1	12.3
CR-2	"	23.5	68.3	10.2
LR-1	Reservoir	58.0	118.3	9.1

It is noted that the installed capacity given above is a tentative figure and will be changed by subsequent further discussions.

For irrigation, four schemes were selected by taking into account the regional food self-sufficiency besides economic viability for the large scale irrigation scheme and the implementation possibility such as accessibility to the project site, gravity irrigation due to little electric power availability and headrace length for the small scale irrigation schemes, and are summarized as follows (refer to Figure 18):

Scheme	District	Net Command Area, ha
Large scale		
Bheri-Babai	Bardiya and Banke	Monsoon season : 72,000 Winter season : 33,000
Small scale		
Surkhet Valley Korelli Khola	Surkhet	2,700
Basin Lift Irrigation	Surkhet	368
Garyang Kot	Jumla	200

For flood mitigation, river training work of Dodhara and Chandani areas was selected as the priority scheme (refer to Figure 11).

9. WATER RESOURCES DEVELOPMENT FOR THE STRATEGIC AREAS

The Jumla strategic area (refer to Figure 13), which includes three Village Development Committees (VDC) of Chandannath, Mahatgaun and Depalgaun, extends in the valley bottom just downstream of the confluence between the Chandanbise River and the Babila River. The area has a hydro plant with an installed capacity of 200 kW, but requires the power development of 360 kW by year 2013 to meet the growing demand, which was estimated

based on the projected population and the assumed unit consumption rate per household. Power sources will be sought in a hydropower scheme to use water of the Garjyangkot Irrigation Project. Main food crop in the area is wheat along with barely, millet and paddy, production amounts of which are insufficient for demand. There is one existing and two on-going water supply schemes in the area. By year 2013, an amount of 302,940 litre per day is required to be developed for meeting the demand. A potential source to supply water to the area was identified in the Rini Khola. The present watershed condition is evaluated as Class 2 "Good" (refer to Figure 12).

The Surkhet strategic area (refer to Figure 14), which includes the municipality of Birendranagar and Uttraganga and Latikoili VDCs, lies in the centre of the Surkhet valley, which extends in the downstream reaches of the Bheri River. The power demand will grow to a level of 5,000 kW by year 2013 and will be supplied from the national power grid through the Birendranagar sub-station. Development of the Surkhet valley with a net irrigation area of 2,700 ha is considered to be the highest priority. At present, paddy, wheat and other cash crops are cultivated in the area. There are three existing and two on-going water supply schemes in the area. To meet the growing demand, an amount of 962,154 litre per day is required to be developed by year 2013. Potential water sources will be sought to the Khorke Khola for Uttraganga and the wells for Latikoili. The present watershed condition is graded as Class 5 "Very poor", but no landslides are reported.

The Dipayal-Silgadhi-Rajpur strategic area (refer to Figure 15), which includes the municipality of Silgadhi-Dipayal and Tikha VDC, lies in the middle reaches of the Seti River. The electric power demand is projected to grow to a level of 1,100 kW by year 2013. The power will be received from the new 33 kW power transmission line. Cropped area is 1,029 ha, of which 200 ha is irrigated. There is one existing and four on-going water supply schemes in the area. An amount of 378,398 litre per day is to be developed for meeting the demand by year 2013. Potential water sources will be sought to the Ritha Khola and the Godre Khola. The present watershed condition of the District is graded as Class 2 "Good".

The Baitadi strategic area (refer to Figure 16), which includes Khalanga, Thaligada, Tripurasundari, Dashrath Chand, Patan and Basantpur VDCs, is developed along the Mahakali River some 5 km downstream of its confluence with the Chamliya River. The area has a hydro plant with an installed capacity of 200 kW, but the demand of 1,020 kW in year 2013 is to meet by the extension of the transmission line from the national grid. Small scale irrigation projects are under construction near the area. Main crops cultivated are paddy and wheat among others. There are 26 existing and nine on-going water supply schemes in the area. The amount to be developed by year 2013 is 517,525 litre per day. Potential water sources will be sought to the Gwalek Khola for the Baitadi zone and the Surnaya Khola and the

Dhadaun Khola for the Patan zone. The present watershed condition in the area is graded as Class 2 "Good".

PART II: DETAILED STUDIES OF THE PRIORITY SCHEMES

10. FIELD SURVEY

As part of this Master Plan Study, further studies were dedicated to the selected nine priority schemes for assessing their economic viability. In particular, further discussions for the selected four hydropower priority schemes, i.e. BR-1, LR-1, SR-3 and CR-2, were based on the newly prepared topographic maps and geological survey. The topographic maps newly prepared for those four schemes are as follows:

Scheme	Mapping Area, km^2	Scale
BR-1	65	1/20,000
LR-1	175	1/20,000
	30	1/10,000
SR-3	35	1/20,000
CR-2	15	1/20,000

Three schemes, BR-1, SR-3 and CR-2, are a run-of-river type and the topographic maps were prepared for the entire area of the scheme site with a scale of 1 to 20,000. Meanwhile, topographic maps for LR-1, which is a reservoir type, were prepared with a scale of 1 to 20,000 for the reservoir area and 1 to 10,000 for the structure sites including the dam.

Geological investigation was carried out by means of seismic exploration and core boring including construction material survey. Work quantities of geological investigation conducted for the four hydropower priority schemes are summarized as follows:

	Seismic Exploration		Core Boring	
Scheme	No. of lines	Length (m)	No. of holes	Length (m)
BR-1	3	860	1	70
LR-1	4	1,165	1	50
SR-3	4	1,205	1	50
CR-2	5	925	1	45
Total	16	4,155	4	215

Initial environmental examination, IEE, was conducted for the four hydropower priority schemes and the Bheri-Babai irrigation scheme in collaboration with the Nepalese

governmental agencies and non-governmental organizations. For the priority schemes selected in irrigation and flood mitigation, scheme evaluation was relied on the results of field investigation carried out through the field work of Phase III.

11. BR-1 HYDROPOWER SCHEME

BR-1 lies in the Bheri River 45 km upstream of its confluence with the Karnali River, where topography shows a rather wide valley. The catchment area at the site is 11,815 km^2 with an average annual rainfall of 1,191 mm, whilst average annual runoff is estimated at 405.4 m^3/sec with a range of the maximum monthly flow of 2,043.4 m^3/sec to the minimum monthly flow of 59.5 m^3/sec. The area is underlain by young sedimentary sequence.

As plan formulation, two types of powerhouse were compared; one is an open-air type and the other is an underground type. The underground powerhouse type (refer to Figure 19) was selected as the optimal plan due to the minimization of adverse effect to the Royal Bardiya National Park, which is an area to protect wildlives. The scale optimization revealed to develop the scheme with an installed capacity of 82.9 MW. In this scale, BR-1 shows a high economic viability of 13.4% in economic internal rate of return (EIRR), whilst the required construction cost was estimated at US$ 174.0 million at a price level of March 1993.

An Initial Environmental Examination (IEE) was undertaken. It was judged from the results of IEE that negative environmental impacts such as water-borne diseases, inundation and involuntary resettlement are unlikely to occur. However, the results of IEE suggest that careful considerations be paid to the protection of fauna and flora in the Royal Bardiya National Park and the assurance of maintenance flow to the downstream reaches of the Bheri River for protecting aquatic fauna including Gangetic Dolphin.

12. LR-1 HYDROPOWER SCHEME

LR-1, which is a reservoir type scheme, lies in the downstream reaches of the Lohore River, which is a tributary of the Karnali Main. Topography at the site forms a steep slope and cliff on the right bank, whilst the left bank is of gentle slope, covered with thick talus deposits. The basin drains an area of 733 km^2 with an average annual rainfall of 1,539.0 mm, whilst average annual runoff is estimated to be 34.4 m^3/sec with a range of the maximum monthly flow of 124.9 m^3/sec to the minimum monthly flow of 5.7 m^3/sec. The area is composed of underlying metasediments called phyllite and overlying thrust-up sequence of augen gneiss, schist and quartzite.

Taking into consideration dam axis and waterway route, four development alternatives were compared to select the optimal layout plan. The economic comparison selected the layout plan given in Figure 20 as the optimal one due to the highest economic viability among four. The scale optimization revealed to develop the scheme with an installed capacity of 81.0 MW, showing a high economic viability of 10.2% in EIRR, whilst the required construction cost was estimated at US$ 142.9 million at a price level of March 1993.

The results of IEE suggest to likely cause relatively large negative environmental impacts such as involuntary resettlement, inundation of the road network in the reservoir area, increase of water-borne diseases transmitted to human being via water such as malaria and change of the aquatic ecosystem, resulting in the requirement of Environmental Impact Assessment (EIA) when the feasibility study is carried out for the scheme.

13. SR-3 HYDROPOWER SCHEME

SR-3 lies in the upstream reaches of the Seti River, one of main tributaries of the Karnali River, just downstream of its confluence with the Bauli River. Topography at the site shows a wide valley with the developed terraces on both banks. The catchment area at the site is 2,421 km^2 with an average annual rainfall of 1,183 mm, whilst average annual runoff is estimated at 68.0 m^3/sec with a range of the maximum monthly flow of 355.6 m^3/sec to the minimum monthly flow of 9.6 m^3/sec. The area is underlain by the thick metasediment sequence composed of phyllite, quartzite and calcareous members.

Two alternatives were proposed by changing the waterway length to search for the optimal layout plan. The economic comparison selected the layout plan given in Figure 21 as the optimal one. The scale optimization revealed to develop the scheme with an installed capacity of 56.4 MW, showing a high economic viability of 11.0% in EIRR, whilst the required construction cost was estimated at US$ 142.0 million at a price level of March 1993. The results of IEE suggest that measures be taken for inundation area, maintenance flow, aquatic fauna and watershed among others, even if negative environmental impacts are not expected to be high.

14. CR-2 HYDROPOWER SCHEME

CR-2 lies in the Chamliya River 32 km upstream of its confluence with the Mahakali River, where topography forms a narrow gorge. The catchment area at the site is 785 km^2 with an average annual rainfall of 1,772 mm, whilst average annual runoff is estimated at 37.6

m^3/sec with a range of the maximum monthly flow of 195.1 m^3/sec to the minimum monthly flow of 5.3 m^3/sec. The area is underlain by a thick sequence of metasediments mainly composed of calcareous beds and phyllite.

Two alternatives were proposed by changing the waterway length to search for the optimal layout plan. The economic comparison selected the layout plan given in Figure 22 as the optimal one. The scale optimization revealed to develop the scheme with an installed capacity of 24.1 MW, showing a high economic viability of 10.3% in EIRR, whilst the required construction cost was estimated at US$ 69.4 million at a price level of March 1993. The results of IEE suggest that measures be taken for maintenance flow, fisheries and others, even if negative environmental impacts are not expected to be high.

15. IRRIGATION PRIORITY SCHEMES

The Bheri-Babai irrigation scheme, the Surkhet Valley irrigation scheme, the Korelli Khola basin lift irrigation scheme and the Garjyangkot irrigation scheme were selected as the priority schemes in the irrigation sector by taking into account the regional food self-sufficiency and economic viability for the large scale scheme and the implementation possibility for the small scale schemes.

The Bheri-Babai irrigation scheme, lying in the Bardiya and Banke districts, commands a net irrigation area of 74,270 ha (refer to Figure 23). The scheme seeks water sources not only to the Babai River but also the Bheri River. Main crops to be planted for the scheme are paddy, maize, cotton and so on in the wet season and wheat, pulses, oil seeds and so on in the dry season. The economic evaluation, carried out under the condition that the diversion facilities from the Bheri River are constructed as an independent hydropower scheme and the completed diversion weir and head woks are treated as sunk costs, revealed a high economic viability of 17.1% in EIRR. The results of IEE suggest that the problems which might arise from the implementation of the scheme are water-borne disease epidemic such as malaria, maintenance flow to the downstream reaches of the Babai and deforestation along the canal.

The Surkhet Valley irrigation scheme commands a net area of 2,700 ha (refer to Figure 24). Water available for the development of scheme is scarce in the valley, and thus the Chingar Khola is sought as its water source. Main crops to be planted are paddy and vegetables in the wet season and wheat, potato and oil seed in the dry season. The economic evaluation revealed an economic viability of 6.0% in EIRR.

The Korelli Khola basin lift irrigation scheme, lying on the left bank of the Bheri River, commands a net area of 368 ha (refer to Figure 25). Since there is no river which can supply sufficient irrigation water to the Korelli Khola basin, the water source is sought to the Bheri River by pumping. Main crops to be planted are paddy, maize and wheat. In economic evaluation, an EIRR of 7.3% was gained.

The Garjyangkot irrigation scheme is located in Garjyangkot village, Jumla district, with a net command area of 200 ha (refer to Figure 26). The water source for the scheme is the Talpunerd Khola. At present, a first 3.8 km portion of the 5.8 km long main cannel has been completed. The main crops to be planted are paddy, wheat, barley and potato. The economic evaluation under the condition that the construction cost for the existing 3.8 km long canal is treated as sunk costs shows a high economic viability of 14.7%.

16. FLOOD MITIGATION PRIORITY SCHEME

The Dodhara and Chandani areas, which are a large dune developed in the Mahakali River and are a food surplus region of the Kanchanpur district (refer to Figure 11), suffer from the threat of losing land due to bank erosion. Unless any measures are implemented against the bank erosion, an area of 500 ha is expected to be lost within 30 years. An economic evaluation was made by taking the production expected to be gained from the losing farm land as benefits, showing an EIRR of 5.8%. This economic evaluation was carried out under the condition that crops are yielded in the rainy season, i.e. without introduction of irrigation. This implies that the introduction of irrigation to the areas will increase the economic viability of the scheme.

17. SELECTION OF TOP PRIORITY SCHEME

Further discussions for the selected nine priority schemes were carried out as dealt above. The results of those discussions are summarized as follows:

For hydropower

Scheme	Installed Capacity, MW	Annual Generation Energy, GWh/year	Construction Cost, million US$	Net Benefit, million US$	EIRR,%
BR-1	82.9	601	174.0	40.5	13.4
LR-1	81.0	323	142.9	2.3	10.2
SR-3	56.4	373	142.0	11.3	11.0
CR-2	24.1	160	69.4	1.4	10.3

Project features for the above hydropower priority schemes are given in Table 8.

For irrigation

Scheme	Irrigation Type	Net Common Area, ha	Construction Cost, million Rs (million US$)	EIRR, %
Bheri-Babai	Gravity	74,270	12,145 (260.3)	17.1
Surkhet Valley	Gravity	2,700	440 (9.4)	6.0
Korelli Khola	Lift	368	44 (0.9)	7.3
Garjyangkot	Gravity	200	26 (0.6)	14.7

For flood mitigation

Scheme	Type of Works	Project Area, ha	Construction Cost, million Rs (million US$)	EIRR, %
Dodhara and Chandani	River training	5,000	58.8 (1.3)	5.8

All the priority schemes selected in the hydropower sector gained the economic internal rate of return (EIRR) higher than 10%, judged to be viable for development in economic terms. As for irrigation, the Bheri-Babai and Garjyangkot schemes gained high economic viability as endorsed by the EIRR higher than 10%, even though a part of construction costs, which have already been invested, is treated as sunk costs for project evaluation. Thus, those two schemes are recommended to continue their development.

The Surkhet Valley and Korelli Khola schemes obtained rather low EIRR of 6.0 and 7.3% respectively. However, the fact that both the schemes lie in the hill area where food shortage is severe tells that those two schemes should be retained for future development. In particular, investigation to search for water sources should be continued for the Surkhet Valley

scheme, whilst the key issue for the Korelli Khola scheme is to secure stable electric power required for lifting irrigation water.

The river training works of the Dodhara and Chandani areas were evaluated under the condition that crops are yielded only in the rainy season, i.e. without introduction of irrigation. This promises a high economic viability of the scheme with the introduction of irrigation, and therefore the scheme is recommended to proceed to further studies for implementation.

The most promising candidate for the top priority scheme is BR-1 in the hydropower priority schemes, since economic viability is highest, i.e. 13.4% in EIRR and US$ 40.5 million in net benefit, among the four priority schemes. Furthermore, the development of BR-1 has such merits that its power generation judging from the development scale (82.9 MW) will induce industrial development in western Nepal, resulting in the contribution to the economic development of the region, and will also enable the expansion of national power supply system into the rural areas of western Nepal, contributing to the socio-economic development in the region.

The Bheri-Babai irrigation scheme gained the highest economic viability, i.e. 17.1% in EIRR, among the irrigation priority schemes, and thus is selected as the candidate for the top priority scheme. The development of 74,270 ha in the Bheri-Babai irrigation scheme is planned with the premise that the Bheri River water is diverted to the Babai River by BR-1; that is, full development of this irrigation project is possible, only after BR-1 becomes operational. BR-1 should thus be implemented prior to the Bheri-Babai irrigation project.

It is clear in comparison between BR-1 and the Dodhara and Chandari river training project that the former will by far give a greater impact on the socio-economic development of the Study Area than the latter. It is recommended as a consequence that the top priority scheme be set on the development of BR-1 hydropower project in view of a great impact on the reduction of regional imbalance.

It is recommended in the coming feasibility study of the BR-1 hydropower scheme that thorough investigation be carried out for geology and natural environment due to the reasons that an underground type is proposed for the powerhouse and that the tailrace outlet lies in the Royal Bardiya National Park.

TABLES

Table 1 ECONOMIC EVALUATION OF POTENTIAL SCHEMES (RESERVOIR TYPE)

Scheme	Draft Rate [1]	Installed Capacity (MW)	Firm Energy (GWh/y)	Secondary Energy (GWh/y)	Construction Cost (US$1,000)	Net Benefit (US$1,000)	EIRR (%)	(US¢/KWh) [2]
LR1	0.6	47.0	135	71	105,078	-11,899	8.5%	5.10
	0.7	58.0	166	70	118,259	-7,807	9.1%	5.01
	0.8	73.0	210	66	144,540	-12,277	8.8%	5.24
BR3A	0.6	660.0	1,874	796	820,923	256,488	13.9%	3.07
	0.7	797.0	2,274	754	914,306	311,548	14.2%	3.02
	0.8	961.0	2,747	686	1,060,168	348,304	14.1%	3.09
BR3B	0.6	801.0	2,243	988	816,255	427,034	16.2%	2.53
	0.7	1,003.0	2,775	1,006	911,115	538,775	16.9%	2.41
	0.8	1,192.0	3,407	911	1,005,558	653,871	17.6%	2.33
BR4	0.6	667.0	1,900	800	1,046,339	115,391	11.4%	3.88
	0.7	804.0	2,245	779	1,216,106	107,230	11.2%	4.02
	0.8	964.0	2,757	679	1,373,534	140,560	11.3%	4.00
BR5	0.6	880.0	2,512	1,047	1,028,160	386,903	14.6%	2.89
	0.7	1,048.0	2,939	968	1,123,183	440,035	14.8%	2.87
	0.8	1,269.0	3,624	888	1,311,537	513,275	14.8%	2.91
SR6	0.6	642.0	1,841	799	926,363	176,302	12.4%	3.51
	0.7	776.0	2,240	752	997,620	244,535	13.1%	3.33
	0.8	966.0	2,809	690	1,175,156	292,445	13.1%	3.36

Note: 1) The draft rate is defined as the ratio of constant release from the reservoir through the year to the long-term average flow.
2) US¢ means US cent.

TABLE 2 ECONOMIC EVALUATION OF POTENTIAL SCHEMES (RUN-OF-RIVER TYPE) (1/2)

Scheme	Operation (Hours)	Installed Capacity (MW)	Firm Energy (GWh/y)	Secondary Energy (GWh/y)	Construction Cost (US$1,000)	Net Benefit (US$1,000)	EIRR (%)	1) (US¢/KWh)
KR2	8	412.8	1,198	1,695	810,044	277,590	14.2%	2.80
	12	275.2	1,198	909	666,503	171,941	13.2%	3.16
	16	206.4	1,198	487	594,236	112,015	12.4%	3.53
KR3	8	434.1	1,260	1,782	689,299	399,762	16.8%	2.27
	12	289.4	1,260	955	515,387	304,022	16.9%	2.33
	16	217.0	1,260	512	404,524	264,567	17.6%	2.28
KR4	8	87.5	254	359	332,577	-83,372	6.3%	5.43
	12	58.3	254	193	278,825	-74,041	6.1%	6.24
	16	43.8	254	103	254,471	-72,183	5.8%	7.13
KR7	8	243.0	705	998	386,925	223,407	16.8%	2.27
	12	162.0	705	535	325,049	146,038	15.4%	2.62
	16	121.5	705	287	288,747	106,704	14.5%	2.91
TR1	8	120.3	349	494	340,586	10,818	10.4%	4.04
	12	80.2	349	265	289,082	-13,456	9.4%	4.71
	16	60.2	349	142	255,233	-22,361	8.8%	5.20
TR2	8	52.6	153	216	314,818	-106,008	4.8%	8.53
	12	35.1	153	116	273,169	-103,805	4.0%	10.15
	16	26.3	153	62	251,963	-103,474	3.4%	11.72
TR3	8	104.7	304	430	290,474	13,486	10.6%	3.96
	12	69.8	304	230	248,230	-9,543	9.5%	4.65
	16	52.3	304	123	229,182	-24,238	8.5%	5.37
TR4	8	10.5	30	43	64,683	-24,573	4.5%	8.86
	12	7.0	30	23	58,522	-25,393	3.4%	11.04
	16	5.2	30	13	53,916	-24,737	2.9%	12.54
MKR1	8	90.5	263	371	282,801	-9,643	9.5%	4.46
	12	60.3	263	199	250,871	-32,389	8.2%	5.43
	16	45.3	263	106	231,977	-43,599	7.3%	6.29
MKR2	8	55.6	161	229	272,091	-71,560	6.1%	6.98
	12	37.1	161	123	244,489	-80,282	5.0%	8.61
	16	27.8	161	66	229,646	-84,972	4.2%	10.12
MKR3	8	124.4	361	511	331,076	25,375	11.0%	3.80
	12	82.9	361	274	300,594	-14,998	9.3%	4.73
	16	62.2	361	147	282,426	-49,536	7.5%	5.56
HKR1	8	178.6	518	733	411,916	78,549	12.4%	3.29
	12	119.0	518	393	354,395	29,847	11.1%	3.89
	16	89.3	518	211	325,096	2,780	10.1%	4.46
HKR2	8	77.7	226	319	354,653	-82,843	6.6%	6.51
	12	51.8	226	171	319,855	-97,520	5.4%	8.06
	16	38.9	226	91	298,353	-103,655	4.6%	9.41

Note: US¢ means US cents.

TABLE 2 ECONOMIC EVALUATION OF POTENTIAL SCHEMES (RUN-OF-RIVER TYPE) (2/2)

Scheme	Operation (Hours)	Installed Capacity (MW)	Firm Energy (GWh/y)	Secondary Energy (GWh/y)	Construction Cost (US$1,000)	Net Benefit (US$1,000)	EIRR (%)	1) (US¢/KWh)
HKR3	8	71.6	208	294	360,684	-99,047	5.9%	7.18
	12	47.7	208	157	331,128	-114,409	4.7%	9.07
	16	35.8	208	84	313,184	-121,128	3.9%	10.73
HKR4	8	111.1	322	456	415,744	-57,799	8.0%	5.34
	12	74.1	322	245	367,532	-79,659	6.9%	6.48
	16	55.5	322	131	341,503	-91,483	6.0%	7.54
BR1	8	82.0	233	362	184,369	44,219	13.0%	3.10
	12	54.7	233	196	146,507	26,975	12.4%	3.42
	16	41.0	233	104	132,146	12,993	11.3%	3.92
BR6	8	49.1	142	187	154,001	-9,494	9.2%	4.68
	12	32.8	142	100	137,381	-20,685	7.9%	5.68
	16	24.6	142	54	125,515	-24,553	7.2%	6.40
BR7	8	29.2	85	111	138,552	-36,910	6.1%	7.07
	12	19.5	85	59	129,270	-44,035	4.8%	8.98
	16	14.6	85	32	123,693	-47,228	4.0%	10.57
BR8	8	30.0	87	114	189,910	-69,822	4.2%	9.45
	12	20.0	87	61	170,743	-70,597	3.3%	11.54
	16	15.0	87	33	161,353	-71,499	2.7%	13.45
SR3	8	75.2	217	280	166,124	30,269	12.3%	3.34
	12	50.1	217	152	137,463	16,616	11.6%	3.73
	16	37.6	217	91	118,304	13,785	11.5%	3.84
SR7	8	52.4	151	196	152,659	-3,407	9.7%	4.40
	12	34.9	151	106	115,410	-1,572	9.8%	4.49
	16	26.2	151	64	103,891	-4,648	9.4%	4.83
THR1	8	8.6	25	40	48,762	-14,117	5.8%	7.50
	12	5.7	25	21	43,730	-15,944	4.5%	9.51
	16	4.3	25	11	40,372	-16,408	3.7%	11.21
BS1	8	8.6	37	49	98,866	-42,497	3.2%	11.50
	12	6.5	37	26	86,278	-40,151	2.5%	13.69
	16	4.3	37	16	79,047	-37,898	2.2%	14.91
CR1	8	9.4	27	35	79,859	-36,635	2.6%	12.88
	12	6.3	27	19	74,089	-37,099	1.7%	16.11
	16	4.7	27	11	70,303	-36,698	1.1%	18.50
CR2	8	23.5	68	88	68,258	894	10.2%	4.38
	12	15.7	68	48	57,931	-3,139	9.3%	4.99
	16	11.8	68	27	51,317	-4,421	8.8%	5.40

Note: US¢ means US cents.

Table 3 LARGE SCALE POTENTIAL IRRIGATION PROJECTS

Unit: Net ha

Name	District	Existing		New Scheme	Total
		DOI	FMIS		
Run-of-River Project					
Sikta	Banke	1,250	2,890	31,930	36,070
Babai	Bardiya		5,308	8,192	13,500
Khutiya II	Kailai		1,000	2,500	3,500
Mahakali II	Kanchanpur		703	6,099	9,800
Multipurpose Project					
West Rapti	Kapilbastu	800	4,996	24,704	30,500
	Dangdeukhuri	435	7,396	1,669	9,500
	Banke	1,250	2,890	31,930	36,070
	Total	2,485	15,282	58,303	76,070
Karnali	Banke	1,250	2,430	32,471	36,151
	Bardiya	960	23,527	39,682	64,169
	Kailali	3,633	28,653	58,344	90,630
	Total	5,843	54,610	130,497	190,950
Bheri-Babai	Bardiya	960	11,312	27,728	40,000
Total:					636,910

Remarks: DOI: Irrigation system managed by DOI
FMIS: Farmer managed irrigation system

Source: MPID2 Annexes-Volume 1

Table 4 SUMMARY OF THE SMALLER IDENTIFIED POTENTIAL IRRIGATION PROJECTS (1/2)

<MID WESTERN DEVELOPMENT REGION>

Unit : ha

District	Number of Projects	Net Command Areas		
		Overall Scheme	Existing Scheme	New Scheme
Dangdeukhuri	8	3,125	480	2,645
Banke				
Bardiya	1	290		290
Total For TERAI	9	3,415	480	2,935
Pyuthan	3	1,000		1,000
Polpa	1	100		100
Salyan	1	70		70
Rukum	5	425		425
Surkhet	4	943	200	743
Jajarkot	4	109	67	42
Dailekh	1	477		477
Total For HILL	19	3,124	267	2,857
Dolpa	2	110		110
Jumla	2	250		250
Kalikot	2	315		315
Mugu	2	201		201
Humla	2	90		90
Total For MOUNTAIN	10	966		965
Total For MID WEST	38	7,505	747	6,757

Source: MPID2, Table A3-3

Table 4 SUMMARY OF THE SMALLER IDENTIFIED POTENTIAL IRRIGATION PROJECTS (2/2)

<FAR WESTERN DEVELOPMENT REGION>

Unit : ha

District	Number of Projects	Net Command Areas (ha)		
		Overall Scheme	Existing Scheme	New Scheme
Kailai	1	649		649
Kanchanpur	1	1,800		1,800
Total For TERAI	2	2,449		2,449
Achhan	1	142		142
Doti	9	1,102	313	789
Dadeldhura	4	305		305
Baitadi	5	227		227
Total For HILL	19	1,776	455	1,321
Bajura	3	295	45	250
Bajhang	16	1,381	965	416
Darchurla	4	629	90	539
Total For MOUNTAIN	23	2,305	1,100	1,205
Total For FAR WEST	44	6,530	1,555	4,975
Total For MID+FAR	82	14,035	2,302	11,732

Source: MPID2, Table A3-3

Table 5 WATER SUPPLY SCHEMES IN THE STUDY AREA

Mid Western Development Region

District	Exisitng Water Supply Sheme		On-going/Planning Water Supply Scheme		Total Water Supply Scheme		Population in 1991	Service Ratio(Design Population/Population in1991), %	
	Number	Design Population	Number	Design Population	Number	Design Population		Existing Scheme	Total Scheme
Karnali Zone									
(1) Humla	19	9,627	49	24,167	68	33,794	34,640	27.8	97.6
(2) Mugu	6	4,009	14	10,112	20	14,121	36,445	11.0	38.7
(3) Kalikot	9	22,010	65	80,650	74	102,660	88,781	24.8	115.6
(4) Jumla	6	3,959	22	15,127	28	19,086	76,305	5.2	25.0
Sub-total	46	44,950	179	140,195	225	185,145	261,247	17.2	70.9
Rapti Zone									
(1) Rukum	50	61,230	25	52,212	75	113,442	155,017	39.5	73.2
Sub-total	50	61,230	25	52,212	75	113,442	155,017	39.5	73.2
Bheri Zone									
(1) Dailekh	28	16,669	37	39,601	65	56,270	187,820	8.9	30.0
(2) Jajarkot	31	31,917	12	36,757	43	68,674	114,267	27.9	60.1
(3) Surkhet	48	113,848	16	69,641	64	183,489	225,296	50.5	81.4
Sub-total	107	162,434	65	145,999	172	308,433	527,383	30.8	58.5
Total	203	268,614	269	338,406	472	607,020	943,647	28.5	64.3

Far Western Development Region

District	Exisitng Water Supply Sheme		On-going/Planning Water Supply Scheme		Total Water Supply Scheme		Population in 1991	Service Ratio(Design Population/Population in1991), %	
	Number	Design Population	Number	Design Population	Number	Design Population		Existing Scheme	Total Scheme
Mahakali Zone									
(1) Darchula	59	23,661	73	32,536	132	56,197	101,614	23.3	55.3
(2) Baitadi	117	44,588	98	60,455	215	105,043	200,229	22.3	52.5
(3) Dadeldhura	32	39,505	40	63,581	72	103,086	104,449	37.8	98.7
Sub-total	208	107,754	211	156,572	419	264,326	406,292	26.5	65.1
Seti Zone									
(1) Bajhang	21	19,860	44	40,589	65	60,449	139,178	14.3	43.4
(2) Bajura	30	17,405	33	38,853	63	56,258	92,083	18.9	61.1
(3) Doti	21	35,488	126	109,733	147	145,221	167,469	21.2	86.7
(4) Achham	50	47,372	184	109,463	234	156,835	197,888	23.9	79.3
Sub-total	122	120,125	387	298,638	509	418,763	596,618	20.1	70.2
Total	330	227,879	598	455,210	928	683,089	1,002,910	22.7	68.1

Table 6 FUTURE DEMAND OF DOMESTIC WATER

Zone	District	Population in1991	Annual Increase Rate, %	Population in 2000	Water Demand in 2000, lpd	Population in2013	Water Demand in 2013, lpd
Mid Western Development Region							
Karnali	Humla	34,640	1.05(5.49)	41,655	1,874,475	56,012	2,520,540
	Mugu	36,445	1.05(-1.80)	39,704	1,786,680	45,280	2,037,600
	Kalikot	88,781	0.13	100,083	4,503,735	119,399	5,372,955
	Jumla	76,305	1.04	83,557	3,760,065	96,787	4,355,415
	Dolpa	25,075	1.30	26,903	1,210,635	31,463	1,415,835
Rapti	Rukum	155,017	1.59	177,246	7,976,070	216,023	9,721,035
Bheri	Dailekh	187,820	1.21	209,557	9,430,065	253,279	11,397,555
	Jajarkot	114,267	1.41	134,070	6,033,150	162,429	7,309,305
	Surkhet	225,296	3.09	296,408	13,338,360	461,138	20,751,210
	Sub-total	943,646		1,109,183	49,913,235	1,441,810	64,881,450
Far Western Development Region							
Mahakali	Darchula	101,614	1.20	108,007	4,860,315	126,702	5,701,590
	Baitadi	200,229	1.12	224,714	10,112,130	267,909	12,055,905
	Dadeldhura	104,449	1.87	134,027	6,031,215	192,519	8,663,355
Seti	Bajhang	139,178	1.16	161,067	7,248,015	207,319	9,329,355
	Bajura	92,083	2.12	107,875	4,854,375	136,762	6,154,290
	Doti	167,469	0.90	198,040	8,911,800	227,104	10,219,680
	Achham	197,888	0.66	211,198	9,503,910	235,282	10,587,690
	Sub-total	1,002,910		1,144,928	51,521,760	1,393,597	62,711,865
	Total	1,946,556		2,254,111	101,434,995	2,835,407	127,593,315

Note: The annual population increase rate of the Humla and Mugu Districts is estimated as one district due to the change of boundary between them.

Table 7 WATER SUPPLY CONDITION IN THE STUDY AREA

Zone	District	Number of Municipality	Number of VDC	Population in 2000	Population in 2013	Number of Exisiting Schemes	Supply Capacity of Existing Schemes, lpd	Number of On-going/ Planning Schemes	Supply Capacity of On-going/ Planning Schemes,lpd	Deficits in 2000,lpd	Dificits in 2013,lpd
Mid Western Development Region											
Karnali	Humla		26	41,655	56,012	19	433,215	49	1,080,255	565,312	1,126,962
	Mugu		24	39,704	45,280	6	311,310	14	1,213,920	1,079,712	1,262,610
	Kalikot		29	100,083	119,399	9	1,065,881	65	4,805,186	926,750	1,444,005
	Jumla		29	83,557	96,787	6	194,648	22	812,817	2,808,168	3,399,399
	Dolpa		23	26,903	31,463	6	284,080	29	625,314	532,396	655,484
Rapti	Rukum		43	177,246	216,023	50	3,013,364	25	3,191,453	3,121,161	4,532,080
Bheri	Dailekh		59	209,557	253,279	28	1,717,370	37	2,910,398	6,336,496	7,611,091
	Jajarkot		30	134,070	162,429	31	1,238,982	12	1,827,058	3,140,088	4,307,119
	Surkhet	1	49	296,408	461,138	48	7,627,301	16	3,410,437	5,624,823	10,870,841
	Sub-total	1	312	1,109,183	1,441,810	203	15,886,151	269	19,876,838	24,134,906	35,209,591
Far Western Development Region											
Mahakali	Darchula		38	108,007	126,702	59	1,142,580	73	1,582,836	1,896,361	2,666,480
	Baitadi		68	224,714	267,909	117	1,897,616	98	3,413,768	5,674,193	7,403,856
	Dadeldhura		25	134,027	192,519	32	2,275,837	40	4,345,643	1,994,863	3,837,918
Seti	Bajhang		46	161,067	207,319	21	853,787	44	2,034,819	4,858,391	6,660,796
	Bajura		27	107,875	136,762	30	798,732	33	1,940,707	2,474,535	3,605,452
	Doti	1	53	198,040	227,104	21	2,473,359	126	6,550,638	3,200,690	3,882,665
	Achham		75	211,198	235,282	50	1,930,567	184	6,674,150	4,228,612	4,954,691
	Sub-total	1	332	1,144,928	1,393,597	330	11,372,478	598	26,542,561	24,327,645	33,011,858
	Total	2	644	2,254,111	2,835,407	533	27,258,629	867	46,419,399	48,462,551	68,221,449

Table 8 PROJECT FEATURES FOR HYDROPOWER PRIORITY SCHEMES

Items		BR-1	SR-3	CR-2	LR-1
General					
	Type	Run-of-river	Run-of-river	Run-of-river	Reservoir
	Catchment area (km2)	11,815	2,421	785	733
	Plant discharge (m3/sec)	58.2	39.6	21.7	72.0
	FSL (EL.)	420	1,250	930	788
	TWL (EL.)	240	1,070	790	630
	Gross head (m)	180	180	140	146
Intake Dam / Main Dam					
	Type	Low-overflow	Low-overflow	Low-overflow	Rockfill dam
	Dam crest (EL.)	425	1,255	935	793
	Dam height (m)	35	35	65	120
	Crest Length (m)	220	400	200	480
Desanding Basin					
	Sub-basin No.	3	2	2	-
	Length (m)	150	150	110	-
Headrace/Tailrace Tunnel					
	Length (m)	9,000	8,800	4,300	3,850
	Diameter (m)	5.5	4.0	3.0	5.5
Penstock Line					
	Length (m)	350	400	600	330
Powerhouse					
	Type	Underground	Open-air	Open-air	Open-air
	Installed Capacity (MW)	82.9	56.4	24.1	81.0
	Annual Generation Energy (GWh/yr)	601	373	160	323

FIGURES

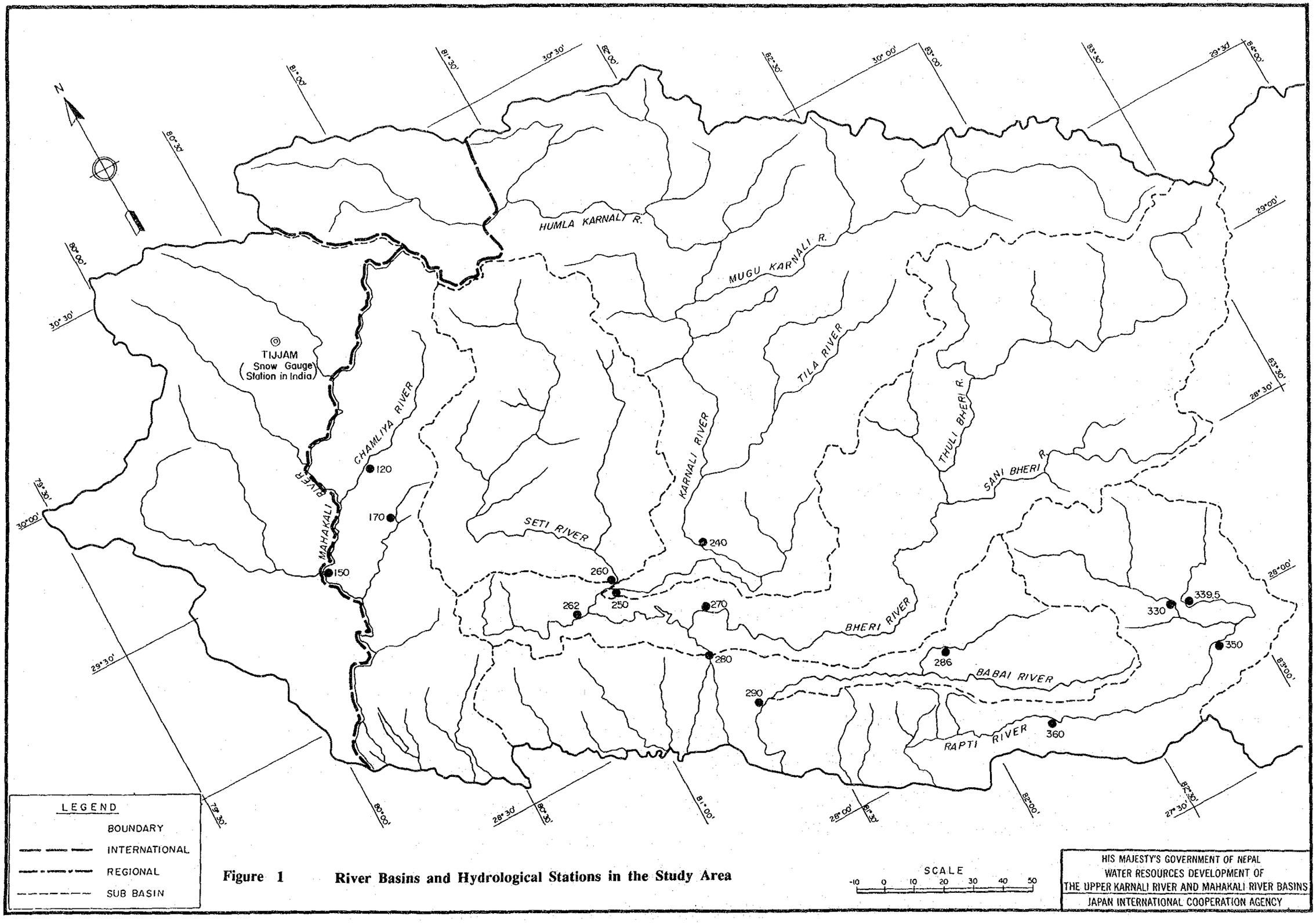


Figure 1 **River Basins and Hydrological Stations in the Study Area**

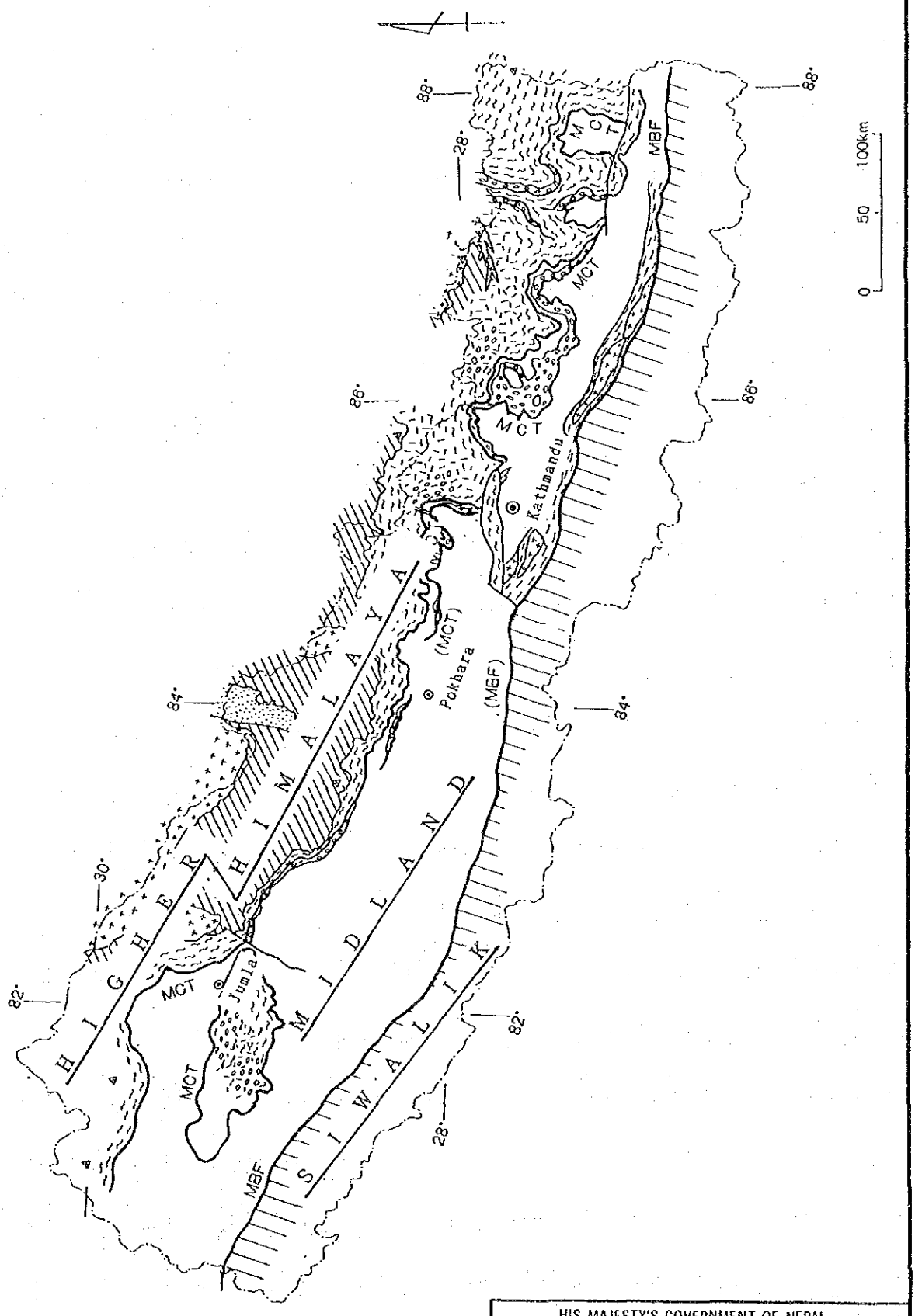


Figure 2 **General Geologic Map of Nepal Showing the Three Zones**

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

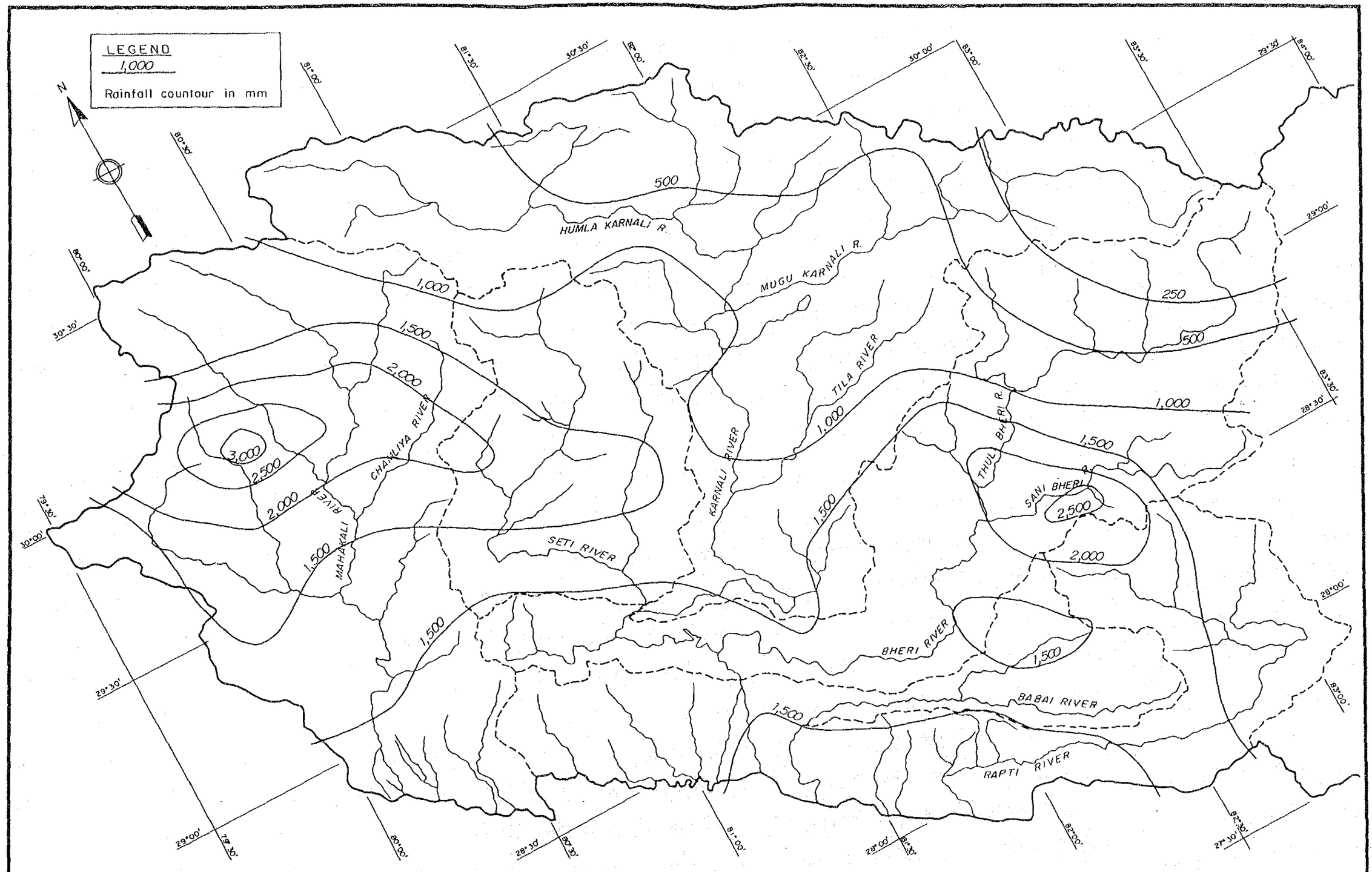


Figure 3 **Isohyetal Map of Annual Rainfall**

Figure 4 **Administration Division of the Study Area**

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

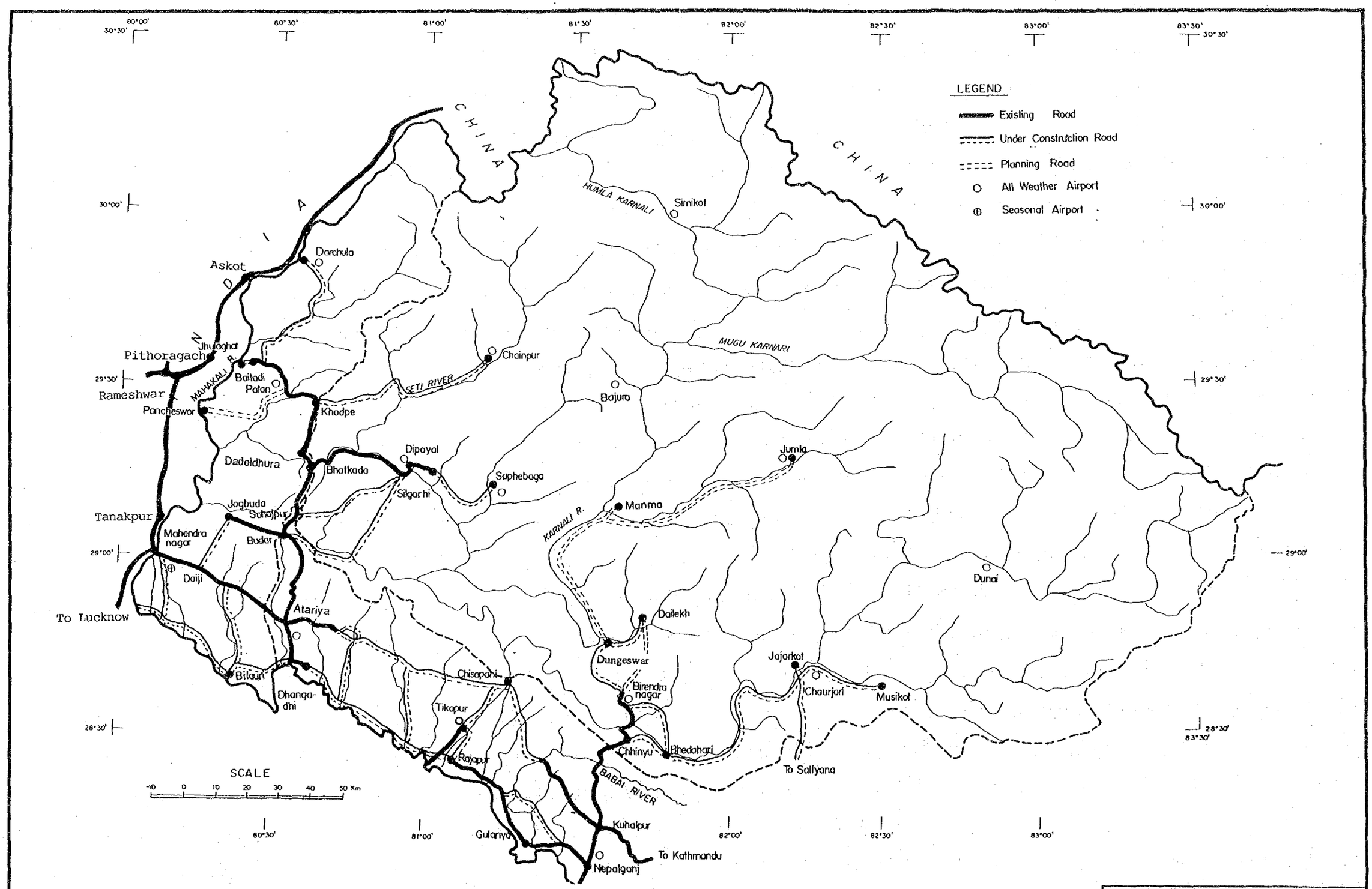


Figure 5 **Road Networks and Airports in the Study Area**

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

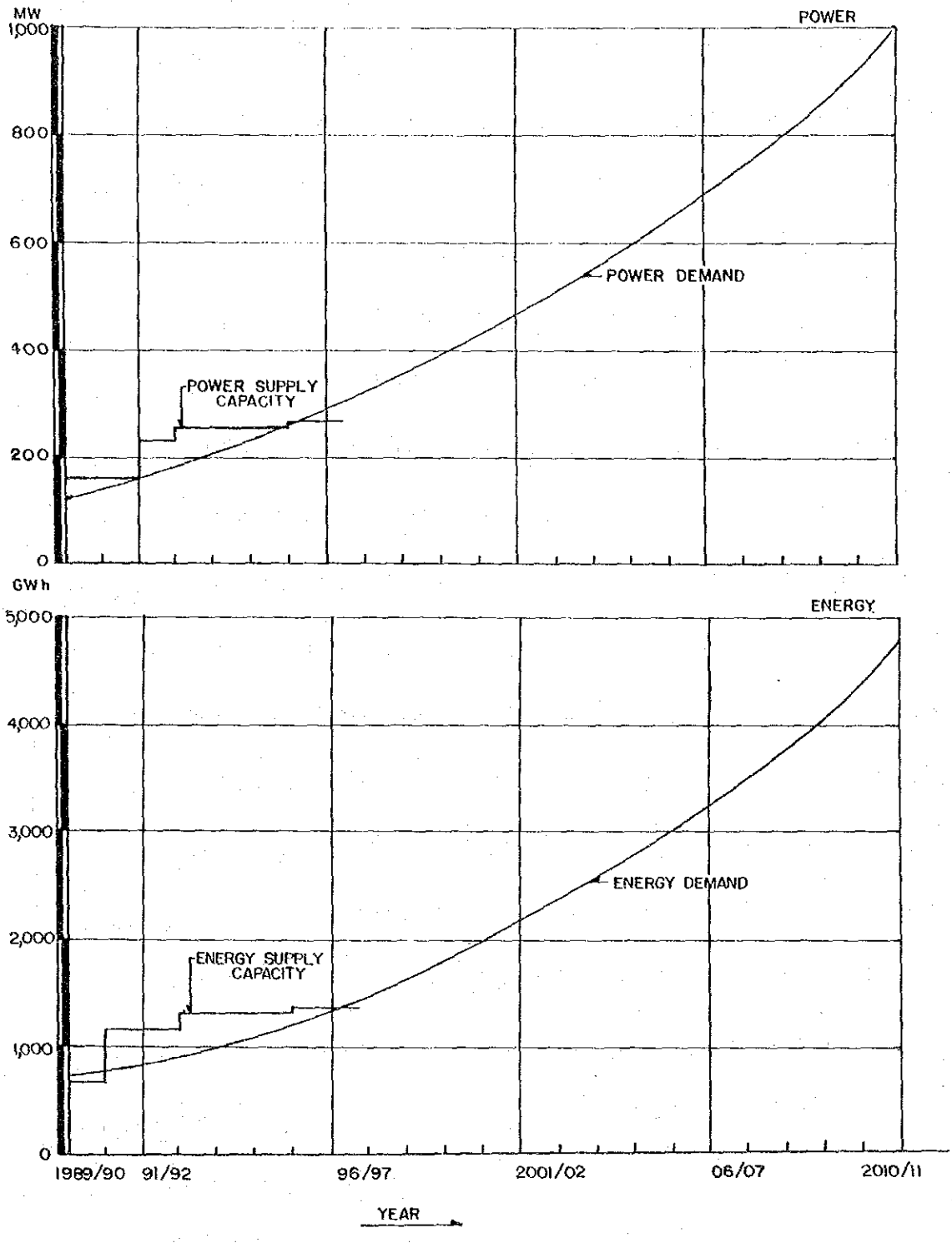
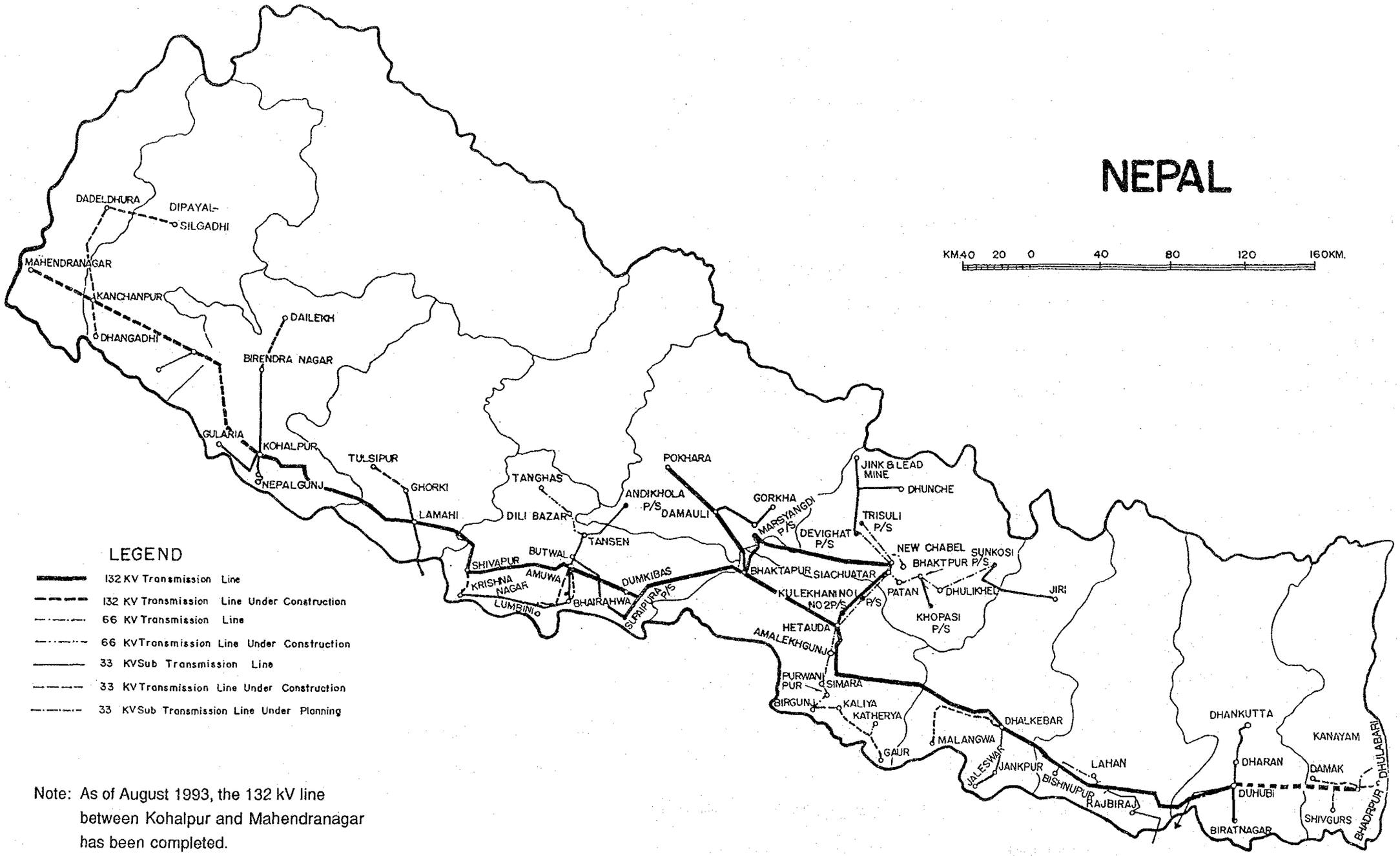


Figure 6 **Relationship between Power Supply Capacity and Demand**

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

NEPAL

KM 40 20 0 40 80 120 160KM.



LEGEND

- 132 KV Transmission Line
- 132 KV Transmission Line Under Construction
- 66 KV Transmission Line
- 66 KV Transmission Line Under Construction
- 33 KV Sub Transmission Line
- 33 KV Transmission Line Under Construction
- 33 KV Sub Transmission Line Under Planning

Note: As of August 1993, the 132 kV line between Kohalpur and Mahendranagar has been completed.

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

Figure 7 Transmission Line Network in Nepal

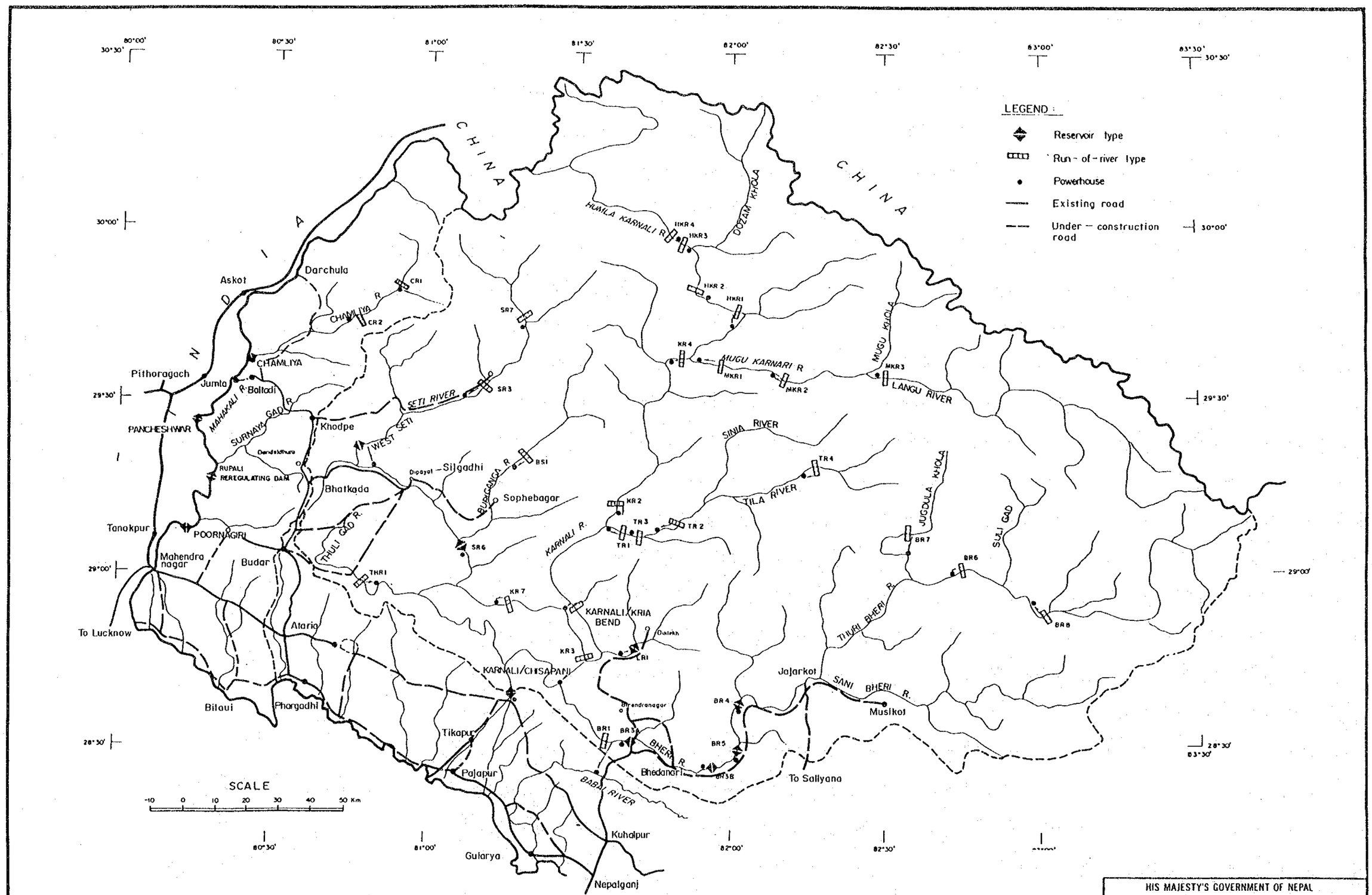


Figure 8 **Hydropower Potential Scheme Sites**

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

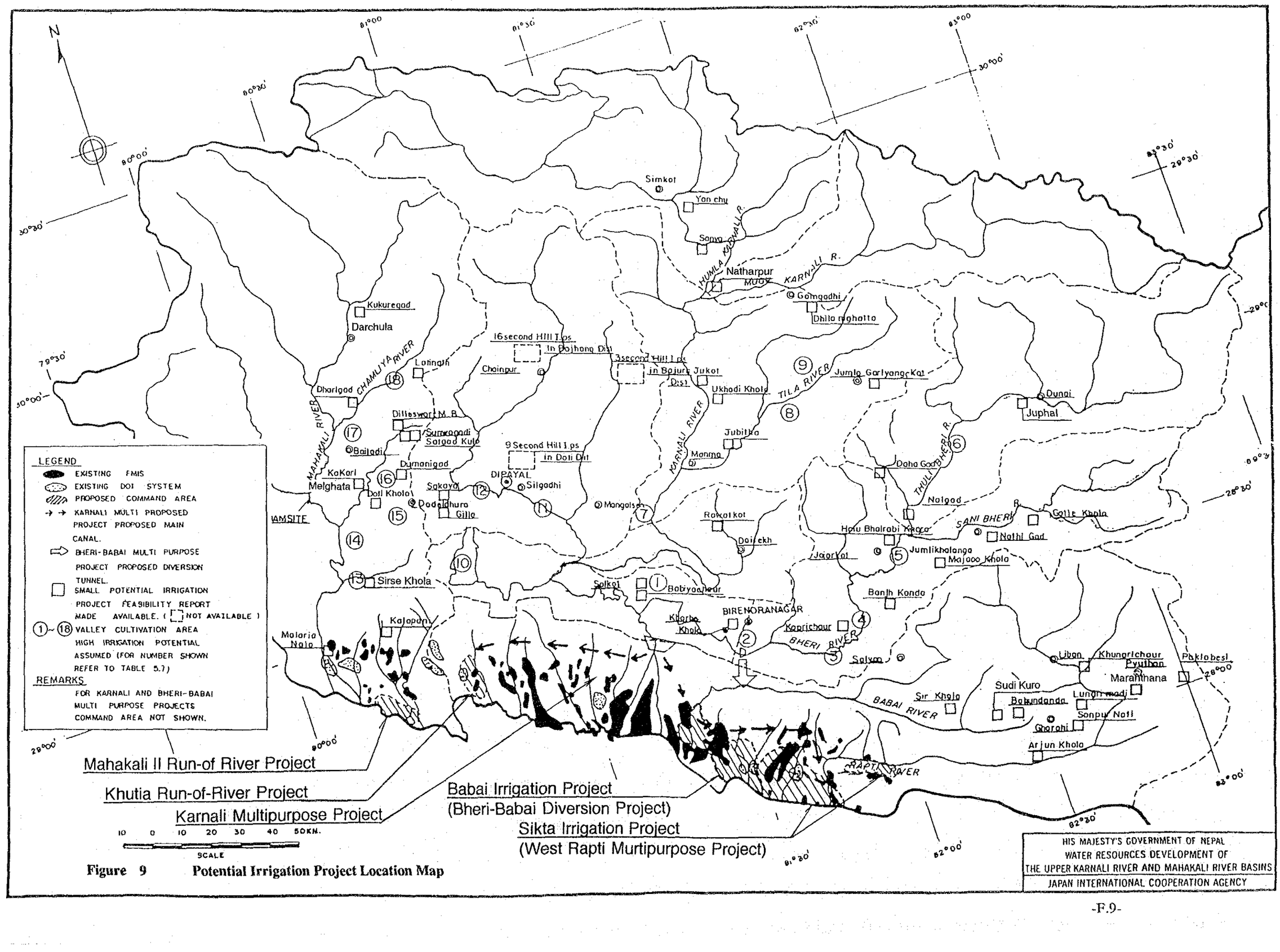
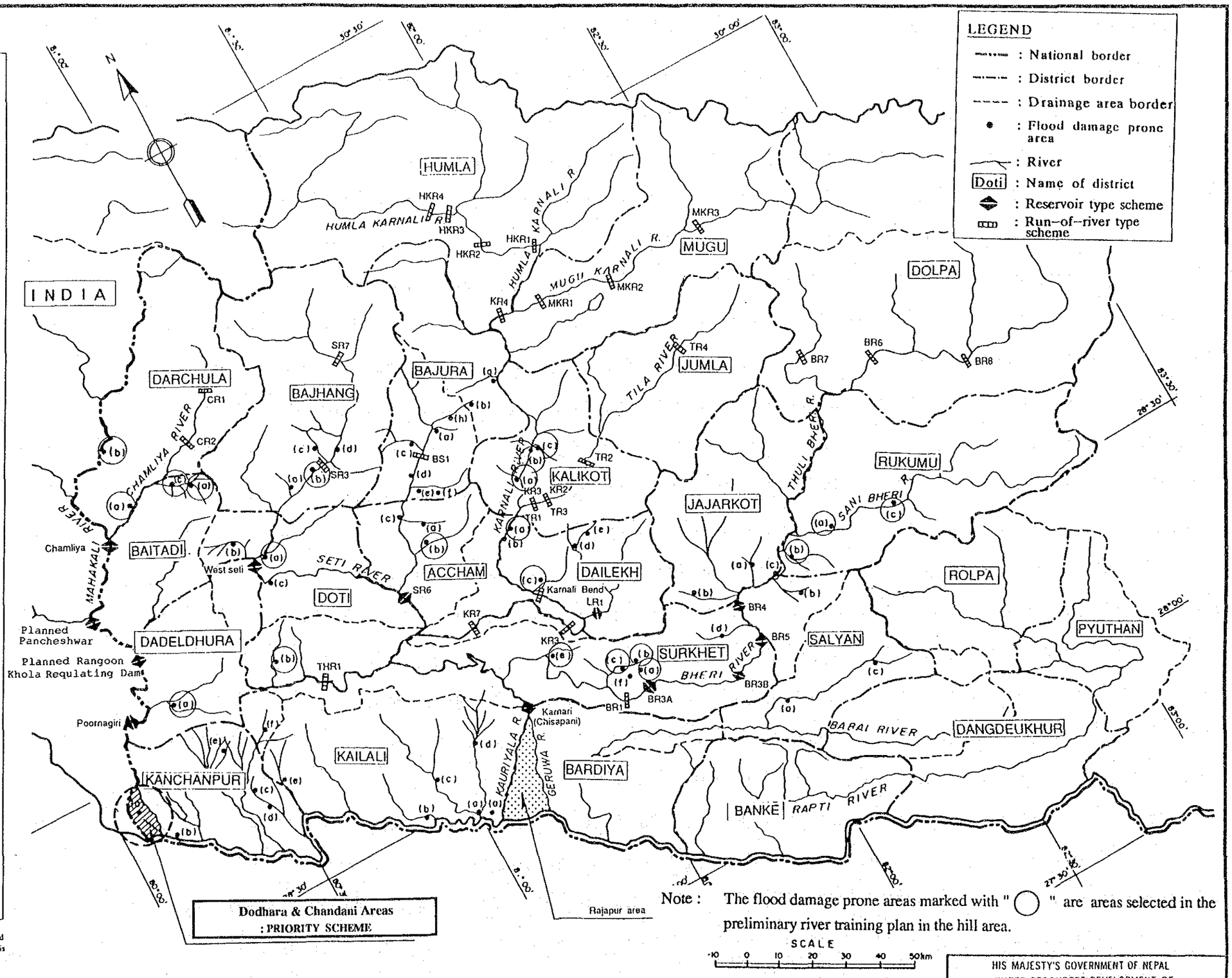


Figure 9 Potential Irrigation Project Location Map

List of Flood Damage Prone Areas

1. Surkhet
   - (a) Birendranagar Ward No. 8,10, 12
   - (b) Birendranagar ward 11,12
   - (c) Birendranagar ward 1 & 2
   - (d) Kada, Simta, Cholpa, Baltakura
   - (e) Chaujung
   - (f) Birendranagar ward 4 & 8
2. Rukum
   - (a) Beltapu
   - (b) Jari Khola River Training Works
   - (c) Dhaune Bagar
3. Salyan
   - (a) Sharda Khola
   - (b) Marua Khola
   - (c) Luhan Khola
4. Dailekh
   - (a) Rakam
   - (b) Singouri
   - (c) Dhamigaun
   - (d) Basai
   - (e) Kotmandir
5. Kalikot
   - (a) Serijiula
   - (b) Ramnakot & Lapha
   - (c) Lapha Gad
6. Jajarkot
   - (a) Punma
   - (b) Junga Thaoachour
   - (c) Japatipur
7. Bajhan
   - (a) Chaughalli
   - (b) Chopakhe and Deval areas
   - (c) Dogad
   - (d) Rainabagar
8. Baitadi
   - (a) Purchaundi Hat
   - (b) Dung Gad
   - (c) Jamari Gad
9. Bajura
   - (a) Bauli
   - (b) Chatabagar
   - (c) Budhi Ganga
   - (d) Kuldavamandu & Brahmatola
   - (e) Kailashmandu
   - (f) Simla
   - (g) Boldik
   - (h) Pandusain
10. Achham
    - (a) Chipiya Khola River
    - (b) Payal
    - (c) Saphe
11. Dadeldhura
    - (a) Jogbudha
12. Doti
    - (a) Tarala
    - (b) Laxminagad
    - (c) Banedungrissaim
13. Darchula
    - (a) Banga Bagar
    - (b) Nuti Bazar
14. Kailali
    - (a) Dhansingpur
    - (b) Bhuinyaphata
    - (c) Kanara River
    - (d) Mohan River
15. Kanchanpur
    - (a) Dodhara & Chandani
    - (b) Dekhat Bhali ward No.6&8
    - (c) Basil Bichwa

Note : Areas attached with " * " are areas selected in the preliminary river training plan of this Study in the hill area.



Note : The flood damage prone areas marked with " ◯ " are areas selected in the preliminary river training plan in the hill area.

HIS MAJESTY'S GOVERNMENT OF NEPAL
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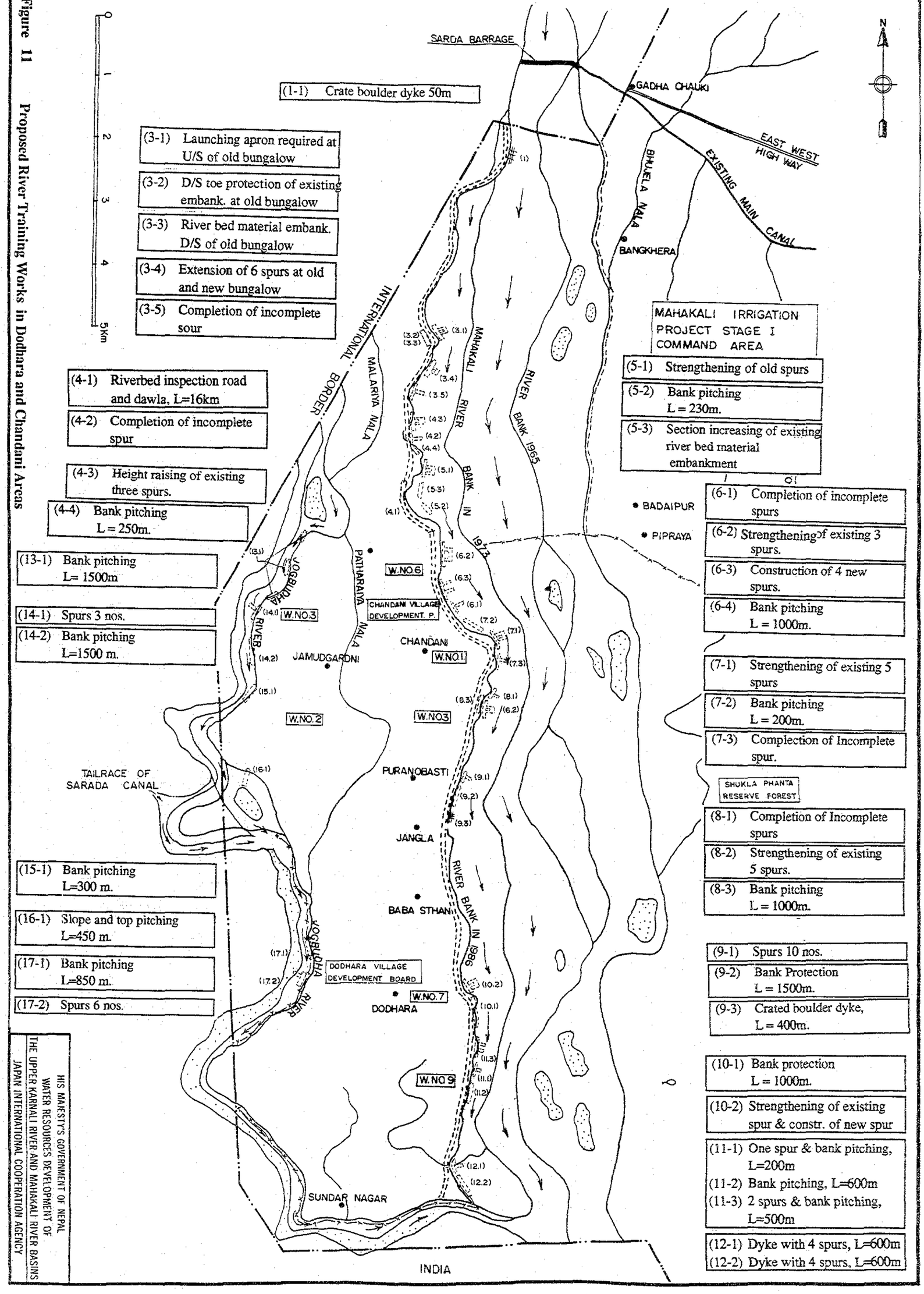
Figure 10 Location Map of Flood Damage Prone Area in the Study Area

Figure 11 Proposed River Training Works in Dodhara and Chandani Areas



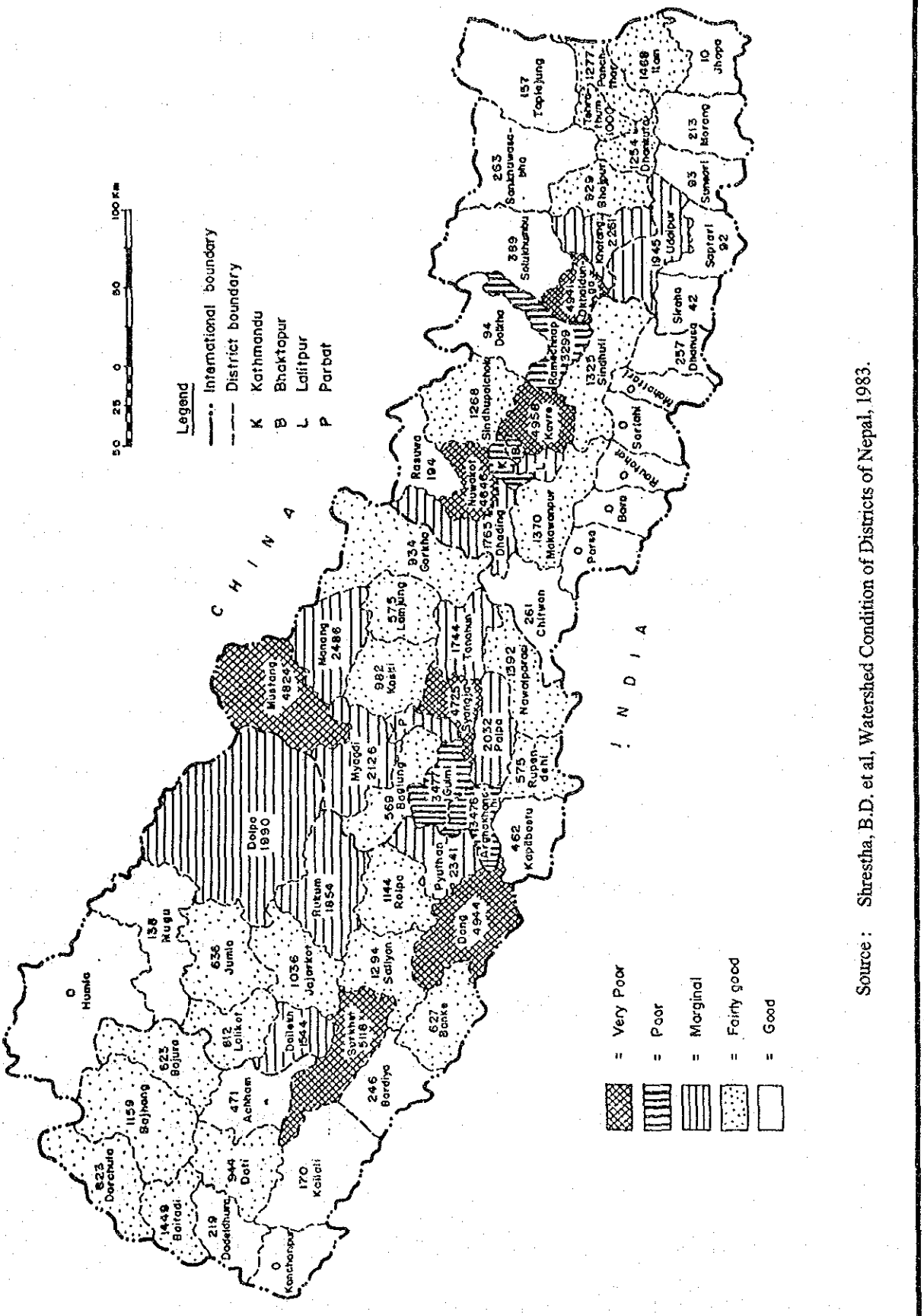


Figure 12 Watershed Condition by District

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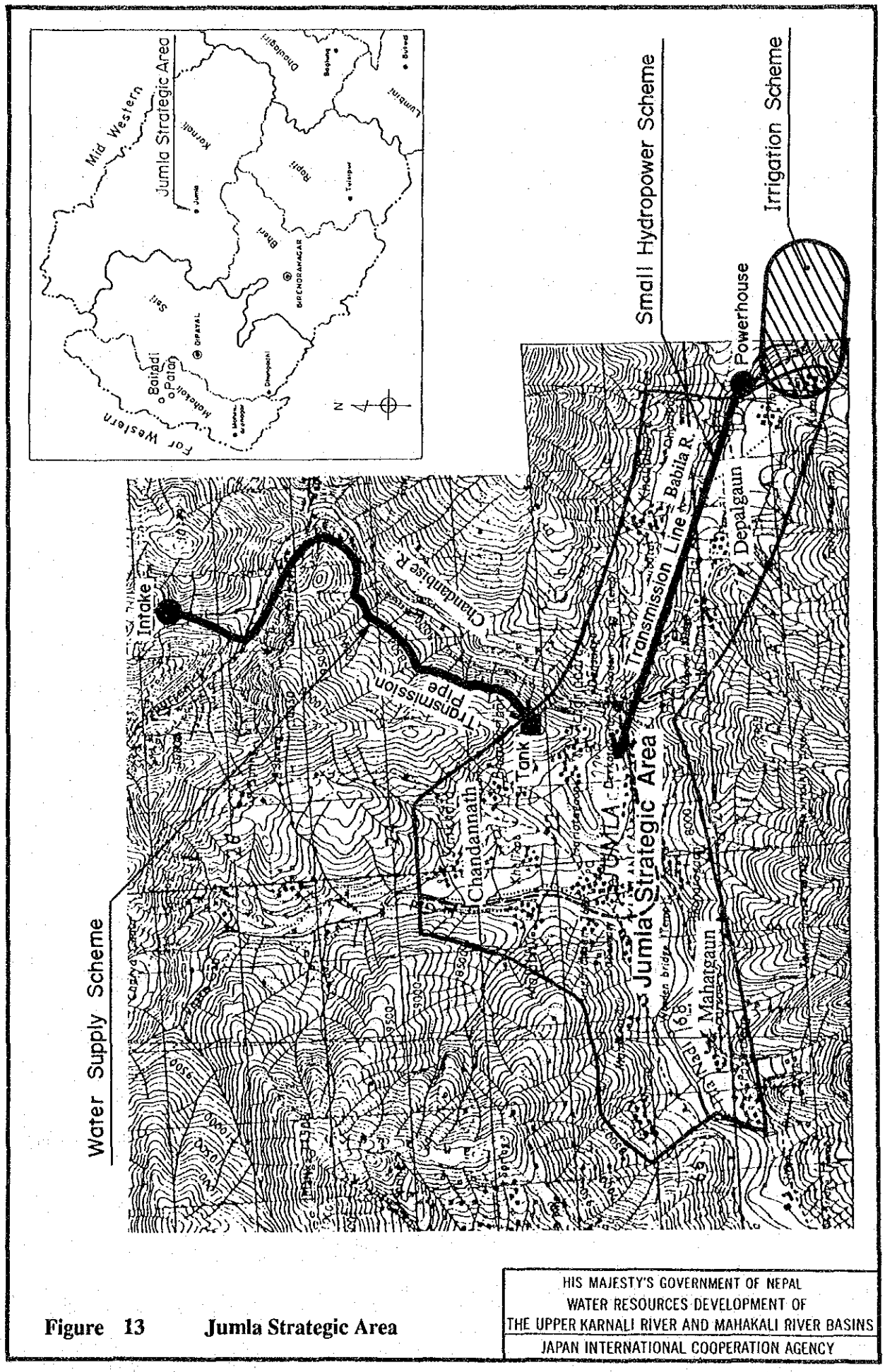

Figure 13 Jumla Strategic Area

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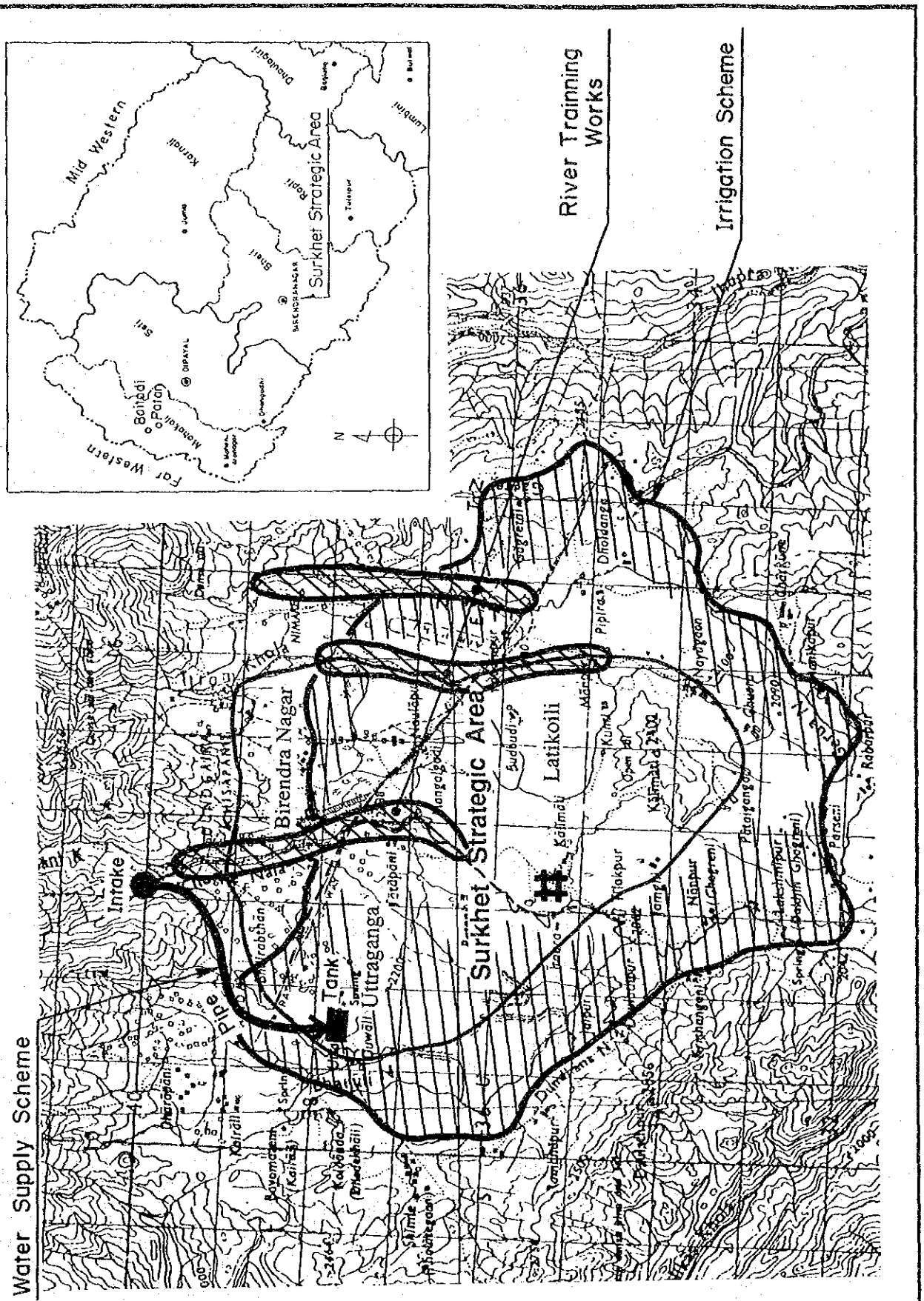

Figure 14 Surkhet Strategic Area

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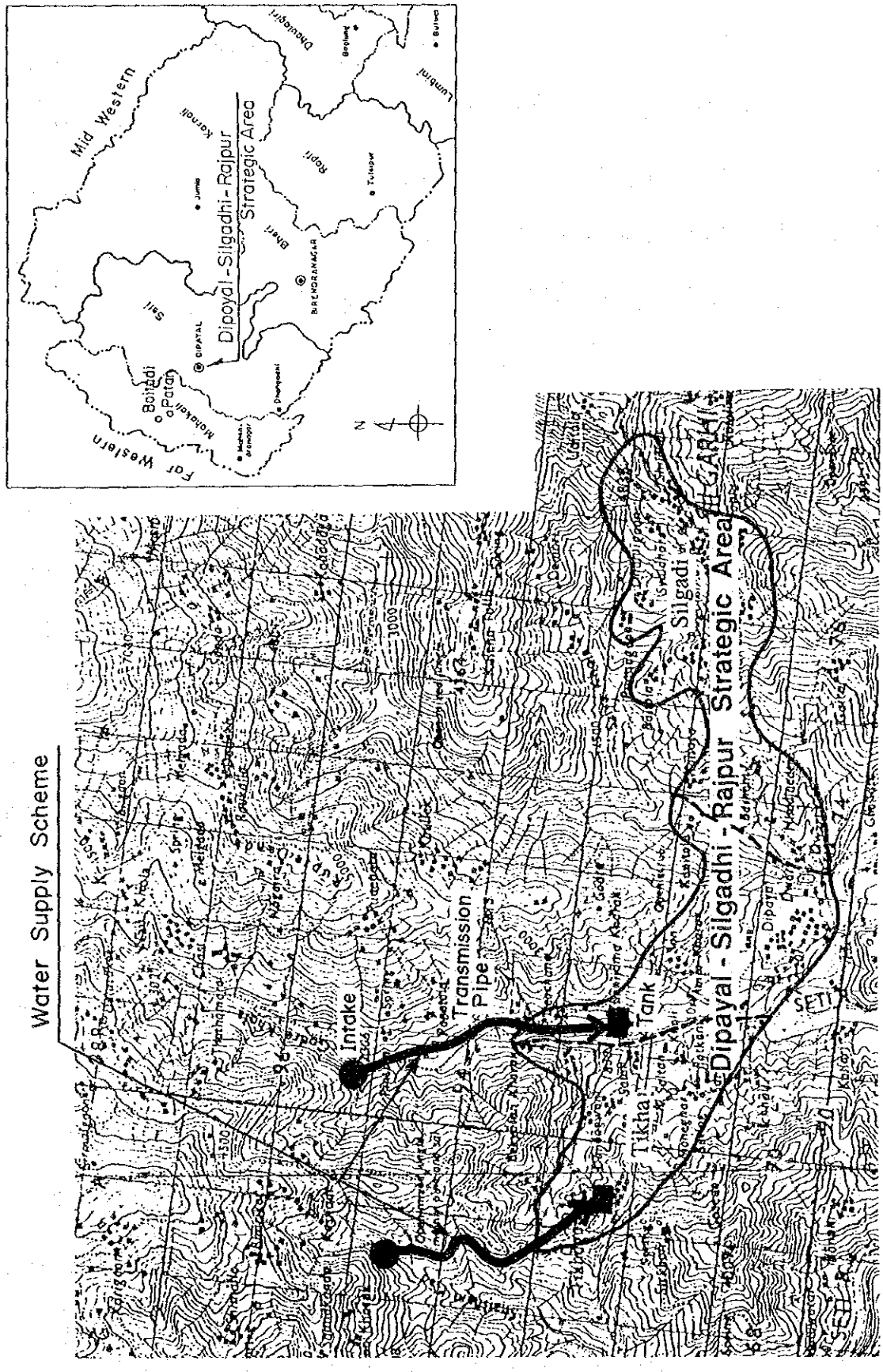

Figure 15 **Dipayal-Silgadhi-Rajpur Strategic Area**

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