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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 [illegible]

MAIN REPORT PART [illegible]
(GENERAL STUDY OF THE MASTER PLAN)

OCTOBER 19[illegible]

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FINAL REPORT

VOLUME II

MAIN REPORT OF PART I (GENERAL STUDY OF THE MASTER PLAN)

OCTOBER 1993

NIPPON KOEI CO., LTD., TOKYO JAPAN
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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,

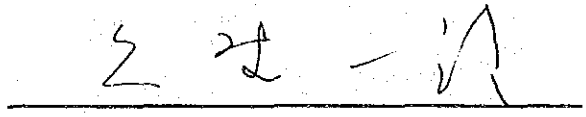
Letter of Transmittal

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

Karnali River Catchment Area

Mahakali River

Mahakali River Catchment Area

Darchula

Chamliya River

Simkot

Humla Karnali

Mugu Karnali

Baitadi

Seti Karnali

Chainpur

Gamgadhi

Martadi

Planned
Pancheshwar
Project

Surnaya Gad

Dipayal

Jumla

Dadeldhura

Seti River

Mangalsch

Manma

Tila River

Mahakali River

Mahendranagar

Dunai

Karnali River

Dailekh

Jajarkot

Sani Bheri

Dhangadhi

Planned Chisapani Project

Birendranagar

Bheri River

Salyan

Liban

Babai River

Gulariya

Nepalganj

Pyuthan

Ghorai

INDIA

CHINA

Gorakhpur

BOUNDARIES International, Regional, Zonal, District

HEADQUARTERS Capital, Regional, Zonal, District, Place names

ROADS High way, Secondary, Seasonal, Under Construction, Tracks

AIRPORTS International, Major Seasonal

Temple, Railway, National Park

River, Lake, Glacier, Canal, Sand

Spotheight, Peak, Pass

Contour Lines

Machhapuchhre Δ 6993

1000

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 blue.

LOCATION MAP

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LIST OF ABBREVIATIONS

ADB	:	Asian Development Bank
ADBN	:	Agricultural Development Bank of Nepal
AIC	:	Agricultural Inputs Corporation
AMIS	:	Agency Managed Irrigation System
BOD	:	Biochemical Oxygen Demand
C.I.F.	:	Cost, insurance and freight
CBS	:	Central Bureau of Statistics
CDR	:	Central Development Region
COD	:	Chemical Oxygen Demand
DHM	:	Department of Hydrology and Meteorology
DLG	:	Department of Local Government
DNPWC	:	Department of National Parks and Wildlife Conservation
DO	:	Dissolved Oxygen
DOA	:	Department of Agriculture
DOI	:	Department of Irrigation
DSCWM	:	Department of Soil Conservation and Watershed Management
DWSS	:	Department of Water Supply and Sewerage
ED	:	Electricity Department
EDF	:	Electricity de France International
EDR	:	Eastern Development Region
EIA	:	*Environmental Impact Assessment*
EIRR	:	Economic Internal Rate of Return
EIS	:	Environmental Impact Study
FCN	:	Food Corporation of Nepal
FMIS	:	Farmer Managed Irrigation Systems
F.O.B.	:	Free on board
FWDR	:	Far Western Development Region
GDP	:	Gross Domestic Product
GOJ	:	Government of Japan
HMG/N	:	His Majesty's Government of Nepal
IDA	:	International Development Aids
IEE	:	Initial Environmental Examination
IRDP	:	Integrated Rural Development Project
IUCNNR	:	International Union for Conservation of Nature and Natural Resources
JICA	:	Japan International Cooperation Agency
KMTNC	:	King Mahendra Trust for Nature Conservation

LRMP	:	Land Resource Mapping Project
MFE	:	Ministry of Forests and Environment
MHDB	:	Marsyandi Hydropower Development Board
MPID2	:	Master Plan for Irrigation Development in Nepal Cycle 2
MWDR	:	Mid Western Development Region
MWR	:	Ministry of Water Resources
NARSC	:	National Agricultural Research Service Centre
NCCNCR	:	National Council for the Conservation of National and Cultural Resources
NEA	:	Nepal Electricity Authority
NEC	:	Nepal Electricity Corporation
NPC	:	National Planning Commission
NPWC	:	National Parks and Wildlife Conservation
NWSC	:	Nepal Water Supply Corporation
RNA	:	Royal Nepal Army
Rs.	:	Nepalese Rupee
SHDB	:	Small Hydro Development Board
SHIP	:	Second Hill Irrigation Projects
S/W	:	Scope of Work
UMN	:	United Mission to Nepal
UN	:	United Nations
UNDP	:	United Nations Development Programme
U.S.A.	:	United States of America
US$	:	Dollars in United States of America
VDC	:	Village Development Committee
WDR	:	Western Development Region
WEC	:	Water and Energy Commission
WECS	:	Water and Energy Commission Secretariat
WSSB	:	Water Supply and Sewerage Board
WWSN	:	World Wide Seismographic Network

LIST OF UNIT OF MEASUREMENT

°C	:	degree centigrade or Celsius
El.	:	Elevation
GWh	:	Giga Watt hour
ha	:	hectare
km	:	kilometer
km^2	:	square kilometer
kW	:	kilo Watt
m	:	meter
m^3/s	:	cubic meter per second
m^3/day	:	cubic meter per day
MW	:	Mega Watt
%	:	percent

1. INTRODUCTION

1.1 Study Area, Objectives and Scope of the Study

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, based on the Scope of Work (S/W) agreed upon between the Ministry of Water Resources (MWR) of His Majesty's Government of Nepal (HMG/N) and the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation programme of the Government of Japan (GOJ), on August 30, 1990 at Kathmandu, Nepal.

The objectives of the Study are 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.

The Study was carried out over a period November 1991 to October 1993 by dividing into three Phases: Phase I, conducted between November 1991 and January 1992, comprises data collection, reconnaissance and basic strategy setting, resulting in the identification of potential schemes. Phase II, between February 1992 and August 1992, consists of field investigation of potential schemes, demand projections and identification of priority schemes. Phase III, between September 1992 and September 1993, contains topographic, geological and material surveys, preliminary design and evaluation of priority schemes, identification of top priority scheme and finalization of the Study. Following is a summary of the work carried out for the Study:

Name of Phase	Major objectives	Period
Phase I	Identification of potential schemes	November 1991 to January 1992
Phase II	Selection of priority schemes	February 1992 to August 1992
Phase III	Formulation of a master plan	September 1992 to October 1993

1.2 Cooperation between JICA and HMG Nepal

The Study was conducted by the Study Team of JICA, in collaboration with the counterpart personnel of MWR. JICA maintained Advisory Committee, in order to support the conduct of the Study Team. HMG/N established a coordinating committee, which consists of high level officials of MWR, Water and Energy Commission Secretariat (WECS) and other ministries and organizations concerned, in view of the multi-disciplinary nature of the Study. Joint meetings were held among the Study Team, Advisory Committee and Coordinating Committee in due course.

1.3 Significance of the Study

Water resources in Nepal are dominated by four large river basins, i.e. the Kosi, Gandaki, Karnali and Mahakali river basins. Their development has been studied by the United Nations (UN) and other agencies with major interest on hydroelectric power potential, except for the JICA Master Plan Study on the Kosi River Water Resources Development in 1985 which included a basin transfer for the purpose of a large scale irrigation. Envisioned in this Study was a regional development approach involving more diversified use of water resources, in view that the Study Area is lagging behind the other parts of the country in socio-economic development.

1.4 Work Progress

The Study was commenced with the arrival of the Study Team in Kathmandu on November 20, 1991. Meetings were held twice between the MWR and the Study Team in November 22 and 25 for discussing the Inception Report presented by the Study Team. Details of undertakings by both the parties were also discussed and mutually agreed upon. The Study Team in collaboration with counterpart personnel thereafter collected and studied data and information. Aerial and terrestrial reconnaissances were made over the Study Area by means of helicopters and four wheel drive cars over periods of December 8 to 11, December 22 to 24 and December 26. The progress of work, findings and preliminary views up to date were compiled in the Progress Report (1).

The Study Team left Kathmandu on December 30, 1991 and continued the Study in Tokyo for the identification of potential schemes. The Interim Report (1) was prepared in February 1992 to summarize the study results carried out in Phase I, consisting of a series of

such work as data collection, reconnaissance, basic strategy setting and potential scheme identification.

An initial half of Phase II work was performed in Nepal between March and April, 1992, in order to collect more detailed information on the potential schemes which were identified in Phase I. The Study Team arrived in Kathmandu on March 3, 1991. A joint meeting was held among the Study Team, Advisory Committee and Coordinating Committee on March 8, 1992, for a briefing of the contents of the Interim Report (1) by the Study Team and exchange of views among personnel concerned. The Study Team thereafter, in close cooperation with counterparts, conducted field work including interview and inquiries to district officers and other personnel in the Study Area and reconnaissance to the potential scheme sites, hydrological stations and transportation facilities. The Progress Report (2), which summarizes the results of study carried out in the field work of Phase II, was prepared in April 1992.

After returning to Tokyo, the Study Team resumed the work for the second half of Phase II, i.e. home office work, in which preliminary economic evaluation was carried out for the identified potential schemes, and eventually priority schemes were selected from among them taking into account not only their economic viability but also their spatial distribution and balanced development of different sectors of economy. The Interim Report (2) was prepared in September 1992 by incorporating all the study results obtained in Phases I and II.

Following the completion of the work of Phase II, investigation for Phase III was immediately commenced with the discussions on Interim Report (2) between the MWR and the Study Team in September 20 and 21, 1992. Main emphasis in the meetings was given to the mutual consent for the selected priority schemes among others.

Succeeding work was the preparation of topographic maps and the geological investigation for four priority schemes selected in the hydropower sector. Besides those work, further field investigation studies were carried out for the priority schemes proposed in the irrigation and flood mitigation sectors among others. The Progress Report (3) was prepared in March 1993 for dealing with the outcomes achieved in the field work of Phase III. Final work of this Study, which includes the formulation of master plan for water resources development in the Study Area and the further detailed studies for four hydropower priority schemes based on the prepared topographic maps and the conducted geological investigation among others, was carried out as home office work of Phase III following its field work. The Draft Final Report was prepared by summarizing all the study results obtained through the course of the study including home office work of Phase III and was submitted to the MWR in August 1993.

A joint meeting was called on August 19, 1993 to discuss the Draft Final Report among the Study Team, Advisory Committee and Coordinating Committee. This Final Report was prepared by incorporating the comments raised for the Draft Final Report from the Nepalese side and was submitted to the MWR in October 1993.

1.5 Composition of the Report

This Final Report of the master plan study is composed of six 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 which provide the details of the Study, and Volume VII is the data book, which contains results of geological investigation and detailed breakdown of construdtion costs for hydropower potential schemes.

2. OVERVIEW OF NEPAL

2.1 Natural Condition

2.1.1 Location and Access

Nepal, which is a landlocked country, lies between 80° 04' and 88° 12' east longitude and between 26° 22' and 30° 27' north latitude. It is bordered by China in the north and India in the south, east and west. The land area is 147,000 km^2. The access to Nepal can be made by land at various points from India and China. By air, Kathmandu has a sole international airport.

2.1.2 Physiography and Climate

Nepal is physiologically characterized by undulating hills and mountains, which cover more than 80 % of the country. The mountains include twelve peaks, which are higher than 8,000 meters above sea level, and eight of the world's ten highest peaks.

Development of Nepal is severely limited by topography and climate, especially due to geologically unstable and environmentally fragile mountain zones. Within a north-south width of about 150 km, there is a wide climatic range from the subtropics in the Terai to the arctic of High Himal.

Nepal is in general divided into five zones in respect of physiography. They are the High Himal, High Mountains, Middle Mountains, Siwaliks and Terai as depicted in Figure 2.1.1. These five zones as briefed below are generally stratified in the direction of east-west, whilst the elevation of these zones increases northeastwards:

Terai

This zone is an extension of the Gangetic plain of India, lying at 60 to 200 m above sea level and being traversed by a large number of rivers. Water of some small rivers is utilized for irrigation, but large fluctuation of river flow between monsoon and dry seasons, resulted from high concentration of rainfall in the monsoon season, makes it hard to utilize it for irrigation efficiently.

The climate of the Terai falls in the subtropical zone. Air temperature climbs beyond 40^0C in summers, going down just above the freezing point in winters reflecting a continental climate. On alluvial soils of the Terai, erosion is generally light, but some areas are subject to severe sheet erosion, resulting in gullying when ground cover is removed.

Siwaliks

Siwaliks, located at the outermost Himalayan foothills which are parallel to the Nepalese border, lies between El. 300m and El. 1,500m and reaches El. 1,800m in some areas. Vegetation varies from dense forests to grasses through shrubs.

The soils in these areas are shallow and drought-prone, resulting in low productivity and arability. However, some wide valleys, which are formed by lacustrine deposits from blocked rivers, are productive and highly cultivated.

Middle Mountains

This zone is the largest central belt of Nepal which covers more than 30 % of Nepal, being characterized by undulating areas where flat terrains are less than five percent. The ground level ranges from El. 200m at river bottom to El. 3,000m at the ridges.

Many parts of this zone are cultivated in the shape of levelled terraces and slope terraces even on the mountain slopes with the gradient of 30^0, being fragile against landslide and soil erosion.

Climate of this zone is generally temperate, but frost and snow occasionally fall in the high elevation areas in winters.

High Mountains

This zone, which occupies approximately 20% of Nepal, is composed of high mountains with steep slopes and narrow valleys. The mountain tops go beyond El. 4,000m, whilst the river valleys cut into El. 2,000m to El. 2,700 m.

Areas with less steep slope extending in relatively low elevations are used for cultivation. Areas with steeper slope are used for summer grazing or left as forest lands.

Climate falls in the cool temperate zone with air temperature below 0°C for five months a year. Precipitation is much smaller than that of Middle Mountains and is concentrated over a period from July to September.

High Himal

The High Himal zone, which accounts for 23% of Nepal, lies between the upper limits of vegetation and the crests of the Himalayas. This area consists of rocky areas, ice-covered massifs, snow field, glaciers and meadow lands. Most of meadow areas have been overgrazed, resulting in the soil breakage and soil movement.

2.2 Socio-economic Condition

2.2.1 Population

According to 1981 census, total population in Nepal was 15,022,839 with an average annual growth rate of 2.66% between 1971 and 1981. Out of economically active population of 6,850,886, 91% was engaged in agriculture, forestry and fishery. Total population in 1991 census was 18,462,081 with an annual growth rate of 2.08% over a period of 1981 to 1991, corresponding to a population density of 125 persons/km^2 according to an initial estimate by the Central Bureau of Statistics (CBS).

Population of Nepal by Development Region, which is an administrative unit dividing the nation into five from the viewpoint of development, between 1981 and 1991 is presented in Table 2.2.1. The Central Development Region (CDR) has the highest population with the number of 6,174,237 in 1991, followed by the Eastern Development Region (EDR) of 4,448,374, the Western Development Region (WDR) of 3,751,922, the Mid Western Development Region (MWDR) of 2,406,095 and the Far Western Development Region (FWDR) of 1,681,453. On the other hand, population growth for the period between 1981 and 1991 is highest in the FWDR with an annual growth rate of 2.45%, whilst the WDR and the EDR recorded the lowest annual growth rate of 1.83%.

2.2.2 National and Government Accounts

The fiscal year in Nepal starts on July 16 of a year and ends on July 15 of next year. The buying rate of US$ 1.00 was Rs. 27.40 in 1989 and Rs. 29.10 in 1990. Nepalese Rupee rapidly decreases its value to a rate of US$ 1.00 to Rs. 42.60 as of December 25, 1991. The government introduced a partial float system on money exchange in March 1992. As a result,

the exchange rate plunged into a rate of US$ 1.00 to Rs. 48.30. As of March 1993, US$ 1.00 is equivalant to Rs. 46.65.

According to a tentative estimate by CBS, Gross Domestic Product (GDP) at the current market price in 1989/90 was Rs. 88,711 million, corresponding to about US$ 160 per capita. The growth rate of GDP varies in a wide range but it is estimated to be 4.5% on an average between 1985/86 and 1990/91 in real term as seen in Table 2.2.2. The composition of GDP in 1989/90 was 53.4% for the agriculture sector, 5.2% for the mining, quarry and manufacturing sector, 7.0% for the construction sector, 6.0% for the trade and private service sector, 12.6% for the public service and utility sector, 7.8% for the financial and real estate sector and 8.0% for indirect tax.

Nepal exports clothing, carpets, leather goods and grains mainly to India, U.S.A. and Europe and imports petroleum products, fertilizer and machinery mainly from India, Japan and Europe. Total export value at F.O.B. prices was Rs. 5,249 million and total import value at C.I.F. prices was Rs. 18,432 million, making up a trade deficit of Rs. 13,183 million in 1989/90.

HMG of Nepal borrowed foreign loan of Rs. 5,960 million equivalent from IDA, ADB, Japan and other donor countries and repaid principal and interest of Rs. 1,122 million equivalent in 1989/90. The revised estimate of the government expenditure for 1990/91 was Rs. 24,479 million, comprising Rs. 7,928 million of regular expenditure and Rs. 16,551 million of development expenditure. The internal revenue of Rs. 10,698 million and foreign grant of Rs. 2,395 million are not enough to balance the expenditure and are supplemented with foreign and internal loans.

2.2.3 Food and Agriculture

Total cultivated area in Nepal is 2,641,000 ha. Major food crops are paddy and wheat in Terai Ecological Belt and millet and maize in Hill Ecological Belt. Cash crops such as potatoes, oilseeds, sugarcane, jute and tobacco are grown mainly in Terai Ecological Belt.

In 1987/88, total cropped area was 3,540,000 ha. Production volume of food grain was 4,941,000 tons including 2,982,000 tons of paddy, 902,000 tons of maize, 745,000 tons of wheat, 24,000 tons of barley, 150,000 tons of millet and 139,000 tons of pulses as given in Table 2.2.3, and total farm gate value was Rs. 33,310 million including Rs. 20,702 million of food grains, Rs. 5,502 million of other food crops, Rs. 3,173 million of cash crops and Rs. 3,933 million of other crops.

Improved seeds and chemical fertilizers are little used. Inadequate water is available even on the irrigated farms. In consequence, crop yields are generally low and largely fluctuate depending on the climate.

Nepal was a net exporter of food grains until the mid-1980's, but import has increased recently. The present food self-sufficiency ratio is at a level of 80 to 90%.

Livestock raising is major agriculture in Mountain Ecological Belt. It is an important agro-ecological cycle between cultivated land and forest in Hill Ecological Belt. High growing population, demanding second crop growing, increased fuel wood supply and unregulated grazing, induces forest destruction and accordingly causes unretrievable damage in the agro-ecological chain. Livestock in Terai Ecological Belt is only subsidiary. According to the Agricultural Statistics of Nepal in 1990, there were 6,284,918 of cattle, 5,302,344 of goats, 3,002,803 of buffaloes and less number of other livestocks.

2.2.4 Forest, National Reserve and Tourism

Forest area is 6,306,500 ha, of which 54% is hard-wood forest. There are seven National Parks occupying 864,400 ha in total, five wildlife reserves sharing 170,490 ha in total and a conservation area of 266,000 ha. Nepal's landscape and historical remains attract tourists. In year 1988, a total of 265,943 foreign tourists visited Nepal.

2.2.5 Public Health

A public health care system in Nepal has been enhanced since the middle of 1950's. Nepal Malaria Eradication Organization was established in 1955, leprosy and tuberculosis control projects were started in 1966 and Small Pox Eradication Programme was launched in 1968. There were 111 hospitals, 18 health centres, 145 Ayurvedic dispensaries and 816 health posts, and the number of doctors was 917 in year 1991.

2.2.6 Infrastructure

The total length of roads was 7,007 km in 1989, including 2,087 km of highways, 1,871 km of feeder roads, 1,974 km of district roads and 1,075 km of city roads. About 40% of the road length was black-topped and the remainder was gravel or earthen roads. Other ground transportation facilities were 53 km of railway and 43 km of ropeway.

Royal Nepal Airlines Corporation operates both international and domestic air services. There are 43 airports/air strips in the country. There were 42 telephone exchanges, 96 public

call offices, 55 wireless stations and 2,232 post offices in 1990. Most urban areas are supplied with piped water. In 1988/89, 31.5 million liters per day of drinking water were publicly supplied.

Nepal's electricity demand is mostly supplied by hydroelectric power. HMG of Nepal is implementing mini hydroelectric power projects in isolated places. There were 260,606 kW of power generation facilities including 231,771 kW of hydro, 28,683 kW of diesel, 130 kW of solar and 20 kW of wind power facilities in year 1990. They produced 759 GWh of energy in 1989/90.

There are irrigated farms of 933,000 ha in a net area, including 725,000 ha in Terai Ecological Belt, 179,000 ha in Hill Ecological Belt and 29,000 ha in Mountain Ecological Belt.

2.3 Legal and Institutional System

2.3.1 Government Organization

The central government organization of Nepal has been newly established after the promulgation of the Constitution in November 1990. It is stated in the Constitution that the responsibility of giving general direction and keeping control and conduction of the administration of the Kingdom of Nepal shall vest in the Council of Ministers which is chaired by the Prime Minister. The government of Nepal has 21 ministries each under the charge of a Minister or a Minister of State. The Minister in each ministry is assisted by the Secretary who offers professional advice to the Minister on policy issues and is generally responsible for the implementation of approved plans and policies within the ministry. Under the Secretary, there are the heads of various line departments.

The National Planning Commission, which is also chaired by the Prime Minister, is responsible for the preparation of national economic development plans and certain trans-sectoral activities such as the national census.

The central government organization of Nepal prepared by the Ministry of General Administration in October 1991 is presented in Figure 2.3.1.

2.3.2 Administrative Division

Nepal is administratively divided into 14 zones and further into 75 districts, each headed by Chief District Officer. Each district is divided into village development committees

/municipalities, the smallest local administrative units. There are 4,051 village development committees and 33 municipalities.

Zones are grouped into five Development Regions for the purpose of promoting country's all-round development. They are the Eastern Development Region (EDR), Central Development Region (CDR), Western Development Region (WDR), Mid Western Development Region (MWDR) and Far Western Development Region (FWDR) as dealt with in Section 2.2, Socio-economic Condition.

For the purpose of research and engineering study, the districts are often grouped into Terai, Hill and Mountain Ecological Belts. In terms of physiographic region, Terai Ecological Belt comprises the whole of Terai, 62% of Siwaliks and minor extent of Middle Mountain, Hill Ecological Belt covers the remaining 38% of Siwaliks, 91% of Middle Mountain, 37% of High Mountain and 14% of High Himal, and Mountain Ecological Belt corresponds to 8% of Middle Mountain, 63% of High Mountain and 86% of High Himal.

2.3.3 Agencies for Water Resources Development

The Ministry of Water Resources (MWR) is responsible to the government for overall water resources development in coordination with the National Planning Commission and the Ministry of Finance. Particular developments in each of the water resources development such as power, irrigation and flood control are undertaken under the responsibility of the MWR's line departments and associated agencies. The agencies under this ministry are: the Water and Energy Commission (WEC), the Nepal Electricity Authority (NEA), the Department of Irrigation (DOI), the Department of Hydrology and Meteorology (DHM) and the mega Hydropower Project Group such as the Karnali Project Office and Pancheshwar Project Office as of November 1991. In July 1993, the Electricity Development Centre was established by amalgamating the hydropoewr project offices for systematic planning, designing and implementation of power projects.

The Water and Energy Commission (WEC), constituted in 1976 and chaired by the Minister for Water Resources, is responsible for preparing water and energy strategy within the context of national policy and recommending appropriate development programmes to the government. In undertaking its planning exercises, the WEC maintains close coordination with the National Planning Commission. The Water and Energy Commission Secretariat (WECS), established in 1981, provides the WEC and the MWR with the planning information necessary for the preparation of sound strategy and development programmes in the water and energy sector.

The Nepal Electricity Authority (NEA) is an autonomous enterprise responsible for all the work related to electricity supply in Nepal. The activities of the NEA are implemented under the direction of the Nepal Electricity Authority Board chaired by the Minister for the MWR.

The Project Group such as the Karnali Project Office was established for the smooth implementation of a specific project, but was amalgamated into the Electricity Development Centre as mentioned above. The DOI undertakes responsibility not only for the implementation of irrigation schemes but also for the execution of flood mitigation schemes.

The organization chart of the MWR is depicted in Figure 2.3.2.

2.4 National Economic Development Plan

The Eighth Plan (1992/93 to 1996/97) is the first economic development plan, which was promulgated under the new Constitution (1990). According to a draft Approach to the Eighth Plan 1992-97 published by the National Planning Commission (NPC) in November 1991, 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. Priority will be attached to the agricultural intensification and diversification, development of rural infrastructures, reduction in population growth, employment generation and human resources development, industry and tourism, export promotion and diversification, energy development, macro-economic stabilization, public administration reform, and monitoring and evaluation.

During the Plan period, real GDP is expected to grow at an annual rate of 5.1%, although this growth rate is higher than any actual performance of the development plans achieved in the past three decades. The policy planners are expecting that the proposed 5.1% growth will be possible because of improved resource allocation and efficiency in resource use arising from economic liberalization and policy reforms.

Out of the total development expenditure of Rs. 121,173 million, the largest share (35%) is allocated to the social services sector for realizing the development target, followed by agriculture (26%), electricity (19%) and transport and communication (17%).

3. GENERAL DESCRIPTION OF THE STUDY AREA

3.1 Topography and Geology

3.1.1 Topography

The Study Area is identified with the entirety of Mid Western Development Region and the Far Western Development Region. Its shape is an approximately 280 km x 220 km rectangle with long sides in a west-northwest to east-southeast direction along the Himalaya range and southern border line and short sides in a north-northeast to south-southeast direction along the western border line and the boundary between the Mid Western and Western Development Regions, being located between 27°40' and 30°30' north latitude and between 80°05' and 83°40' east longitude. The total land area is 61,917 km^2, consisting 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. 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.

The drainage areas of those sub-basins together with that of the Mahakali River are given below:

Basin Name	Drainage Area (km^2)
Karnali Basin	(43,679)
- Karnali Main	19,260
- Seti	7,460
- Bheri	12,290
Mahakali Basin	12,600

It is noted that the drainage area for the respective basins is measured at their representative stream gauge sites, i.e. 280 for the Karnali Basin, 240 for the Karnali Main, 260 for the Seti, 270 for the Bheri and 150 for the Mahakali (refer to Figure 3.1.1).

3.1.2 Regional Geology

General Geology

The Himalaya is divided into following three zones, based on the litho-structural condition, from the south to the north (refer to Figure 3.1.2):

Geo-Unit	Geologic age
Siwalik(Sub-Himalaya)	Tertiary
Midland(Lesser-Himalaya)	Precambrian to Permian
Higher Himalaya(Greater-Himalaya)	Precambrian to Neogene

Each unit is bounded by thrust faults, and over-thrusting of older rocks on the younger sequence is the principal structure.

Following are the short description of the each geological unit:

Siwalik

The Siwalik is young sedimentary molasse deposits of Tertiary age. The group is distributed along the southern margin of the Himalayan Range. South of the Siwaliks is the Gangetic plain while in the north is the Midland zone separated by the Main Boundary Thrust (MBT). The Siwalik is divided into four units: Lower, Lower Middle, Upper Middle and Upper which consist of mudstones, sandstones and conglomerates. The width of this zone varies from a few km in Eastern Nepal to about 35 km in Western Nepal, where the lower units of the Siwalik are tectonically thrust over the younger units, and a series of thrust over the structure has made the structurally complicated zone widely.

Midland

This zone is developed between the Siwalik in the south and the Higher Himalaya in the north with an average width of 100 km. Geomorphologically it is characterized by a high mountain chain in the south and lower hills in the middle section and again higher hills in the north. Wide distribution of low grade metamorphic rocks such as phyllites, quartzites and limestones, and to a lesser degree, mica schists and gneisses are found in this zone. Structurally it is complicated by foldings and faulting, and a number of thrusts are identified in this zone. Their age ranges from Precambrian to Upper Paleozoic.

Higher Himalaya

The Higher Himalaya consists of crystalline rocks at the base and sedimentary rock succession at the top. The high peaks, Segarmatha (Mt. Everest), Lhotse and Makalu, are located in this zone. The rocks of the Higher Himalaya are separated from the Midland zone by a thrust fault named the Main Central Thrust (MCT). The MCT is represented by a series of thrusts.

Structural Geology

Active Fault

There are two groups of active faults in Nepal. The group of hill-front faults caused by the collision of the Indian Subcontinent and the Asian Continent, extends east-west and dips to the north. The well known Himalaya Front Fault (HFF) and the Main Boundary Fault (MBF) belong to this group. The Main Central Thrust (MCT), the older E-W trending thrust, has ceased being active about 10 to 20 million years ago according to "The Geologic History and Structure of the Himalaya" by P. Molnar (1989).

The second group named Karakoram Faults is NW-SE trending, vertical, right-hand strike slip fault.

Epicentre

Most of the published papers are of the opinion that epicentres are concentrating in the area between MCT and MBF. Relatively large scaled earthquakes observed by World Wide Seismographic Network (WWSN) indicate that epicentres are concentrated at the depth of 15 km beneath the lesser Himalaya.

From the initial shock, the plane generating the earthquake is considered to be gently dipping (<15 deg.) to the north. These features are understood by Himalayan geologists to indicate the activity of 15 km deep seated Main Boundary Fault which is gently dipping to the north.

All of those considerations and/or hypothesis are reflected to the schematic profile (refer to Figure 3.1.3) attached.

Crustal Movement (uplifting and erosion)

Many researchers have contributed many figures to the uplifting rate in the Himalayan area. The largest value is from China, in the paper titled "The Map Compilation of the Recent Vertical Deformation Rate in China". Zhang Zusheng (1987) reported 10 mm/y at the southern front of Tibetan Plateau measured by repeated geodetic survey.

Geomorphological study conducted by Gansser (1985) revealed that the annual uplifting rate of 5 mm/y in the greater Himalaya, whilst the uplifting rate of the lesser Himalaya with the gentle rolling terrain is smaller than that of steep Siwalik hills. The uplifting rate in the zone of Mahabharat mountains is less than 1 mm/y in the Kaligandaki River area, and 2 mm/y for the period of sedimentation of the upper Siwalik formation according to the "Uplifting Himalaya"(Kisaki;1985). In the Siwalik mountains between the Main Boundary Fault (MBF) and the Himalayan Front Fault (HFF), the annual uplifting rate reaches 4 mm/y (Kisaki -do-).

Compared to the uplifting rate, the data on erosion are quite limited. In the proceedings of Silting Symposium of Reservoir, Gupta (1977) has given 2.638 mm/y for the average erosion rate in the Himalayan area. JICA Study Team for the Sapt Gandaki hydropower development project calculated to be 2 mm to 3 mm for the Nepal Himalayan area in its feasibility study report (1983). But in the high mountain area, a value of 3 mm to 4 mm is proposed by Kisaki (-do-) as given in Figure 3.1.4.

3.2 Meteorology and Hydrology

3.2.1 Meteorology

(1) General Climate

The climate in Nepal is generally 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. Ample rainfall in the rainy season is brought from the Bay of Bengal by the monsoon which whirls from south-east in the summer.

Westerly or north-westerly wind, which is dominant in winters, brings dry air from Siberia, resulting in a dry season. When wind comes from the Mediterranean, it brings winter rainfall, especially in the western part of Nepal.

The climate of Nepal is divided into five zones in terms of elevation; subtropical, warm temperate, cool temperate, alpine and arctic zones. The Terai and the Siwaliks fall in the subtropical zone with ample rainfall in the monsoon period of June to September.

The Middle Mountains is in the warm temperate zone with occasional snowfalls in winters in the highest areas. The climate of the cool temperate zone extends in the High Mountains. Snow, falling in the winter period, persists on the mountain tops throughout the winter. Alpine climate appears in the higher mountain regions with low temperature in summers and an extremely frosty condition in winters. Arctic climate is above snowline where there is perpetual frost.

(2) Climate in the Study Area

Air temperatures are lowest in winters (January) and increase as spring advances. The highest mean air temperature in a year occurs generally in May or June. The hottest part of the Study Area is in the Terai Belt where mean annual air temperature is 25°C, reaching over 30°C in May and June. The coldest part of the Study Area is in the High Mountain where air temperature varies between 20°C and 4°C with an average value of 13°C.

Mean annual relative humidity in the Study Area varies in a range of 63.7% to 84.0% with an average value of 72.3%. Relative humidity in seasonal variation is, on the other hand, high in July, August and September (83.6, 84.7 and 82.7%, respectively) by receiving the effect of monsoon, whilst low relative humidity is observed in March, April and May with the values of 61.9, 52.8 and 57.3%, respectively.

The maximum daily evaporation is recorded in May and the minimum in January. Annual open-air evaporation ranges from 1,300 to 2,000 mm.

(3) Rainfall and Snowfall

There exist 71 rain gauges in and around the Study Area. Based on the observed records over a period of 1963 to 1989 at those stations, an isohyetal map of annual rainfall was drawn as given in Figure 3.2.1. Average annual rainfall of the Study Area was estimated at 1,262 mm from the isohyetal map, which is compared with that of 1,500 mm for the whole area of Nepal.

Seasonally speaking, rainfall brought by southeast monsoon, which blows from the Bay of Bengal with moist air and is dominant over a period of June to September as

mentioned earlier, accounts for more than 75% of annual rainfall, whilst remaining eight months of October to May are in a dry season.

There are five main stream gauges in the Study Area. Average annual rainfall for the catchment area draining at those gauges was computed as follows:

Basin	Stream Gauge No.	Basin Annual Rainfall (mm)
Karnali	280	1,147
Karnali	240	855
Seti	260	1,629
Bheri	270	1,211
Mahakali	150	1,928

A certain percentage of total annual precipitation falls as snow in Nepal. In particular, a ratio of snowfall to rainfall in terms of annual precipitation is estimated to be high in the Himalayan region.

Snowline descends to El. 3,500 m contour in winters, and ascends to El. 6,000 m contour in summers. Snow accumulated between those two contour lines melts and drains in the river as runoff, as the snowline goes up. That is to say that snow acts as a balancing reservoir in the hydrological cycle due to the delay of appearance as runoff.

3.2.2 Hydrology

(1) Stream Runoff

There are 15 hydrological stations in the Study Area (refer to Figure 3.1.1). Daily runoff data were collected for those 15 stream gauges. Mean annual runoff and its specific discharge estimated for those stations were summarized as shown below:

Mean Annual Runoff and Specific Discharge
at Hydrological Stations

Station No.	Catchment Area (km^2)	Mean Annual Runoff (m^3/sec)	Specific Discharge ($m^3/s/km^2$)
120	1,150	65.5	0.057
150	12,600	591.6	0.047
170	188	7.1	0.038
240	19,260	502.4	0.026
250	21,240	615.6	0.028
260	7,460	288.4	0.039
262	896	33.1	0.037
270	12,290	429.0	0.035
280	43,679	1,378.4	0.032
286	816	14.7	0.018
290	3,000	87.3	0.029
330	1,980	60.4	0.031
339.5	683	30.0	0.044
350	3,380	93.2	0.028
360	5,150	122.8	0.024

Mean annual runoff observed in the Mahakali River basin (Station No. 120, 150 and 170) falls in the range of 0.038 to 0.057 $m^3/sec/km^2$ in terms of specific discharge, whilst the specific discharge of mean annual runoff varies from 0.026 to 0.039 $m^3/sec/km^2$ in the Karnali River basin (Station No. 240, 250, 260, 262, 270 and 280) and from 0.018 to 0.044 $m^3/sec/km^2$ in the Babai River and Rapti River basins.

(2) Sediment Yield

Long-term sediment yielded from the Karnali and Mahakali rivers was estimated at Chisapani (catchment area; 43,679 km^2) and Pancheshwar (catchment area; 12,600 km^2) respectively by applying the developed sediment yield curves. The results are summarized below:

Station	Unit	Karnali River at Chisapani	Mahakali River at Pancheshwar
Drainage Area	km^2	43,679	12,600
Suspended Load	million ton / year	123	45
Bed Load	million ton / year	19	9
Total Load	million ton / year	142	54
Specific yield	ton / km^2 / year	3,251	4,290
Specific yield	m^3 / km^2 /year	2,322	3,060

The density of sediments deposited in the reservoir is assumed to be 1.4 ton/m^3 for the estimate of specific yield. Further details on meteorology and hydrology are referred to Appendix II.

3.3 Land Resources

3.3.1 Soil and Land System

The soil of Nepal is, in general, poor in fertility, although soil type varies extremely with location and physiographic changes. Soil conditions are naturally better in lowlands than hills and mountains.

In the Terai area, the soil type is mainly alluvial, and the texture is fine to medium. That of the Siwaliks area is fine loamy or sandy with pebbles. In the mountainous areas, the major soil types show light to medium texture.

Area of high agricultural potential is estimated at 666,724 ha and accounts for only 10.7% of the Study Area, while for Nepal as a whole area of high agricultural potential occupies 15% of the country's total land area (refer to Table 3.3.1). On the other hand, areas of low agricultural potential and non-agricultural potential account for 14.6% and 74.7% of the Study Area, while accounting for 18.7% and 66.4% of the whole of Nepal, respectively.

3.3.2 Vegetation

The flora of Nepal is rich in variety and forest type has been classified into as many as 35 categories, because of the wide range of climate (from sub-tropic to polar), soil types and moisture conditions.

Forested areas are shrinking gradually. Many forests on steep slopes have degraded, and eroded especially in the high altitude areas. It is presumed that this shrinkage of forest land started to become evident in the 1940's.

Forest is essential for human beings as a source of fodder, fuelwood and construction material in the short-run and for soil and watershed conservation in the long-run. These two aspects of long-run and short-run functions often conflict with the participation by human beings in the utilization of forest resources, and as a result the current trend is the degradation of forest land.

3.3.3 Present Land Use

The land use according to LRMP (1986) has been classified into five categories, i.e. cultivated land, grazing land, forest land, shrub land and others. In the Study Area, the proportional extent of these land uses is 17.49% for cultivated land, 15.20% for grazing land, 42.35% for forest land, 2.21% for shrub and 22.75% for others.

3.4 Natural Environment

3.4.1 National Parks and Wildlife Conservation

The Department of National Parks and Wildlife Conservation is responsible for the implementation of the National Parks and Wildlife Conservation (NPWC) Act (1973) and regulations.

There are five categories of protected areas, i.e. national parks, strict nature reserves, wildlife reserves, hunting reserves and conservation project areas. The protected areas are listed in Table 3.4.1, and their locations in Figure 3.4.1, totalling 15,933 km^2 and accounting for 10.8% of the whole of Nepal territory (147,181 km^2). The area within the Study Area is 5,366 km^2 which is equivalent to one-third of the protected area in the nation.

3.4.2 Fauna

In Nepal, some fauna are protected country-wide, but there are no flora protected. The protected species of Mammalia, Aves and Reptilia as of December 1, 1989 are counted to be 27 for Mammalia, 9 for Aves and 3 for Reptilia as listed in Table 3.4.2.

In addition in Nepal there are 19 species of animal, 10 species of birds, and 5 species of reptile listed in the 1988 IUCN Red List of Threatened Animals. Once listed in this so called Red Data Book, the species are internationally recognized as animals in danger and become objectives for conservation.

Since there are many protected animal species in the Study Area, proposed projects are likely to affect their habitat or ecosystem, and thus friction between economic development and natural conservation might arise.

3.4.3 Fishes

Fishes are a good source of protein in the hill area, and the fishes observed in the Karnali River are eighteen species according to the ecological report prepared by Norconsult and Electrowatt, December 1976. The twelve main fishes observed in the Study Area are (a) Tor putitora, (b) Tor, (c)Schzothorax spp., (d) Culpisoma garna, (e) Labeo dochyeilus, (f) Labeo pangusia, (g) Crossocheilus latius, (h) Barilius bendelisis, (i) Barilius vagra, (j) Botia almorhae, (k) Arguilla bengalensis, (l) Wallago attu.

Research work on fishes of the Karnali River is at the moment limited. Furthermore, there exist few professional fishermen in the Study Area.

3.4.4 Water Quality

Water quality tests were conducted to generally identify water quality of the Karnali and Mahakali rivers by the Study Team in December 1991, and the results are summarized in Table 3.4.3. The results of the water quality analyses by New ERA in the beginning of the rainy season, 1987, are shown in Table 3.4.4. The differences are clearly caused by different rainfall amounts in the rainy and dry seasons. In addition the data of water quality survey by Karnali Multipurpose Project, 1993 were obtained (refer to Table 1.4.3 of Appendix III).

It is possible to conclude that the water in the Study Area can be used for irrigation due to the intermediate level of contents of calcium, which is a substance to cause coagulation of surface soil and to make farming difficult. It is, however, good to give further detailed water

surveys on quality to secure the irrigation in the Karnali River basin. As a source of drinking water, on the other hand, appropriate treatment is required.

3.4.5 Water-Borne Diseases

There are three types of water-borne diseases in the Study Area, i.e. (1) the infection is directly transmitted to human being via water, (2) the pathogenic agents need wet condition to survive and make contact with the host and (3) the pathogenic agents are transmitted by a vector for which water or wet condition is essential for survival and propagation. The examples of the first type are many digestive tract diseases and hepatitis A. A common example of the second type is entozoon. The third type includes Japanese encephalitis and malaria transmitted by mosquitoes.

For mitigating negative impacts caused by the diseases mentioned above, hygienic education and prophylactic measures are essential in addition to the improvement of health care facilities.

4. SOCIO-ECONOMIC CONDITIONS IN THE STUDY AREA

4.1 Administrative Division and People

4.1.1 Administrative Division

The Study Area administratively lies within the boundaries of the Mid Western and Far Western Development Regions as shown in Figure 4.1.1. The Mid Western Development Region (MWDR) with the development centre in Birendranagar (Surkhet) consists of three zones, i.e. Rapti, Karnali and Bheri, which are subdivided into 15 districts. Among these 15 districts, there are three municipalities and 588 village development committees. The Far Western Development Region (FWDR) with the development centre in Dipayal comprises two zones, Seti and Mahakali, which are subdivided into nine districts, among which there exist three municipalities and 396 village development committees (refer to Table 4.1.1).

4.1.2 Population

Population in the Study Area increased from 3,275,637 in 1981 to 4,079,548 in 1991 with an annual increase rate of 2.22% which exceeded the national average rate of 2.08% per annum (refer to Table 2.2.1) during the same period as given in Table 4.1.2. Among the five zones within the Study Area, Bheri Zone showed the highest growth rate of 2.72% per annum, followed by Seti Zone of 2.49% per annum. The highest population density was recorded in Bheri Zone of 104 persons per km^2, followed by Rapti Zone of 100 persons per km^2. The Karnali Zone had the lowest density of 12 persons per km^2. Average population density in the Study Area was 66 persons per km^2 in 1991 which was approximately half the national average.

The total population of 4,079,548 in 1991 consists of 1,605,050 (39.3%) in Terai Ecological Belt, 1,888,377 (46.2%) in Hill Ecological Belt and 594,121 (14.5%) in Mountain Ecological Belt. Annual growth rates of population during the period of 1981 to 1991 were 1.1% in the Mountain and 1.4% in the Hill Ecological Belts against nearly 4% annual growth rate of population in Terai Ecological Belt. The difference of the population growth rates among these ecological belts indicates the out-migration of the population from the Mountain and Hill Ecological Belts to the Terai Ecological Belt.

4.1.3 Ethnic Group

On the basis of mother tongue statistics, major ethnic groups are classified into 13("Nepal in Map" by S.H. Shrestha, Educational Enterprise Pvt. Ltd.): Brahman, Chhetri, Thakuri, Bhojpuri, Tamang, Tharu, Newar, Awadhi, Magar, Rai, Gurung, Limbu and Sherpa. The core areas occupied by these major ethnic groups are depicted in Figure 4.1.2. The first three groups, i.e. Brahman, Chhetri and Thakuri, are Nepali-speaking groups and account for over 58% of the total population.

A dominant ethnic group living in the Study Area is the Chhetri, which is distributed in the area except for the Terai and the High Himal. Other Nepali speaking groups such as the Thakuri and the Brahman are inhabited in the Far Western Development Region. The Bhotiya and the Magar are inhabited in the high Himal areas. The Tharu, which is a dominant ethnic group in the Terai Zone, lives in the Surkhet valley. The Newar occupies such town area as Dipayal and Silgadhi, being mainly engaged in commercial activities.

4.2 Production

4.2.1 Agricultural Production

(1) Food crops

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 as shown in Table 4.2.1. Comparison of crop production by Development Region indicates that the Mid Western and Far Western Development Regions are in most cases ranked fourth or fifth in the production level. However, these Regions are ranked first and second in the production of barley.

(2) Cash crops

Major cash crops in the Study Area are oilseeds and potatoes. Production of oilseeds was 44,400 tons as the sum of two Development Regions in 1988/89 (refer to Table 4.2.1), accounting for 45% of the total production of Nepal, whilst potatoes were produced with an amount of 111,380 tons in 1988/89. Tobacco and sugarcane are comparatively minor cash crops in the Study Area, although the production of sugarcane in the Far Western Region showed a tendency of increase between 1986/87

and 1988/89. Total production of pulses in 1988/89 was 51,030 tons with a share of 33% of the total production in Nepal.

(3) Production of livestock products

Table 4.2.2 shows the level of livestock products in the Study Area (FWDR and MWDR). Compared with other Regions, the Study Area stays at a low level except for mutton, goat meat and wool in the MWDR, which are ranked first, second and first, respectively. Wool production in the MWDR totalled 422,930 ton in 1988/89, of which 270,341 tons or 63.9% was produced in the Mountain Ecological Belt.

4.2.2 Manufacturing Production

According to the Census of Manufacturing Establishments in 1986/87, there were 3,633 industrial units in the country. Of them, about 54% or 1,963 units were located in the CDR, followed by the WDR of 19% (679 units), the EDR of 18% (648 units), the MWDR of 5% (196 units) and the FWDR of 4% (147 units). Less than 10% of the manufacturing establishments in the country were thus located in the Study Area.

The Census also indicated that the value added of manufacturing establishments in the Study Area amounted to Rs. 213.51 million or 4.76% of the total value added of the country. The value added of manufacturing establishments in the MWDR amounted to Rs. 122.16 million, of which food manufacturing accounted for about 45.8% and beverage industries shared about 5.6%. The value added of the same in the FWDR amounted to Rs. 91.35 million, of which food manufacturing accounted for 38.9%.

The fact mentioned above indicates that the manufacturing sector in the Study Area has a less significant role in the national economy.

4.3 Infrastructures

Road networks in the Study Area, which were prepared on the basis of the information collected from the head, regional and district offices of the Department of Road, are shown in Figure 4.3.1, in which roads are classified into (a) existing road, (b) under-construction road and (c) planned road.

The East-West highway, which is a trunk road of the nation, runs east to west through Mahendranagar, Atariya, Chisapani and Kohalpur in Terai. The double-lane road with black

top pavement is completed except for the section between Atariya and the Babai River, the construction of which will be completed by year 1992/93 when the construction works for the bridge spanning over the Karnali River and other six small rivers are completed.

There exist two roads branching off from the East-West highway at Kohalpur. One is running to Nepalganj to the south and the other is reaching Birendranagar (Surkhet) via Chhinchu to the north in the Mid Western Development Region. The section between Kohalpur and Nepalganj is a double-lane road with black top, whilst the section between Kohalpur and Birendranagar is a single lane earth road except for the section of six km long black top. It is planned for the whole section of a length of 91 km to be paved with gravel.

Two roads branch off from Atariya; one to Dhangadhi and the other to Baitadi through Budar, Bhatkada, Dadeldhura and Khodpe in the Far Western Development Region. The entire section between Dhangadhi and Baitadi has a single lane; black top pavement between Budar and Dadeldhura and earth road between Dadeldhura and Baitadi, for which black topping is planned. A branch road from Bhatkada is in service as an earth road up to Silgadhi via Dipayal in the Region.

Road construction in the Study Area is under way for four routes in the Mid Western Development Region and for seven routes in the Far Western Development Region. A total length of roads which are under construction is 914 km. Following is a summary of the under-construction roads :

Road Section	Total length (km)	Width (lane)	Progress (completion as at the end of 1991)
Mid Western Development Region			
- Chhinchu-Jajarkot	92	Single	80% of earth work in the first 22 km
- Surkhet-Dailekh via Dungeswar	83	Single	15 km
- Surkhet(Phuliapit)-Bhadahari	30	Single	60% of earth work
- Salyan-Musikot	107	Single	8 km
Far Western Development Region			
- Baitadi-Darchula	121	Single	45 km up to Digadha
- Baitadi-Jhulaghat	22	Single	6 km
- Khodpe-Chainpur	112	Single	14 km
- Silgadhi-Saphebagar	67	Single	Just started
- Budar-Dipayal	125	Single	6 km
- Sahajpur-Dipayal	120	Single	Just started
- Daiji-Jogbuda	35	Single	Just started

The under-construction roads can be used as approach roads when the implementation of water resources development schemes is planned in the Study Area.

Besides the existing and under-construction roads, road extension is planned between Birendranagar and Dailekh and between Dungeswar and Jumla in the Mid Western Development Region and between Patan and Pancheshwar in the Far Western Development Region. However, those extension would not be considered to be used as the access road of water resources development schemes due to high uncertainties on completion timing.

While, there exists a black top road extending from Tanakpur to the China border along the Mahakali River in the Indian territory, which will be utilized as an approach road for water resources development schemes in the Mahakali River basin, even if short extension of the road and the construction of bridges are required.

There are airports in the Study Area as shown in Figure 4.3.1. Domestic airway services from the Kathmandu airport to those airports are conducted by the Royal Nepal Airlines Corporation. The service centre in the region is Nepalganj.

4.4 Quality of Life

4.4.1 Education

One of the main objectives of the education sector is to promote rapid increase in literacy through primary and adult education. According to the information from the Ministry of Education and Culture, the literacy ratio in the Study Area ranged from 13% to 20% in 1988, which was lower than the national average of 34.8% in that year due partly to lower gross enrollment ratios in primary, lower secondary and secondary school education. The gross enrollment ratio in the Study Area in 1989 was as low as about 50% in primary (against 73% national average), about 10% in lower secondary (against 24% national average) and about 5% in secondary school education (against 16% national average). In the case of girls, these ratios are lower.

For those to acquire higher education, Tribhuvan University is the only university in the country, having 12 different institutes throughout the country. Furthermore, respective institutes have a few to several campuses in different parts of the country. In the Study Area, there exist 13 campuses in ten districts with the subject of education, management, humanities and law. Among them, the Birendranagar multiple campus offers a bachelor course for management and humanities. Furthermore, the Doti and Baitadi Patan multiple campuses have bachelor courses for humanities. Further details are given in Table 4.4.1.

4.4.2 Public Health

Health service is one of the basic needs of the common people, and the health sector plays a significant role in creating healthy manpower. The government's target is to provide at least one hospital in each district based on the recognition mentioned above.

It was found through the site reconnaissance that the construction of hospitals has been completed for five districts, Rolpa district in Rapti Zone and Humla, Mugu, Kalikot and Dolpa districts in Karnali Zone, which were left behind as the districts without hospitals in the Study Area. Although the government's target to provide at least one hospital for one district has been more or less accomplished, no doctor is reported for the hospitals of Dailekh, Darchula and Bajura districts in addition to the above five districts which had new hospitals. Furthermore, the treatment by doctors, even if they are stationed, is limited due to poor facilities.

Common diseases in the Study Area are tuberculosis, cholera, diarrhoea, parasitism and so on according to the local people. Malnutrition is furthermore inferred from the living

standard of local people, which is below the subsistence level, especially in the High Himal Zone.

4.5 Cultural Assets

There are many historical and cultural heritages distributed in the Study Area according to the information collected from the Department of Archaeology.

The major cultural assets are temples, forts, palaces, historical places, Buddhist temples, shelters or houses and caves. Among them, Tripura Sundari in Jhulaghat and the Pancheshwar Mahader Temple particularly receive visits of devotees and holy men as a sanctuary of Hinduism. Since archaeological research work is still limited, it would be expected that other monuments exist which need to be protected from ruin in the Study Area.

5. WATER RESOURCES DEVELOPMENT POTENTIAL AND DEMANDS IN THE STUDY AREA

5.1 Hydroelectric Power Generation

5.1.1 Present Situation of Electric Power Supply In The National Grid

(1) Institution for Electricity Industry

Electricity industry in Nepal is managed by the Nepal Electricity Authority (NEA) administratively organized under the Ministry of Water Resources (MWR). The NEA was established on August 15, 1985 through the merger of the Nepal Electricity Corporation (NEC), the Electricity Department (ED) and the Small Hydro Development Board (SHDB) under the MWR.

The NEA is responsible for the planning, construction, operation and maintenance of all generation, transmission and distribution facilities in Nepal's interconnected power system and principal isolated systems. Private sectors are also encouraged to join the electricity industry not only for the development of mini hydro plants which are used for local industries such as water mills, but also for the construction of plants to be added to the interconnected power system.

(2) Generating Plants and Transmission Line Systems in the National Grid

As given in Table 5.1.1, 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.

To meet growing power and energy demands, Jhimruk Piuthan hydropower plant with an installed capacity of 12.5 MW is under construction and is expected to be added to the system in year 1994. After the Jhimruk Piuthan, Arun 3 is expected to be developed by year 2000, but the financial arrangement for its construction is continuing.

The trunk power transmission lines in the country, which run in the Terai plain, extend from Kathmandu toward the east and west directions by linking the major power plants

and the large demand centres as given in Figure 5.1.1. The voltage employed is 132, 66 and 33 kV.

In the Mid Western and Far Western Development Regions where the Study Area lies, a 132 kV transmission line is under construction between Kohalpur and Mahendranagar along the East-West highway in the Terai and is expected to be in service in February 1993. The construction of a 66 kV transmission line (at present 33 kV) extending from Kanchanpur to Dipayal-Silgadhi, which is the headquarters of the Far Western Development Region, is to be commenced in year 1991/92 and to be completed in year 1993/94. In the Mid Western Development Region, the extension of power line from Birendranagar to Dailekh is expected to be completed in year 1993/94.

(3) Rural Electrification in the Study Area

The NEA places high priority on the rural electrification of remote load centres as well as power development in the national power grid by reflecting the government policy paying endeavours for the rural development and narrowing the economic disparities between urban and rural areas. The present situation of rural electrification in the Study Area is summarized as given in Table 5.1.2, and the locations of towns with the service of rural electrification are shown in Figure 5.1.2.

The first goal of rural electrification raised by NEA is to supply electricity to all of the district headquarters. In the Study Area, four district headquarters, Manma (Kalikot district), Dunai (Dolpa district) and Dailekh (Dailekh district) in the Mid Western Development Region and Mangalsen (Achham district) in the Far Western Development Region are not yet served with electricity.

5.1.2 Power Balance in the National Grid

(1) Power Demand

Electric power and energy demands were projected by NEA (Electricity Load Forecast - 1986) and by Electricity de France International, EDF (Ten Year Transmission and Distribution Plan, Load Forecast Study, December 1989). Power and energy growths in future were reviewed and updated by JICA using the latest power data (Master Plan and Feasibility Study on Extension and Reinforcement of Power Transmission and Distribution System in Kathmandu Valley in Nepal, Final Report, December 1991).

According to the JICA's forecast, power and energy demands by year 2010/11 will grow as follows:

Year	1989/90	1995/96	2000/01	2005/06	2010/11
Energy Demand, GWh	746.5	1,319.0	2,133.9	3,207.4	4,722.9
Maximum Power Demand, MW	171.6	292.8	462.3	681.1	989.2

(2) Power Balance

Power supply capacity given in Table 5.1.1 and power demand in future discussed above were compared as shown in Figure 5.1.3, in which power and energy deficits are expected to occur in 1994/95. Furthermore, actual situation would be worse, because a reserve capacity of 10 to 20% of total power demand is additionally necessary.

There is another problem involved in seasonal power generation. That is to say that most of power plants in the national power supply system are hydro plants of the run-of-river type, and therefore they decrease their power generation in winters which correspond to dry seasons. This implies that energy deficits would occur earlier; probably sometime in year 1993/94, even if there is some margin between energy supply capacity and demand in that year. In fact, power rationing was experienced in the winter of 1991/92.

To meet growing power and energy demands, the first phase of Arun 3 hydropower project as mentioned earlier is expected to be commissioned with an installed capacity of 201 MW (402 MW in total capacity) by year 2000. Power shortfall of some 200 MW, which is expected before the commission of Arun 3, shall be met by other promising projects, which would be hydro projects such as Kali Gandaki A (90 MW), Kankai (60 MW) and Khimti (60 MW) and fossil fuel plants among others.

5.1.3 Power Demand in the Study Area

The extension of power transmission lines in the Study Area, i.e. a 132 kV line to be completed between Kohalpur and Mahendranagar in 1993 and 66 kV branch lines between Birendranagar and Dailekh and between Kanchanpur and Dipayal-Silgadhi through Dadeldhura

as shown in Figure 5.1.1, will spur its economic development, resulting in the increase of power demand.

Future power demand in the Study Area was estimated relying on the projections done by JICA (Master Plan and Feasibility Study on Extension and Reinforcement of Power Transmission and Distribution System in Kathmandu Valley in Nepal, Final Report, December 1991) and EDF (Ten Year Transmission and Distribution Plan, Load Forecast Study, December 1989) as summarized below:

Year	1993/94	1995/96	2000/01	2005/06	2010/11
Maximum Power Demand, MW	10.0	12.1	21.5	32.4	48.7

Power demand in the Study Area will reach a level of more or less 50 MW in year 2010, and will be higher after the extension of transmission lines to Baitadi, Darchula and Chainpur.

Installation of a hydropower plant with a capacity of 50 to 100 MW is an urgent requirement for the economic development in the region due to the fact that high power demand is expected as projected above and that the periphery of the region in terms of electric power supply hinders the stable power supply, resulting in the reluctancy of entrepreneurs to invest money in the Study Area.

5.1.4 Hydropower Potential Schemes in the Study Area

(1) Potential Schemes in the Study Area

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 as summarized in Table 5.1.3. The locations of those schemes are shown in Figure 5.1.4.

Scheme identification in the past studies was limited to the ones with a large development scale, say 50 MW or above, aiming at bulk power supply to the national grid and at energy export to India. This naturally results in the scheme identification at the lower reaches of the basins where a large scale reservoir can be created with gentle slopes and wide valleys. What is more, access to the site and length of the

transmission lines, which are relatively easy and short, would be another reason for the scheme identification at the lower reaches. The identified schemes include mutually exclusive ones as Pancheshwar-Chamliya and Karnali Bend (KR-1A)-KR-3 (Lakharpata) are given as examples.

The Karnali (Chisapani) Project and BR1, which is a diversion scheme from the Bheri River to the Babai River for power generation and irrigation, are compatible even with conflicts for water use. Thus, the study to seek the compatibility of Karnali and BR1 will be a main theme to develop the lower reaches of the Karnali River including the irrigated agriculture development in the Terai plain, and will be dealt with in subsequent Section 5.6, Studies on the Bheri-Babai Division Scheme.

Site identification of hydropower potential schemes in this Study was tried using existing 1 to 50,000 scale topographic maps and longitudinal profiles prepared from them. A total of 15 schemes was newly identified in the Study Area as given in Table 5.1.4. The location of those schemes is shown in Figure 5.1.4 together with the schemes identified in the past studies.

Lying in the upper reaches of the basin, the schemes newly identified in this Study are the run-of-river type except for BR-3B and LR-1, which are the reservoir type. The computation of annual energy output is based on the flow duration curve for the run-of-river type and the storage-draft curve for the reservoir type (refer to Appendix II, Meteorology and Hydrology). The shift of those curves from the stream gauge site to the scheme site relies on the ratios of catchment area and mean annual rainfall between two sites.

(2) Power and Energy Outputs of the Potential Schemes

Economic viability of the hydropower schemes identified in the Study Area is evaluated for the purpose of selecting priority schemes as discussed in the subsequent Chapter 7, Selection of Priority Schemes for Development. Power and energy generation was computed for the identified schemes except for those with the study level of feasibility and pre-feasibility, i.e. Karnali/Chisapani, Karnali Bend, West Seti and Pancheshwar including Rupali Regulating Dam, Poornagiri and Chamliya.

Power and energy outputs for the six reservoir type schemes among the identified schemes were calculated by changing the draft rate, which is expressed as the ratio of constant release from the reservoir through the year to the long-term average flow, in a range of 0.6 to 0.8 with an incremental step of 0.1 to seek the optimal development

scale as given in Table 5.1.5. Plant discharge for the reservoir type scheme was determined by assuming an eight-hour peaking operation for the selected draft rate.

The dead storage in the reservoir was determined by assuming the horizontal formation for the 50-year sediment influx. The minimum operating level, MOL, was set with 1 m allowance above the sediment formation level. The full supply level, FSL, was set by giving the required active storage corresponding to the draft rate above the MOL. Secondary energy of the reservoir type schemes as given in Table 5.1.5 was sought by simulating runoff data estimated at the scheme site. KR-2 and KR-7, which were originally considered as a reservoir type, are treated as a run-of-river scheme due to filling-up of sediments in the reservoir for the project life.

Power and energy outputs for the 25 run-of-river type schemes were calculated by changing operating hours for the firm discharge, which is defined as 95% guarantee flow on the flow duration curve, i.e. 8-hour, 12-hour and 16-hour peaking operation, as shown in Table 5.1.6. It is noted that the computation of power and energy outputs for the potential schemes was based on the assumption that there is no reservoir type scheme, which affects the flow regime, upstream of the contemplated hydropower scheme. Furthermore, it was assumed in the power and energy computation that the combined efficiency for turbine and generator is 85% and that head losses are 5% of gross head.

(3) Economic Evaluation of Potential Schemes

As dealt with in the preceding Sub-section, power and energy generated from 31 potential hydropower schemes, six reservoir and 25 run-of-river type schemes, were computed by changing the development scale. Construction costs for the respective development scales of the identified 31 hydropower schemes were estimated based on the work quantities obtained from their preliminary design and the unit price applied for each work item (refer to Tables 5.1.7 and 5.1.8).

Applying the assumptions and conditions set up for the evaluation of the estimated benefits and costs of each scheme, economic viability of the 31 identified schemes was assessed as summarized in Tables 5.1.7 and 5.1.8. The reservoir type schemes, which are mainly constructed in the downstream reaches of the main tributaries, show the high economic viability due to ample river flow for energy generation, even if the required construction costs are great.

There is a tendency that the run-of-river type schemes, which are mainly constructed in the upper reaches requiring hardness in access to the site, show the economic viability relatively lower than those of the reservoir type chiefly due to the high costs necessary for the construction of access roads and transmission lines. Even with such a severe condition, KR-2, KR-3, KR-7, TR-1, TR-3, MKR-3, HKR-1, BR-1, SR-3 and CR-2 gained the EIRR higher than 10%, showing the viability for the implementation.

The optimal development scale of each scheme is at this moment defined as the scale which gives the maximum net benefit among three development alternatives. For the evaluation of BR-1, Bheri/Babai Diversion Scheme, the negative benefits for the Karnali multipurpose are not counted in this evaluation (refer to Section 5.6 for further discussion).

5.1.5 Hydropower Priority Schemes

Economic viability of the 31 identified schemes was assessed in the preceding Section 5.1.4. A next topic to be dealt with is to select priority schemes, for which further studies are carried out. Following aspects were considered for the selection of priority schemes:

(a) High economic viability,
(b) Reasonable development scale considering the power and energy consumption in the region, and
(c) Less financial burden to the implementing agency.

It is natural to seek a high return for the investment, when a scheme is implemented. In this sense, a value of 10% is in principle proposed as the minimum of investment efficiency in terms of economic internal rate of return (EIRR).

Power demand in the Study Area would at most be 50 MW judging from its development status as dealt with in the preceding Section 5.1.3, Power Demand in the Study Area. When a large scale hydropower scheme with an installed capacity greater than 100 MW is developed in the Study Area, surplus power not consumed in the Study Area will be transmitted to the Kathmandu area where large power demand is expected. In this case, the installation of another transmission line would be required between the power plant and Kathmandu due to the limited capacity of the existing transmission line with a single circuit. This naturally results in the increase of project cost of the contemplated scheme. Thus, a limit of 100 MW is set up as the condition of installed capacity.

The implementation of a scheme with a large construction cost will give heavy financial burden to the implementing agency. In this sense, a limit of US$ 200 million is given as the maximum of the construction cost.

The schemes to meet the above three conditions among the potential schemes (refer to Tables 5.1.7 and 5.1.8) are listed below:

Scheme	Installed Capacity, MW	Construction Cost, million US$	EIRR, %
BR-1	82.0	184.4	13.0
SR-3	75.2	166.1	12.3
CR-2	23.5	68.3	10.2

The above three schemes are selected as the priority schemes. Furthermore, LR-1 is also added in the list of the priority schemes, since the scheme is a reservoir type and is considered as one of sources to give stable power supply in dry seasons when power generation drops to lowest. If the term of stable power supply is counted, LR-1 will retain the EIRR of greater than 10%. The feature of LR-1 is summarized as follows:

Installed Capacity, MW	:	58.0
Construction Cost, million US$	:	118.3
EIRR, %	:	9.1.

5.1.6 Rural Electrification in the Study Area

The NEA places high priority on the rural electrification of remote load centres as well as power development in the national power grid by reflecting the government policy paying endeavours for the rural development and narrowing the economic disparities between urban and rural areas. The first goal of rural electrification raised by NEA is to supply electricity to all of the district headquarters. In the Study Area, Simikot and Gamgadhi are the district headquarters, which require the identification of small hydropower schemes.

There exist four towns, which are not district headquarters, with a population density of more than 300 persons/km^2 in the Study Area. Those are Binayak, Baldanda, Jayagadh and Gajara in Achham district and would be the priority towns to be supplied with electricity after all the district headquarters in the Study Area become the beneficiaries of electricity supply.

There are two national parks, Lake Rara and Khaptad National Parks, in the Study Area. As the tourism centre, the lodges and the quarters of rangers of the national parks are desired to be supplied with electricity. However, field survey carried out in Phase III revealed that entry to the Khaptad National Park is not allowed to foreigners and is only allowed for devotees and holy men, and therefore the identification of small hydropower scheme is only sought for Lake Rara. As a summary, scheme identification was studied for Simikot, Gamgadhi, four towns in Achham district and Lake Rara in the field investigation of Phase III. Furthermore, Jumla was added as the town to study power supply due to the fact that Jumla, selected as one of four strategic areas together with Surkhet, Dipayal/Silgadhi/Rajpur and Baitadi areas, will face power shortage by year 2013, but will not link to the national power grid. Further detailed discussion are given place to Appendix IV, Hydroelectric Power Generation.

5.1.7 Impacts of Dam Schemes on the Natural Environment

In order to understand the potential environmental impacts caused by development projects, three case studies, i.e. Mahakali Irrigation Project, Babai Irrigation Project and Arun III, were conducted and the results are as follows:

(a) For water resources development activities, environmental impact study in respect of physical, biological, social, economic and cultural fields is essential,

(b) Environmental impacts should be carefully studied and predicted, considering the present situation as well as future plans in collaboration with the agencies concerned, such as the Department of National Parks and Wildlife Conservation for the impact to fauna, flora and aquatic organisms, and the Department of Housing and Town Planning under the Ministry of Housing and Physical Planning for involuntary resettlement,

(c) The countermeasures to mitigate or eliminate negative environmental impacts must be proposed on the basis of the analyses and discussions with the concerned agencies mentioned above, and

(d) Necessary arrangement in respect of institutional and administrative matters is essential in order to avoid the delay of construction activities.

5.1.8 Involuntary Resettlement under Dam Schemes

Dam schemes inevitably cause socio-economic impacts, principal of which is displacement of local people from the reservoir inundation area.

Compensation is usually paid in the form of either land or cash under national dam projects. The form of compensation in many countries has recently shifted from "cash for land" to "land for land", especially in the case that the displaced people are largely dependent on land for their food and income. On the other hand, the compensation under dam projects in Nepal is recently being made in cash.

The Ministry of Housing and Urban Development, which is at present responsible for the implementation of involuntary resettlement programmes, comments that the compensation under future resettlement programmes will be made in cash due to scarcity of available land.

5.2 Irrigation

5.2.1 Present Situation of Agricultural Development and Irrigation Demand in the Study Area

A total production of five main food grains, paddy, maize, millet, wheat and barley, in the nation reached a level of 5,394,980 ton in year 1988/89 according to Agricultural Statistics of Nepal, 1990. On the other hand, the population in year 1988 was estimated at 17,351,722 persons in the country based on the 1981 and 1991 population censuses, resulting in the food requirement of 311 kg per person per year by assuming the food self-sufficiency ratio of 100%, which at present stays at a level of 80 to 90%.

The balance between supply and demand for five main food grains 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.

Taking into consideration the situation above, the Government of Nepal has made large investment in the Mid Western and Far Western Development Regions, within which the Study Area lies, to increase agricultural production. HMG of Nepal places emphasis on large scale

irrigation development in the plains, and small scale irrigation development in the hilly area to reduce shortage of food supply in the country.

However, steep topographic conditions in the hilly area do not easily permit the introduction of irrigated farming practices. Thus at present, small scale rainfed farming is widely seen in these hilly areas, resulting in extreme shortage of food.

On the other hand, many large scale irrigation development projects have been implemented in the flat plains by the government, taking advantage of the topography found there. Nevertheless, planned agricultural production has not yet been achieved even in the flat plains due to shortage of water in the dry season and lack of proper irrigation facilities in these areas.

The Study Area encompasses a total cultivated area of 655,000 ha including land in the Terai Ecological Belt, of which 594,000 ha have been 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.

5.2.2 Irrigation Projects in Mid Western Development Region

The present situation of irrigation development in the Mid Western Development Region is discussed by Ecological belt as below:

(1) Hill Ecological Belt

The Hill Ecological Belt comprises five districts, i.e. Surkhet, Dailekh, Jajarkot, Rukum and Salyan, in the Mid Western Development Region. The area is characterized by river valleys and plateaus of the Siwaliks and Churia range of mountains. The Bheri River is the main river in this area except for Dailekh district. The cultivated lands are mainly distributed on the banks of the Bheri River.

A total of 1,096 projects with a net command area (NCA) of 33,845 ha has been identified in this area. These projects comprise 1,065 existing projects (26,923 ha), 16 on-going projects (2,931 ha) and 15 planned projects (3,991 ha). In addition to DOI schemes, the foregoing projects include FMIS and AMIS projects (refer to Table 5.2.1).

(2) Mountain Ecological Belt

The Mountain Ecological Belt comprises five districts, i.e. Jumla, Kalikot, Mugu, Dolpa and Humla, in the Mid Western Development Region. The area is mountainous, so irrigation is difficult. Moreover, the area is devoid of any roads, so irrigation projects are costly.

A total of 53 projects (total NCA = 3,074 ha) has been identified in this area. These projects comprise 12 existing projects (645 ha), four on-going projects (235 ha), 35 planned projects (1,909 ha) and two cancelled projects (285 ha). In addition to DOI schemes, the foregoing projects include FMIS and AMIS projects (refer to Table 5.2.1).

5.2.3 Irrigation Projects in Far Western Development Region

(1) Hill Ecological Belt

The Hill Ecological Belt comprises three districts, i.e. Doti, Achham and Dadeldhura, in the Far Western Development Region. This area lies in the Siwaliks and Churia range of mountains. In Doti and Achham districts, the Seti River and its tributaries are the main water source, whereas the Mahakali River flows along the western boundary of Dadeldhura and Baitadi districts. A pre-feasibility level study of a re-regulating dam at Rupalgad in Dadeldhura for the Pancheshwar high dam is being conducted. The possibility of irrigation by using the proposed reservoir at Pancheshwar to the downstream area is also proposed for a detailed study.

A total of 627 projects (total NCA = 9,554 ha) has been identified in this area. These projects comprise 596 existing projects (7,198 ha), 16 on-going projects (1,265 ha), 12 planned projects (829 ha), and three cancelled projects (262 ha). In addition to DOI schemes, the foregoing projects include SHIP, FMIS and AMIS projects (refer to Table 5.2.1).

(2) Mountain Ecological Belt

The Mountain Ecological Belt comprises four districts, i.e. Baitadi, Darchula, Bajura and Bajhang, in the Far Western Development Region. The area is in the southern slopes of the Himalayan range. Only Baitadi district is linked by black top road with Terai. There are markets for agricultural products from Baitadi and Darchula districts in nearby Indian towns. Bajura and Bajhang are more remote without any road links.

A total of 61 projects (total NCA = 4,504 ha) has been identified in this area. These projects comprise 15 existing projects (1,034 ha), 27 on-going projects (1,965 ha) and 18 planned projects (1,445 ha). In addition to DOI schemes, the foregoing projects include SHIP, FMIS and AMIS projects (refer to Table 5.2.1).

5.2.4 Irrigation Potential Schemes in the Study Area

During Phases I and II of the Study the irrigation group of the Study Team visited Regional and District Irrigation Offices and flew over potential irrigation areas, to identify irrigation potential schemes in the Study Area and to select priority schemes from among these potential schemes. The group also visited Mahakali Irrigation Project Stage II and Babai Irrigation Project offices. Duration of Phase I and Phase II site visits was December 1991 and March to April 1992.

Following seven large scale potential schemes were identified. Those are four run-of-river projects including Sikta, Babai, Khutiya II and Mahakali II, and three multipurpose projects including West Rapti, Karnali and Bheri-Babai (refer to Table 5.2.2).

Small potential schemes identified by MPID2 are 82 potential projects including 11 projects in the Terai Ecological Belt, 38 projects in the Hill Ecological Belt and 33 projects in the Mountain Ecological Belt (refer to Table 5.2.3).

Valley cultivation area where high irrigation potential is anticipated is 18 potential projects including six projects in the Bheri River system, four projects in the Karnali River system, two projects in the Seti River system and six projects in the Mahakali River system (refer to Figure 5.2.1).

(1) Large Scale Irrigation Potential Schemes

A number of large and medium scale irrigation schemes have been studied for command area development in the Terai Ecological Belt. The Karnali (Chisapani) Multipurpose Project Mahakali Irrigation Project Stage I and II, Babai Irrigation Project, Bheri-Babai Diversion Irrigation Project and Sikta Irrigation Project along with medium sized schemes cover irrigable land in the Terai Ecological Belt.

The Bheri-Babai Diversion Project has been under consideration since the early 1980's. The diverted flow from the Bheri River is to permit the development in Bardiya and Banke districts for year round irrigation. The economic impact of this project is

extremely high, since the total food production target for the year 2000 for both districts is to be achieved under the project. A detailed description of the Bheri-Babai Diversion Project is given in the subsequent Section 5.6, Studies on the Bheri-Babai Diversion Scheme, from the viewpoint of hydropower generation, although irrigated agriculture development is included as main beneficiaries of diversion.

(2) Small Scale Irrigation Potential Schemes

MPID2 identified small potential irrigation projects (2,000 ha and less). So far as the Study Area is concerned, there are 82 potential projects of 11,732 ha in total area, including 11 projects of 5,384 ha in the Terai Ecological Belt, 38 projects of 4,178 ha in the Hill Ecological Belt and 33 projects of 2,170 ha in the Mountain Ecological Belt. Of them, 15 projects were excluded because of lying outside the Study Area. Excluding these 15 projects, the remaining 67 projects are in the Study Area, of which 44 projects (66%) are completed or on-going and 23 projects are yet to start (refer to Table 5.2.4).

Of these 67 projects, 15 are located in the Mid Western hill area, 10 in the Mid Western mountain area, 19 in the Far Western hill area and 23 in the Far Western mountain area. There are 23 planned projects (13 in the Mid Western Development Region and 10 in the Far Western Development Region), and it is expected that survey and/or feasibility study will be carried out in a timely manner for these in order to augment the on-going projects and further promote irrigation development in the hill and mountain areas.

(3) Valley Cultivation Potential Schemes

During Phase I of the Study, the Study Team visited or conducted aerial inspection for the sites with high irrigation potential. These areas were revisited or flown over during Phase II site visits. For most of the area, DOI is considering irrigation development. At present, these areas get some irrigation under FMIS and AMIS schemes.

Study of valley cultivation potential schemes has been completed for eight districts (Salyan, Rukum, Surkhet, Jajarkot, Dailekh, Achham, Doti and Dadeldhura) under the Water Use Inventory Study.

5.2.5 Irrigation Priority Schemes

Irrigation priority schemes have been selected from among the projects identified under the Phase I and Phase II study. In selecting irrigation priority schemes, candidates for the priority schemes were first determined and then narrowed down according to the criteria and conditions formulated for the selection of irrigation priority schemes.

(1) Candidates for Irrigation Priority Schemes

< Large Scale Irrigation >

Seven large scale irrigation schemes were identified. Of these, the Khutia II Irrigation Project and the Mahakali Irrigation Project (stage II) were excluded from consideration due to lying outside the scope of this Study. Accordingly, five schemes were evaluated.

< Small Scale Irrigation >

Out of the 78 planned projects within the small scale scheme category of 1,835 projects, 14 projects were selected as the candidates of irrigation priority schemes according to the formulated criteria and conditions.

(2) Criteria and Conditions for Selection of Priority Schemes

< Large Scale Irrigation Schemes >

(i) Located in the Terai Ecological Belt, these schemes should comprise long term water resources development projects aiming at self sufficiency of principal food crops.

(ii) IRR for economic evaluation is above 10%.

(iii) On-going projects under rehabilitation or other foreign agency fund are excluded.

< Small Scale Irrigation Schemes >

(i) Accessibility from project site to nearest town is good, and nearby markets exist for farm products.

(ii) Study has been completed by DOI on scheme area, beneficiaries, target crops, design water source, etc. and project features and benefits are consequently clearly defined.

(iii) Top priority is given to gravity irrigation, with lift irrigation considered the next best option.

(iv) Upper ceiling for project site altitude is 2,500 to 2,600 m.

(v) Upper ceiling for headrace length to site is roughly five to ten km in light of operation and maintenance issues.

(3) Priority Schemes

Priority schemes selected from among the large scale and small scale irrigation potential projects are Bheri-Babai Diversion, Surkhet Valley, Korelli Khola Basin Lift Irrigation and Garjyang Kot schemes (refer to Figure 5.2.1).

5.3 Domestic Water Supply

5.3.1 Background Information

(1) Past Performance

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 1980, urban population of 83% could receive the public water supply, whilst only 7% for the rural population.

The proclamation of the International Drinking Water and Sanitation Decade (1981 to 1990) by the UN contributed to the improvement of the public water supply sector in Nepal, giving the water supply coverage ratio of 66% for the urban population and 34% for the rural population at the end of 1990. Compared with public water supply, sanitation gained little improvement with a coverage ratio of about 6% at the end of the said Decade.

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 following the proclamation of the International Drinking Water and Sanitation Decade, but the accomplishment rate of water supply schemes is far behind from that of national average.

(2) Institution

During the Panchayat system, water supply schemes were managed by two departments and one board; Department of Water Supply and Sewerage (DWSS), Water Supply and Sewerage Board (WSSB) and Ministry of Panchayat and Local Development (MPLD).

The DWSS and the WSSB administratively organized under the Ministry of Water Resources were responsible for the development of rural and urban water supply schemes, respectively. The MPLD (Ministry of Local Development at present) was given responsibility for the development of rural water supply systems serving less than 1,500 people.

After a new democratically elected Government was formed, the development of water supply schemes is managed by the DWSS and the Nepal Water Supply Corporation (NWSC) administratively organized under the Ministry of Housing and Physical Planning. The NWSC is in charge of water supply schemes of twelve municipal areas (Kathmandu, Pokhara and ten municipalities in Terai). The DWSS is responsible not only for all the rural water supply programmes including the schemes taken over from the MPLD, but also for the water supply projects of municipalities except for those managed by NWSC. Thus, all the water supply schemes in the Study Area are under the control of the DWSS.

(3) Water Supply Policy and Target

Rural water supply schemes are in principle implemented based on the request of local people as a policy guideline of the government; that is, a community which needs a water supply scheme is at first required to form a water users committee, through which the request to implement the water supply scheme is submitted to their district office of the DWSS.

Once the water supply scheme is decided to be implemented, the DWSS will supply materials not available around the project area and will manage construction works if

the beneficiaries to be served by the scheme exceed 1,000 people. However, the beneficiaries are to provide at least the labour for the earthworks.

If the beneficiaries are less than 1,000, the DWSS will only supply materials not available around the project area, and the water users committee will manage all the construction works with technical assistance of the district officer of the DWSS. In other words, rural water supply schemes in Nepal are, in principle, implemented with the contribution of local people and with the assistance of the Government.

Based on the basic policy of the Government for the rural water supply schemes mentioned above, a national target to provide safe drinking water throughout the nation by year 2000 was launched.

5.3.2 Water Supply Condition in the Study Area

(1) Existing and On-going/Planned Water Supply Schemes

In the first field work carried out in November and December 1991, the information on the water supply schemes in the Study Area was collected from the Department of Water Supply and Sewerage (DWSS). Taking into consideration the fact that the water supply schemes in the Study Area are basically implemented on the district level, the information on the present status of water supply schemes was collected by distributing questionnaires on them to each district office in the second field investigation carried out in March and April 1992.

According to the result obtained through the questionnaires, water supply schemes in service are at present 203 in the Mid Western Development Region where the Study Area lies; 46 in the Karnali Zone, 50 in the Rapti Zone and 107 in the Bheri Zone, whilst there are 330 existing schemes in the Far Western Development Region where the Study Area lies; 208 in the Mahakali Zone and 122 in the Seti Zone as summarized in Table 5.3.1. Total schemes including on-going ones count 472 in the Mid Western Development Region (225 in the Karnali, 75 in the Rapti and 172 in the Bheri) and 928 in the Far Western Development Region (419 in the Mahakali and 509 in the Seti).

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 the ratio of 28.5%; 17.2% for the Karnali Zone, 39.5% for the Rapti Zone and 30.8% for the Bheri Zone. On the other hand, the Far Western Development Region accomplished a slightly lower ratio of 22.7%, composed of 26.5% for the

Mahakali Zone and 20.1% for the Seti Zone. Although water supply service in the Study Area less gained in comparison with the national average of 34% for the rural population as at end of 1990, the service ratio of water supply will be improved at 64.3% in the Mid Western Development Region and 68.1% in the Far Western Development Region when the on-going and planned schemes are completed.

Water sources of hilly and mountainous areas, where the Study Area lies, are normally stone spouts and natural springs, and sometimes surface water when the former water sources are not available in the vicinity of the scheme. Due to the quality of water, treatment is not applied for the former source, but rough filtration is done for the latter source. Water conveyance from the source to the service area relies upon gravity with little exceptions, taking into consideration available electric power and operation and maintenance of pumps.

(2) Future Demand of Domestic Water Supply

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 by multiplying the unit water consumption rate per head by the population predicted in the respective target years.

The target years to estimate domestic water demand were selected in year 2000 and 2013. The former is launched as the target year to provide safe drinking water throughout the nation, whilst the latter is proposed as the target year in this master plan study.

The population increase and the resulted future demand of domestic water supply projected by Village Development Committee (VDC) are summarized by district as given in Table 5.3.2. In the Mid Western Development Region, the population will grow from the current level of 943,646 persons (year 1991) to 1,109,183 persons in year 2000 and 1,441,810 persons in year 2013, resulting in water demand 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. The unit water consumption rate was assumed at 45 litres per head per day on the computation of above water demand.

The Far Western Development Region has the almost same population growth as the Mid Western Development Region: 1,144,928 persons in year 2000 and 1,393,597 persons in year 2013, resulting in domestic water requirements of 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.

(3) Balance between Future Domestic Water Demand and Supply Capacity

The balance between the domestic water demand projected in year 2000 and 2013 and the present supply capacity was computed by VDC to estimate the amount to be developed. Water deficits, which are the amount to be developed so as to meet the demand, were summarized by district as given in Table 5.3.3.

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. 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.

5.3.3 Primary Areas Requiring Water Supply Schemes

Water supply condition will be improved from the current level of 28.5% to a level of 64.3% in the Mid Western Development Region and from 22.7% to 68.1% in the Far Western Development Region in terms of service ratio by implementing on-going/planned schemes as seen in Table 5.3.1. This shows that much progress can be expected within a few to several years for the water supply in the Study Area, even if its achievement rate is behind from the national average.

There are 312 VDCs in the Mid Western Development Region, of which 78 VDCs have not received the services of water supply. On the other hand, 51 VDCs out of 332 are left as the ones without receiving the service of water supply in the Far Western Development Region. It can be considered urgent for the VDCs without receiving the service of water supply to make a plan of water supply schemes.

The number of beneficiaries of one water supply scheme is estimated to be 1,286 persons in the Mid Western Development Region from the design population of 607,020 for the scheme number of 472 consisting of existing and on-going/planned schemes (refer to Table 5.3.1). Relying on this beneficiary number of one scheme, the Mid Western Development Region is required to develop 417 schemes by year 2000 and 608 schemes by year 2013.

On the other hand, the Far Western Development Region has a capacity to supply for 683,089 persons with the schemes of 928, resulting in the beneficiaries of 736 persons for one

scheme. Applying this figure, the number of schemes to be developed by year 2000 and 2013 becomes 735 and 997, respectively. Compared with the number of on-going/planned schemes, i.e. 472 in the Mid Western Development Region and 997 in the Far Western Development Region, the number of schemes to be developed by respective target years falls in the reality for implementation in both the Development Regions.

5.4 Flood Mitigation

5.4.1 Objectives of Flood Mitigation Study

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.

5.4.2 Present Status

(1) Institutional status

There are two Regional Irrigation Directorates controlling DIOs in Mid Western Development Region and Far Western Development Region. The former is located at Birendranagar in Surkhet District and the latter at Dhangadhi in Kailali District. Damage caused by floods or landslides is surveyed by District Administrative Office and reported to Natural Disaster Relief Division of Ministry of Home. Water Induced Disaster Prevention Training Centre (DPTC) is established in order to strengthen the capability of HMG/N to cope with water induced disasters through technical development, provision of training and establishment of data base.

(2) Financial status

The budget for river training works requested by district of the Far Western and Mid Western Development Regions in 1990/91 was Rs. 29.4 million, of which the composition was 31 % for the nine districts located in the hill area and the remaining 69 % for three districts in the Terai area. The budget requested by each district in the hill area ranges from Rs. 0.2 to 0.8 million, which is a less amount compared with that in the Terai area.

(3) Flood damage records

The damage records composed of such issues as the number of incidents and loss of lands of each district in Far Western and Mid Western Development Regions for the three-year period from 1989 to 1991 are shown in Tables 5.4.1 to 5.4.3 respectively.

5.4.3 River Problems in the Hill Area

As the results of the inquiry surveys, 48 locations are identified as the areas prone to flooding or riverbank erosion as plotted in Figures 5.4.1 to 5.4.13. Table 5.4.4 summarizes the information collected regarding the river training works constructed or required to be constructed. Primary river problems in the hill area are categorized as below :

Category of river problems	Number of locations
- Riverbank erosion	39 (58%)
- Inundation of cultivated lands	18 (27%)
- Contraction of river channels by deposition of land slide material	10 (15%)
* Total	67 (100%)

Note : In the above Table, 19 locations have multiple river problems, e.g. riverbank erosion with inundation.

Riverbank erosion is the most common river problem and the total length of the riverbank prone to erosion is reported to be about 56 km. Inundation problems in the hill area form a smaller proportion than those in the Terai area, since most of cultivated areas are positioned at higher levels than the river. Flood waters intrude into irrigation canals, causing inundation of lands. Damages caused by landslide are typical river problems in the hill area. Landslides sometimes occur along river channels due to intensive rainfall or scouring of toe portion of slopes by floods. Landslide material deposits to block river channels and decreases its discharge capacities. Decrease in discharge capacities often causes inundation of lands. Contraction of river channels leads to deflection of river flows, followed by erosion of the other side of riverbank.

5.4.4 River Problems in the Terai Area

(1) Dodhara and Chandani areas along the Mahakali River

There is a flood-prone area in Kanchanpur District named Dodhara and Chandani areas some seven km downstream of Sarda Barrage. Dodhara and Chandani areas are encircled by the Mahakali River in the east and by the Jogbudha River in the west as shown in Figure 5.4.14.

A total land area is estimated to be some 5,000 ha, of which some 70 %, or 3,300 ha, is farm lands at present. The agricultural land is fertile, and half of crop yield in Kanchanpur District is reported to be produced from this area. The total population in year 1992 was estimated to be some 55,000 persons.

Erosion of the right bank is a serious problem. The Mahakali River has shifted its right bank by some 1,200 m on an average towards Dodhara and Chandani areas during the 21-year period from 1965 to 1986 as shown in Figure 5.4.14, resulting in loss of 2,700 ha of land. The reduction of the area is tabulated below and plotted in Figure 5.4.15:

Year	Area (ha)	Loss of area (ha)	Average annual erosion rate (ha/year)
1965	7,670	-	-
1973	5,880	1,790	220
1986	4,950	930	70

In addition, some 25 % of the agricultural land area suffers from inundation in the monsoon period regularly. The locations frequently prone to inundation are shown in Figure 5.4.14. River training works along the right bank have been scatteringly constructed since 1987 as part of the Mahakali Irrigation Project by means of crated boulders, bank pitching and spurs.

(2) Rajapur area along the Karnali River

The Karnali River, as shown in Figure 5.4.16, bifurcates its river course at Chisapani, the Kauriyala River in the west and the Geruwa River in the east, making an alluvial fan of some 15,000 ha almost used as cultivated land. The total population and the

number of households in the area called Rajapur were estimated at 67,027 and 7,637, respectively.

The Karnali River has shifted its main stem eastward from the Kauriyala River to the Geruwa River after the 1983 flood due to a huge volume of sediment deposition in the river course downstream of Chisapani. River banks along the Kauriyala and Geruwa rivers are prone to erosion. This area is threatened by inundation every year. The flood damages caused by the 1983 flood counted for the inundation of 7,200 ha, which corresponds to about 35 % of the total cultivated land area as shown in Figure 5.4.17.

(3) River Problems of Other Rivers

There are a number of rivers lying between the Mahakali and Karnali rivers. Rivers originating from the southern slopes of the Siwaliks are characterized for high flash flow in the monsoon season, whilst a considerable number of dry river channels are observed in the dry season. Among them, the Mohana, Donda, Kanara and Chaumala rivers are primary rivers causing riverbank erosion or inundation, of which locations are plotted in Figures 5.4.18 and 5.4.19.

5.4.5 Preliminary River Training Work Plan in the Hill Area

(1) Basic Concept

There have been only limited surveys of river training works in the hill area mainly due to the following two reasons, i.e. (a) lack of budget for surveying and (b) difficulty in access to the site for engineers of District Irrigation Offices. Such insufficient information has made it difficult to prepare a proper flood mitigation plan not only for the River Training Office but also for Regional Irrigation Directorate and District Irrigation Offices. In this Study, a preliminary river training work plan is, thus, prepared to aim at giving priority to river training work schemes out of the identified areas prone to flood damage. Priority is given to such areas that flood damages were judged serious, and that the past flood damage, the length of riverbank to be protected and types of river training works have been already surveyed by District Irrigation Offices.

Although minor river training works in the hill area are actually constructed by inhabitants with voluntary tasks, the areas given priority are judged to be too large to be done by voluntary inhabitants. Therefore the construction cost of river training works for each area is estimated on a local contract basis. The unit price of each work item is

referred to that applied, at present, for the existing river training works under the Mid Western Regional Irrigation Directorate.

(2) Preliminary river training work plan

Out of 48 areas prone to flood damage in the hill areas, 21 river training work schemes are given priority as listed in Table 5.4.4, of which locations are plotted in Figure 5.4.20. The length of riverbank to be protected varies from 180 m to 3,000 m as shown in Table 5.4.4 and the total length is estimated to be about 19,300 m.

River training works are planned to be constructed by revetment or spurs made of boulders crated in gabion boxes as practiced in the hill area. The cost of G.I.wire and its transportation cost from each Regional Irrigation Directorate to each river training work site is included. The result of cost estimation of each scheme is shown in Table 5.4.4 and summarized below :

Summary of cost estimate of preliminary river training work in hill area

Items	Unit	Amount
- Total length of riverbank to be protected	m	19,300
- Total required weight of G.I.wire	ton	3,600
- Total cost of the preliminary river training work plan	Million Rs.	510
: Construction cost excluding G.I.wire	Million Rs.	(314)
: G.I.wire cost	Million Rs.	(130)
: Transportation cost of G.I.wire	Million Rs.	(66)

The total required weight of G.I.wire is estimated to be some 3,600 ton. This amount corresponds to that having been consumed in Mid Western and Far Western Development Regions for the three-year period since 1989, more than half of which, however, actually have been consumed for river training works in the Terai area. Since the total cost of Rs. 510 million includes the construction cost as well as the cost of G.I.wire, it is a large amount compared with the actual annual expenditure of about Rs. 11.1 million in 1989/90, which was expended for the survey and transportation of G.I. wire only.

There is still need of collecting information by the District Irrigation Offices to mature the preliminary river training work plan in the hill area. It is recommended in the succeeding implementation that priority be given to the preparation of topographic maps and design work for the selected 21 river training work schemes as given in Table 5.4.4.

5.4.6 Flood Mitigation Priority Scheme

(1) Selection of flood mitigation priority scheme

The river training work scheme of the Dodhara and Chandani areas is selected as a flood mitigation priority scheme in the Study Area 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, the 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 high priority is, therefore, recommended to be given to this scheme.

(2) A proposal by Mahakali Irrigation Project

The proposed river training works aim not to control inundation by embankment but to mitigate a permanent loss of the land due to bank erosion, because the loss of land is considered more serious for local residents than damages caused by inundation. Figure 5.4.21 shows the proposed river training works. The total project cost was estimated to be Rs. 21.1 million including engineering service fee and physical contingencies but excluding the cost of G.I. wire for gabions.

(3) Review of construction cost

The total project cost, estimated at Rs. 21.1 million by the Mahakali Irrigation Project Office, is updated in this Study by (a) revising the unit rate of each work item and (b) including the cost of G.I.wire. The updated total project cost is estimated to be Rs. 58.58 million by accumulating the direct and indirect costs as given in Table 5.4.5.

(4) Assessment of flood mitigation benefit

The average economic prices of the agricultural products per hectare is assumed as the annual unit flood mitigation benefit. Economic prices of the agricultural products of international tradable commodities were estimated by referring to the World Bank projections of world market prices. The economic prices of crops per kg were estimated at Rs. 9.7 for paddy, Rs. 10.4 for maize and Rs. 12.7 for legumes. The average annual unit flood mitigation benefit is assessed by multiplying the economic