HIS MAJESTY'S GOVERNMENT OF NEPAL

MINISTRY OF WATER RESOURCES

MASTER PLAN STUDY ON THE KOSI RIVER WATER RESOURCES DEVELOPMENT

FINAL REPORT

Volume 1

MAIN REPORT

MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

HIS MAJESTY'S GOVERNMENT OF NEPAL

MINISTRY OF WATER RESOURCES

MASTER PLAN STUDY ON THE KOSI RIVER WATER RESOURCES DEVELOPMENT

FINAL REPORT

Volume 1

MAIN REPORT

MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of His Majesty's Government of Nepal, the Government of Japan decided to conduct a master plan study on the Kosi River Water Resources Development and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Nepal a study team, headed by Mr. Minoru Sayama and comprising experts of the Chuo Kaihatsu Corporation, the Tokyo Electric Power Services Co., Ltd. and the Kokusai Kogyo Co., Ltd. for the total period of eleven months between June, 1983 and January, 1985.

The team had discussions on the study with the officials concerned of the Government of Nepal and conducted a field survey in the Kosi River Basin. After the team returnd to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the water resources development of the Kosi River and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of His Majesty's Government of Nepal for their close cooperation extended to the team.

March, 1985

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency

L I S T O F R E P O R T S

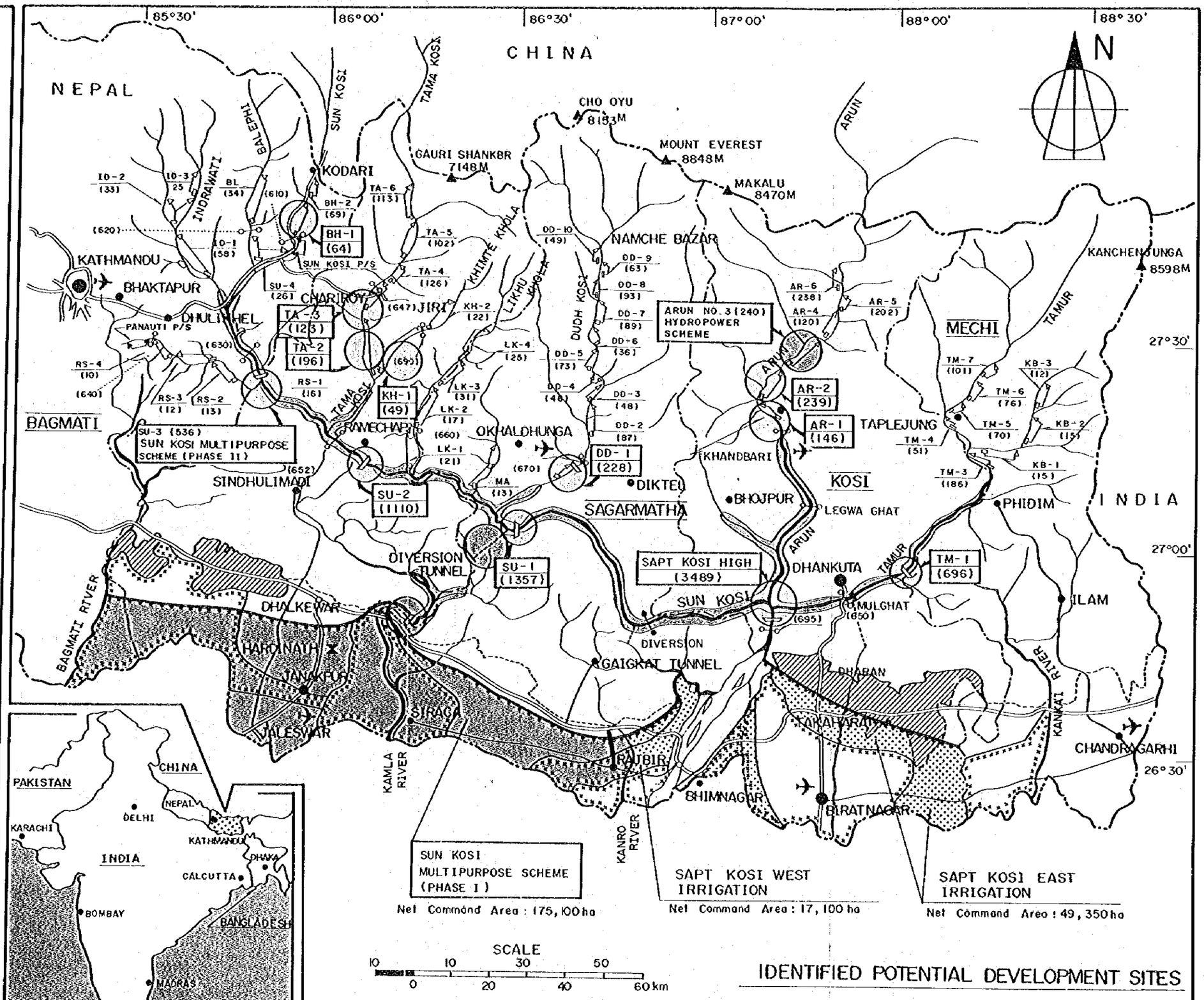
Volume	**1**	Main Report
Volume	**2**	Appendix I Socioeconomy
		Appendix II Meteorology and Hydrology
		Appendix III Geology
Volume	**3**	Appendix IV Multipurpose Dam and Hydropower
Volume	**4**	Appendix V Agriculture Development
		Appendix VI Watershed Management and Others
Volume	**5**	Data Book

LEGEND

- :INTERNATIONAL BOUNDARIES
- :DISTRICT BOUNDARIES
- :RIVERS
- :HIGHWAYS, ROADS
- (62) :GAUGING STATIONS (STATION NO.)
- :HIMALAYAN PEAKS
- :METEOROLOGICAL STATIONS
- :CITIES, TOWNS
- :AIRPORT
- :PROPOSED DAMS
- :HYDROPOWER SITES
- :EXISTING HYDRO-POWER STAIONS
- :FORESTS
- :EXISTING AND ON-GOING IRRIGATION
- :PROPOSED IRRIGATION AREA
- :FARM BOUNDARIES
- :MAIN CANALS
- :PRIORITY SCHEMES FOR HYDROPOWER
- :TOP PRIORITY SCHEME FOR HYDROPOWER
- :TOP PRIORITY SCHEME FOR IRRIGATION (SUNKOSI MULTIPURPOSE SCHEME)

SU - 1 (1357)	SUN KOSI NO.1 INSTALLED CAP. (MW)

DD : DUDH KOSI
LK : LIKHU KHOLA
MA : MAULUNG KHOLA
TA : TAMA KOSI
KH : KHIMTE KHOLA
BH : BHOTE KOSI
BL: BALEPHI, RS: ROSI KHOLA
ID: INDRAWATI, TM: TAMUR
KB: KABELI NADI, AR: ARUN



IDENTIFIED POTENTIAL DEVELOPMENT SITES

THE KOSI BASIN WATER RESOURCES DEVELOPMENT MASTER PLAN STUDY

GLOSSARY

Hill Area	a part of the Hill Zone in the Study area
Hill Zone	includes all area in Nepal which lies between altitudes of 300m and 3,000m including the Mahabharat ranges and the Siwalik Hills
Kosi Basin	catchment area of the Sapt Kosi and all its tributaries in the Study area
Kosi High Dam	a planned high dam 3km upstream from Barahkshetra on the Sapt Kosi proposed by the Government of India in 1981
Kosi River	Sapt Kosi River and all its tributaries
Mountain Area	a part of the Mountain Zone in the Study area
Mountain Zone	the entire area in Nepal over 3,000m including the Himalayan peaks
Part A	basic study stage of the Master Plan, June to August 1983
Part B	field investigation and project analysis stage, November 1983 to July 1984
Part C	Kosi Master Plan formulation stage, July 1984 to March 1985
Study	Master Plan Study on Kosi River Water Resources Development
Study area	the Kosi Basin and the Terai Area
Sapt Kosi High Dam Scheme	alternative plan to the original Kosi High Dam Project, located on the same axis
Tar	(Nepali) terraces, flat area
tar irrigation	irrigation planning for the Tars along rivers
Team	JICA Study team dispatched to conduct the Study
Terai Area	part of the Terai Zone situated between the Bagmati and Kankai Rivers
Terai Zone	a strip of level alluvial terrain in Nepal situated between the Indian frontier and the foothills

ABBREVIATIONS

(1) Domestic Organizations

ADBN	Agricultural Development Bank of Nepal
AIC	Agricultural Inputs Corporation
APROSC	Agricultural Projects Services Center
CBS	Central Bureau of Statistics
CDO	Chief District Officer
CEDA	Center for Economic Development and Administration
DIHM	Department of Irrigation, Hydrology and Meteorology
DOA	Department of Agriculture
DSCWM	Department of Soil Conservation and Watershed Management
DWSS	Department of Water Supply and Sewerage
ED	Department of Electricity
HMG	His Majesty's Government of Nepal
MPLD	Ministry of Panchayat and Local Development
MWR	Ministry of Water Resources
NEC	Nepal Electricity Corporation
NPC	National Planning Commission
SHDB	Small Hydel Development Board
WEC	Water and Energy Commission
WSSB	Water Supply and Sewerage Board

(2) International Organizations

ADB	Asian Development Bank
CIDA	Canadian International Development Agency
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization
IBRD	International Bank for Reconstruction and Development
JICA	Japan International Cooperation Agency
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

(3) Others

C.A.	catchment area
CFDTP	Community Forestry Development and Training Project
CNPS	Central Nepal Power System
EL.	elevation above sea level
ETo	reference crop evapotranspiration
ETcrop	crop evapotranspiration
ENPS	Eastern Nepal Power System
GS	gauging station
G.T.	gravity type
He	effective head
Hg	gross head
HWL	high water level
IHDP	Integrated Hill Development Project
IRD	Integrated Rural Development
kc	crop coefficient
KHARDEP	Kosi-Hill Area Rural Development Project
LWL	low water level
L.T.	lifting type
MBF	Main Boundary Fault
NAFP	Nepal-Australia Forest Project
PRR	pondage run-of-river type power development scheme
RCUP	Resources Conservation and Utilization Project
RH	relative humidity
SRR	simple run-of-river type power development scheme
S/W	Scope of Works
Sg	discharge
T.T.	tubewell type
Ve	effective volume of reservoir
Vg	gross volume of reservoir
UK	United Kingdom
US	United States
WNPS	Western Nepal Power System

(4) Measurement

Length

mm	millimeter
cm	centimeter
m	meter
km	kilometer
ft	foot

Area

cm^2	square centimeter
m^2	square meter
ha	hectare
km^2	square kilometer

Volume

cm^3	cubic centimeter
ℓ	liter
kℓ	kiloliter
m^3	cubic meter

Weight

g	gram
kg	kilogram
t/ton	metric ton

Time

s	second
min	minute
h	hour
d	day
yr	year

Currency

US$	US dollar
¢	US cent
¥	Japanese Yen
NRs.	Nepalese Rupees

Electrical Measures

V	Volt
A	Ampere
Hz	Hertz (cycle)
W	Watt
kW	Kilowatt
MW	Megawatt
GW	Gigawatt

Other Measures

%	percent
PS	horsepower
'	minute
"	second
^oC	degree in centigrade
10^3	thousand
10^6	million
10^9	billion

Derived Measures

m^3/s	cubic meter per second
cusec	cubic feet per second
kWh	Kilowatt hour
MWh	Megawatt hour
GWh	Gigawatt hour
kWh/yr	Kilowatt hour per year
KVA	Kilovolt ampere
$m^3/km^2/yr$	cubic meter per square kilometer per year

MAIN REPORT

CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Objective of the Study

1. The objective of the Kosi Master Plan Study is to prepare a comprehensive water resources development plan for the Kosi River taking into consideration the potential for hydroelectric generation, irrigation, flood control, navigation and others including inter-basin development schemes for the purpose of economic growth and social improvement. To achieve this goal, the Study was carried out to identify the resources of the Kosi River, ascertain the needs and the possibilities of development and form balanced plans for the orderly development of the river. The target year was set for 2005/2006.

Strategy of the Study

2. The Master Plan Study was carried out based on the concept that fulfillment of the national needs of Nepal should be given first priority, although it is expected that water resources development of the Kosi River will yield considerable potential to neighbouring downstream countries in terms of flood mitigation, sedimentation control and incremental water utilization.

Background of the Study

3. Nepal is faced with rapid population growth, a relatively narrow resource base, extreme inaccessibility of many parts of the country, difficult natural environment and a landlocked position. To overcome these problems, HMG gives highest priority to water resources development which can lead, stimulate and enhance national and regionally balanced development.

4. Having great development potential including hydropower and irrigation, the Study area is considered to be the most important region for the social and economic development of Nepal. Accordingly, the area has been subjected to various studies in such fields as irrigation, agriculture, land use and, hydropower since 1960.

Development Needs

5. Hydropower Development Needs: Abundant and economical energy is indispensable for the country's development. The HMG official electricity demand forecast up to 2001/02 estimates that the required peak load will be 723.3MW in 2001/02 compared to 67.8MW in 1982/83. The Team extended the official forecast up to the year 2005/06, which is the Master Plan target year, and estimated that peak load will reach 1,040MW with a load factor of 54.3% as shown in the table below.

	Peak Load Demand (MW)	Energy Demand (GWh)	Load Factor (%)
1985/86	106.1	453.6	48.8
1995/96	397.1	1,788.0	51.4
2005/06	1,039.8	4,945.0	54.3

This table suggests that electric power development must reach more than 1,250MW considering the supply allowance and firm capacity in the forth-coming 20 years. Hydropower is the most economical energy source in Nepal. HMG is implementing the Kulekhani No. 2 (32MW), hydropower development plan, and plans to implement the Marsyangdi 66MW and the Sapt Gandaki 225MW which are scheduled to be developed by 1993. Taking into account the total capacity of these existing development projects, a minimum of about 900MW remains to be developed from new hydropower sources by the year 2005/06.

6. Irrigation Development Needs: Although the economy of Nepal is agriculturally based, the nation is now being transformed into a food import country. The Team studied the food balance of Nepal up to 2005/06, which revealed the results as tabulated below.

	Estimated Gross Requirement (10^3ton)	Estimated Gross Production (10^3ton)	Food Balance (10^3ton)
1985	4,484	3,950	-536
1995	6,311	4,325	-1,988
2005	9,406	4,641	-4,765

It is obvious from the above figures that increased agricultural production is urgently required. However, as agricultural area in Nepal is almost completely developed the most viable method for increasing agricultural production is irrigation development. Irrigation projects, if properly managed, will be able to supply sufficient water throughout the year, increasing farm productivity in terms of both crop intensity and crop yield.

7. Flood Control, Navigation and Other Needs: In order to establish integrated use of water resources, the needs for flood control, navigation, inland fishery and other utilities were examined. Definite schemes were not identified in terms of these utilities due mainly to the absence or inadequacy of necessary data. Potential studies, however, were conducted for flood control, navigation, inland fishery and tar irrigation to provide possible further areas for investigation.

Study Methodology

8. The Study was conducted in three stages as mentioned below.

(1) Basic Study

In this stage, potential project sites for the Study were identified on the basis of existing reports and available data such as topographical maps, and meteorological and hydrological data.

(2) Field Investigation and Project Analysis

Reconnaissance field survey was carried out in each potential project site identified in the basic study stage. At the same time, a provisional project analysis study was executed for the same to select tentative priority sites. For the hydropower priority sites, 1:10,000 topographical maps were developed from the existing aerial photos, and 1:20,000 topographical maps were also developed to cover the proposed reservoir areas. 1:1,000 topographical maps were developed by ground survey in the area of main hydropower structures. Geological investigations consisting of drilling works and seismic surveys were carried out at priority sites when necessary.

(3) Project Formulation

In this final stage the optimum development schemes to be formulated in the Master Plan were determined on the basis of comprehensive examination and comparative studies of the alternative development schemes from the viewpoints of national need, technical feasibility, economic viability and socioeconomic aspects.

Multipurpose Dam Development Potential

9. Multipurpose dam development potential was examined throughout the Basin, using available data such as 1:50,000 topographical maps and hydrological data for effective utilization of water resources considering river discharge, topography and heavy siltation at each site. As a result of the study, 5 dam sites were identified for formulation of possible multipurpose dam schemes. Among these 5 dam plans, Sun Kosi No.3 site was incorporated in the Sun Kosi Multipurpose Scheme (Phase II).

Hydropower Development Potential

10. Project identification study was carried out based on topographical maps, discharge data and other existing data and information. A reconnaissance survey was then conducted of the identified sites to confirm topographical, geological and hydrological conditions. As a result, 52 project sites with minimum capacities of more than 10MW were identified for hydropower scheme formulation.

11. The hydropower potential of each river is 5,013MW for the Sun Kosi River (36 sites), 1,185MW for the Arun River (6 sites), 1,222MW for the Tamur River (9 sites) and 3,489MW for the Sapt Kosi River. A total of 52 sites with installed capacity of 10,909MW were identified in the Basin.

Irrigation Development Potential

12. The area considered for the formulation of irrigation schemes including the diversion of water from the Kosi Basin is the Terai Area between the Bagmati and Kankai rivers. Cultivated land within the said area is estimated to be about 620,000ha; from which the irrigated areas under existing year-round irrigation projects and areas considered as infeasible due to obviously adverse conditions were excluded. The potential irrigation area thus delineated is 474,800ha, and consists of 6 sub-areas; namely, i) Bagmati River - Marha River (BM: 88,700ha); ii) Marha River - Kamla River (MK: 138,200ha); iii) Kamla River - Bhati Balon River (KB: 99,000ha); iv) Bhati Balon River - Kanro River (BK: 44,200ha); v) Kanro River - Sapt Kosi River (KS: 33,200ha); and vi) Sapt Kosi River - Ratuwa River (SR: 71,500ha).

Other Sector Potentials

13. Development potential for other components such as flood control, navigation and inland fisheries will be created by the implementation of large reservoir schemes. But the said potential and effects are very difficult to estimate at this time due to insufficient data for evaluation.

A general description of these potentials is given below.

(1) Flood Control

Proposed large dam schemes in the Kosi Basin such as the Sapt Kosi High Dam, Sun Kosi Nos 1-3, and Tamur No. 1 have great potential for flood control in downstream areas. In the Nepalese portion of the Kosi Basin, flood control is required between Chatra and Bimnagar Barrage on the Sapt Kosi River. Embankments on both banks of the Sapt Kosi River were completed in the same in 1963 and no flood damage has occured since that time with a maximum peak flood of 26,000m^3/s. However, rising of the riverbed is a serious problem as heavy sedimentation causes the riverbed to rise at a rate of 5cm a year.

After completion of the proposed large dam schemes in the Basin, flood peak discharge in the lower reaches of the Sapt Kosi

including Indian territory will be substantially reduced, ensuring the safety of peoples's lives and property along the river. At the same time, sedimentation control is envisioned particularly in the area between Chatra and Bimnagar Barrage.

The Kamla Dam scheme proposed on the Kamla River is also expected to facilitate flood control in downstream areas due to the large storage volume of 1/3 of the annual river discharge. The further study on the flood control should be recommended for the implementation of the above in large scale reservoir schemes.

(2) Navigation

The proposed dam schemes mentioned above will increase river flow in dry season in the downstream area. For example, the proposed Sapt Kosi High Dam Scheme, with an effective storage volume of 4,420 $10^6 m^3$ will increase downstream flow by about $410 m^3/s$ from $340 m^3/s$ to $750 m^3/s$ according to the average dry season discharge for a 32 year period (1947-1978). This increased river flow in dry season will create navigation potential in the downstream reaches of the Sapt Kosi High Dam throughout the year.

Moreover inland navigation on the Sun Kosi River will be facilitated by the cascade development of the large Sapt Kosi High Dam and Sun Kosi Nos 1-3, the reservoir surface of which can be used for water borne traffic in future.

To formulate a navigation project, the following basic information is required.

- longitudinal and cross-sectional profiles of relevant rivers
- daily discharge records and effective depth of flow
- siltation and sedimentation loads
- location of bridges and barrages crossing rivers
- transportation information

(3) Inland Fishery

The importance of inland fishery is becoming recognized throughout the country as a new industry providing an inexpensive source of protein and an attractive opportunity for employment and

income generation. The mitigation of flood discharge, increased river discharge in dry season and the creation of large water surfaces by the development of proposed reservoirs will increase the opportunities for inland fishery development.

In the development of hydropower in the Basin therefore, protection and maintenance of fishery resources, should be considered and detail study and formulation of a development program for the same is recommended as a development component of water resources.

Priority Schemes in the Master Plan

14. Based on the existing data and information and the results of field surveys, various schemes in each sector were identified and formulated. The identified schemes were compared and evaluated considering technological and economic aspects. From the identified schemes, those consistent with sound engineering, economic principles and the policies of HMG were selected as priority schemes using the project priority evaluation system. Priority schemes thus selected include one multipurpose scheme with irrigation and hydropower components and thirteen (13) hydropower schemes which include 5 high dam projects.

The said schemes are summarized as follows:

A. Multipurpose scheme: Sun Kosi Multipurpose Scheme

Irrigation	175,100ha (net)	B/C = 1.51
Hydropower (2 plants)	93MW	B/C = 1.62

B. Hydropower Scheme[1/]

Scheme	Type	Installed Capacity (MW)	Capital Cost (10^6US$)	Annual General (GWH)	B/C	Energy Cost (Cent/kWh)
1) Sapt Kosi High Dam	Reservoir	3,489	2,773	16,810	2.97	2.78
2) Arun No. 3	SRR	240	307	1,965	2.52	2.65
3) " No. 2	"	239	326	1.967	2.36	2.80
4) Sun Kosi No. 1	Reservoir	1,357	1,093	4,640	2.49	3.99
5) " No. 3	"	536	622	2,070	1.83	5.07
6) " No. 2	"	1,110	1,085	4,760	2.28	3.84
7) Arun No. 1	SRR	146	294	1,166	1.56	4.29
8) Bhote Kosi No. 1	"	64	97	444	1.94	3.60
9) Tama Kosi No. 3	PRR	123	219	603	1.35	6.14
10) Tamur No. 1	Reservoir	696	890	2,750	1.68	5.45
11) Tama Kosi No. 2	SRR	195	278	1,013	1.72	4.64
12) Khimte Khola No. 1	"	49	77	344	1.85	3.78
13) Dudh Kosi No. 1	PRR	228	478	978	1.06	8.28
Total Capacity			8,472 MW			

The above priority hydropower de lopment schemes should be considered for implementation to meet future Nepalese energy requirement with possible combination of priority schemes in other basins.

Detailed figures of the above priority hydropower schemes are mentioned in TABLE 5-23.

15. Energy Export Schemes

Some of the large scale schemes identified in the Kosi Master Plan Study can be considered as energy export oriented schemes due to the large energy output capability exceeding 1,000MW. These schemes, namely (1) Sapt Kosi High Dam with 3,489MW, (2) Sun Kosi No.1, 1,357MW, (3) Sun Kosi

1/ Capital costs include the costs of the hydropower station, transmission/substation and access roads which are taken into account by independent development.

No.2, 1,110MW, are of superior quality and economically attractive with seasonal water regulation capability through large reservoirs, and with B/C ratios exceeding 1.50. However, these schemes are too large for present Nepalese domestic energy needs. Implementation of the same, will therefore only be justified if a substantial portion of the energy output can be exported.

In this study the schemes are mainly planned for hydropower development; in future however, the same should be expanded into multipurpose projects containing such components as flood control, irrigation, navigation, and inland fishery.

Top Priority Schemes in the Master Plan

16. Two top priority schemes were carefully selected from the priority schemes in order to fulfill the immediate and critical needs of food and electric power supply and maximize various other socioeconomic benefits on the national level. The said schemes are the Sun Kosi Multipurpose scheme and the Arun No.3 hydropower scheme.

Outline of Proposed Top Priority Schemes

17. Sun Kosi Multipurpose Scheme

This scheme is a multipurpose project with the objective of irrigation and hydropower development. The scheme will contribute greatly to the integrated socioeconomic development of Nepal by creating a substantial increase in agricultural production through modernized irrigation of approximately 175,100ha and an attractive hydropower development scheme. Irrigation water for the same will be supplied from the Sun Kosi River basin and diverted to a tributary of the Kamla River through a 16.6km long diversion tunnel.

Implementation of this scheme with an access road connecting the Terai Area to the Sun Kosi River will also promote substantial hill area development in addition to contributing directly to the national economy.

(1) Scheme Outline

The Sun Kosi Multipurpose Scheme consists of 4 major components on the following page:

- Sun Kosi No.3 Dam
- Sun Kosi Diversion
- Kamla Dam
- Irrigation Development in the Terai Area

Various items of each component are further described below.

1) Sun Kosi No.3 Dam

a) Dam and reservoir

C.A	5,520km^2
HWL	EL 700m
LWL	EL 674m
Vg	1,220 10^6m3
Ve	550 10^6m3
Dam type	concrete gravity
Dam height	140m

b) Hydropower

Qmax	570m^3/s
He	113m
Pmax	536
Generated Energy	2,070GWh

c) Construction cost 582 10^6US$

2) Sun Kosi Diversion

a) Kurule diversion dam

Dam type	concrete gravity
Dam height	48.9m

b) Diversion tunnel

Length	16,600m
Design discharge	72m^3/s

c) Diversion power station

Qmax	72m^3/s
He	102.5m
Pmax	61,400kW
Generated energy	511GWh

d) Construction cost 228.2 10^6US$

3) Kamla Dam Project

a) Dam and reservoir

C.A	1,450km^2
HWL	EL 178m
LWL	EL 163m
Vg	713 10^6m3
Ve	493 10^6m3
Dam type	gravel fill
Dam height	51.0m

b) Kamla dam power station

Qmax	120m3/s
He	32m
Pmax	32,000kW
Generated Energy	121 GWh

c) Construction cost 90.0 10^6US$

4) Irrigation Development in the Terai Area

a) Command area (net) 175,100ha

b) Chisapani Barrage

-Height	3m
-Length	300m

c) Main canal

Length: Right bank	78.4km
Left bank	74.1km
Design discharge:	
Right bank	135m3/s
Left bank	84m3/s

d) Construction cost[1/] 232.5 10^6US$

1/ Including costs for main canal and other irrigation facilities.

18. Arun No.3 Hydropower Scheme

(1) Background

Arun No.3 has the most economical scheme in terms of energy cost among the 52 hydropower schemes studied in the Basin. The SRR type with a cascade series is considered to be the optimum development method for the Arun River due to steep river gradient. There are six SRR hydropower schemes in the cascade series which have been named Arun No.1 to No.6 from downstream to upstream.

Accessibility is the most difficult item in development of the said river. However, the access road for Arun No.3 (approximately 100km) will be a major impetus for regional development upon completion. Other attractive hydropower schemes planned along the Arun River should be promoted; particularly, four schemes -- Arun No.1, No.2, No.5 and No.6 -- which are more economical in comparison with the others.

(2) Project Description

Despite difficult accessibility, this medium scale project has been selected as the top priority projects among the 52 potential sites in the Basin due to the low kWh development cost. The intake site is located approximately 110km upstream from the Tribeni confluence of the Arun and Sun Kosi rivers, at a point where the Arun River changes direction from southeast to north making a loop. The surrounding topographical conditions make this location a very attractive hydropower site with a steep river gradient which would provide a 194m water head through a 7.1km headrace tunnel. An optimization study on this site was carried out based on a site reconnaissance survey and a 1/10,000 scale topographical map. Boring investigation revealed hard foundation rocks along the penstock line with 5m talus deposits and at the powerhouse with 17.8m river deposits.

Main Features of the Arun No.3 Scheme

a)	Project Type	SRR
b)	Catchment Area	32,500km^2
c)	Intake Weir	
	Crest level	EL 810.0m
	Crest length	120m
	Weir height	23m
d)	Headrace Tunnel	7,100m
e)	Maximum Design Discharge	156m^3/s
f)	Gross Head	194m
g)	Installed Capacity	240MW
g)	Generated Energy	1,965GWh
h)	Construction Cost	307 million US$
i)	Energy Cost	2.64 US cent/kWh (including access road, transmission and substation)

Implementation Schedules of Top Priority Schemes

19. Sun Kosi Multipurpose Scheme

(1) Division of the Scheme

It is recommended that the Sun Kosi Multipurpose Scheme be divided into two large phases based on the following conditions:

a) Diversion of water from the Sun Kosi to the Kamla is allowed according to the Agreement between HMG and India.

b) Although Sun Kosi No.3 Scheme is planned to mitigate the effect of diversion on downstream areas, the scheme, which includes electric generation of 536MW, was considered too large to meet Nepalese domestic needs in the near future.

c) Implementation of an irrigation scheme in the Terai Area is urgently required to meet agricultural development needs.

Phase I:

a) Sun Kosi diversion works with a 16.6km tunnel and Kurule diversion dam

b) Two hydropower plants with total installed capacity of 93,400kW

c) Kamla Dam with available storage capacity of 493 million m^3

d) Irrigation facilities in the Terai Area

Phase II:

e) Sun Kosi No.3 Dam
Dam height: 140m
Vg: 1,220 million m^3
Ve: 550 million m^3
Installed Capacity: 536 MW

(2) Stage Development Plan for Phase I Scheme

Total investment cost of the Phase I scheme is estimated at 550 million US$ and the command area of the same extends 140km in length from east to west on both banks of the Kamla River in the Terai Area. Therefore, a stage development plan is recommended to avoid various difficulties in implementation such as financial arrangement, acquisition of manpower and construction material, and extension of modern agricultural practice. An implementation schedule of 3 stages is recommended as shown in FIG. S-1.

20. Arun No.3 Hydropower Scheme

The Arun No.3 hydropower scheme is the most attractive scheme not only in the Kosi Basin but throughout the country and implementation of the same as soon as possible is desireable to meet projected power demands in the 1990's. Although the Arun No. 3 scheme has been identified as the most attractive power generation project by the Master Plan Study, the fact that only preliminary study of the project has been carried out necessitates implementation of a feasibility study on the same immediately.

The recommended implementation schedule as shown in FIG. S-1 has been developed in due consideration of construction of a long access road sufficiently ahead of the hydropower facility to provide adequate logistic means for construction work.

Watershed Management

21. Watershed management, consisting of afforestation, soil conservation, slope and landslide protection works, and mitigation of riverbank erosion, is indispensable for achievement of effective water resources development, as heavy siltation and sedimentation are extremely harmful to water resources development facilities. In this report, suggested watershed management countermeasures are presented.

The devastation of the Kosi Basin, as well as other basins throughout the country, is very severe. Countermeasures will consequently entail a long implementation period and huge investment cost. A part of the cost for development of favorable water resources in the Kosi Basin should therefore be used for conserving and improving natural resources which are essential to the fulfillment of basic human needs.

Economic Analysis

22. In the Master Plan Study, the economic viability of each project was assessed by calculating B/C ratio. A discount rate of 12% per annum was utilized for measuring the same.

23. Preliminary cost estimates were prepared for all schemes considered in the Master Plan based on 1983 price levels. It was assumed that the schemes would have an economic life of fifty (50) years from the date of commissioning and that at the end of their economic life, they would have no residual value.

24. Economic benefits to be derived from the hydropower projects were estimated on the basis of the least costly alternative power cost criterion. The coal-fired thermal plant of 100MW unit capacity was selected as the best alternate source of power. Economic power benefits consist of capacity benefit (kW-value) and energy benefit (kWh-value). Economic benefits to be derived from the irrigation schemes were estimated by "with" and "without" comparisons. The costs and benefits that will arise "with" the proposed project are identified and compared with the situation as it would be "without" project. The difference is the incremental net benefit arising from project investment.

Development Impacts

25. Kosi Basin Water Resources Development will contribute substantially to regional and national development particularly in the following three categories.

(1) Generation of a large amount of economical electric energy will contribute to electrification, supply quality energy for the development of new industries, and the mitigation of devastation of forest in the basin presently caused by consumption of wood for fuel.

(2) Promotion of both industrial development through economical energy supply and agricultural development through large scale irrigation projects in the eastern Terai will contribute significantly to both regional and national economic development.

(3) Development of access roads in connection with water resources development will provide a large scale transportation facility in the mountain and hill areas which will contribute to better logistic flow as well as stimulating development of new income generating industries.

Conclusion

26. As a result of the Study, it is concluded that water resources development in the Study area should be implemented as soon as possible in order to meet national power and irrigation needs. Development of the water resources of the Kosi River will not only meet short, medium and long term national needs but will also create surpluses for export.

Among all the schemes identified in the Master Plan, the top two priority schemes, namely, the Sun Kosi Multipurpose and Arun No.3 Hydropower schemes, were recommended for immediate implementation of a feasibility study. These two schemes are technically sound and economically feasible. Feasibility studies should therefore be conducted for the same at the earliest opportunity.

I. INTRODUCTION

1.1 Background to the Study

The Kingdom of Nepal, with the 3 major river systems of Karnali, Gandaki and Kosi, possesses abundant potential for water resources development. Basic water resources development for the Karnali and Gandaki basins has been studied to a considerable extent, but the water resources development potential of the Kosi Basin including areas of the Terai concerned in the eastern part of Nepal has not been examined in a comprehensive manner. To this end, the subject Master Plan Study was carried out.

The Kosi River is composed of the Sapt Kosi and all its tributaries, the main affluents being the Tamur, Arun and Sun Kosi rivers which converge to form the Sapt Kosi River, subsequently flowing through the Terai Area. To date this basin has been subjected to only limited study. Reconnaissance level work has been completed on a few upper basin sites and feasibility studies are available for the Kosi High Dam Project located at the outlet of the Basin and the Mulghat and the Kurule sites located on the Tamur and Sun Kosi rivers, respectively.

Under these circumstances, His Majesty's Government of Nepal (HMG) requested the Government of Japan to provide cooperation and assistance in order to conduct a comprehensive study of the Kosi Basin and Terai Area. In response to the request, the Government of Japan agreed to extend technical assistance through JICA.

1.2 Objective of the Master Plan

(1) Objective

The objective of the master plan is basically to determine the optimum plan for Kosi River Water Resources Development which will contribute most effectively to the socioeconomic development of Nepal.

Water resources development of the Kosi River will contribute to national development not only with such direct effects as hydropower, irrigation and other components but also indirectly by promoting rural development in the relevant area through

development of access roads, a telecommunication network and electricity transmission lines which will be required for the overall water resources development scheme. Accordingly, the Master Plan study included the following items:

a) development potentiality of water resources in the Kosi Basin, including inter-basin diversion potentiality from the Kosi Basin to the Terai Area;

b) preliminary development plan of individual projects studied in the Master Plan Study;

c) priority projects to meet domestic need and energy export needs for hydropower development;

d) priority projects to meet agricultural development needs for irrigation development;

e) high priority projects required for development in the near future (up to 2005);

f) flood control, navigation and inland fishery development potential in the Kosi River;

g) requirement and importance of watershed management in the Kosi Basin; and,

h) development impact.

(2) Implementation Schedule for the Development Period

Implementation schedule was prepared for the forthcoming 20 years (1985-2005) and in general, the Master Plan has been formulated in light of the assumed socioeconomic conditions 20 years hence. Given this characteristic, the Plan should be reviewed once in 5 years, taking into consideration the changes in the socioeconomic situation.

1.3 Scope of Works

As a result of a series of discussions held between the preliminary survey team of JICA and the officials of ED and other Nepalese government agencies concerned, the Scope of Works for the Study was agreed to and signed on February 1, 1983 between the two parties concerned. The agreed Scope of Works (S/W) is summarized below.

(1) Study Area

The Study area is composed of the Kosi Basin and the Terai Area between the Bagmati and Kankai rivers in Nepal. In the case

of the Terai portion, however, the Study is defined in terms of effective development of the Kosi River and as such, schemes which are not based on diversion from the Kosi River shall be excluded from consideration.

(2) Scope of the Study

The Study included the following:

a) Review and evaluation of all data and previous studies directly relevant to the Study and formulation of a program for further studies;

b) Examination of existing and on-going development programs directly relevant to the Study area; and,

c) Examination and evaluation of alternative schemes to prepare an optimum sequence of water resources development of the Kosi River with a view to identifying and defining the program of development that will meet the short, medium and long term needs of Nepal.

1.4 Study Works

1.4.1 Activities of the Study Team

According to the S/W agreed between ED and JICA, the Study works were divided into the following.

Part A: Basic Study

Part B: Field Investigation and Project Analysis

Part C: Master Plan Formulation

In addition to the above, Part D -- transfer of technological knowledge to Nepalese counterpart personnel, including seminars on water resources development -- was incorporated into the Study works.

The major activities of Part A (conducted from June to August in 1983) of the Study were:

a) to collect existing data and information;

b) to review previous reports and studies;

c) to conduct a site identification study on the basis of a 1:50,000 scale map, and prepare a preliminary list of potential dam sites; and,

d) to prepare a program for the detailed field investigation under Part B.

Field investigation of Part B was conducted from November 1983 to August 1984 to: (i) assess the prospective dam sites identified during Part A of the Study; (ii) examine the agricultural condition and determine the irrigable area; (iii) carry out water management study including flood control, soil erosion, watershed management, etc.; (iv) undertake a socio-economic impact study; and (v) collect additional data and information relevant to the Study.

During this period of field investigation, additional field survey works were conducted as follows:

- Preparation of topographical maps with a scale of 1:20,000 covering reservoir areas of Sun Kosi Nos.1 to 3 sites.
- Preparation of topographical maps with a scale of 1:10,000 covering thirteen (13) priority sites
- Ground survey for preparing topographical maps with a scale of 1:1,000 at Sun Kosi Nos. 2 and 3, and Tama Kosi No.3 site
- Seismic survey at Sun Kosi Nos. 2 and 3 sites, and Tama Kosi No.3 site
- Boring survey at Sun Kosi No.2, Sun Kosi No.3, Tama Kosi No.3 and Arun No.3 sites.

Based on review of previous studies, analysis of the existing data and the results of field investigation, the Master Plan was formulated during Part C.

1.4.2 Submitted Reports and Documents

The following reports and documents have been prepared by the Study Team and submitted to HMG:

- Inception Report:	July 1983
- Progress Report:	August 1983
- Plan of Operations for Part B:	November 1983
- Discussion Notes:	January 1984
- Memorandum of Understanding:	February 1984
- Interim Report:	July 1984
- Draft Final Report:	February 1985

1.5 Personnel Involved in the Study

The JICA Study Team and full-time counterpart officers of HMG were direct participants in the Study. A list of these direct participants is presented below.

During the course of the Study, many organizations assisted and supported the Study works. The members and staff of these organizations are listed on the subsequent pages.

LIST OF DIRECT PARTICIPANTS IN THE STUDY

MEMBERS OF JICA STUDY TEAM

Mr. M. Sayama	Team Leader, CKC
Mr. S. Matsushita	Dam Planning Engineer Senior Deputy Team Leader, TEPSCO
Dr. T. Abe	Water Resources Development Engineer Deputy Team Leader, CKC
Mr. T. Kanokogi	Hydropower Planning Engineer, TEPSCO
Mr. T. Izumi	Power Demand/ Transmission Planning Engineer, TEPSCO
Mr. S. Kouda	River Engineer, TEPSCO
Mr. T. Sugawara	Hydrologist, TEPSCO
Mr. K. Hirata	Hydrologist (Home Office Work), TEPSCO
Mr. M. Kawada	Agronomist (Part A), CKC
Mr. S. Akeda	" (Part B & Part C), CKC
Mr. S. Matsunaga	Irrigation Planning Engineer, CKC
Mr. T. Ozeki	Geotechnical Engineer (Part A), CKC
Mr. C. Itoh	" " (Part B & Part C), CKC
Mr. K. Kobayashi	Land Use Expert, CKC
Mr. Y. Zaitsu	Soil Expert, CKC
Mr. M. Arai	Survey and Design Expert, CKC
Mr. S. Masumura	Economist, CKC
Mr. S. Watanabe	Boring Supervisor, CKC
Mr. K. Mori	Boring Expert, CKC
Mr. A. Muranaga	Seismic Survey Specialist, CKC
Mr. T. Tsuji	" " " CKC
Mr. M. Imamura	" " " CKC
Mr. S. Shirahama	Survey Specialist, TEPSCO
Mr. T. Onuma	" " TEPSCO
Mr. K. Toyoda	Mapping Specialist, KKC
Mr. K. Tajiri	" " KKC

Note CKC: Chuo Kaihatsu Corporation, TEPSCO: Tokyo Electric Power Services Co. Ltd., KKC: Kokusai Kogyo Co., Ltd.

FULL-TIME COUNTERPART OFFICERS

Mr. G.S. Rajbanshi	Administrative Coordinator, ED
Dr. J.L. Karmacharya	Technical Coordinator, ED
Dr. M.R. Tuladhar	Power Engineer, ED
Dr. J.N. Jha	Dam and Power Engineer, ED
Mr. J.K. Maskay	Power Engineer, ED
Mr. D.B. Nepali	Hydrologist, ED
Mr. K.B. Bhaila	Geologist, ED
Mr. D.B. Thapa	Senior Geologist, ED
Mr. J.P. Thanju	Senior Irrigation Engineer, ED
Mr. U.K. Jha	Irrigation Engineer, DIHM
Mr. S. Lakoul	Power Engineer, ED
Dr. M.D. Joshi	Economist, ED
Mr. M.P. Pant	Agronomist, DOA
Mr. D.P. Sherchan	Soil Scientist, DOA

LIST OF MEMBERS OF JICA ADVISORY COMMITTEE AND HMG OFFICERS WHO SUPPORTED THE STUDY

MEMBERS OF JICA ADVISORY COMMITTEE

Mr. T. Tanimoto	Chairman of Committee, MOC (June '83 thru March '84)
Mr. T. Tomaru	Chairman of Committee, MOC (April '84 thru March '85)
Mr. S. Ohno	Member, MOC (June '83 thru March '84)
Mr. T. Fukunari	Member, MOC (April '84 thru March '85)
Mr. B. Satoh	Member, MITI
Mr. T. Hashimoto	Member, MAFF

JICA

Mr. Y. Okazaki	Project Coordinator, JICA (June '83 thru March '84)
Mr. H. Ono	Project Coordinator, JICA (April '84 thru March '85)

Note: MOC = Ministry of Construction of Japan
MITI = Ministry of International Trade and Industry of Japan
MAFF = Ministry of Agriculture, Forestry and Fishery of Japan

HMG SENIOR OFFICERS

ED:	Mr. H.M. Shrestha	Chief Engineer
	Mr. B.M. Singh	Deputy Chief Engineer
	Mr. S.N. Pradhan	Deputy Chief Engineer
	Mr. R.C. Chaudhary	Superintending Engineer
DIHM:	Mr. C.D. Bhatt	Director General
	Mr. N.A. Ansari	Deputy Director General
	Mr. N.K. Agrawal	Superintending Engineer
	Mr. J.R. Sharma	Acting Executive Engineer
	Mr. K.P. Timilsina	Project Manager

WEC:	Mr. B.K. Pradhan	Executive Secretary
	Mr. S.B. Upadhyaya	Executive Director
	Dr. H.M. Shrestha	Executive Director
	Dr. C.K. Sharma	Executive Director
DOA:	Mr. A.M. Pradhanang	Deputy Director General
	Mr. M.M. Shrestha	Chief Water Use Officer
DSCW:	Mr. K.P. Upadhyaya	Chief, Soil Conservation Office
MWR:	Dr. A.B. Thapa	Chief, Monitoring Unit
NPC:	Mr. S.P. Kayastha	Under Secretary

II. BACKGROUND

2.1 General Characteristics

2.1.1 Location and Natural Features

Nepal is a landlocked Kingdom on the southern slopes of the Himalayan Mountains, the nearest sea coast being about 1,127km from its border. Located between northern latitudes of 26°22' and 30°27' and eastern longitudes of 80°4' and 88°12', it is bordered by the Tibetan region of China to the north and India to the south, east and west.

The country, with a total land area of 141,000km^2, is divided physically into the following 3 ecological zones stretching from east to west.

a) The Mountain Zone, situated at an altitude exceeding 3,000m, accounts for 34% of the total area but only 5% of cultivated land.

b) The Hill Zone lying between 300-3,000m is a subtropical belt and occupies 43% of the total area and 30% of cultivated land.

c) The Terai Zone lying below 300m forms the southern belt extending along the Indian border and accounts for 23% of the total area and 65% of cultivated land.

An alternative classification can be applied to Nepal on the basis of three major river basins; (i) the Kosi Basin; (ii) the Gandaki Basin; and (iii) the Karnali Basin. These rivers, originating in the Himalayan Mountains, are snow-fed, perennial flows with significant discharge even in the dry season, and, as such, offer promising water resources for the development of irrigation, hydropower and other potentials.

2.1.2 Climate

Weather conditions vary from region to region. Annual mean temperatures range from high (25°C) in the Terai Zone, to moderate (18°C) in the Hill Zone, and to low (7.5°C) in the Mountain Zone. Nepal has a monsoon climate, with average annual rainfall estimated at 1,600mm. On an average, about 80% of precipitation is confined to the rainy period (June - October).

2.1.3 Population

According to provisional data of the 1981 census, the total population of Nepal now exceeds 15 million, of which 94% reside in rural areas. The following table represents population growth data processed from the Central Bureau of Statistics.

POPULATION GROWTH

Census Year	Population	Average Annual Growth (%)
1952/54[1/]	8,256,625	-
1961	9,412,996	1.88
1971	11,555,983	2.07
1981	15,020,451	2.66

Source: Central Bureau of Statistics

1/: The population census was conducted in two stages; the eastern part of the country was enumerated in 1952 and the western part in 1954.

The annual rate of population growth which averaged 1.88% during 1952/54-1961 and 2.07% during 1961-71, increased to 2.66% during 1971-81. This growth pattern is beginning to have a significant impact on the area available for cultivation.

Population distribution in each of the major river basins in 1981 is summarized as follows.

POPULATION DISTRIBUTION BY MAJOR RIVER BASINS

Location	Population Distribution (%)	Population Density (per Km^2)
1. Kosi Basin	45.9	156
2. Gandaki Basin	27.3	108
3. Karnali Basin	21.7	56
4. Kathmandu Valley	5.1	1,357

Source: Population Increase in Nepal 1971-81, New ERA
Note: Each basin includes the Terai portion.

As the above table shows, population density in the Kosi Basin is second only to the Kathmandu Valley, and represents almost 50% of the entire population of Nepal. Accordingly, the development of this basin will have a significant impact on the nation as a whole.

The population of 10 years and over was estimated at 8.2 million in 1971 of which 59.3% was found to be economically active. This percentage represents a slight change from the midterm census of 1976 in which 66.5% out of 9.3 million was found to be economically active. According to a projection of labor force made by CBS, the labor force will grow to 6.9 million in 1976, 7.8 million in 1981 and 8.7 million in 1986.

2.1.4 Administrative Set-up

For administrative purposes, the country is divided into 14 zones which are comprised of 75 districts. Each administrative zone is made up of 4-7 districts comprised of town and village panchayats. A village panchayat is the smallest administrative unit consisting of wards. There are a total of 14 zones, 75 districts, 29 town panchayats and 4,023 village panchayats at present in the country.

At the national level, the Government formulates, directs and evaluates all national policies and economic development programs. The Zonal Commissioner is responsible for maintaining law and order in the zone, and the Local Development Officer (LDO) and Chief District Officer (CDO) are similarily responsible at the district level.

2.2 National Economy

2.2.1 Gross Domestic Product

Nepal's economy is predominantly agriculturally based, with some 94% of the population engaged in farming and only about 6% involved in non-agricultural production. The agricultural sector accounts for about 60% of the total Gross Domestic Product (GDP).

The performance of the economy in the first two years of the Sixth Plan was favourable. GDP increased by 5.6% in 1980/81 and 3.8% in 1981/82. In the third year of 1982/83, however, production in the agricultural sector declined by 9.7%, adversely affecting prices, foreign trade, balance of payments and foreign exchange reserves. Thus, GDP in 1982/83 registered a decline of about 1.3%.

In the last few years, efforts have been directed at increasing national production by maximum utilization of existing infrastructures. Yet production has not increased as much as expected due to limited irrigation facilities, ecological degradation and lack of timely and adequate supply of agricultural inputs to farmers. Actual GDP growth rate during 1975/76-1982/83 period is shown in the following table.

GDP GROWTH RATE: 1975-83

	Fifth Plan 1975/76-1979/80	Sixth Plan 1980/81	1981/82	1982/83
1. GDP	2.1	5.6	3.8	-1.3
2. Agriculture	-0.9	10.4	3.5	-3.4
3. Non-agriculture	7.5	-1.3	4.3	2.0

Source: CBS

There have been some improvements. Although the table indicates that the non-agricultural sector underwent a set-back in 1982/83, industrial production within this sector, which declined in 1980/81 due to shortages of raw materials and electricity, actually increased significantly in 1982/83 because of normalization of supply of the same.

2.2.2 Agriculture and Food Balance

Agriculture is the mainstay of Nepal's economy; in 1980, this sector accounted for about 60% of GDP, over 90% of employment and nearly 80% of export earnings. In the agricultural sector, food grain production is the most important component, amounting to about 90% of total agricultural output. The main food grains produced are rice, maize, wheat and millet.

Except for wheat, production of food grains has not shown any significant increase in the last five years. Paddy production which was 2.28 million tons in 1977/78, 2.34 million tons in 1978/79, 2.06 million tons in 1979/80, 2.46 million tons in 1980/81 and 2.56 million tons in 1981/82, decreased to 1.83 million tons in 1982/83. Maize production, which was 0.74 million tons in 1977/78, was recorded at only 0.71 million

tons in 1982/83. Wheat production, on the other hand, increased from 0.41 million tons in 1977/78 to 0.66 million tons in 1982/83.

Major cash crops are oilseeds and potatoes in the Hill Zone, and jute, sugar cane and tobacco in the Terai Zone. Major agricultural exports include jute, hides and skins and a number of minor commodities. Rice exports declined from a high level of 160,000t in 1975/76 to 36,000t in 1981/82 and no exports were recorded after July, 1982 when HMG imposed restrictions on export of the same.

Food balance projection up to the year 2005 was conducted on the basis of population projections by APROSC, past production records, estimated gross production of food grains and estimated gross requirement of total food grains as shown below.

FOOD BALANCE PROJECTION IN NEPAL

Unit: '000 ton

Year	Estimated Gross Requirement	Estimated Gross Production	Food Balance
1985	4,484	3,950	-534
1990	5,211	4,179	-1,032
1995	6,311	4,323	-1,988
2000	7,638	4,477	-3,206
2005	9,406	4,641	-4,765

From the food balance projection noted above, it is observed that the accelerated rate of population growth is creating a greater demand for food while the decline in productivity is reducing total food availability. To supply minimum food and nutritional needs, therefore, cereal production should at least be doubled from the present level (3.8 million tons) by the year 2000. This requires that in the decade ahead a growth rate of about 4% must be achieved in annual food production in order to provide the entire population with sufficient food and to ensure a minimum level of calorie requirements.

Increased grain production can be attained by increasing the productivity of farmland through improvement of irrigation infrastructures as well as the introduction of new agricultural technology and farming practices.

2.2.3 Industry

The role which the manufacturing industry plays in the national economy is marginal. The industrial sector (manufacturing and mining) accounts for only 4% of the GDP and provides employment to 1% of the working population.

Agro-processing units such as rice husking, flour milling, oil extracting, jute processing and sugar refining predominate in the industrial sector. Oil and grain mill products occupy more than 80% of the total gross output in the country. Among agro-processing industries, rice mills exist in almost all the important production centers.

According to the census of manufacturing establishments 1976/77, out of 3,528 industrial units, 745 or 21% were located in the Eastern Development Region, 1,787 or 51% in the Central Region, 665 or 19% in the Western Region and 331 or 9% in the Far Western Region. The Eastern and Central Regions dominate industrialization because of their distinct advantage in transport and communication facilities and access to raw materials from local as well as foreign markets.

2.2.4 Energy Situation

Energy consumption is increasing rapidly in Nepal. Nepal Oil Corporation's import of petroleum products in 1982/83 is estimated to be 153,000kℓ worth Rs.700 million compared to 130,000kℓ valued at Rs.470 million in 1981/82, and the demand for electric power is increasing by 15-20%/annum. Although wood provides nearly 90% of all energy in Nepal, excessive use of the same for fuel has led to reckless exploitation of forest resources. Therefore, adoption of an alternative energy source has become an urgent priority. The Table below presents commercial and non-commercial energy consumption in Nepal.

TOTAL COMMERCIAL AND NON-COMMERCIAL
ENERGY CONSUMPTION BY TYPES OF FUELS (1974/75)

Fuels	Coal Ton Replacement	%
A. Commercial		10.74
1. Coal	64,480	0.90
2. Petroleum Fuels	613,546	8.58
3. Electricity	90,331	1.26
B. Non-Commercial		89.26
1. Fuel wood	6,204,000	86.78
2. Husks	86,000	1.21
3. Dung cake	28,800	0.39
4. Vegetable wastes, etc.	62,757	0.88
Total	7,149,114	100.00

Source: Energy Sector Study by University of Tribhuvan, 1976.

Nepal has a theoretical hydropower potential of 83,000MW whereas economically feasible hydroelectric generation is estimated at 25,000MW. Of this potential, only 128MW has been harnessed to date. The total installed generating capacity in the country is 153MW of which 128MW is produced by hydropower, 20MW by diesel and 5MW by privately owned steam plants.

The objectives of electrical development in the Sixth Plan are production of sufficient electric power to meet the growing demands of different sectors, to extensively broaden domestic use of electricity with a view to arresting further depletion of forest resources, and to supply power required for electrifying the transport system as a substitute for petroleum.

To meet the growing need for electric power for agricultural, industrial and domestic use, emphasis is expected to be given more to exploitation of hydropower potentiality than to the installation of thermal power plants.

2.2.5 Sixth Plan

Nepal has adopted six successive development plans since 1956. The first five plans accorded priority to the creation and strengthening of socioeconomic infrastructures in such areas as education, health services, transport, communications and power. In the Sixth Plan, initiated in 1980, HMG places greater emphasis on direct productive activities.

The objectives of the Sixth Plan, initiated in 1980, are: i) to increase production at a faster rate, ii) to increase productive employment opportunities, and iii) to meet the minimum needs of the people. In order to achieve these objectives, the following development strategies have been laid down: i) according priority to agricultural development, ii) emphasizing the development of cottage and small industries, iii) laying stress on export trade and development of tourism, iv) laying stress on the conservation of natural resources and wealth and development of water resources, v) emphasizing full utilization of infrastructures already created, vi) increasing the absorptive capacity of the economy, and vii) controlling population growth.

To help attain the Sixth Plan's objectives, real GDP growth rate has been targeted for an average of 4.3%/year, with an agricultural GDP growth rate of 3.2%/year. In the allocation of development expenditure in the Sixth Plan, it should be noted that the irrigation subsector and power subsector have shown substantial increases compared to the Fifth Plan as shown in the following table.

IRRIGATION AND POWER SECTOR:
COMPARISON OF THE FIFTH AND SIXTH PLANS

Unit: %

	Fifth Plan 1975-80	Sixth Plan 1980-85
1. Agriculture, Irrigation and Forestry	26.5	30.4
a) Irrigation only	(9.7)	(14.1)
2. Industry, Mining and Power	18.9	25.8
a) Power only	(11.8)	(17.5)
3. Transport and Communications	26.8	19.4
4. Social Services	11.6	7.6
Total	100.0	100.0

Source: The Sixth Plan, NPC

2.3 Institutional Structures

2.3.1 Agencies for Water Resource Development[1/]

The Ministry of Water Resources is accountable to HMG for overall water resource development in Nepal. Particular developments in each of the water resource sectors, power, irrigation, and water supply and sanitation, are the responsibility of the Ministry's line departments and associated agencies.

(1) Water and Energy Commission

The Commission is responsible for preparing water and energy strategy within the context of national policy and recommending appropriate development programs to the government. In undertaking its planning exercises, the commission will maintain close coordination and cooperation with the National Planning Commission. The secretariat will provide the Commission and the Ministry of Water Resources with the planning information necessary to the preparation of sound strategy and development programs in the water and energy sectors.

1/ Source: Water, the Key to Nepal's Development, MWR, 1981

(2) Power Sector

There are four government agencies involved in the electric power sector in Nepal. ED develops all major generation plants, provides bulk supply transmission and also distributes electricity in the Far Western and Fifth Development Regions. The Small Hydel Development Board (SHDB) is responsible for developing small hydroelectric projects in remote communities. The Nepal Electricity Corporation (NEC) distributes electricity in the Central and Western Development Regions, and the Eastern Development Region.

(3) Irrigation Sector

The responsibility for data collection, project investigations, planning, design and implementation of irrigation projects in Nepal lies with the Department of Irrigation, Hydrology and Meteorology (DIHM). The central office carries out surveys, planning and design functions for the department and manages construction of most major projects through a system of project boards. The smaller projects and local irrigation improvements are planned, designed and implemented from the regional directorates of which there is one located in each development region.

(4) Water Supply and Sanitation Sector

The national water supply and sanitation program is a coordinated effort among three government agencies: the Department of Water Supply and Sewerage (DWSS), the Ministry of Local Development (MLD), and the Water Supply and Sewerage Board (WSSB). DWSS is responsible for providing water supplies to all rural communities in the hills and mountains with populations in excess of 1,500, and to develop shallow groundwater potential within the Terai Zone in the Central, Far Western and Fifth Development Regions. MLD is responsible for providing water supplies to the remaining rural areas. WSSB is responsible for supplying water and sewerage facilities to the urban communities.

2.3.2 Agricultural Institutions

Agricultural development and policy are the concern of four ministries: the Ministry of Agriculture (MOA), the Ministry of Water Resources (MWR), the Ministry of Land Reform (MLR) and the Ministry of Forests and Soil Conservation (MFSC). MOA includes the Department of Agriculture (DOA) which is in charge of promoting production through extension, training and research. MOA also has overall responsibility for a number of public institutions such as the Agricultural Development Bank of Nepal (ADBN), the Agricultural Inputs Corporation (AIC) and the Nepal Food Corporation (NFC).

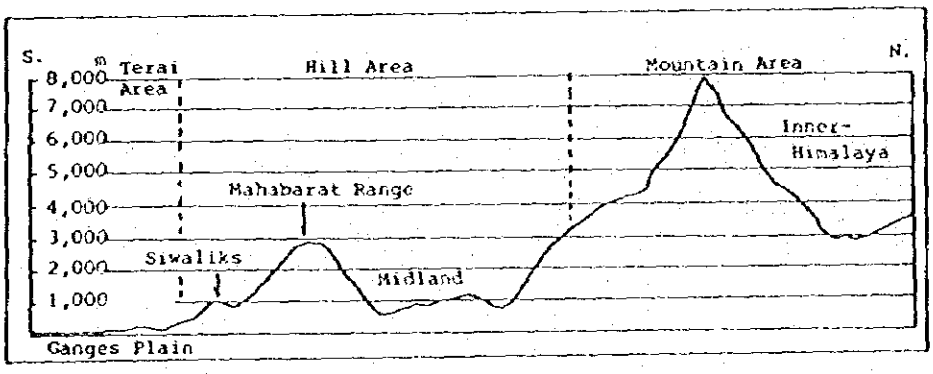
III. STUDY AREA

3.1 Physical Features

3.1.1 Location and Topography

The Study area is located in the eastern part of Nepal. As defined in the S/W, the area is composed of the Kosi Basin and Terai Area between the Bagmati and Kankai rivers. The Kosi Basin is one of Nepal's 3 major river systems and lies between northern latitudes of 26°50' and 28° and eastern longitudes of 85°30' and 88°12'. The catchment area within Nepal is estimated to be 33,000km^2. The Terai Area, situated south of the Kosi Basin is bordered by the Bagmati River to the west, the Kankai River to the east, the Indian border to the south, and the Siwalik Hills and Mahabharat range (EL. 1,500-2,700m) to the north (Location Map). In the said portion, the Study is defined in terms of effective development of the Kosi River and as such, schemes which are not based on diversion from the Kosi River are excluded from consideration.

The Study area is divided into three major topographic and ecological areas: the Mountain Area in the north, the Hill Area in the midland and the Terai Area in the South. The Mountain Area is situated at an altitude exceeding 3,000m, with the highest point reaching to more than 8,000m. The Hill Area lying between 3,000-300m consists of high ridges and steep slopes including the Mahabharat range and Siwalik hills. The Terai Area, lying below 300m, forms the southern belt extending along the Indian border. The figure below provides the topographical profile of eastern Nepal.



TOPOGRAPHICAL PROFILE OF EASTERN NEPAL

3.1.2 Geology and Soils

The Study area consists of three major geological zones: (i) Himal Group (granite, gneiss and schist); (ii) Midland Group (clastic rock and carbonate) and (iii) Siwalik Group (shale, sandstone and conglomerate). Moving from north to south, the rocks become softer and the rate of erosion consequently becomes more intense.

Geological groups in the Study area are presented below.

GEOLOGICAL GROUPS OF EASTERN NEPAL

Possible Period	Group	Lithology
1. Cenozoic	Recent	Unconsolidated sediments, gravels, alluvium
	Siwalik	Shale, sandstone, conglomerate
	Main Boundary Fault	
2. Mesozoic - Paleozoic	Tethys	Shale and limestone
3. Paleozoic - Precambrian	Kathmandu	Mainly clastic rock and carbonate
	Midland	Mainly clastic rock and carbonate
	Main Central Thrust	
4. Precambrian	Himal	Gneiss and schist (highly metamorphic rock)
	Igneous Rock	Granite and paragranite

The geotectonic lines which determine the geological structure of the area consist of 2 major thrusting faults; the Main Central Thrust and the Main Boundary Fault. These faults extend in an E-W trend across Nepal, acting as the major division between the formation groups.

The mountainous region is in the process of large scale erosion, and sediment produced from the same is carried by the rivers to the lower reaches. Sediment volume in each river is great because of: i) steep terrain; ii) young orogenic movement; iii) location in the subtropical monsoon belt and rainfall of over 2,000mm during rainy season (June to October) resulting in sediment runoff; iv) weathering of bedrock due to climatic conditions of high humidity and heavy rainfall, and location in the tectonic

belt; v) steep river gradient; vi) poor vegetation on the steep mountain slopes; vii) soil composition of easily eroded unconsolidated sediments; and viii) lack of river treatment and soil erosion control schemes in both the mountains and lowland.

The combination of the above factors results in widespread landslides, slope failure, etc., which further increase the amount of sediment in the rivers.

(2) Geology of the Dam Site

The majority of proposed dam sites are located in the lower Himalaya Zone with Midland Group formation. The 3 sites on the Arun River, however, are located on Himal Gneiss on the northern side of the Main Central Thrust.

All priority sites are marked on the geological map in FIG. 3-1. Site location either on the 2 fault lines or on the carbonaceous sediment zone was avoided owing to difficulty in dam construction. The following points should be considered in geological evaluation of each site:

a) Midland Group rocks are subject to folding and are of complex geological structure. Sun Kosi No. 2 site, for example, has slip-faced layers on a folding axial plan and numerous cracks which should be carefully noted in planning.

b) Excluding Tama Kosi No. 3, the main formation rock of the Midland Group zone site is schist formed by metamorphism of clastic rock with some phyllitic slate interbedded.

c) Tamur No. 3 is an example of sites where the foundation rock is mainly formed of phyllitic rock.

d) As schist is formed from phyllitic rock it is easily broken lamellately, and permeability and rock strength of the same is considered inferior.

e) Tama Kosi No. 3 is composed of paragneiss. The paragneiss, like gneiss and schist, is highly anisotropic rock, which is one cause of weathering.

Detailed investigation of the above for each site is required in the next survey. At present however, the above items do not appear to interfere with dam planning.

(3) Diversion Project Site

The Sun Kosi Diversion Scheme which is one of the top priority projects in the Study, consists of construction of a diversion tunnel 16.6km long to divert water from the Sun Kosi River to the Terai Area. The tunnel route passes through the Neogene formations represented by Mahabharat Range, the Midland Group and Kathmandu Group formed during the Palezoic and Precambrian periods. The Main Boundary Fault divides the above 2 group formations.

The Main Boundary Fault was caused by the upheaval of the Mahabharat Range and a wide shear zone exists in the area of the same. More detailed data are required for further study at the feasibility level.

3.1.3 Climate

The area has two distinct seasons; dry season from November - May and the rainy season from June - October. Prevailing winds during the dry season are westerly while those in the rainy season are easterly, changing direction from the months of April to May, and October to November. During the above periods winds in the upper atmosphere are light and weather conditions are generally fair and stable.

Rainfall during the rainy season has a cycle of about 10-15 days; however, rainfall does not occur in every part of the Kosi Basin at the same time. Rainfall conditions also differ according to elevation. Areas over 3,000m have a high percentage of drizzle while those lower than 2,000m are subject to heavy downpours.

The Study area has a difference in annual average temperature ranging from about 5-25^{o}C. Daily temperature change during the rainy season is comparatively slight. With the end of the rainy season and the coming of strong westerly winds in November, temperature drops rapidly reaching minimum temperatures in January. As temperatures during the dry

season rise during sunshine hours and decrease quite suddenly with nightfall, daily fluctuation in temperature averages about 15-20°C.

Humidity during the rainy season has a monthly average of 90%, with little daily variation in humidity. Humidity in the dry season, on the other hand, varies widely during a one day period and is much lower than that of the rainy season totaling only about 20% of the same. Water content near the soil surface is likewise high during rainy season at 10%, dropping in dry season. Data collected from 15 sites throughout Nepal show that the annual average evaporation rate is 960mm at high elevations and 1,980mm at low elevations.

The majority of precipitation in the Kosi Basin is borne from Bengal Bay by airflows during the rainy season. These airflows cross the Terai Area to the Mahabharat Range and the Himalayan Mountains with heavier rainfall along the plain and between the 2 mountain ranges, decreasing as the airflows reach the higher altitudes in the Himalaya Mountains and pass over to the northern side.

Rainfall distribution in the Kosi Basin can be divided into 2 areas, the Sun Kosi and Arun River basins, where rainfall is distributed in a concentric circular pattern. Maximum rainfall in the Sun Kosi is 3,500mm with a minimum of 2,000mm and rainfall is particularly heavy in the upper reaches of the Sun Kosi along the Bhote Kosi basin where rainfall exceeds 3,500mm.

Maximum rainfall in the Arun River basin is 4,000mm and minimum is 2,000mm. Rain gauge stations in those areas where rainfall reaches levels close to 4,000mm, however, are scarce and figures are therefore based on estimation rather than on actual observation. The Tamur River basin is located in the southeast portion of the Arun catchment basin. Concentric rainfall circle and rainfall for the former is estimated at about 2,500mm.

3.1.4 Rivers in the Study Area

The rivers in the Study area are classified into three types according to nature and origin. The Kosi River with all its tributaries is classified as a type "A" river which have their sources in snow and glaciers in the Himalayan Mountains. The catchment area is estimated to be about 61,000km^2 of which 45% lies in the Tibetan plateau of China.

Type "B" rivers originate in the Mahabharat range and include the Bagmati, Kamla and Kankai rivers. Type "C" rivers originate from the Siwalik Hills and consist of small rivers and streams. The latter are not taken into account in the Study as water is not available from the same in dry season.

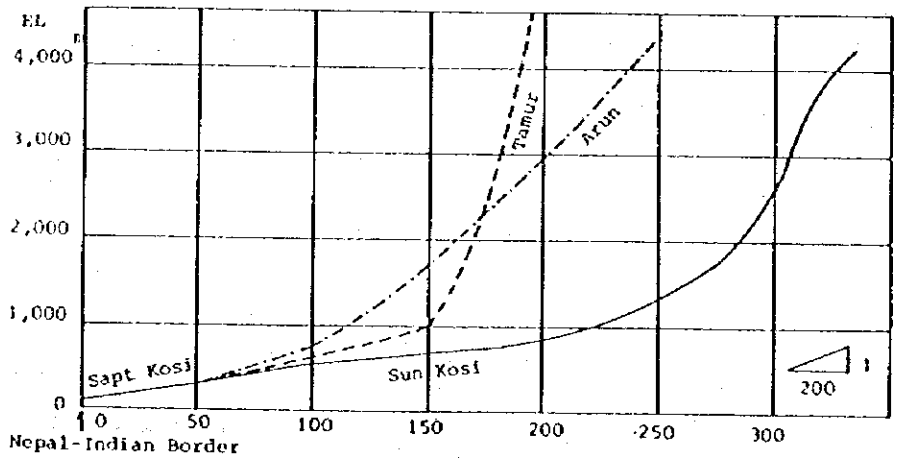
The Kosi River is the largest river in the country, and is formed by seven smaller rivers, the main affluents being the Sun Kosi, Arun and Tamur rivers. These three main affluents finally join near Tribeni village in the Basin to form the Sapt Kosi.

Catchment area and annual runoff of the affluents of the Kosi River at Tribeni are tabulated below.

CATCHMENT AREA AND ANNUAL RUNOFF

River	Catchment Area (km^2)	Annual Runoff ($10^6 m^3$)
Sapt Kosi	61,000 (100%)	50,900 (100%)
Sun Kosi	19,000 (31%)	22,400 (44%)
Arun	36,000 (59%)	18,300 (36%)
Tamur	6,000 (10%)	10,100 (20%)

The river gradients of each of the above are steep particularly in the middle and upstream reaches as shown below.



LONGITUDINAL PROFILE OF AFFLUENTS OF THE KOSI RIVER

In the Terai Area, type "B" rivers, the Bagmati, the Kamla and the Kankai, run from the Mahabharat range to the Ganges plain. These three rivers are relatively large with a catchment area of over 1,000km. A multipurpose dam is planned in the middle reaches of each river for irrigation and hydropower development. The Bagmati and Kankai dam projects are excluded from the objectives of this Master Plan but the Kamla Dam project which was studied in 1967-72 by UNDP/FAO is included in the same as an important component of the Sun Kosi Multipurpose Scheme.

At each guaging station near the proposed irrigation intake sites, the catchment area and annual discharge are as follows:

CATCHMENT AREA AND ANNUAL DISCHARGE

River	Catchment Area (km^2)	Annual Runoff ($10^6 m^3$)
Bagmati	2,720	5,052
Kamla	1,470	1,409
Kankai	1,150	1,643

River flow of type "C" rivers in the Terai Area, which consist of numerous small streams and creeks originating from the Siwalik Hills, fluctuates widely throughout the year. In rainy season, floods cause heavy siltation, erosion of the river banks and damage to farmland while in dry season, these rivers become wadi.

Typical characteristics of rivers in the Study area are as follows:

a) Large fluctuation in river discharge with 80% of discharge concentrated in the rainy season (June to September);

b) Heavy siltation caused by topographical, geological and climatic conditions which contribute to devastiation of the Basin; and,

c) Steep gradient, particulary in the middle and upper stream.

Sedimentation load (suspended load) for the Kosi Basin studied by Dr. C.K. Sharma is presented in the table on the following page.

SUSPENDED LOAD OF THE KOSI BASIN

River	Catchment Area (km^2) at Tribeni	Annual Sediment (m^3)	Sediment Load (suspension) (m^3/km^2)
Sun Kosi	19,230	54,200,000	2,818
Arun	36,533	34,600,000	947
Tamur	5,900	29,600,000	5,016
Total (Sapt Kosi)	61,663	118,400,000	1,920

3.2 Social Features

3.2.1 Administration

Administratively, the Study area consists of 24 districts, out of which 4 districts belong to the Mechi zone, 6 to the Kosi zone, 6 to the Sagarmatha zone, 6 to the Janakpur zone and 2 to the Bagmati zone. The 24 districts comprise a total physical area of 41,674km^2. Each district is directed by a Chief District Officer (CDO). The CDO is the head of the district administration and is responsible for maintenance of law and order and coordination of development activities of different departments. Each district is divided for administrative and political purposes into about 50-90 village panchayats and each of these into nine wards.

3.2.2 Population

The population of the Study area is estimated at 5.9 million in 1981, with 2.6 million in the Kosi Basin and 3.3 million in the Terai Area. The population increased from 4.5 million in 1971 to 5.9 million in 1981 with an average growth rate of 2.78%/annum. Population growth rate of the districts in the Kosi Basin (the Mountain and Hill Areas) was 1.37%/annum between 1971-81, while that of the districts in the Terai Area was 4.08%/annum. The higher rate of population growth in the Terai Area is mainly due to migration from the Mountain and Hill areas.

3.3 Economic Base

3.3.1 Agriculture

The Study area in the Eastern and Central Development Regions makes a substantial contribution to agricultural production in the country, supplying about 60% of national food grains. According to the latest statistical data of 1982/83, the major share of food grain production at the national level in the said area, namely, paddy, wheat, maize, millet and barley is 61%, 65.8%, 56.5%, 44.6% and 28.6% respectively. During the said statistical year, total food grain production in Nepal was about 3.26 million tons while about 1.97 million tons was produced in the Study area.

Commercial crops like potato, sugar cane, tobacco and jute are mostly concentrated in the Eastern and Central Development Regions. Approximately 72.1% of potato, 68.3% of sugar cane, 94.9% of tobacco and almost 100% of jute are produced in the said areas. Moreover, compared with the Western, Middle Western and Far Western Development Regions, fishpond operations, tea gardens and citrus orchards in the Study area are particularly prominent.

3.3.2 Industries

According to the census of manufacturing establishments conducted in 1976/77, there are 1,289 manufacturing establishments in the Study area, of which 1,040 (83% of the total) were oil and grain mills. Activities of other mentionable establishments include baking, sugar refining, tea packing, yarn and textile, carpet and rugs, footwear, sawmilling, printing, soaps, jute processing, ice, furniture, cigarette production and brick making. It is also observed that about 33% of the manufacturing establishments in Nepal are concentrated in the 8 Terai districts of the Study area and that 3 out of 4 large establishments with more than 1,000 working persons are situated in this area, one in Janakpur and two in Biratnagar.

3.3.3 Labor and Employment

According to official statistics, about 66% of the population 10 years and older is considered to be economically active. Based on this estimate, the economically active population in the Study area is

estimated to be about 2.7 million in 1981 and is expected to grow to about 5 million by 2001.

Employment patterns at national and regional levels were surveyed by the National Planning Commission in 1976/77. It was found from survey results that 79% of the economically active population is employed as farm/fish workers followed by 6.9% as production labor workers, 6.9% as clerical workers, 3.5% as sales workers, and 2.4% as service workers and others at the national level. At the regional level, farm/fish workers constituted 85% of the economically active population in rural areas and 35% in urban areas of the Eastern Development Region and 84% and 30% in the Central Development Region.

Persons falling into the economically active population category (age 10 and above) but without participation in any main or subsidiary occupation are defined as unemployed. At the national level, 5.3% of males and 6% of females fall into the unemployed category. The percentage of unemployed for both sexes is 5.6% of the total labor force. At the regional level, rural unemployment for both sexes is higher than the national average percentage (5.6%) of the Central Development Region and lower than the national average in the Eastern Development Region. Urban unemployment for both sexes is higher than the national average (6%) for both the Eastern and Central Development Regions.

Based on the survey report mentioned above, about 85% of the economically active population in the rural areas and about 35% in the urban areas of the Study area are estimated to be employed in the agricultural sector.

3.4 Infrastructures

3.4.1 Transportation

Transportation in the Study area depends mainly on road traffic. The East - West Highway runs through the Terai Area, providing all weather access along the proposed irrigation area. This highway is well maintained and plays a major role in transport of both goods and passengers. There are highways connecting major towns in the Terai Area such as the Biratnagar - Dhankuta Road, Jaleswar - Janakpur Road and others (FIG. 3-4). However, the transportation systems in the mountain

and hill areas is very poor. Most of these areas have not been covered by the national transportation network system, except for the Kathmandu - Kodari Road along the upper reaches of the Sun Kosi River, and common transportation is by footpath. People in these areas spend days in walking, sometimes crossing rivers to reach their destination, whether it be for pleasure or trading purposes. Ferry services and manual ropeways also exist at many locations along rivers.

In order to improve the present limited transportation system in the hill and mountain areas the HMG intends to construct an east-west highway along the Sun Kosi and the Tamur. The planned route will link Dolalghat on the Kathmandu-Kodari Highway with Phidim on the Illam-Taplejung Highway passing through Ramechap, Bhojpur, and Dhankuta. This road will substantially contribute to socioeconomic development in the regions concerned. However, it may take quite some time to complete the road due to the substantially large construction cost. Environmental impacts and economic viability of the road should also be clarified before implementation.

3.4.2 Irrigation Facilities

Various irrigation projects have been formulated and implemented in the Terai Area, which has a cultivable area of 749,000ha. These include the Bagmati, Kamla, Rajbiraj Pump Canal, Kosi West Canal, Trijuga/Chandra Canal, Sunsari Morang and Kankai irrigation projects, most of which are on-going projects. Designed intake for the same consists of construction of barrage or head works on the upper stream of the main rivers. Main canals of these projects have a design capacity of about 1 ℓ/sec/ha. The Bagmati, Kosi West canal, Rajbiraj Pump Canal, Sunsari Morang and Kankai irrigation projects are planned to provide year-round irrigation water. However, Kamla and Trijuga/Chandra Canal projects can supply irrigation water primarily during rainy season and only 10 to 30% of the water requirement in dry season. A considerable amount of sediment load can be observed upstream of the barrage and in the main canals because most barrages are fixed weir type. The main portions of main canals are made of earth, but those portions with permeable soils are lined with concrete or brick.

3.4.3 Electricity Services

The Electricity Department (ED) is responsible for power development planning for the entire country, construction of all major generation and transmission facilities, and regulating private utilities. It is also in charge of the operation and maintenance of power supply facilities even after construction of the same in the Far and Mid Western Development Regions. The Nepal Electricity Corporation (NEC) is exclusively responsible for the operation and maintenance of all power supply facilities in Nepal except the Far and Mid Western Development regions. Planning and implementation of power distribution facilities are also executed by NEC. Since the Butwal Power Company and the Eastern Electricity Corporation were incorporated into NEC in 1982, NEC has been in charge of regulating power exchange with India along the border. The current level of power export to India, exclusively through the Raxaul region, is about 6.0GWH/year while Nepal imports approximately 55.0GWH/year from India at 15 points along the border to supply non-integrated load centers in Nepal.

Electric power supply in the Study area is mainly served by NEC through the Central Nepal Power System (CNPS) and Eastern Nepal Power System (ENPS). In addition, there are a number of small systems around the towns of Janakpur and Biratnajar.

3.5 Water Resources

3.5.1 Water Resources in the Kosi Basin

The Kosi River is the largest river in Nepal and is composed of the Sapt Kosi and all its tributaries with a catchment area of about 60,000km^2. Main affluents, the Sun Kosi, Arun and Tamur rivers meet at Tribeni about 5km upstream of Barahkshetra and form the Sapt Kosi. The latter flows into the Terai Area with an average annual discharge of approximately 50 billion m^3. River discharges of main affluents are shown below.

DISCHARGE OF SAPT KOSI, SUN KOSI, ARUN AND TAMUR RIVERS

River	Sapt Kosi	Sun Kosi	Arun	Tamur
C.A (km^2)	61,000	19,000	36,000	6,000
at Barahkshetra	100%	32%	58%	10%
Annual discharge (10^6m^3)	50,900	22,400	18,300	10,100
(1948-71 Average)	100%	44%	36%	20%

The Kosi River is endowed with not only abundant water resources but also with topography and steep riverbed gradient suitable for water resource development. Although theoretical hydropower potential of the same is estimated at 22,000MW, there are only 3 power plants, total capacity of which is only 12,690kW. Moreover, the Sapt Kosi, through the Sunsari-Morang and Kosi West Canal projects, directly irrigates only about 90,000ha of the approximately 750,000ha of arable land in the Terai Area which covers about 250km E-W and about 40km S-N.

In addition to major studies on the Kosi High Dam, Mulghat and Kurule projects, various irrigation projects have been previously studied, some of which are now being implemented. However, a comprehensive study on water resource development of the entire catchment area, has not been made. To this end, the subject Study was carried out to clearly identify the potential of water resources in the Kosi Basin. The Study consists of hydropower development plans in the Basin and new irrigation plans in the Terai Area fully utilizing the water resources of the Kosi River, including trans-basin diversion projects and other components such as flood control, navigation, inland fisheries, and taking into consideration soil erosion, sedimentation, etc.

The Kosi Basin is severely devastated in several areas. Problems to be solved for water resource development in the Kosi Basin concern the following:

- Heavy siltation
- Watershed management, soil conservation
- Access road
- International influence

3.5.2 Water Resources in the Terai Area

There are numerous rivers and rivulets traversing the Terai Area from north to south. The Sapt Kosi which is actually a confluence of the Sun Kosi, Arun and Tamur, runs through the Terai Area, dividing the same into two parts, one in the east and the other in the west. Type "B" rivers which originate in the Mahabharat ranges include the Bagmati, Kamla and Kankai. The Bagmati consitutes the western boundary of the Study area. The Kamla River is situated between the Bagmati and the Sapt Kosi rivers and forms the district boundary between Siraha on the east and Dhanusha on the west. The area between the Bagmati and the Sapt Kosi which includes 5 districts is referred to as the Sapt Kosi West area. The area between the Sapt Kosi and the Kankai which includes 3 districts is known as the Sapt Kosi East area.

River discharge of the main rivers in the area are presented in the following table.

River	Sapt Kosi	Bagmati	Kamla	Kankai
C.A (km^2)	61,000	2,720	1,470	1,150
Annual discharge ($10^6 m^3$)	50,900	5,052	1,409	1,643

There are also numerous small rivers and creeks originating from the Siwalik Hills. These rivers were not taken into account in irrigation planning as no dependable water is available during the dry season.

Ground water development by tubewell is underway in some parts of the Terai Area. Most ground water irrigation projects consist of small scale shallow tubewell systems, e.g., the Sagarmatha Irrigation Project with command area of 15,300ha irrigated by 510 tubewells. Since the Study is confined in terms of effective development of the Kosi River, ground water development was not studied in this report.

3.5.3 Present Use of Water Resources

(1) Hydropower

Theoretical hydropower potential of the Kosi River with its steep incline and abundant discharge is estimated at 22,000MW. At present however, only 3 hydropower stations have been developed within the catchment area accounting for only 0.06% of the above potential as tabulated below.

EXISTING HYDROPOWER STATIONS

Power Station	Installation Capacity	Commissioned
Panauti	2,400kw	1963/64
Sun Kosi	10,050kw	1972/73
Dhankuta	240kw	1972/73
Total	12,690kw	

(2) Irrigation Use

1) Tar irrigation

Land is cultivated up to an elevation of 2,500m in the Kosi Basin, as in other valleys in Nepal. A tar irrigation field is spread along the river, with a command area varying widely from a few to 200ha and served by primitive irrigation facilities.

2) Existing irrigation projects

The soil of the Terai is well-drained and fertile, and the area is developing into Nepal's agricultural belt. Annual rainfall for the same however is only 1,000-1,600mm. Accordingly, several on-going and existing projects have been developed to ensure adequate irrigation and water supply systems.

Irrigation projects are divided into gravity (G.T.), lifting (L.T.), and tubewell types (T.T.) while those for water supply systems are divided into year-round and supplementary systems. Those projects which occur within the

Study area are listed below. In addition to those projects in the table, there are 2 existing canals; namely, the Kosi Eastern Canal (Q max 500m^3/s) and the Kosi Western Canal (300m^3/s), both originating from the Bimnagar Barrage on the Sapt Kosi and crossing the Nepal-India border, as well as several tubewell irrigation projects in various localities in the Terai Area.

ON-GOING & EXISTING PROJECTS IN THE STUDY AREA

Water Source	Name of Project & Gross Command Area	Status	Water Source & Intake Quantity	Irrigation Type	Water Supply System
Sapt Kosi River	1. Sunsari Morang 107,700ha	On-going	Sapt Kosi Q max=45m^3/s	G.T.	year-round
	2. Rajbiraj Pump-up 16,450ha	On-going	Sapt Kosi - West canal Q max=8.7m^3/s	L.T.	year-round
	3. Kosi West Canal 15,000ha	On-going	Sapt Kosi Q max=17m^3/s	G.T.	year-round
	4. Trijuga-Chandra 16,250ha	Existing	Trijuga Q max=11.3m^3/s	G.T.	year-round
Other Rivers	5. Bagmati Left Bank 109,500ha	On-going	Bagmati River Q max=64.4m^3/s	G.T.	supplementary (future; year-round)
	6. Kamla 65,450ha	Existing	Kamla River Q max=28m^3/s	G.T.	supplementary
	7. Kankai Right Bank 17,450ha	On-going	Kankai River Q max=25m^3/s	G.T.	supplementary (future; year-round)

(3) Other Use

1) Inland navigation

Ferry crossings have been established at various intervals along the Kosi River and its tributaries. The majority of boats serving the same, however, are small and ferry activity is minimal. Passengers or goods are not transported along the length of the river from upstream to downstream nor vice versa.

2) Inland fisheries

The importance of inland fisheries has been recognized in recent years in Nepal and opportunities for development of fish farms in each area are being investigated. Although capture fisheries are popular among residents along the Kosi River, the same have not reached the level of actual occupation.

IV. DEVELOPMENT STRATEGY

4.1 Government Policy for Development

4.1.1 Basic Policy and Strategy

Since Nepal launched its initial development plan in the mid 1950s, the country has continued with planned development efforts through the formulation and implementation of four five-year plans and a three-year plan. In the Sixth Plan, initiated in 1980, HMG places greater emphasis on direct productive activities. The main objectives of the Sixth Plan are: i) increase in production and employment opportunities and ii) fulfilment of the basic needs of the people. To achieve these objectives, development strategies as set in below have been established.

a) agricultural development as priority;

b) development of cottage and small industries;

c) focus on export trade and development of tourism;

d) conservation of natural resources and development of water resources;

e) full utilization of infrastructures already created; and,

f) increased absorptive capacity of the economy.

Water resources development strategies are specifically aimed at maximum utilization of the unlimited water resources available in the country for hydropower, irrigation, and other utilities which can not only meet long term national needs but also create surpluses for export, thus generating employment opportunities and export earnings. In development of these resources, however, countermeasures must be taken for the control of soil erosion and the conservation of forest resources.

4.1.2. Strategy for Regional Development

Regional development (both geographical and administrative) and development of the national economy should be viewed as parts of a single process. The progress of the national economy will be reflected in the rate of growth realized by different regions and, in turn, greater deployment of resources in the regions must contribute towards accelerating the rate of progress for the country as a whole.

Due to differences in resources and the disproportionate population, regional imbalances exist not only in north-south geographical regions but in east-west regions as well. For the development of the national economy, a balanced regional development is one of the most important policies of HMG. To gradually remove regional imbalances, HMG places emphasis on: i) increased food production in all food scarcity areas; ii) development of cottage and small industries; iii) increased economic investment in less developed areas; and iv) participation of local people in development activities.

Taking into account the policy of HMG mentioned above, the strategy for regional development and selection of projects should be based on: i) maximum utilization of natural resources in each region; ii) maximum utilization of local labour; and iii) economic integration of isolated economies by construction of approach and access roads for the proposed projects.

4.1.3 Sectoral Policies

(1) Power and Industry

In view of the importance of water resources in the country, priority is given to hydropower projects which are designed to meet the short and mid-term power needs of the country along with the implementation of multipurpose hydroelectric projects covering power supply, irrigation, flood control and drinking water as far as practicable. One of the basic policies governing electricity production is to develop hydropower schemes which can meet not only the long-term power needs of the country but also create a surplus, the export of which can augment foreign exchange earnings.

Main objectives of the Sixth Plan of industrial development are to create industrial employment opportunities and absorb excess manpower from the agricultural sector, to become self-sufficient in daily essentials and some building materials within the shortest possible time, and to develop export-oriented industries which will have the effect of improving the national economy. In the industrialization process of Nepal, cottage and small industries play a pivotal role. The prospects of large industry development

are limited chiefly owing to the fact that the purchasing power of the majority of the people is low and the domestic market is small. Under these circumstances, the needs of the scattered local market can be met by setting up small industries. Since these industries are by nature labor-intensive, employment opportunities will be created.

(2) Agriculture and Irrigation

Since agriculture contributes about 60% to the gross domestic product, generates 90% of the employment and produces 80% of the export, it is obvious that agriculture is a prominent source of increasing production and employment. The long-term objectives in relation to agriculture are:

a) increased production of food grains, fruits and animal based foodstuffs in proportion to the nutritional needs of the growing population;

b) increased agricultural production to create surplus needed for capital formation in other sectors of the economy and to increase production of exportable commodities so as to maintain the country's balance of payments;

c) provision of raw materials for agro-based industries and provision of employment to the growing number of unemployed; and,

d) launching more agricultural development programs in the mountainous region in order to remove intersectoral and inter-regional imbalances, while putting the hill economy on a firm footing.

Irrigation is accorded very high priority in agricultural development and regarded as the key to increased crop production, particularly in the Terai Zone. At the end of the Sixth Plan period, irrigation would be provided to 233,482ha as compared to 95,425ha during the Fifth Plan period. Out of the total, 22,730ha would be supplied with ground water and the remaining with surface water. The Terai Zone would account for more than 200,000ha of the total.

(3) Other Sectors

In consideration of the yearly increase in natural calamities such as landslides and floods in Nepal, priority is given in the

Sixth Plan to conservation and expansion of water resources, forest and endangered animal species in the interest of ecology. The policy under the Sixth Plan is to prevent the diversion of cultivable land to unproductive use and to develop forests and meadows in lands which have no agricultural use. Watershed management in the principal catchment areas of the country should be conducted by means of tree planting, soil erosion protection works and other effective actions to prevent further deterioration.

4.2 Development Strategy for the Kosi Master Plan

4.2.1 Main Development Objectives

Generally, objectives of the Water Resources Development scheme are to develop, inter alia, hydropower, irrigation water, flood control, potable water, industrial water, navigation, inland fishery and tourism. At the same time, watershed management for the maintenance of natural flow, protection against devastation of the Basin and environmental conservation is incorporated into the development plan as an important component.

In the case of the Kosi River, hydropower and irrigation development will be the main objective of water resources development for the following reasons.

a) Despite a huge potential for hydropower development, Nepal has one of the lowest per capita energy consumptions in the world. As with other rivers throughout the country, the Kosi River has not been adequately developed as a hydropower resource, despite favorable natural conditions such as abundant water quantity and steep topography.

   Development of this attractive large hydropower potential is envisioned to enhance domestic use and energy export.

b) Agriculture in Nepal is an extremely important industry for the country, representing more than 60% of the GDP and 90% of the labor force. However, given the forecasted food balance between demand and supply, Nepal may become a food importing country in the near future.

   The Terai Area, which is the Nepalese food supply belt, is not fully productive due to unsatisfactory irrigation facilities despite the area's favorable climate and land conditions.

To improve this situation agricultural development in the Terai Area is highly desirable. To this end, tapping of adequate irrigation water from the Kosi Basin is planned.

c) Since construction of river embankments was completed between the Nepal - India border and Chatra in 1963, no flood damage has occured in Nepalase territory.

In future, large reservoir projects will be required to further strengthen flood control. Previous to such work, however, assessment of the nesessity for flood control on the Indian side is required.

d) Potable and industrial water developments from the rivers in the Kosi Basin are not presently required. It is estimated that ground water in the Terai Area is adequate as a potable and industrial water source in terms of socio-economic development. Generally, ground water in the area is most suitable due to high quality and constant lower temperature.

e) Navigation, inland fishery and tourism are also anticipated to greatly improve as a result of water resources development.

Water surfaces of these reservoirs and increased river flow in dry season can be used for navigation, inland fishery as well as tourism.

In addition, development of access roads will also contribute to rural development and tourism.

(1) Watershed Management as a Development Strategy

Watershed management is indispensable for water resources development. In the Kosi Basin, the devastation of watershed is progressing rapidly due to severe natural conditions and insufficient management. Present heavy siltation of the Kosi Basin will not only shorten the life of developed reservoirs but also reduce the capacity of irrigation facilities by heightening the riverbed at intake sites and increasing sedimentation in irrigation canals.

Although it is a complicated task due to the many causes of present devastion, some countermeasures and recommendations are presented for watershed management in this report.

(2) Environmental Impact

Substantial changes will occur in the present environment with construction of water resources development facilities. Upon completion of the works, a new water environment will be created by dams reservoirs and other facilities.

In order to retard the present devastation of the natural environment in the Kosi Basin and improve the situation, numerous reports have been prepared in such fields as afforestation, soil conservation and landslide protection. Many of the same have pointed out the difficulty in implementation of protection works due mainly to limited funds and accessibility.

In this connection, water resources development in the Basin could be effective as the same would stimulate development while providing accessibility to areas of severe erosion. In addition, electrification of nearby project sites will be promoted, thus reducing fuel wood consumption. Consequently deforestation in the Basin is anticipated to decrease. Present inland fishery activity will be affected by the proposed reservoir and a substantial social impact will occur by the implementation of water resources development projects. Appropriate measures should therefore be taken to compensate those effected.

(3) Development Strategy for Hydropower

The Kosi River has a substantial hydropower development potential with comparatively low cost in comparison with any other energy source including nuclear, coal, oil and LNG. As is commonly known, hydropower, once developed can supply at almost a constant price without economic inflation.

The Master Plan for hydropower development in the Kosi Basin has been carefully made to meet energy export as well as domestic requirements. Hydropower planning was carried out in due consideration of effective long term development. Hydropower planning was undertaken for the entire Basin and on sites which would result in an installed capacity of over 10MW.

The planning concept was established after discussion with HMG as follows:

- 1st category	local demand
- 2nd "	domestic demand
- 3rd "	energy export

The Projects in the 1st category are mainly intended to provide energy for local needs, while projects in the 3rd category are largely export oriented, the development of which will depend upon international negotiation. To strengthen the national economy the projects in the 2nd category should be given priority for development.

(4) Development Strategy for Irrigation

Nepal anticipates to become a food import country in the near future despite her agricultural base. Arable lands in the Terai and Hill areas up to El.2,500m are almost completely developed for farmland. Present status of agricultural production in the country is very low and unstable due to insufficient irrigation water supply and other agricultural inputs. Therefore, increased agricultural production is possible by the expansion of irrigation command area through the establishment of a stable irrigation water supply through the year.

At present, it is reported that 15% of the farmland in the area is covered by existing irrigation projects (including on-going projects), but these existing projects are for the most part supplementary irrigation water supply systems in rainy season, rather than year-round irrigation systems. Supplementary irrigation systems limit potential increase in crop intensity. Thus to increase crop intensity and agricultural production, year-round irrigation water supply systems are required.

Fortunately, there are abundant water resources in the Kosi Basin from which irrigation water can easily be supplied via a diversion tunnel from the Kosi Basin to the fertile and well-drained soil of the Terai Area.

According to the Scope of Works, the study should only be based on diversion from the Kosi Basin. Therefore, irrigation schemes by diversion from the Kosi Basin to the Terai Area are planned. In this case, as a development strategy, the irrigation command area will be examined to maximize the same as much as economically possible, considering agricultural conditions forecasted for future food balance in the country.

V. DEVELOPMENT POTENTIAL STUDY

5.1 General

5.1.1 General Concept for the Study

Numerous potential hydropower and multipurpose dam development sites were technically and economically investigated giving relevant attention to the previously studied and subsequently proposed 3 projects; namely, the Kosi High Dam, the Kurule, and the Mulghat projects. Hydropower, irrigation and flood control components were mainly studied including the multipurpose dam plans, and with additional studies on watershed management, siltation, navigation and inland fishery.

In the case of hydropower development, all the potential development sites were first identified on the basis of topographical maps and available hydrological data. After field reconnaissance and investigation of these potential development sites, appropriate development schemes were formulated considering technological and economic aspects. Concerning irrigation potential in the Terai Area by utilizing Kosi River water resources, project studies were undertaken for cases of either direct intake from the Sapt Kosi River or trans-basin diversion from either the Sun Kosi or the Tamur rivers.

The goal of irrigation planning is to maximize both cropping intensity and agricultural productivity through year-round irrigation of as large an area as topographically possible in the Terai Area utilizing Kosi River water resources. In this connection, various existing and on-going irrigation projects in the Terai Area were reviewed. All supplementary irrigation projects among the same were incorporated within the Study in such a way that the same will be converted into year-round schemes.

In addition to the aforementioned hydropower and irrigation development planning, studies were conducted on heavy siltation, soil erosion and access road issues inherent to the Kosi River. Development potential for flood control, navigation and inland fishery were also studied to give suggestions for future detailed studies.

5.1.2 Kosi Basin

The Sapt Kosi River, a tributary of the Ganges River, consists of 7 large tributaries, i.e., the Sun Kosi, Arun, Tamur, Dudh Kosi, Likhu Khola, Tama Kosi, and Indrawati rivers. These rivers also have their own tributaries: the Rosi Khola, Khimte Khola, Bhote Kosi, Balephi Khola, Maulung Khola, and Kabeli Nadi rivers. The Sapt Kosi River and its tributaries are characterized by large sediment load and steep gradient.

The Nepal side of the Kosi Basin is favored with abundant precipitation (over 2,000mm), and total annual discharge at the confluence of 3 large tributaries, the Sun Kosi, Arun and Tamur rivers is estimated to be approximately $50 10^9 m3$. Theoretical power potential of the major and small rivers were estimated in HMG's previous study as 18,750MW and 3,600MW, respectively and 22,350MW in total in the Sapt Kosi River.

Development potential of the 3 major rivers is described below.

(1) Sun Kosi River Development

Topographically, the river gradient of the middle and lower reaches of the Sun Kosi River is gentle, and this area will be developed by a reservoir type dam with maximized capacity. River flow fluctuation between the rainy and dry seasons is very high. To cope with this natural condition, a multipurpose dam and reservoir type power station can be planned to effectively regulate annual flow. Reservoir capacity, however, is restricted by topography, geology and other factors. The reservoir capacity of the Sapt Kosi High Dam was derived from the "Feasibility Report on Kosi High Dam Project" prepared by the Government of India in May, 1981.

Regarding the tributaries, the lower reaches of the Dudh Kosi, Tama Kosi and Indrawati rivers have relatively low river gradient. To meet the daily peak demand, pondage run-of-river (PRR) type power stations are planned. In the upper reaches of the rivers, to fully develop potential energy in Nepal, simple run-of-river (SRR) type power stations are planned.

(2) Arun River Development

The runoff fluctuation is small in comparison with the Sun Kosi and Tamur rivers. It is difficult to develop a large reservoir type dam on this river due to topographical conditions and heavy sedimentation. SRR type development was selected through comparative study of PRR and SRR types based on topographical maps, site reconnaissance, hydrological data and other information.

(3) Tamur River Development

A feasibility study of a medium-size hydropower project at Mulghat site was completed in 1982. This site will be submerged after completion of the planned Sapt Kosi High Dam, and was studied as a temporary project until the said High Dam is implemented. Hydropower generation at Mulghat site was disregarded in the Master Plan as a result of the overall development study.

The Tamur River has a relatively low gradient in the middle reaches, where the development of reservoir or PRR type power projects is possible. Reservoir type development was adopted on the basis of comparative study.

5.1.3 Diversion and Irrigation

The Terai Area has great potential for agricultural development. It has a tropical climate, is well drained, has fertile soil, and is in an important productive agricultural belt in Nepal. The area has an annual rainfall of 1,000-1,500mm which is concentrated in the rainy season of June to September, during which up to 80% of annual rainfall occurs. Consequently, despite the favorable climate and soil conditions, the area's agricultural potential has not been fully exploited due to irregular water supply. Seasonal fluctuations are further complicated by yearly fluctuations in annual rainfall, resulting in variations in agricultural production from year to year. For this reason, numerous irrigation projects are presently being undertaken. However, most of these projects (apart from those irrigation projects deriving their water supply from the Sapt Kosi River) are not functioning as year-round irrigation systems because water supply is derived only from medium sized rivers in the Terai Area. These supplementary irrigation projects can not

be expected to significantly increase agricultural production, as cropping intensity under the same will be limited to as little as 140%.

The Kosi River, on the other hand, has abundant water resources and could be tapped by diverting its water to the Terai Area through a tunnel. The idea to divert water from the Kosi River to the Terai for realization of a substantial increase in agricultural production in the latter, was studied under sponsorship of FAO and UNDP during 1968-72. However, the same has not yet been realized.

In this Study, the previous study reports were carefully reviewed and a new diversion scheme was proposed under present conditions from the viewpoint of full utilization of the water resources of the Kosi River.

5.2 Previous Studies

In the Kosi Basin, the following studies for water resources development have been carried out with regard to utilizing the Kosi River.

- Feasibility Study of Irrigation Development Project in Terai Plain, UNIDO, 1972
- Feasibility Study of Kosi High Dam Project, Government of India, 1981
- National Hydroelectric Projects Reconnaissance Profiles, Water and Energy Commission, 1981
- Feasibility Study of Mulghat Hydropower Project, Asian Development Bank, 1982

5.2.1 Feasibility Study of Irrigation Development Project in the Terai Area (Sun Kosi Diversion Plan)

In the Feasibility Study of Irrigation Development in the Terai Plain (Phase II) commissioned by FAO/UNDP and completed in 1972, irrigation development potential in the eastern Terai, located between Birganj - Sapt Kosi River, (gross land area: 540,000ha) was studied. Considering four major sources of water, namely, the Bagmati River, Kamla River, ground water and possible diversion of Sun Kosi River water, the following five new irrigation development plans were examined and assessed in the feasibility study report.

- Kamla River Development
- Bagmati River Development
- Sun Kosi River Non-diversion Development

- Groundwater Development
- Sun Kosi Diversion with Kamla River Development

Project analysis was made of the alternative cases for each plan to find the optimum scale of each project. The last plan mentioned above proposed provision of irrigation water from the Kurule site, about 10km downstream from the confluence of the Sun Kosi and Dudh Kosi River, to the Kamla River through a 15km long tunnel. The first plan, on the other hand, proposed water supply from the Kamla River alone without diversion of the Sun Kosi River. The results of project analysis for these two plans are presented below.

RESULTS OF PROJECT ANALYSIS

Project	Internal Rate of return (%)	Irrigation Area Rainy Season (ha)	Irrigation Area Dry Season (ha)	Effective Storage Capacity ($10^6 m^3$)	Power Peak (MW)	Power Firm (MW)
Kamla (without diversion)						
1-A Phase I	19.5	20,000	17,000	0	0	0
1-B Phase II	9.3	76,000	72,000	1,040	0	0
1-C Phase I+II	10.8	96,000	96,000	1,040	0	0
1-D Phase I+II+Flood Control	12.2	96,000	96,000	1,040	0	0
1-E Phase I+II+Fl. C+Power	11.9	96,000	96,000	1,040	10	9
Sun Kosi Diversion to Kamla						
2-A 100 m^3/sec div.	11.5	799,000	489,000	660	0	0
2-B 150 m^3/sec div.	10.5	885,000	498,000	1,040	0	0
2-C 150 m^3/sec div.+Power	10.9	885,000	498,000	1,040	189	120

Source: F/S Report of Irrigation Development in the Terai Plain (Phase II),1972

5.2.2 Feasibility Study of the Kosi High Dan Project

The development of the Sapt Kosi River has been planned and investigated by the Government of India and the "Feasibility Study Report on the Kosi High Dam" was submitted in 1981. The project envisions construction of a large dam at the gorge 2km upstream from Barakashetra aiming at power generation, flood mitigation, irrigation, and protection of sand and soil downstream. An outline of this project is presented on the following page.

OUTLINE OF THE KOSI HIGH DAM
PROJECT PROPOSED BY INDIA

Item	Dimensions
Reservoir	
Catchment Area (km^2)	59,539
High Water Level (m)	El. 335.25
Inundation Area (km^2)	194.2
Total Water Storage Volume ($10^6 m^3$)	13,450
Available Capacity ($10^6 m^3$)	9,370
Dam	
Height (m)	269
Type	Concrete gravity
Power Generation	
Dam Generation (MW)	3,000 (500MW x 6 units)
Canal Generation (MW) (canal length: 45km)	300 (100MW x 3 stations)
Irrigation	
Gross Command Area (ha)	
- India	976,000
- Nepal	546,000
- Total	1,522,000
Chatra Barrage Length (m)	969.9

The project will be reviewed and assessed from the viewpoint of the overall water resources development plan of the Kosi River. The assessment of the project will be made on the basis of available data in Nepal and national needs will be given first priority.

5.2.3 National Hydroelectric Projects Reconnaissance Profile

The Water and Energy Commission of MWR, HMG carried out a reconnaissance field survey for hydropower development in the Kosi Basin under CIDA assistance. The surveyed projects are listed below.

Arun River

- Tumlingtar Micro Project

  This project is planned as a micro hydropower project with an installed capacity of 2MW and is thereby disregarded in the Master Plan Study.

- Upper Arun Diversion Project

  This corresponds to the Arun No. 3 project (in this Master Plan Study).

Tamur River

- Pithun Project

  This corresponds to the Tamur No. 7 project.

- Taplejung Project (Alternative B)

  This corresponds to the Tamur No. 4 project.

- Bhaniyang Project

  This corresponds to the Tamur No. 3 project.

Indrawati River

- Indrawati Diversion Project

  This corresponds to the Indrawati No. 3 project.

- Indrawati Storage

  This site will be submerged by the Sun Kosi No. 3 project and is therefore disregarded in this Report.

Tama Kosi River

- Tama Kosi Diversion Project

  This diversion project intakes water from the Khimte Khola to the Tama Kosi River through a 10km headrace tunnel. This is disregarded on the basis of the comparative study of the projects (Khimte Khola No. 1, No. 2), which have headrace tunnels on the Khimte Khola river and powerhouse near the confluence of Tama Kosi River. The Tama Kosi and Khimte Khola rivers have been planned for independent development in this Report.

Likhu Khola River

- This site is selected between Likhu Khola No. 3 and No. 4.

Dudh Kosi River

- Dudh Kosi (1) Project

  This corresponds to the Dudh Kosi No. 6 project.

- Dudh Kosi (2) Project

  This corresponds to the Dudh Kosi No. 5 project.

- Dudh Kosi (3) Project

  This corresponds to the Dudh Kosi No. 3, 4 projects.

- Dudh Kosi Diversion Project
  This is disregarded due to submergence by the Sun Kosi No. 1 dam.
- Mulghat Project
  This is disregarded due to submergence by the Sapt Kosi High Dam in this Report.

5.2.4 Feasibility Study of the Mulgat Hydropower Project

ADB prepared the feasibility study for the Mulghat Hydropower Project for MHG in May 1982. Features of the project are as follows:

- C.A.	5,640km^2
- Dam	
Type	Concrete gravity
Height	68m
Crest length	200m
- Reservoir	
H.W.L.	EL 311.0m
L.W.L.	EL 310.0m
Vg	63.5 10^6m^3
Vg	4.0 10^6m^3
- Power Generation	
Type	160.0m^3/s
Q max	49.0m
P max	70.0 MW (23.3 x 3)
- Tail race water level	EL 257.0m

This project is planned to obtain effective benefit in the period before the completion of the Kosi High Dam as it will be submerged by the Kosi High Dam (H.W.L. 335.25m) proposed by the Government of India.

5.3 Multipurpose Dam

5.3.1 General

The large reservoir of the high dam will effectively utilize water resources not only for hydroelectric power generation but also for irrigation, flood mitigation and other potentials. River flow in Nepal fluctuates greatly as approximately 80% of annual rainfall is concentrated in the rainy season. To utilize water resources fully or effectively, a large reservoir is required.

The potential for reservoir development was studied on all rivers in the Kosi Basin, including the Sun Kosi, Arun, Tamur and Sapt Kosi rivers. Studies were based on the existing and newly prepared topographical maps to confirm the reservoir capacities required to counteract the high sedimentation volume in the rivers.

The longitudinal profiles of all rivers were prepared to determine reservoir development potential, and the following four rivers were studied in detail to confirm effective reservoir volumes, topography and geological conditions.

- Sun Kosi River
- Arun River
- Tamur River
- Sapt Kosi River

5.3.2 Sun Kosi River

(1) Layout of the Study

The total length of the Sun Kosi River is approximately 330km, of which 280km lies in Nepalese territory. The river gradient is approximately 1/210 throughout the entire length of its course in Nepal and 1/450 between Tribeni and Dolaghat. The Sun Kosi, Tamur and Arun rivers meet at Tribeni and the Indrawati River joins the Sun Kosi River at Dolaghat.

Reservoir development can be effected along the river course between Tribeni and Dolaghat. For optimum development of the said area, the following were considered:

a) Construction of a high dam is planned downstream of the confluence of the three main affluents;

b) In the upstream courses of the dam site, the construction of three other dams, the Sun Kosi No.1, No.2 and No.3, was considered;

c) A dam site at Kurule is considered as the best choice for the Sun Kosi No. 1 scheme in consideration of the high water level of the Sapt Kosi High Dam and the future inter-basin diversion project from the Sun Kosi River to the Terai Area;

d) Alternative dam heights were studied for the Sun Kosi No.1 scheme;

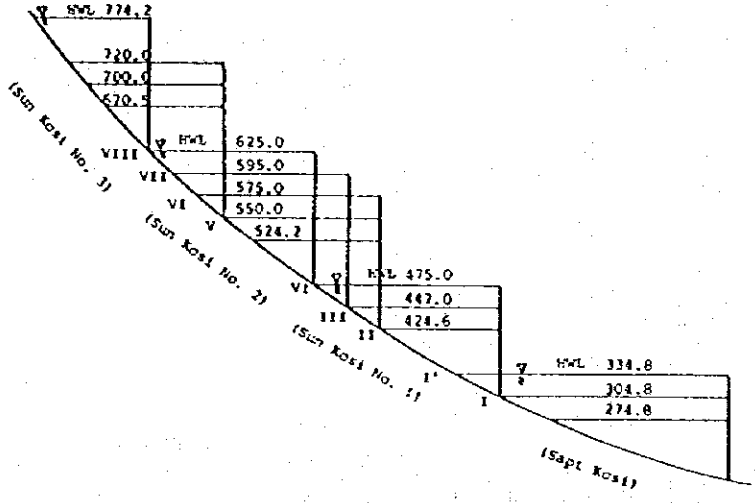
e) The Sun Kosi No.2 dam site should be placed at the elevation coinciding to the highest water level of

the Sun Kosi No.1 site and the alternative dam heights of 60-80m for the same were studied at each site;

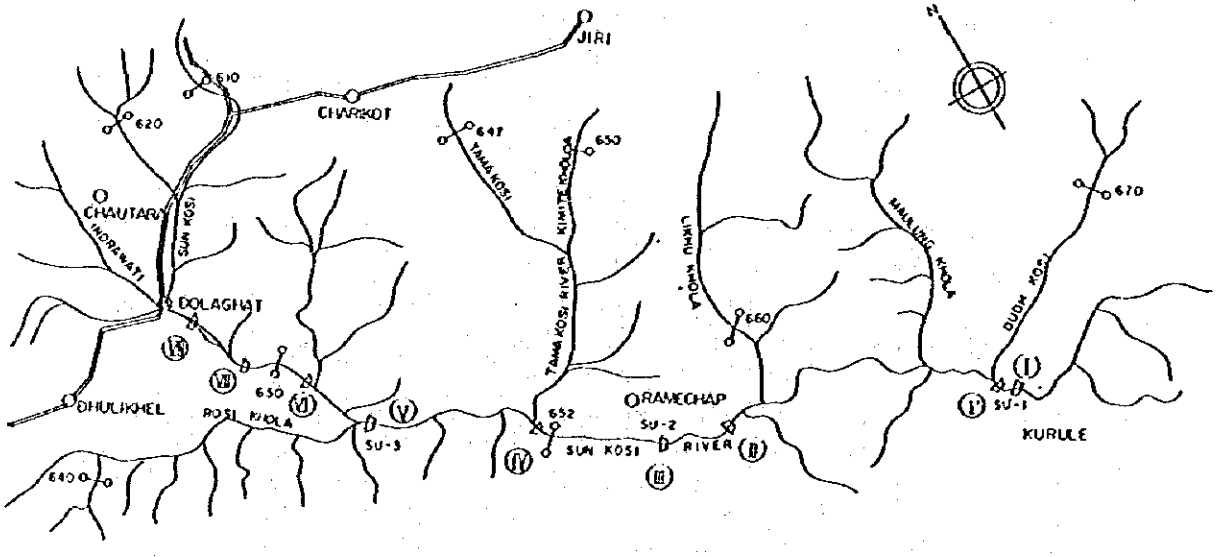
g) The Sun Kosi No.3 dam site was selected and studied in the same way as Sun Kosi No.2;

h) Three cases of dam height were studied for the Sapt Kosi High Dam.

The above-mentioned layouts are shown below.



LAYOUT PROFILE OF SAPT KOSI AND SUN KOSI NO. 1 - 3



LAYOUT PLAN OF SUN KOSI NO. 1 - 3

(2) Optimum Dam Planning

The optimum dam plan on the Sun Kosi River was determined through comparative study of the alternative combinations of the Sapt Kosi High Dam and Sun Kosi No.1 - No.3. Comparative study was carried out by quantifying cost and benefit in terms of electricity which are shown in the section on hydropower. The selected combinations are listed in TABLE 5-1.

The planning criteria were as follows:

a) Reservoir storage capacities were estimated on the basis of newly prepared maps (scale: 1/20,000) for Sun Kosi No.1 -No.3 Dams and of the "Feasibility Study Report on Kosi High Dam" for the Sapt Kosi High Dam; and,

b) The available storage volumes were estimated applying the Brune's trap efficiency to the sediment load of 2,840m^3/km^2/year. In this case, four reservoirs were independently estimated.

The selected development combinations shown in TABLE 5-1 are as follows:

Alternative: 1

This is the most economical alternative in view of the hydropower component. Irrigation water supply to the Terai Area through the diversion tunnel taken at Kurule, will be ensured after completion of the Sun Kosi No.2 dam. Downstream effects will be mitigated by annual regulation to compensate river water in dry season.

Alternative: 2

This is less economical than Alternative 1. However, irrigation water will be ensured after completion of the Sun Kosi No.3 dam, development of which is easier than that of the Sun Kosi No.2 dam due to lower construction cost and easier access. SU-3 cannot provide complete downstream compensation by diversion due to smaller capacity of the same in comparison with SU-2.

Alternative: 3

This is less economical than Alternatives 1 and 2, and represents maximum development of the Sun Kosi River. In

particular a large area of inundation is required around Dolaghat and can be achieved by raising the HWL of Sun Kosi No.3. This coupled with the rapid river gradient results in less economic viability.

5.3.3 Arun River

The total length of the Arun River is approximately 510km, of which only 150km lies in Nepalese territory. Backwater from the Sapt Kosi High Dam at H.W.L. EL.304.8m would reach 70km upstream of the Arun River. In this course, the river gradient is 1/360. A river gradient of 1/100 occurs 100km upstream where the two sites were selected, while from this point to the border upstream, river gradient is steep at 1/50.

The reservoir capacity (200m class) upstream, above the H.W.L. of the Sapt Kosi High Dam, would be 400-500$10^6$m3. However, annual sediment load is estimated at approximately 30$10^6$m3/annum. Applying this value and a trap efficiency of 0.6, estimated reservoir life is under 30 years. Reservoir type development on the Arun River was therefore abandoned and PRR and SRR types were studied.

5.3.4 Tamur River

The total length of the Tamur River is approximately 190km. The middle course of the river is relatively gentle with a river gradient of 1/350. Reservoir type development with a high dam approximately 3km upstream of Lukpa is planned based on comparative study with PRR type development.

The said study evaluated cost and benefit in terms of electricity, which is described in detail in the chapter on hydropower. Features of the dam and reservoir are tabulated below.

THE FEATURES OF TAMUR NO.1 SITE

Item	Tamur No.1 Dam
Dam Site	3km upstream of Lukpa
H.W.L. (EL m) 487.6	
Dam Height (m)	153.0
Gross Storage Capacity ($10^6 m^3$)	1,890.0
Available Storage Capacity ($10^6 m^3$)	760.0

5.3.5 Sapt Kosi River

The Sun Kosi, Arun and Tamur rivers join at Tribeni to become the Sapt Kosi River which flows into the Terai Zone at Chatra. The river course between Tribeni and Chatra is characterized by a deep gorge. The Sapt Kosi High Dam is planned 2km upstream of Barakshetra in the same course. Both banks of the river at the dam site are narrow and steep with rock outcrops. The Government of India has studied the site since 1946 conducting various investigations, topographical surveys, drilling, seismic prospecting, adit excavation and hydrological measurement. The "Feasibility Study Report on the Kosi High Dam" was prepared by the same and submitted to HMG in 1981. According to the Report, the project consists of hydroelectricity, irrigation and flood mitigation in Nepal and India.

The Team reviewed the project and found that it was difficult to assess the costs and benefits of irrigation and flood mitigation in India as data for the estimation were not available. The Team therefore reviewed the project in terms of hydroelectricity by the same evaluation method as other schemes in the Study.

5.3.6 Potential for Multipurpose Dam Schemes

In conclusion, 5 potential sites for multipurpose dam development were identified in the Study. The features of those dams are shown in TABLE 5-2.

Among the 5 proposed dams, Sun Kosi No.3 was incorporated in the Sun Kosi Multipurpose Scheme, to be developed at a comparatively early stage. The remaining four dams require extensive implementation periods due to their large scale. In particular, the hydropower components are extremely large and should be planned as energy export projects to neighboring countries.

Additional purposes for multipurpose development of the dams, such as flood control, navigation and irrigation could not be studied in detail due to the limited data available.

5.4 HYDROPOWER

5.4.1 Present Status

(1) Present Power Supply Situation

1) Power Supply System

There are three (3) main power supply systems in Nepal, namely, the Central Nepal Power System (CNPS), Eastern Nepal Power System (ENPS) and Western Nepal Power System (WNPS), load centers for which are Kathmandu, Biratnagar and Bhairawa, respectively. CNPS and WNPS are interconnected as the Integrated Central Nepal Power System. ENPS is not yet interconnected with CNPS, but interconnection is scheduled for completion in the near future.

In addition to the above three (3) systems, a number of small systems exist throughout the nation, especially around the towns of Nepalganj, Dhangadhi, Mahendranagar and Janakpur.

2) Power Generating Facilities

The total installed generating capacity owned by the public power sector (NEC and ED) is 153.3MW as of June 1984 of which 127.6MW (83%) is hydro plants and 25.7MW (17%) is diesel plants. In addition to the above generating facilities owned by public power sectors, generating plants (10.9MW) are owned and operated by private sectors for their own use. Location of such facilities are scattered throughout the country.

The generating capacity of public and private sectors installed in each development region are shown in TABLE 5-3 and TABLE 5-4. Major hydropower plants are Kulekhani No.1 Power Station (Reservoir Type) with a capacity of 60MW and Trisuli Power Station (SRR Type) with a capacity of 21MW. Kulekhani No.2 Power Station (SRR Type) with a capacity of 32MW is being constructed and expected to be commissioned in September 1986. Hetauda Power Station is the largest diesel power station with a capacity of 14.5MW.

3) Transmission and Distribution Facilities

Three (3) voltage levels, namely 132kV, 66kV and 33kV are used for transmission lines. The total route lengths of the existing transmission lines for each voltage level are 239km, 227km and 26km for 132kV, 66kV and 33kV, respectively. ED has a plan to complete interconnection of the national trunk transmission lines (132kV) by 1987 extending over 800km from east to west. The above-mentioned 239km of 132kV line, part of the 800km, was completed as of March 1983. FIG. 5-1 and 5-2 show the transmission line route and system diagram.

The existing distribution system consists of 11kV, 3.3kV and 0.4kV lines with respective lengths of 436.5km and 2,286km. The low voltage circuit is operated using an AC 50Hz, 400V/230V, 3-phase 4 wires system.

4) Substations

Sixteen (16) substations of over 66kV levels exist in The Central Region and Western Region. Total capacity of substations is 295.2MVA as of June 1984.

(2) Present and Historical Power Demand

Total supplied energy for all of Nepal including imported power from India in the fiscal year of 1982/83 is about 341GWh. The peak power demand and annual load factor in the fiscal year of 1982/83 is 83.7MW and 46.5%, respectively. Historical power supply and consumption by tariff categories from 1973/74 to 1982/83 are shown in TABLE 5-5 and FIG. 5-3. Historical power supply and consumption in various regions are shown in TABLE 5-6.