JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF WATER RESOURCES
HIS MAJESTY'S GOVERNMENT OF NEPAL

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

FINAL REPORT

VOLUME V

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APPENDIX IV [illegible]
APPENDIX V DOMESTIC WATER SUPPLY

OCTOBER 1993

NIPPON KOEI CO., LTD., TOKYO, JAPAN
[illegible] CORPORATION, TOKYO, JAPAN

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SUPPORTING REPORT

APPENDIX IV HYDROELECTRIC POWER GENERATION
APPENDIX V DOMESTIC WATER SUPPLY

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

This Report consists of

Volume I	Executive Summary	
Volume II	Main Report of Part I (General Study of the Master Plan)	
Volume III	Main Report of Part II (Detailed Analysis of Priority Schemes)	
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	Appendix I	Topography and Geology
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The cost estimate was based on the March 1993 price level and expressed in US Dollar according to the exchange rate of US$ 1.00 = Nepal Rupees 46.65 = Japanese Yen 116.30 as of March 31, 1993.

VOLUME V

SUPPORTING REPORT

APPENDIX IV HYDROELECTRIC POWER GENERATION
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LIST OF ABBREVIATIONS

ADB	:	Asian Development Bank
ADBN	:	Agricultural Development Bank of Nepal
AIC	:	Agricultural Inputs Corporation
AMIS	:	Agency Managed Irrigation System
BOD	:	Biochemical Oxygen Demand
C.I.F.	:	Cost, insurance and freight
CBS	:	Central Bureau of Statistics
CDR	:	Central Development Region
CIDA	:	Canadian International Development Agency
COD	:	Chemical Oxygen Demand
DHM	:	Department of Hydrology and Meteorology
DIO	:	District Irrigation Office
DLG	:	Department of Local Government
DNPWC	:	Department of National Parks and Wildlife Conservation
DO	:	Dissolved Oxygen
DOA	:	Department of Agriculture
DOI	:	Department of Irrigation
DPTC	:	Water Induced Disaster Prevention Technical Centre
DSCWM	:	Department of Soil Conservation and Watershed Management
DWSS	:	Department of Water Supply and Sewerage
ED	:	Electricity Department
EDF	:	Electricity de France International
EDR	:	Eastern Development Region
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
EIS	:	Environmental Impact Study
FCN	:	Food Corporation of Nepal
FMIS	:	Farmer Managed Irrigation Systems
F.O.B.	:	Free on board
FWDR	:	Far Western Development Region
G.I.wire	:	Galvanized Iron wire
GLOF	:	Glacier Lake Outburst Flood
GDP	:	Gross Domestic Product
GOJ	:	Government of Japan
HMG/N	:	His Majesty's Government of Nepal
ICIMOD	:	International Centre for Integrated Mountain development
IDA	:	International Development Aids

IEE	:	Initial Environmental Examination
IRDP	:	Integrated Rural Development Project
IUCNNR	:	International Union for Conservation of Nature and Natural Resources
JICA	:	Japan International Cooperation Agency
KMTNC	:	King Mahendra Trust for Nature Conservation
LRMP	:	Land Resource Mapping Project
MFE	:	Ministry of Forests and Environment
MHDB	:	Marsyandi Hydropower Development Board
MPID2	:	Master Plan for Irrigation Development in Nepal Cycle 2
MWDR	:	Mid-Western Development Region
MWR	:	Ministry of Water Resources
NARSC	:	National Agricultural Research Service Centre
NCCNCR	:	National Council for the Conservation of National and Cultural Resources
NEA	:	Nepal Electricity Authority
NEC	:	Nepal Electricity Corporation
NPC	:	National Planning Commission
NPWC	:	National Parks and Wildlife Conservation
NWSC	:	Nepal Water Supply Corporation
RNA	:	Royal Nepal Army
Rs.	:	Nepalese Rupee
SHDB	:	Small Hydro Development Board
SHIP	:	Second Hill Irrigation Projects
S/W	:	Scope of Work
UMN	:	United Mission to Nepal
UN	:	United Nations
UNDP	:	United Nations Development Programme
U.S.A.	:	United States of America
US$	:	Dollars in United States of America
VDC	:	Village Development Committee
WDR	:	Western Development Region
WEC	:	Water and Energy Commission
WECS	:	Water and Energy Commission Secretariat
WSSB	:	Water Supply and Sewerage Board

LIST OF UNIT OF MEASUREMENT

°C	:	degree centigrade or Celsius
cusec	:	cubic foot per second = 0.02832 m^3/s
El.	:	Elevation
GWh	:	Giga Watt hour
ha	:	hectare
km	:	kilometer
km^2	:	square kilometer
kW	:	kilo Watt
kV	:	kilo Volt
m	:	meter
m^3/s	:	cubic meter per second
m^3/sec	:	cubic meter per second
m^3/day	:	cubic meter per day
MW	:	Mega Watt
%	:	percent

APPENDIX IV

HYDROELECTRIC POWER GENERATION

APPENDIX IV
HYDROELECTRIC POWER GENERATION

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1. INTRODUCTION

A 132 kV transmission line to be extended from Kohalpur to Mahendranagar in the Terai plain is under construction with the branch lines of 66 kV to Dailekh and Dipayal-Silgadhi through Dadeldhura. Even after the completion of those transmission lines, the Study Area will however have to rely on the power sources mainly located in the central area of Nepal due to no power plants in the Area. Thus, the Study Area lies in the peripheral zone of the nation in terms of electric power supply.

Taking into consideration the situation mentioned above, this Appendix IV, Hydroelectric Power Generation, gives its primal objective in searching for promising hydropower schemes to meet electric power demands in the Study Area. In this context, identification of hydropower potential schemes is tried including the review of existing potential schemes, followed by the selection of promising schemes for development. The construction of access roads and transmission lines, which is one of main shackles to develop hydropower projects in the Study Area, is reflected as the cost in the selection.

Following the government policy to place high priority on rural electrification, this Appendix also deals with electric power supply not only to the district headquarters which are isolated from the national power grid, but also the areas designated as the strategic areas.

2. PRESENT SITUATION OF ELECTRIC POWER SUPPLY

2.1 Institution for Electricity Industry

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

The NEA is responsible for the planning, construction, operation and maintenance of all generation, transmission and distribution facilities in Nepal's interconnected power system and principal isolated systems. The Marsyandi hydroelectric project (69 MW) was put into operation in 1990, constructed by the Marsyandi Hydropower Development Board (MHDB), the agency especially established by MWR for the smooth implementation of the project and was abolished and transferred to NEA after the completion.

Private sectors are also encouraged to join the electricity industry for the development of mini hydro plants which are used for local industries such as water mills and also for the construction of plants to be added to the interconnected power system. Andhi Khola hydro project with an installed capacity of 5.1 MW was constructed by United Mission to Nepal (UMN), and generated energy is sold to NEA based on the agreement between them. Jhimruk Piuthan hydro plant (12.5 MW) is also under construction by UMN.

Due to the under-development of transmission lines in Nepal and India, both the governments have an agreement to exchange electric power for supplying it to border towns. Whilst the agreement allows the power exchange of 50 MW at most, Nepal imports 15 MW and exports 7 MW at present.

2.2 Generating Plants and Transmission Line Systems in the National Grid

2.2.1 Existing and Under-construction Generating Plants

As given in Table 2.2.1, the installed and effective capacities of generating facilities are 283.3 and 253.4 MW as of December 1991 in the national power supply system, respectively.

By type, hydropower dominates accounting for 82% in installed capacity and 83% in effective capacity.

Of eight main existing hydropower plants, reservoir type, which can make flow regulation possible, is Kulekhani I, although Kulekhani II is located downstream of Kulekhani I and is the beneficiary of regulated flow by it. Others are a run-of-river type. This situation makes vulnerable to the variation of river flow; that is, power generation drops beyond effective capacity in severe drought, requiring load rationing as experienced in the dry season of year 1992.

To meet growing power and energy demands, Jhimruk Piuthan hydropower plant is under construction as mentioned above and is expected to be added to the system in year 1994. After the Jhimruk Piuthan, Arun 3 is expected to be developed by year 2000, but the financial arrangement for its construction is continuing.

2.2.2 Power Transmission Lines

The trunk power transmission lines in the country, which run in the Terai plain, extend from Kathmandu toward the east and west directions by linking the major power plants and the large demand centres as given in Figure 2.2.1. The voltage employed is 132, 66 and 33 kV.

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

2.3 Rural Electrification in the Study Area

The NEA places high priority on the rural electrification of remote load centres as well as power development in the national power grid by reflecting the government policy paying endeavours for the rural development and narrowing the economic disparities between urban and rural areas. The present situation of rural electrification in the Study Area is summarized as given in Table 2.3.1, and the locations of towns with the service of rural electrification are shown in Figure 2.3.1.

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

Mangalsen is expected to be supplied with electricity in year 1994 when a small hydropower plant (400 kW) under construction is completed. On the other hand, feasibility study has been completed for the hydropower schemes to supply power to the other three district headquarters, Manma, Dunai and Dailekh (Ref. IV-1, 2 and 3).

Besides the district headquarters with no electricity supply as mentioned above, Simikot and Gamgadhi have a maintenance problem for the solar plants installed for those towns, resulting in irregular services. The diesel plant installed in Dadeldhura has also irregular power supply due to irregular fuel supply, resulting in power deficit in the town.

The hydro plant in Chainpur is worn out, requiring its rehabilitation. Power demands of Dipayal-Silgadhi exceed the supply capacity of the existing plant, so that this municipality is suffering from power deficits.

Since the transmission lines are planned to be extended to Dailekh, Dadeldhura and Dipayal-Silgadhi (refer to Figure 2.2.1) and the Achham hydro plant is under construction for Mangalsen, the district headquarters to require the improvement of power supply are Simikot, Gamgadhi and Chainpur besides Dunai and Manma which are un-served areas of electricity.

According to the Central Service Map prepared by Suspension Bridge Division, Ministry of Works and Transport, there exist four towns, even if those are not district headquarters, with a population density of more than 300 persons/km^2 in the Study Area as given in Table 2.3.2. These would be the priority towns to be supplied with electricity after all the district headquarters in the Study Area become the beneficiaries of electricity supply.

There are two national parks in the Study Area; Lake Rara and Khaptad National Park. Since these are potential areas to attract foreign tourists, the lodges and the quarters of rangers are desired to be supplied with electricity.

3 POWER BALANCE STUDIES

3.1 Power Balance in the National Power Supply System

3.1.1 Power Demand

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

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

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

The above figures fall in the range between high and median forecasts of EDF; that is, it is implied in JICA's prediction that higher improvement in the performance of Nepal's economy is anticipated after the sluggish development experienced in 1988/89 and 1989/90. It is noted that the JICA's forecast is projected on the sent-out basis including gradually decreasing system losses of 29.7 % to 18.0 % and annual load factors of 44.1 % to 50 % in the Bagmati area and 56.6 % to 60 % in other areas.

3.1.2 Power Balance

Power supply capacity given in Table 2.2.1 and power demand in future discussed above were compared as shown in Figure 3.1.1, in which power and energy deficits are expected to occur in 1994/95. Furthermore, actual situation would be worse, because a reserve capacity of 10 to 20% of total power demand is additionally necessary.

There is another problem involved in seasonal power generation as dealt with in the preceding Section 2.2.1, Existing and Under-construction Generating Plants. That is to say that most of power plants in the national power supply system are hydro plants of the run-of-river type, and therefore they decrease their power generation in winters which correspond to dry seasons. This implies that energy deficits would occur earlier; probably sometime in year 1993/94, even if there is some margin between energy supply capacity and demand in that year. In fact, power rationing was experienced in the winter of 1991/92.

To meet growing power and energy demands, the first phase of Arun 3 hydropower project as mentioned earlier is expected to be commissioned with an installed capacity of 268 MW (402 MW in total capacity) by year 2000. Power shortfall of some 200 MW, which is expected before the commission of Arun 3, should be met by other promising projects, which would be hydro projects such as Kali Gandaki A (90 MW), Kankai (60 MW) and Khimti (60 MW) and fossil fuel plants among others.

3.2 Power Demand in the Study Area

The extension of power transmission lines in the Study Area, i.e. a 132 kV line to be completed between Kohalpur and Mahendranagar in 1993 and 66 kV branch lines between Birendranagar and Dailekh and between Kanchanpur and Dipayal-Silgadhi through Dadeldhura as shown in Figure 2.2.1, will spur its economic development, resulting in the increase of power demand.

Future power demand in the Study Area was estimated basically relying on the projections done by JICA (Master Plan and Feasibility Study on Extension and Reinforcement of Power Transmission and Distribution System in Kathmandu Valley in Nepal, Final Report, December 1991). Since the JICA's estimate was carried out by dividing the national power grid into two regions of Kathmandu Valley Area and the other area, power demand in the Study Area was projected by multiplying the adjustment factor by the EDF's demand for the Study Area (Ten year Transmission and Distribution Plan, Load Forecast Study, December 1989). The adjustment factor is herein defined as the ratio of JICA's power projection for the national grid to EDF's and is assumed at 1.08, which is a rough average of the ratios obtained by comparing two demand projections of respective years; that is, JICA estimate gives higher projection than EDF's.

Power demands in the Study Area were projected with the procedure mentioned above by year 2010/11 as summarized below:

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

Power demand in the Study Area will reach a level of more or less 50 MW in year 2010, and will be higher, since the extension of transmission lines to Baitadi, Darchula and Chainpur is highly anticipated (refer to Figure 2.2.1). In the above projection, following industrial projects are included as potential demands to receive electric power (over 200 kW) from the national grid:

Industrial Project	Location	Power Request (kW)	Remarks
Nepal Paper Udyog Ltd.	Banke	2,000	Current supply of 3,000 kW
Binayak Biscuit Pvt. Ltd.	Banke	480	
Gaja Nad Textile Industries	Banke	200	

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

4. HYDROPOWER POTENTIAL SCHEMES IN THE STUDY AREA

4.1 Existing Potential Schemes

A total of 23 hydropower potential schemes was identified in the Karnali River and Mahakali River basins including the Karnali (Chisapani) and Pancheshwar projects by the past studies as summarized in Table 4.1.1. The locations of those schemes are shown in Figure 4.1.1.

Scheme identification in the past studies was limited to the ones with a large development scale, say 50 MW or above, aiming at bulk power supply to the national grid and energy export to India. This naturally results in the scheme identification at the lower reaches of the basins where a large scale reservoir can be created with gentle slopes (refer to Figures 4.1.2 to 4.1.5) and wide valleys. What is more, access to the site and length of the transmission lines, which are relatively easy and short, would be another reason for the scheme identification at the lower reaches.

The identified schemes include mutually exclusive ones as Pancheshwar-Chamliya and Karnali Bend (KR1A)-KR3 (Lakharpata) are given as examples. The Chamliya reservoir type scheme, situated at the lowermost narrow gorge of the Chamliya River just before merging into the Mahakali River and assessed to be economically viable, will be inundated when the full supply level of Pancheshwar is set at higher than El.555 m. In fact, the full supply level of Pancheshwar is proposed at El.632 m.

Karnali Bend (KR1A) is the run-of-river type scheme to create head for power generation by short-cutting the river course with a big bend situated at the lower reaches of the Karnali main stem. On the other hand, KR3 (Lakharpata) is the scheme to divert the Karnali River water from the top of that big bend to the Bheri River, resulting in mutual exclusiveness of both schemes in water use.

The Karnali (Chisapani) project and BR1, which is a diversion scheme from the Bheri River to the Babai River for power generation and irrigation, are compatible even with conflicts for water use, but it is noted that surcharge water level of the Karnali project for probable maximum flood is El. 443.8m against full supply level of El. 415m according to its feasibility study (Ref. IV-4), and that if all the structures in the reservoir area located at the places lower than El. 443.8m shall be evacuated, BR1 and BR3 become mutually exclusive against the Karnali project. Thus, the study to seek the compatibility of Karnali and BR1 will be a main theme to develop the lower reaches of the Karnali River including the irrigated agriculture development in the Terai plain, and will be dealt with in the subsequent Section 4.4, Simulation Studies for the Bheri-Babai Division Scheme.

4.2 Newly Proposed Potential Schemes

Major development centres in the Study Area such as Mahendranagar, Dadeldhura, Dipayal-Silgadhi and Dailekh besides Nepalganj, Dhangadhi and Birendranagar in the Terai plain are expected to receive electricity supply from the national grid by year 1993/94 (refer to Figure 2.2.1). This extension of transmission lines would stimulate not only local industry but also commercial activities and pumped irrigation in the region, resulting in the increase of power demand as discussed in the preceding Section 3.2, Power Demand in the Study Area.

Taking into consideration not only the high power demand growth in the Study Area but also the periphery of the region in terms of electric power supply, site identification of hydropower potential schemes was tried using existing 1 to 50,000 scale topographic maps and longitudinal profiles prepared from them (refer to Figures 4.1.2 to 4.1.5). A total of 15 schemes was newly identified in the Study Area as given in Table 4.1.2. The location of those schemes is shown in Figure 4.1.1 together with the schemes identified in the past studies, whilst a vertical relation among the schemes is given in Figures 4.1.2 to 4.1.5.

Lying in the upper reaches of the basin, the schemes newly identified in this Study are the run-of-river type except for BR3B and LR1, which are the reservoir type. The computation of annual energy output is based on the flow duration curve for the run-of-river type and the storage-draft curve for the reservoir type (refer to Appendix II, Meteorology and Hydrology). The shift of those curves from the stream gauge site to the scheme site relies on the ratios of catchment area and mean annual rainfall between two sites. Power and energy outputs for those identified schemes will be dealt with in the subsequent Section 4.3.

A reservoir type scheme called LR1 was identified in the Lohore River, a tributary of the Karnali River. Lying near Dailekh, the scheme has advantage in the construction of access roads and transmission lines.

The engineers of NEA made a reconnaissance to the Chamliya River, a tributary of the Mahakali River, in November 1991, identifying a scheme called CR2, which would be appropriate to be developed as a run-of-river type with a diurnal regulating pondage. The proposed site has a rather gentle river slope (1/70) compared with other potential scheme sites, but it has advantage in accessibility, being located within 15 km from the Baitadi-Darchula road.

BR-3B dam site in the Bheri River was newly proposed as an alternative of the BR-3A for the following reasons:

(a) An irrigation area with about 4,960 ha (existing: 3,767 ha, : 1,193 ha) in Ramghat area upstream of BR-3A site will be submerged by the construction of a high dam exceeding 200 m at BR-3A.

(b) About 32,000 people (probably more than 5,000 households) living in the said area will be forced to be displaced to other places. A large scale resettlement may cause serious social environmental problems.

(c) The existing road between Nepalganj and Birendranagar shall partly be relocated, and the suspension bridge near the BR-3A damsite shall be reconstructed.

(d) The BR-3B damsite is located about 34 km upstream of BR-3A. The topography is suitable for the layout of a rockfill type dam.

(e) Geology at the BR-3B damsite is fair to good schist/phyllite, whilst that of the BR-3A damsite is poor Siwaliks sandstone/mudstone/conglomerate, which is not appropriate as the foundation of a high dam.

4.3 Power and Energy Outputs of the Potential Schemes

Economic viability of the hydropower schemes identified in the Study Area is evaluated for the purpose of selecting priority schemes as discussed in the subsequent Section 5.2, Scheme Evaluation. Power and energy generation was computed for the identified schemes except for those with the study level of feasibility and pre-feasibility, i.e. Karnali/Chisapani, Karnali Bend, West Seti and Pancheshwar including Rupali Regulating Dam, Poornagiri and Chamliya.

Power and energy outputs for the six reservoir type schemes were calculated by changing the draft rate, which is expressed as the ratio of constant release from the reservoir through the year to the long-term average flow, in a range of 0.6 to 0.8 with an incremental step of 0.1 to seek the optimal development scale as given in Table 4.3.1. Plant discharge for the reservoir type scheme was determined by assuming an eight-hour peaking operation for the selected draft rate.

The dead storage in the reservoir was determined by assuming the horizontal formation for the 50-year sediment influx. The minimum operating level, MOL, was set with 1m allowance above the sediment formation level. The full supply level, FSL, was set by giving the required active storage corresponding to the draft rate above the MOL. Secondary energy of the reservoir type schemes as given in Table 4.3.1 was sought by simulating runoff data estimated at the scheme site. KR2 and KR7, which were originally considered as a reservoir type, are treated as a run-of-river scheme due to filling-up of sediments in the reservoir for the project life.

Power and energy outputs for the 25 run-of-river type schemes were calculated by changing operating hours for the firm discharge, which is defined as 95% guarantee flow on the flow duration curve, i.e. 8-hour, 12-hour and 16-hour peaking operation, as shown in Table 4.3.2. It is noted that the computation of power and energy outputs for the potential schemes was based on the assumption that there is no reservoir type scheme, which affects the flow regime, upstream of the contemplated hydropower scheme. Furthermore, it was assumed in the power and energy computation that the combined efficiency for turbine and generator is 85% and that head losses are 5% of gross head.

4.4 Simulation Studies for the Bheri/Babai Diversion Scheme

The implementation of the Karnali multipurpose project would be viable with no doubt, but it will require much time, say at least 25 years, before starting the construction of the project for tackling such issues as the agreement on energy sale with India, the displacement of people from the reservoir area, financial arrangement for the implementation and so on.

The delay of implementing the Karnali project implies that the project will lose the opportunities to earn the benefits originally planned by selling generated energy. The earlier implementation of the Bheri-Babai diversion scheme prior to that of the Karnali would make up for a part of benefits which are gained from the Karnali project in economic terms. This section deals with the possibilities of earlier implementation of the Bheri-Babai diversion scheme in economic terms by dividing into two parts. The first part discusses the potentiality to extend the irrigation command areas lying downstream of the Babai River. The second part deals with the economic viability to implement the Bheri-Babai diversion scheme as the hydropower generation scheme prior to the Karnali project.

4.4.1 Development Potential of Irrigation by the Bheri-Babai Diversion Scheme

A 10-year drought discharge of the Babai River after receiving the flow released from the Bheri-Babai power plant was computed based on simulation to grasp the general idea for extending the irrigation command areas lying in the lower reaches of the Babai River.

The procedures applied for the estimate of 10-year drought discharge were as follows:

(a) Monthly discharge observed at Station 270 was shifted to the intake site of BR1 (Bheri/Babai) by multiplying 0.945, which is the catchment area ratio between two sites. Mean annual rainfall was assumed to be the same between two sites due to no substantial difference in the size of catchment area between two sites.

(b) The design discharge to divert from the Bheri River to the Babai River was assumed in the range of 20 to 70 m^3/sec.

(c) Actual diversion amount of each month for a selected design discharge was computed as the remainder after subtracting the river maintenance flow of the Bheri River and the potential irrigation demands in the Surkhet valley. The river maintenance flow of the Bheri River will mainly be required for protecting aquatic fauna, terrestrial animals and flora and for sustaining fishery among the items which are normally considered, i.e. navigation, fish catch, protection of fauna and flora, operation and maintenance of intakes for water supply and irrigation, maintenance of facilities in the river, checking sea water intrusion, prevention of estuary clogging, conservation of groundwater and preservation of riparian lands. However, environmental studies to determine the amount required as maintenance flow have not been carried out so far. Thus, river maintenance flow of the Bheri River was at this moment assumed at 48 m^3/sec, which is the historical minimum discharge at the BR1 site. Potential irrigation demands for the command area of 2,700 ha including water supply demand were assumed in the Surkhet valley as follows (refer to Detailed Feasibility Study Report of Surkhet Valley Irrigation Project):

Unit: m^3/sec

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.3	1.6	1.3	2.1	1.5	0.3	3.8	5.2	5.4	4.6	0.6	0.8

(d) A 10-year drought discharge of the Babai River after receiving the flow released from the Bheri-Babai power plant was computed by summing up discharge measured at Station 290, which is the gauge in the Babai, and the released flow from the Bheri-Babai power plant.

As discussed in the preceding Section 4.3, Power and Energy Outputs of the Potential Schemes, design discharges of BR1 were selected at 29.1, 38.3 and 58.2 m^3/sec. A 10-year drought discharge of the Babai with the diversion from the Bheri was computed through the simulation mentioned above, ensuring 30.4 for 29.1 m^3/sec diversion flow, 32.7 for 38.3 m^3/sec and 33.8 for 58.2 m^3/sec as summarized in Figure 4.4.1.

Further detailed simulation studies as dealt with in Appendix V, Irrigation, were carried out to delineate the irrigable areas for the given cropping patterns. The conditions given for the simulation are 58.2 m^3/sec as the design discharge of BR1 and 16-year runoff data. Maintenance of 48 m^3/sec for the Bheri River is of course included as a condition of simulation. As a conclusion, paddy cropping in the monsoon season is possible for the entire irrigation area of 74,270 ha, whilst upland cropping such as wheat and sugarcane can be planted for an area of 33,270 ha in the winter season.

4.4.2 Assessment of Economic Viability for the Earlier Implementation of the Bheri-Babai Diversion Scheme

The diversion of the Bheri River water to the Babai River naturally reduces energy generation from the Karnali project, even if the Bheri-Babai diversion scheme makes up for some of it. Figure 4.4.2 shows the relationship between the reduced energy generation of the Karnali project and the make-up energy generation of the Bheri-Babai diversion scheme.

Without introducing the Bheri-Babai diversion scheme, the Karnali project produces average annual energy of 21,128 GWh/year. With the diversion of 29.1 m^3/sec, the Karnali project reduces its energy generation to a level of 20,575 GWh/year, whilst 20,424 GWh/year for 38.3 m^3/sec and 20,141 GWh/year for 58.2 m^3/sec. Introduction of the Bheri-Babai diversion scheme recovers the energy generation to a level of 20,912 GWh/year for 29.1 m^3/sec, 20,852 GWh/year for 38.3 m^3/sec and 20,736 GWh/year for 58.2 m^3/sec. That is to say that net energy decrease of the Karnali project by introducing the Bheri-Babai diversion scheme is 216 GWh/year for 29.1 m^3/sec diversion, 276 GWh/year for 38.3 m^3/sec diversion and 392 GWh/year for 58.2 m^3/sec diversion.

The economic viability of the Bheri-Babai as a hydropower project was evaluated by assessing the trade-off between the early energy generation from the Bheri-Babai power plant and the net energy loss in the Karnali project. A time lag of 25 years was assumed for the implementation of the Bheri-Babai and the Karnali, i.e. 25-year early installation of the former scheme. The net energy loss of the Karnali project was treated as the negative benefits of the Bheri-Babai diversion scheme, which produce in 25th year onward after the implementation of the Bheri-Babai diversion scheme as referred to the cash flow diagram given in Table 4.4.1. Construction costs and assumptions and conditions applied for economic evaluation are referred to the subsequent Section 5.2, Scheme Evaluation.

The viability of the Bheri-Babai diversion scheme taking into consideration the conditions mentioned above revealed in terms of economic internal rate of return (EIRR) and the net present value (NPV) as follows:

Design discharge of diversion, m^3/sec	EIRR, %	NPV, million US$
29.1	10.0	0.3
38.3	11.3	10.6
58.2	12.1	21.6

Since the above three cases gained the EIRR greater than 10%, the earlier implementation of the Bheri-Babai verified its viability. It is noted that since the above economic evaluation does not include the irrigation benefits, the economic viability of the Bheri-Babai diversion scheme will be higher, if such benefits are included in the economic evaluation.

A sensitivity test of the Bheri-Babai diversion scheme was carried out by changing the installation timing of the Karnali project to a 30-year delay as summarized below:

Design discharge of diversion, m^3/sec	EIRR, %	NPV, million US$
29.1	10.7	5.5
38.3	11.8	17.4
58.2	12.6	30.9

In case of design diversion discharge of 58.2 m3/sec, EIRR was improved from 12.1% to 12.6% by changing installation time lag from 25 years to 30 years. A discount rate of 10% was applied for the calculation of NPV.

5. EVALUATION OF POTENTIAL SCHEMES IN THE STUDY AREA

5.1 Basis for the Estimate of Construction Costs

5.1.1 Preliminary Findings for the Potential Schemes

Field reconnaissance was made for the hydropower schemes identified in the Study Area in order to collect such data as geological conditions, topographical conditions, availability of construction materials and so on at the sites. Results of the reconnaissance studied for dam types, powerhouse types, access roads to be newly constructed and so on are summarized in Table 5.1.1 for those identified in the past studies and Table 5.1.2 for those newly proposed. Preliminary cost estimate for the identified hydropower schemes as dealt with in the subsequent Section 5.2, Scheme Evaluation, will be based on the findings obtained through the reconnaissance. Updating of construction costs will be made for the schemes in the advanced study stage, i.e. Karnali (Chisapani) Multipurpose Project, Pancheshwar Multipurpose Project and so on, taking into account the price escalation.

The costs necessary for the construction of access roads and transmission lines are expected to share a considerable part of the total construction cost. The necessary length of access roads and transmission lines to be constructed as part of the project was estimated as follows:

Access Roads

The length of access roads to be newly constructed was estimated by assuming that the roads under construction at present (refer to Figure 5.1.1) are completed when the construction of a planned hydropower scheme is commenced. Following shows the starting point of access roads to be constructed for the schemes in the respective tributaries:

Tributary	Starting Point
- Karnali main	Dungeswar
- Tila	Dungeswar
- Mugu Karnali	Dungeswar
- Humla Karnali	Dungeswar
- Sani Bheri	Chaurjhari
- Buriganga	Saphebagar
- Seti	Dadeldhura-Dipayal or Chainpur
- Thuli Gad	Budar-Silgarhi
- Chamliya	Budar-Silgarhi

The length of roads to be newly constructed for the respective schemes was measured between the respective starting point and the scheme site as shown in Tables 5.1.1 and 5.1.2. On the other hand, the length of the existing roads to be improved for the implementation of the scheme was decided by referring to "The Upper Karnali Hydroelectric Project" of the Himalayan Power Consultants (HPC) in 1987 (refer to Tables 5.1.1 and 5.1.2).

Transmission Lines

The length of transmission lines to be newly constructed for the scheme was estimated from the terminal point of the under-construction transmission lines (refer to Figure 2.2.1). Following is the starting point of the transmission lines to be constructed as part of the project:

Tributary	Starting Point
- Karnali main	Dailekh
- Tila	Dailekh
- Mugu Karnali	Dailekh
- Humla Karnali	Dailekh
- Bheri	Birendranagar
- Sani Bheri	Birendranagar
- Buriganga	Dipayal
- Seti	Dadeldhura or Dipayal
- Thuli Gad	Kohalpur-Kanchanpur
- Chamliya	Dadeldhura

The length of transmission line required for the respective schemes as part of the project was also measured as given in Tables 5.1.1 and 5.1.2.

5.1.2 Plans Preliminarily Proposed for the Potential Schemes

A preliminary plan to develop hydropower was prepared for each potential scheme except for those in the advanced development stage. Following is a brief summary for the development plan of each scheme:

(1) Humla Karnali River basin

HKR-1

HKR-1, which was identified in the past study, is a run-of-river type scheme lying 2km upstream of the confluence between the Humla Karnali and the Mugu Karnali. The scheme plans to harness a head of 323 m created with the short-cut waterway of 9,350 m long (refer to Figure 5.1.2) for the big bend of the river course turning from south-east to south-west.

HKR-2

HKR-2, which was newly identified in this Study, is a run-of-river type scheme located 20km upstream of the confluence between the Humla Karnali and the Mugu Karnali in a direct distance. The scheme will fully utilize the rapids in the river course for creating a head of 150 m with the waterway of 3,400 m long (refer to Figure 5.1.3).

HKR-3

HKR-3, which was newly identified in this Study, is a run-of-river type scheme situated just downstream of Simikot, headquarters of Humla District. The scheme plans to create a head of 176 m with the waterway of 7,500 m long for the river course with rapids and bends (refer to Figure 5.1.4).

The river stretches between HKR-2 and HKR-3 show less topographic favour in terms of hydropower development due to rather gentle river slope without large head drops and a big bend.

HKR-4

HKR-4, which was newly identified in this Study, is a run-of-river type scheme lying in the uppermost reaches of the Humla Karnali, some 8km upstream of Simikot. The waterway running parallel with the river course with a length of 7,500 m creates a head of 296 m by harnessing rapids efficiently (refer to Figure 5.1.5).

(2) Mugu Karnali River basin

MKR-1

MKR-1, which was identified in the past Study, is a run-of-river type scheme located 14km upstream of the confluence between the Mugu Karnali and the Humla Karnali. The scheme plans to efficiently utilize rapids existing in the river course, creating a head of 216 m with the waterway of 6,200 m long (refer to Figure 5.1.6).

MKR-2

MKR-2, which was newly identified in this Study, is a run-of-river type scheme situated 36 km upstream of MKR-1 in the Mugu Karnali. The 4,250 m long waterway running parallel with the river course takes advantage of rapids existing in its course, creating a head of 150 m (refer to Figure 5.1.7).

The stretches of the Mugu Karnali River between MKR-1 and MKR-2 have a rather gentle straight course, resulting in less favour in hydropower development.

MKR-3

MKR-3, which was newly identified in this Study, is a run-of-river type scheme lying in the uppermost reaches of the Mugu Karnali, some 72 km upstream of MKR-2. This plan harnesses the rapids existing in the river course, creating a head of 580 m with the 6,050 m long waterway (refer to Figure 5.1.8).

The reaches of the Mugu Karnali River between MKR-2 and MKR-3 also show a gentle slope, which is less attractive in hydropower development.

(3) Karnali main stem basin

KR-2

KR-2, which was identified in the past Study, lies in the Karnali main stem 15 km upstream from the confluence between the Karnali main and the Tila River. Originally considered as a reservoir type scheme, the scheme is developed as a run-of-river type with a 202 m high dam due to sedimentation (Figure 5.1.9).

KR-3

KR-3, which was identified in the past Study and called Lakharpata, is a run-of-river type scheme to harness a head of 186 m created by diverting water from the top of the big bend situated in the lower reaches of the Karnali main stem to the Bheri River with a 10,800 km long waterway (Figure 5.1.10). This scheme is mutually exclusive with the Karnali Bend (KRIA) scheme in water use.

Lying in a narrow gorge, the project site shows the attractiveness to build a high dam, but does not create a large reservoir enough for seasonal regulation due to the narrow valley in the reservoir area and sedimentation into it. This only results in the increase of head in run-of-river type development even if a large dam is constructed for KR-3. Thus, the discussion of merits to increase head for KR-3 by building a high dam will be given place to the further detailed study which will be undertaken in future.

KR-4

KR-4, which was identified in the past Study, is a run-of-river type scheme lying in the uppermost reaches of the Karnali main stem, just downstream of the confluence between the Humla Karnali River and the Mugu Karnali River. The 3,450 m long waterway running along the river course takes advantage of rapids existing in its course, creating a head of 82 m (refer to Figure 5.1.11).

KR-7

KR-7, which was identified in the past Study, lies in the Karnali main stem 20 km upstream of the confluence with the Seti River. Originally contemplated as a reservoir type scheme, the scheme is developed as a run-of-river type with a 80 m high dam due to sedimentation (Figure 5.1.12).

LR-1

LR-1, which was newly identified in this Study, is a reservoir type scheme lying in the Lohore River near Dailekh, a tributary joining the Karnali main stem near the Big Bend. The scheme creates a head of 101 m with a 120 m high dam and a 730 m long waterway (Figure 5.1.13).

(4) Tila River basin

TR-1

TR-1, which was identified in the past Study, is a run-of-river type scheme lying in the lowermost reaches of the Tila River, 9 km upstream of the confluence with the Karnali main stem, constituting a part of the serial development of the Tila River together with TR-2 and TR-3. The 8,350 m long waterway creates a head of 398 m (refer to Figure 5.1.14).

TR-2

TR-2, which was identified in the past Study, is a run-of-river type scheme lying in the Tila River, 10 km downstream of the confluence with the Sinia River. The 4,300 m long waterway short-cutting the river course creates a head of 500 m (Figure 5.1.15).

TR-3

TR-3, which was identified in this Study, is a run-of-river type scheme developed between TR-2 and TR-3. The plan harnesses the rapids existing in the river course, creating a head of 250 m with the 5,400 m long waterway (refer to Figure 5.1.16).

There exist river stretches with a steep gradient just upstream of TR-3. However, large meandering of the river course makes it hard to create large head for hydropower generation without running the waterway beneath the river course. Thus, these stretches are left for small scale hydropower development.

The stretches of the Tila River lying upstream of the confluence with the Sinia River do not show a steep slope to attract hydropower development except for these near TR-4 discussed below.

TR-4

TR-4, which was newly identified in this Study, is a run-of-river type scheme lying in the Tila River, 6 km upstream of Jumla. The 4,900 m long waterway running along the river course creates a head of 185 m (refer to Figure 5.1.17).

(5) Bheri River basin

BR-1

BR-1, which was identified in the past Study, is a run-of-river type scheme lying in the Bheri River, 40 km upstream of the confluence with the Karnali main stem, taking advantage of a head of 170 m created by diverting the Bheri River water to the Babai River with a 8,100 m long waterway (refer to Figure 5.1.18). This diversion scheme causes a conflict in water use with the Karnali multipurpose project.

BR-3A

BR-3A, which was identified in the past Study, is a reservoir type scheme located in the Bheri River, 8 km upstream of BR-1. The scheme creates a head of 141 m with a 162 m high dam and a 2,600 m long waterway (refer to Figure 5.1.19). This scheme with a reservoir area of 135 km^2 will require the displacement of some 30,000 people and the submergence of agricultural land with an area of about 4,960 ha.

BR-3B

BR-3B, which was newly identified in this Study, is a reservoir type scheme located 30 km upstream of BR-3A. This scheme is an alternative of BR-3A contemplated for avoiding a large scale displacement of people. A combination of a 289 m high dam and a 730 m long waterway creates a head of 192 m (refer to Figure 5.1.20).

BR-4

BR-4, which was identified in the past Study, is a reservoir type scheme lying in the Bheri River, just downstream of the confluence with the Thala River. Harnessing topographic advantage, the scheme creates a 82 km^2 scale reservoir with a 197 m high dam. A combination of the dam and the 1,430 m long waterway makes a head of 173 m available for power generation (refer to Figure 5.1.21).

BR-5

BR-5, which was identified in the past Study, is a reservoir type scheme lying in the Bheri River between BR-4 and BR-3B. The scheme creates a head of 211 m with a 237 m high dam and a 1,000 m long waterway (refer to Figure 5.1.22).

BR-6

BR-6, which was identified in the past Study, is a run-of-river type scheme lying in the Thuli Bheri River 18 km upstream of its confluence with the Jogdula River. The scheme creates a head of 272 m with a 5,150 m long waterway running along the river course (refer to Figure 5.1.23).

BR-7

BR-7, which was newly identified in this Study, is a run-of-river type scheme located in the Jogdula River. The scheme creates a head of 730 m by short-cutting the big bend in the river with a 6,300 m long waterway (Figure 5.1.24).

BR-8

BR-8, which was newly identified in this Study, is a run-of-river type scheme lying in the uppermost reaches of the Thuli Bheri River 15 km upstream of Dunai, the headquarters of the Dolpa district. The scheme takes advantage of rapids in the river, creating a head of 305 m with a 4,300 m long waterway (refer to Figure 5.1.25).

(6) Seti River basin

SR-3

SR-3, which was identified in the past Study, is a run-of-river type scheme lying in the Seti River 45 km upstream of the West Seti scheme. The 9,050 m long waterway running along the river course creates a head of 240 m by harnessing the rapids (Figure 5.1.26).

SR-6

SR-6, which was identified in the past Study, is a reservoir type scheme lying in the Seti River just downstream of its confluence with the Buriganga River. The scheme creates a 72 km^2 scale reservoir with a 216 m high dam. A 193 m high head is available for power generation by combining the dam with a 1,550 m long waterway (Figure 5.1.27).

SR-7

SR-7, which was newly identified in this Study, is a run-of-river type scheme lying in the uppermost reaches of the Seti River 25 km upstream of SR-3. The scheme harnesses the rapids in the river, creating a head of 165 m with a 7,000 m long waterway (Figure 5.1.28).

BS-1

BS-1, which was newly identified in this Study, is a run-of-river type scheme situated in the uppermost reaches of the Buriganga River, a tributary of the Seti River. The scheme creates a head of 33 m with a 4,100 m long waterway (Figure 5.1.29).

(7) Thuli River basin

THR-1

THR-1, which was identified in the past Study, is a run-of river type scheme located in the Thuli River, a tributary joining the Karnali main stem 12 km downstream of its confluence with the Seti River.. The scheme creates a head of 328 m in the short-cutting the big bend in the river with a 4,400 m long waterway (Figure 5.1.30).

(8) Chamliya River basin

CR-1

CR-1, which was newly identified in this Study, is a run-of river type scheme lying in the uppermost reaches of the Chamliya River, a main tributary of the Mahakali River. The scheme utilizes the steep slope of the river, creating a head of 185 m with a 2,800 m long waterway (Figure 5.1.31).

CR-2

CR-2, which was newly identified by NEA, is a run-of-river type scheme situated in the middle reaches of the Chamliya River. The scheme takes advantage of the bend at site, creating a head of 43 m with a 4,050 m long waterway (Figure 5.1.32).

5.1.3 Unit Prices for the Estimate of Construction Cost

The unit prices applied for estimating the construction cost of each scheme are shown in Table 5.1.3.

Cost data were collected from the feasibility study reports of the Karnali (Chisapani) Multipurpose Project, the West Seti Hydropower Project (Ref. IV-5) and the Pancheshwar Multipurpose Project (Ref. IV-6) as shown in Table 5.1.4. Actual unit prices applicable to the large scale construction works to be carried out under the international tender are not available in the Study Area due to no experience of such works in the area.

Applicable unit prices for estimating the construction cost of the project were in principle taken from the highest price among those given in Table 5.1.4. However, the unit price of core embankment applied in the Karnali project is seemed high, showing large difference with that of the West Seti. Taking into consideration the unit prices of common excavation and embankment, the unit price of core embankment was assumed at US$ 5.00/m^3.

Compared with that of common excavation, the unit price of common embankment was estimated at US$ 4.00/m^3, which is slightly less than that of core embankment.

As for the unit price of shaft concrete, the Karnali's price is highest with the nearly double price of tunnel concrete. Taking into account that of West Seti, the unit price of shaft concrete was adjusted at US$ 200.00/m^3. Since no available cost data were found for backfill grouting, its unit price was estimated at US$ 200.00/m^3, taking into account the unit price applied in other countries.

5.1.4 Unit Cost for the Access Road and the Transmission Line

Construction cost for the access road with a length of 63 km was estimated on unit price basis in the feasibility study report of the Pancheshwar Project, giving US$ 600,000 per km.

The West Seti Project also assumed the same unit price of US$ 600,000 per km, whilst US$ 555,000 per km for the Karnali Project. Based on the above estimate, the unit price for the new construction of access roads was assumed at US$ 600,000 per km in this Study. As for the upgrading of existing roads, the unit price of US$ 50,000 per km was applied.

Cost data for the construction of electric power transmission lines were collected from NEA as shown in Table 5.1.5. The estimate of construction cost for the transmission lines is based on those data.

5.2 Scheme Evaluation

5.2.1 Assumptions and Conditions

Economic viability of hydropower schemes is assessed by calculating the return (benefits) gained by selling generated energy for the investment (costs) required for the construction of facilities. Following assumptions and conditions were placed on assessing the benefits and costs of the hydropower schemes:

(a) Economic viability is assessed in terms of economic internal rate of return (EIRR), present worth and cost for unit energy generation.

(b) An evaluation horizon is 50 years from the in-service date of the scheme.

(c) A discount rate of 10% is applied for evaluating the present worth of benefits and costs.

(d) The value of secondary energy is assumed to be 80% of firm energy in benefit calculation taking into account the sales opportunities of secondary energy.

(e) Unit value to estimate the benefit of firm energy is assumed at US$ 0.052/kWh, which is a long run marginal cost, LRMC, for power generation in the nation. The unit benefit for secondary energy results in US$ 0.042/kWh.

The value of US$ 0.052/kWh for the LRMC was obtained based on that of Rs 2.0/kWh estimated by EDF under the condition of without-exports for the energy generation of Arun 3 (Ref. IV-7) and the annual inflation rate of 5% for two years between 1990 (the year of EDF's estimate) and 1992.

(f) The costs required for the implementation of the scheme are composed of direct construction costs and indirect construction costs consisting of land acquisition, engineering services, government administration and operation and maintenance cost.

Indirect construction costs were estimated as the ratio with the direct construction costs by type, reservoir (RES) and run-of-river (ROR), as given below:

unit: %

Item	RES	ROR
Land acquisition	5	1
Engineering service	7	7
Government administration	1	1
Operation and maintenance	0.5	0.5

Operation and maintenance costs are needed every year for a period of 50 years (project life) after the commission. No replacement was assumed for the installed facilities in the evaluation period.

(g) The construction cost of each scheme is estimated based on the work quantities of each component and the unit prices applied for it. The disbursement of construction costs is assumed depending on the years required for the construction as follows :

Construction time period, years	Disbursement				
4	0.2	0.3	0.3	0.2	
5	0.10	0.25	0.30	0.25	0.10

It is assumed that a construction time period of 5 years is required when the construction cost is over US$ 100 million.

(h) Economic costs are assumed at 85% of construction costs taking into account the transfer of payment and the opportunity cost.

5.2.2 Economic Evaluation of Potential Schemes

As dealt with in the preceding Section 4.3, Power and Energy Outputs of the Potential Schemes, power and energy generated from 31 potential hydropower schemes, six reservoir and 25 run-of-river type schemes, were computed by changing the development scale. Construction costs for the respective development scales of the identified 31 hydropower schemes were estimated based on the work quantities obtained from their preliminary design and the unit prices applied for each work item (refer to Tables 5.2.1 and 5.2.2). Further breakdown of construction costs for those schemes is referred to Volume VII.

Applying the assumptions and conditions set up for the scheme evaluation as discussed in the preceding Section 5.2.1 to the estimated benefits and costs of each scheme, economic viability of the 31 identified schemes was assessed as summarized in Tables 5.2.1 and 5.2.2. The reservoir type schemes, which are mainly constructed in the downstream reaches of the main tributaries, show high economic viability due to ample river flow for energy generation, even if the required construction costs are great.

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

The optimal development scale of each scheme is at this moment defined as the scale which gives the maximum net benefit among three development alternatives. For the evaluation of BR-1, Bheri-Babai Diversion Scheme, the negative benefits for the Karnali multipurpose project, which were discussed in the preceding Section 4.4.2, are not counted in this evaluation.

5.3 Selection of Priority Schemes

Economic viability of the 31 identified schemes was assessed in the preceding Section 5.2.2. A next topic to be dealt with is to select priority schemes, for which further studies are carried out, among from the 31 identified potential schemes. Following aspects were considered for the selection of priority schemes:

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

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

Power demand in the Study Area would at most be 50 MW judging from its development status as dealt with in the preceding Section 3.2, Power Demand in the Study Area. When a large scale hydropower scheme with an installed capacity greater than 100 MW is developed in the Study Area, surplus power not consumed in the Study Area will be transmitted to the Kathmandu area where large power demand is expected. In this case, the installation of another transmission line would be required between the power plant and Kathmandu due to the limited capacity of the existing transmission line with a single circuit. This naturally results in the increase of project cost of the contemplated scheme. Thus, a limit of 100 MW is set up as the condition of installed capacity.

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

The schemes to meet the above three conditions among the potential schemes (refer to Tables 5.2.1 and 5.2.2) are listed below:

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

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

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

6. STUDIES FOR HYDROPOWER PRIORITY SCHEMES

6.1 BR-1 Scheme (Bheri River)

6.1.1 Plan Formulation

(1) General

BR-1 is one of four priority schemes selected in the hydropower sector as discussed in the preceding section 5.2, Scheme Evaluation. This scheme aims at hydropower generation and irrigation development in Bardiya and Banke districts by diverting water from the Bheri River to the Babai River.

The development plans proposed by the HPC (Himalayan Power Consultant) Study Team and by This Study Team (refer to Section 5.1.2) have an open-air type powerhouse inside the Royal Bardiya National Park, which includes the potential to raise the issues on natural environment.

The studies of this Plan Formulation were mainly focussed on the development of the optimal powerhouse type taking into consideration not only construction cost but also impacts to the natural environment. The results of these studies are mentioned below :

(2) Powerhouse type

As discussed above, two types of powerhouses were compared; one is an open-air type and the other is an underground type.

<u>Alternative-I (open-air type)</u>

This is a plan to construct an open-air powerhouse in the Royal Bardiya National Park. Water used for power generation is led from the intake located in the Bheri River to the powerhouse through an about 7,200 m long headrace tunnel and an about 900 m long open penstock line (Refer to Figure 5.1.18).

<u>Alternative-II (underground type)</u>

This is a plan to construct most of such structures as a permanent access road, an underground powerhouse and an outdoor switchyard among others at the Bheri River side except for the tailrace outlet thrust in the Babai River with an open channel.

Alternative-II (underground type powerhouse) would make it possible to minimize the impact to the natural environment, because of minimizing the access to the Babai area, the Royal Bardiya National Park, during the period of not only the construction but also operation and maintenance. A permanent access road to reach such structures as intake, underground powerhouse, tailrace surge tank and the middle portion of the tailrace tunnel will be constructed along the left bank of the Bheri River by branching off from the existing Nepalganj-Surkhet road. Only a temporary road and a work adit No. 2 will be provided in the Babai River side during the time when tailrace tunnel and its outlet channel are constructed.

Furthermore, the underground powerhouse of Alternative II lies just downstream of the desanding basin with a rather short inclined penstock line and inside of fresh and massive rocks, resulting in cheaper construction cost of steel penstock pipes and then making sure stable power supply to the system due to short closure time of the guide vane. The long penstock line normally requires long closure time of the guide vane to avoid high water hammer pressured in it, resulting in supply of less reliable power to the system. For the above reasons, Alternative-II (underground type powerhouse) is selected for the BR-1 scheme.

(3) Alternatives of installed capacity

As the second step, the optimization study was carried out for the installed capacity. Following three were chosen as the alternatives to select the optimal installed capacity:

Case	Operation Hours	Design Discharge (m^3/sec)	Installed Capacity (MW)
Alternative-I	8 hours	58.2	82.9
Alternative-II	12 hours	38.8	55.3
Alternative-III	16 hours	29.1	41.5

The selection of optimal installed capacity was based on the economic comparison. As given in Table 6.1.1, the maximum EIRR of 13.4 % was obtained for 8-hour peaking operation with an installed capacity of 82.9 MW. BR-1 is thus developed as the scheme with an installed capacity of 82.9 MW.

6.1.2 Basic Design

This Section describes the basic design concepts and main features for the principal structures of the proposed BR-1 scheme. The design was made in a master plan study level to provide the information on whether the scheme should proceed to the next feasibility study.

As the result of the optimization study to determine the development scale of the project, principal features of BR-1 were worked out as follows:

- Full supply level (FSL) : EL. 420.00 m
- Tail water level (TWL) : EL. 240.00 m
- Gross Head : 180 m
- Maximum plant discharge : 58.2 m^3/sec
- Peaking operation hours : 8 hours
- Installed capacity : 82.9 MW.

A general layout of BR-1 is shown in Figures 6.1.1 and 6.1.2. Following are the discussions for the basic idea of respective structural components.

(1) Intake site

Because of a run-of-river type, an intake dam is constructed with a desanding basin, lying at the bend portion of the Bheri River so that the waterway length can be shortened as much as possible as shown in Figure 6.1.2. The general plan at the intake site is shown in Figure 6.1.3, whilst a perspective view of the intake dam is depicted in the covering page of Volume III.

The intake dam is a low overflow crest gate-controlled structure. The crest of the dam and the weir are set at EL. 425.00 m and EL. 405.00 m, respectively, whilst EL. 420.00 m for full supply water level (FSL). The intake dam of 35 m in height and about 220 m in width is designed near the bend portion.

The dam has five tainter gates to safely release a peak discharge of 8,480 m^3/sec, which is 200-year probable flood. The gate is 15 m wide and 15 m high. The concrete piers to separate the gate bays are 5 m wide. The profile and typical cross section of the intake dam are shown in Figure 6.1.4.

At the left end of the spillway, a sand flush gate with a dimension of 10 m wide and 5 m high is provided so that the sluice can safely flush water under both the normal and flood flow conditions. Sand and gravel, which are deposited in low flow seasons, are regularly flushed through the sluice so as that deposited materials do not block water into the intake.

Located in the left abutment is the desanding basin, the function of which is to trap sand and to protect the turbines. This function is vital for a run-off-river type power plant such as BR-1. The principal dimensions of the desanding basin were determined to be 150 m long with three sub-basins of 11 m wide and 11 m deep taking into consideration the fact that particles with a diameter less than 0.2 mm should be trapped in the basin.

(2) Waterway

The waterway for power generation as shown in Figure 6.1.2 will be composed of an intake, a penstock line, a tailrace surge tank, a tailrace tunnel and an outlet channel. Its route selection was made so as to minimize its total length including work adits.

The intake is located at the end corner of the desanding basin. A caterpillar gate will be installed in the intake gate shaft. The penstock line consists of an upper horizontal tunnel, an inclined tunnel and a lower horizontal tunnel. The lower horizontal tunnel is bifurcated 20 m upstream of the powerhouse with the spherical branch. A total length of the penstock pipe is approximately 350 m between the intake and the powerhouse.

Since the tailrace tunnel is designed to have a pressure tunnel of 9,000 m long (Refer to Figure 6.1.2), a surge tank will be provided 120 m downstream of the turbine. The tailrace tunnel with a circular section is 9,000 m long for the distance between the powerhouse and the tailrace outlet as given Figure 6.1.1. The tunnel will be concrete-lined for the whole length to reduce friction losses. For the construction of the tailrace tunnel, two work adits will be provided, the location of which is determined not so as that the tunnel length between both the entrances exceeds 4.0 km at maximum from the required construction time and effective ventilation system during the construction. A stoplog slot will be provided at the outlet portal of the tailrace tunnel for the future maintenance of the tunnel.

(3) Power station

The power station lies underground in the left abutment of the Bheri River. The power station consists of a powerhouse, an access tunnel and an outdoor switchyard located about 1,200 m downstream of the intake dam. The powerhouse will house two units of vertical synchronous generators and Francis type hydraulic turbines. The main transformers will be installed in the same cavern and be connected with an outdoor switchyard through an access tunnel and a gallery provided under the inclined penstock line.

The underground powerhouse is designed as a 'D'-shaped cavern to house two 41 MW generating units. The dimensions of a cavern are determined essentially from the size of turbines and generators and from the area and height required for erecting and installing the generating equipment. The basic arrangement for the underground powerhouse is shown in Figure 6.1.5.

An about 2,000 m long access tunnel is provided between the outside access road and the erection bay in the powerhouse with a 10 % slope for transportation of generating equipment as well as construction materials during construction. The tunnel has a 'D'-shaped cross section sized to meet the requirement of equipment transportation. Two draft gates are provided 30 m downstream of the centre of the units. For these gates, provided is a chamber which is connected with the access tunnel. Ventilation of the underground powerhouse will be made through the power cable gallery provided under the penstock line. For this purpose, a ventilation house will be provided in the outlet portal of the cable duct near the intake.

The outdoor switchyard is located in the left bank of the Bheri River to make short the length of power cable. The switchyard is planned to accommodate main switchgear equipment and a control house. The underground powerhouse is basically remote-controlled from this control house.

(4) Others

A check dam is designed in the upstream end of backwater about 10 km upstream of the intake in the Bheri River as shown in Figure 6.1.6. The purpose is to prevent inflow of large gravel and bolder into the intake dam. The debris upstream of the check dam must be taken out in the dry season.

A permanent access road to the intake, underground powerhouse and the control house will be newly constructed along the left bank of the Bheri River by branching off from the existing Nepalganj-Surkhet road. The length is estimated at about 15 km.

Power generated from the plant will be supplied to the national grid by extending the transmission line from the outdoor switchyard to the existing Kohalpur-Birendranagar transmission line. The length required for the extension is expected 7 km.

6.1.3 Construction Plan and Cost Estimate

(1) Intake dam, intake and desanding basin

An intake dam is constructed by half-river closure method, taking into consideration rather wide riverbed at the site. Immediately after the dry season, an upstream cofferdam will be constructed in the left abutment in order to commence the construction of the left-half intake dam. Immediately after its completion, the remaining right-half intake dam will be started to construct by discharging river flow from the left side.

Immediately after the half closure of the Bheri River, foundation excavation will be started and then, foundation treatment works of curtain grouting and consolidation grouting shall be followed in the intake dam. After that, concrete placement carried out by cable crane will be followed. Banker line and batcher plant are provided in the left abutment.

Installation of tainter gates will be commenced after the completion of centre piers of the intake dam. The intake and desanding basin are constructed at the same time when the left-half of intake dam is constructed.

(2) Underground powerhouse and penstock line

The construction of the underground powerhouse will be commenced with digging of the access tunnel, which will be utilized as the access to the powerhouse during the construction. Three work adits branching off from the access tunnel will reach the arch crown of the powerhouse cavern, inclined penstock tunnel and tailrace surge tank for the transportation of excavated materials, concrete and required construction equipment.

All of excavation of the access tunnel will be made by means of the dump-truck method and the full-face attack method. After the excavation, concrete lining works will be commenced. Since the access tunnel is designed to have a descending slope of 10 % from the entrance, drainage pumps with a sufficient capacity shall be provided to release leaked water into the tunnel.

Excavation of the powerhouse cavern will first be carried out from the arch portion through the upper work adit, which branches off from the access tunnel. The cavern will be excavated conventionally downward from the arch. Excavated materials of the main body are hauled from a glory hole connecting between the arch and the access tunnel. Immediately after exposing the rock surface, rock bolting, shotcreting and PC anchoring are planned for protecting it.

Concrete works of the substructure will be carried out by using agitator trucks, concrete pump cars and buckets with a temporary overhead crane. Concrete will be transported to the powerhouse through the main access tunnel.

Following concrete placement to the substructure, draft tube installation, concrete placement to other structures and second concrete placement to the draft tubes, an overhead travelling crane will install the casings, turbines and generators. The powerhouse building works will be performed in parallel with the installation of turbines and generators.

(3) Tailrace tunnel and tailrace surge tank

The tailrace tunnel is about 9,000 m long with a circular section. Two work adits will be constructed prior to the construction of tailrace tunnel. Both adits are planned to be inclined due to the topographic conditions.

The tunnel excavation works are recommended to apply a full-face attack method for driving tunnel, whilst hauling of broken rocks will be done by the rail method. Six tunnel faces are planned to be attacked simultaneously using six sets of tunnel equipment crew. The most upstream face will be excavated from the access tunnel, following the excavation of the tailrace surge tank.

For concrete lining works, a full circular method is recommended to apply , and six sets of sliding steel forms with a travelling needle beam will be provided. Following the completion of concrete lining works at each section, backfill grouting and consolidation grouting works will be commenced.

The underground tailrace surge tank will be excavated from the tunnel connecting between the main access tunnel and the surge tank arch portion. A proposed construction schedule for BR-1 is shown in Figure 6.1.7, requiring five years for completion.

(4) Cost estimate

Construction costs for BR-1 are estimated on the basis of the preliminary design. Unit prices of each work item are estimated considering local conditions, available construction materials and suitability of the construction method and referring to similar projects in Nepal. A currency used for the estimate of construction cost is US Dollar. Cost estimate was made based on the prices at the end of March, 1993 by applying an exchange rate of US$ 1.00 to Rs. 46.65.

Construction costs are divided into direct construction cost and indirect construction cost. Direct construction costs are the cost required for general items and preparatory works, civil works, metal works, generating equipment, transmission lines and substation equipment. On the other hand, indirect construction costs are the one required for land acquisition and compensation, administration expenses, engineering services and contingencies.

Direct cost

Costs for general items comprise the costs for bond and insurance of works. Costs for preparatory works are composed of the costs for temporary buildings, water supply system, electric power supply system, telecommunication system, provision of medical facilities, operation of medical services, inland transportation, testing laboratory and temporary access roads. Costs for the general items and preparatory works of BR-1 are estimated at 11 % of the sum of civil works by the following reasons :

- Basic rate is 10 %.
- Minus 1 % because the site is close to the East-West Highway
- Plus 1 % because of cost increase due to long waterway requiring more expensive temporary facilities such as air supply, water supply, electric supply, temporary access roads and so on
- Plus 1 % for environmental countermeasures in the Royal Bardiya National Park.

Cost estimates of civil works are based on unit prices, which are prepared by counting cost for labour, cost for the procurement of primary construction materials such as cement, reinforcement bars, steel pipes, etc. and equipment, and contractor's overhead expenses and profits. Other important factors besides the unit prices are the geological conditions for excavation works, and the haul distance between construction sites and borrow areas to collect concrete aggegates and embankment materials.

Since foundation rocks are relatively soft, the unit prices on open and underground excavation are estimated to be US$ 1.00 and 2.00 respectively less than those of other schemes. Unit prices of each work item are estimated in accordance with the above conditions as shown in Table 6.1.2. Costs necessary for civil works are estimated by multiplying the work quantity obtained from the preliminary design by the respective unit prices.

Indirect cost

All the work required for land acquisition and compensation shall be carried out by the Nepali Government not to cause a delay to the project implementation schedule, and those costs include the costs required for the acquisition of the inundation areas and construction areas, transmission line routes and road alignment. Since BR-1 is a run-of-river type, costs required for land acquisition and compensation are estimated at 1 % of direct cost.

Administration expenses are estimated at 1 % of direct construction cost. Costs of engineering services, which are necessary for the feasibility study and the detailed design including the preparation of tender document, are estimated at 7 % of the sum of direct construction cost.

Physical contingencies are provided to cope with unforeseen physical conditions, the rate of which is assumed at 15 % of the sum of direct construction cost. Based on the above, total construction cost of BR-1 is estimated at US$ 173,967,646, a detailed break down of which is shown in Table 6.1.2.

6.1.4 Economic Evaluation

Economic viability of BR-1 is assessed by calculating the return (benefits) gained by selling generated energy for the investment (costs) required for the construction of facilities. Following assumptions and conditions were placed on assessing the benefits and costs of the scheme :

(a) Economic viability is assessed in terms of economic internal rate of return (EIRR), present worth and cost for unit energy generation.

(b) An evaluation horizon is 50 years from the in-service date of the scheme.

(c) A discount rate of 10 % is applied for evaluating the present worth of benefits and costs.

(d) The value of secondary energy is assumed to be 80 % of firm energy in benefit calculation taking into account the sales opportunities of secondary energy.

(e) Unit value to estimate the benefit of firm energy is assumed at US$ 0.052 /kWh, which is a long run marginal cost, LRMC, for power generation in the nation (refer to preceding Section 5.2). The unit benefit for secondary energy results in US$ 0.042 /kWh.

(f) The construction cost is estimated based on the work quantities of each component and the unit prices applied for it.

(g) Economic costs are assumed at 85 % of construction costs taking into consideration the transfer of payment and the opportunity cost.

Applying the above assumptions and conditions, BR-1 shows a high economic viability of US$ 40.5 million in net benefit and EIRR of 13.4 %. A cash flow for the evaluation is given in Table 6.1.3. It is noted that the economic evaluation was made by assuming that there is a time lag of 25 years in implementation between the BR-1 scheme and the Karnali project.

6.2 LR-1 Scheme (Lohore River)

6.2.1 Plan Formulation

(1) General

LR-1, which is one of four priority schemes selected in the hydropower sector, is a reservoir-type hydropower scheme to construct a dam in the Lohore River. A main focus of this plan formulation is to search for the optimal layout plan and the optimal development scale based on 1 to 10,000 scale topographic maps. The results of this study are mentioned below:

(2) Layout alternatives

LR-1 dam (Axis-I) is planned to be situated about 1.5 km downstream from the confluence of the Lohore and Chham rivers in the original plan (refer to preceding Chapter 5), taking into consideration the topographic conditions. Since the field investigation to the site revealed relatively weak portions in terms of stability at the left abutment of the site, an alternative dam axis (Axis-II) lying about 1.5 km downstream from Axis-I was newly proposed to avoid the stability problem. In Axis-II, a slightly weak portion in terms of stability was found downstream of the dam axis in the right abutment.

As for power plant, two alternatives were proposed; one is a plan to have a power house immediately downstream of the dam foot, and the other is a plan to have a long waterway tunnel to increase power generation. By combining the above two factors, following four alternatives were examined to select the optimal development plan of LR-1 (refer to Figure 6.2.1).

<u>Alternative-I</u>

The dam is situated in the upstream axis (Axis-I). An open-air type power station is situated immediately downstream of the dam foot with a waterway length of approximately 750 m. Full supply level (FSL) and tail water level (TWL) are set at EL. 798 m and EL. 680 m, respectively. It is noted that a draft rate of 0.7 (refer to subsequent discussions to determine the optimal development alternative) was selected to set FSL at EL. 798 m.

<u>Alternative-II</u>

The dam is situated in the upstream axis (Axis-I). An open-air type power station is situated in the downstream bend corner. A 5,150 m long waterway is arranged with two curves to make short the length of the work adits required for construction of the headrace tunnel. Full supply level (FSL) and tail water level (TWL) are set at EL. 798 m based on a draft rate of 0.7 and EL. 630 m, respectively.

<u>Alternative-III</u>

The dam is situated in the downstream axis (Axis-II). An open-air type power station is situated immediately downstream of the dam foot with a waterway length of approximately 650 m. Full supply level (FSL) and tail water level (TWL) are set at EL. 788 m based on a draft rate of 0.7 and EL. 670 m, respectively.

Alternative-IV

The dam is situated in the downstream axis (Axis-II). An open-air type power station is situated in the downstream bend corner. A proposed 4,300 m long waterway is almost straight from the intake to the tailrace outlet. The shorter work adit than that of Alternative-II is arranged for the construction of the headrace tunnel. Full supply level (FSL) and tail water level (TWL) are set at EL. 788 m based on a draft rate of 0.7 and EL. 630 m, respectively.

Figure 6.2.2 shows a map in the reservoir area of LR-1, which is prepared based on the newly prepared topographic maps with a scale of 1 to 20,000. Storage-volume curves for Axis-I and Axis-II are prepared based on Figure 6.2.2 as shown in Figure 6.2.3 and Figure 6.2.4, respectively.

The selection of the optimal alternative among the above four was made in economic comparison. As given in Table 6.2.1, Alternative-IV demonstrates the highest viability of 10.2 % in EIRR. Thus LR-1 is concluded to be developed with Alternative-IV as project layout. It is noted that the installed capacity of the plant is estimated based on an 8-hour peaking operation for a selected draft rate.

(3) Development alternatives

The study to seek the optimal development scale of LR-1 reservoir type scheme was carried out by changing the draft rate, which is expressed as the ratio of constant release from the reservoir through the year to the long-term average flow, in a range of 0.6 to 0.8 with an incremental step of 0.1. Plant discharge was determined by assuming an eight-hour peaking operation for the selected draft rate.

Dead storage in the reservoir was determined by assuming the horizontal formation for the 50-year sediment influx. The minimum operating level, MOL, was set with 1 m allowance above the sediment formation level. Full supply level, FSL, was set by giving the required active storage corresponding to the draft rate above the MOL. Secondary energy of the scheme was sought by simulating runoff data estimated at the scheme site.

For the selected layout alternative IV, following three are examined as dam scale alternatives:

Alternative	Draft Rate	Dam Crest (EL.)	FSL (EL.)	LWL (EL.)	Installed Capacity (MW)
Alternative-I	0.6	785.00	780.00	751.5	67
Alternative-II	0.7	793.00	788.00	751.5	81
Alternative-III	0.8	808.00	803.00	751.5	98

The principal features of these alternatives are given in Table 6.2.2. The results of economic evaluation reveals the highest viability of 10.2 % in EIRR for Alternative II as summarized in Table 6.2.2. Thus, LR-1 is concluded to be developed with an installed capacity of 81 MW for layout Alternative IV.

6.2.2 Basic Design

(1) General

This Section describes the basic design concepts and main features for the principal structures of the proposed LR-1 scheme. The design was made in a master plan study level to provide the information on whether the scheme should proceed to the feasibility study.

As the result of the optimization study to determine the development scale of the project, principal features of LR-1 were worked out as follows:

- Full supply level (FSL) : EL. 788.00 m
- Minimum operating level (MOL) : EL. 751.50 m
- Tail water level (TWL) : EL. 630.00 m
- Gross rated head (GRH) : 146 m
- Maximum plant discharge : 72 m^3/sec
- Peaking operation hours : 8 hours
- Installed capacity : 81 MW.

A general layout of LR-1 is shown in Figure 6.2.5. Following are the discussions for the basic idea of respective structural components.

(2) Diversion scheme

Diversion tunnels and cofferdams are provided for the purpose of diverting river flow during the construction period of the main dam. The diversion tunnels will have two lines considering the flow characteristic of the river and topographic conditions as shown in Figure 6.2.6; one will be provided in the right abutment to discharge large flow of the Lohore River and the other is in the right abutment to discharge small flow of the Mathel Khola.

A 25-year probable flood with a peak discharge of 1,150 m^3/sec was adopted as the design flood discharge of the diversion scheme. Without counting the flood retention effect of the reservoir, the river diversion scheme is determined as follows:

- Diameter of diversion tunnels	:	D = 6.5 m
- Elevation of cofferdam	:	EL. 720.00 m.

(3) Main dam

The proposed reservoir has FSL at EL. 788.0 m as determined in the optimization study. The dam crest elevation is determined at EL. 793.0 m by adding a freeboard of 5.00 m to FSL 788.0 m. The freeboard includes the safety against flood discharge, water waves caused by wind or earthquake and other allowances.

Figure 6.2.6 depicts the design of main dam, main features of which are as follows:

Height	:	about 120 m at the maximum section
Crest length	:	480 m
Width of the crest	:	10 m
Upstream slope	:	1 : 2.50
Downstream slope	:	1 : 2.00.

The dam is zoned into three; impervious core zone, filter zone and rock zone.

(4) Spillway

In view of the topographic and geological conditions at the damsite, a spillway is recommended to be provided in the left abutment to avoid the unstable portion in the right abutment. The spillway is predetermined to be an ungated-type considering free operation and maintenance, and is composed of an ungated weir, an open chuteway and a stilling basin with the horizontal apron.

The ungated weir of spillway with a length of 120 m is designed to discharge a 1,000-year probable flood with a peak discharge of 1,840 m^3/sec. A 100-year probable flood with a peak discharge of 1,500 m^3/sec was applied for the design of energy dissipator. A stilling basin with a 80 m long horizontal apron and 15 m-high walls was adopted from the hydraulic viewpoint.

(5) Waterway

The waterway for power generation will be composed of an intake, an intake gate shaft, a headrace tunnel, a surge tank, a penstock line and an tailrace outlet, and will be arranged in the right bank by connecting the intake and the tailrace outlet through the open-air type powerhouse. The route is selected so as to minimize its length including work adits and to ensure adequate cover over the headrace tunnel. A profile of the waterway is shown in Figure 6.2.7.

The intake is located about 400 m upstream of the main dam in the right abutment. A caterpillar gate will be installed in the intake gate shaft. The headrace tunnel with a circular section is 3,850 m long for the distance between the intake and the surge tank. The tunnel will be concrete-lined for the whole length to reduce friction losses. The alignment of the tunnel is determined from the topographic point of view as the general layout is depicted in Figure 6.2.5. For the construction of the headrace tunnel, two work adits will be provided, the location of which is determined not so as that the tunnel length between both the entrances exceeds 4.0 km at maximum from the time required for the construction.

The penstock line consists of an upper horizontal tunnel, an inclined tunnel and a lower horizontal tunnel. The lower horizontal tunnel is bifurcated 20 m upstream of the powerhouse with the spherical branch. A total length of the penstock pipe is approximately 330 m between the surge tank and the powerhouse.

(6) Power station

The power station is planned to be an open-air type in the right bank of the Lohore River. The power station consists of a powerhouse and an outdoor switchyard. The powerhouse will house two units of vertical synchronous generators and Francis type hydraulic turbines.

The powerhouse consists of a machine room, an erection bay and control rooms, the dimensions of which are determined essentially from the size of turbines and generators and from the area and height required for erecting and installing the generating equipment. The basic arrangement for the powerhouse is shown in Figure 6.2.8.

Two draft gates are provided just downstream of the powerhouse. An outdoor switchyard is located at the side of the powerhouse, accommodating a main transformer and switchgear equipment.

(7) Others

Since the permanent road is under construction between Birendranagar and Dailekh through Dungeswar near the Karnali bend, no access road except for upgrading is required to be newly constructed for this scheme. The length of the upgrading is estimated at about 79 km.

Power generated from the plant will be supplied to the national grid by extending the transmission line from the outdoor switchyard to the Surkhet-Dailekh transmission line under construction. The length to be required for the extension is expected 8 km.

6.2.3 Construction Plan and Cost Estimate

(1) Construction Plan

Diversion tunnels and cofferdam dam

River diversion for the construction of an intake dam is planned to be carried out by the diversion method. After the completion of an access road, excavation works will be performed from both portals of the tunnels. A full-face attack method is applied for the tunnel excavation. Rocks will be drilled by drill jumboes, and broken rocks will be loaded by side-muck loaders into dump trucks. Immediately after the completion, concrete lining works will be performed by means of steel sliding forms and concrete pumps.

Succeeding the completion of diversion tunnels, the upstream cofferdam will be constructed at the beginning of the dry season, and river water will be diverted into the diversion tunnels. Plug concrete will be placed for the closure of the diversion tunnels after the completion of the main dam.

Main dam and spillway

Immediately after the diversion of the Lohore River water into the diversion tunnels, foundation excavation will be started by bulldozers, back hoes and dump trucks, and then foundation treatment works of curtain grouting and consolidation grouting will be followed in the main dam. After that, embankment works will start. Embankment rocks are planned to be obtained from quarried rocks and excavated rocks of the spillway. Rocks in the quarry is planned to be excavated by bench-cut method. Rocks will be drilled by crawler drills and loaded by wheel loaders into dump trucks for the transportation to the site. At the embankment site, materials will be spreaded by bulldozers and compacted by vibrating rollers.

Impervious core materials are obtained from the borrow areas. The materials will be excavated by bulldozers and back hoes and loaded by wheel loaders into dump trucks for the transportation to the site. At the embankment site, materials will be compacted by tamping rollers.

Excavation works of the spillway will be performed in parallel with the foundation excavation of the main dam. Excavated rock materials will be hauled to the stockpile and will be used for rock embankment materials. Excavation works will be carried out using crawler drills, bulldozers with a ripper, wheel loaders and dump trucks.

Succeeding the excavation works, concrete placement will be carried out by crawler crane with a bucket. Batcher plant, crushing plant and aggregate plant are provided in the left abutment of the Lohore River.

Waterway

The headrace tunnel is 3,850 m long with a circular section. Two work adits will be constructed prior to the construction of headrace tunnel. The No. 2 work adit, located near the surge tank, is planned to be utilized for the construction of the surge tank and the penstock line.

Tunnel excavation works are recommended to apply a full-face attack method for driving tunnel, whilst hauling of broken rocks is by the rail method. Four tunnel faces are planned to be attacked simultaneously using four sets of crew.

For concrete lining works, a full circular method is recommended to apply, and four sets of sliding steel forms will be provided. Following the completion of concrete lining works at each section, backfill grouting and consolidation grouting works will be commenced.

Powerhouse, penstock and tailrace

Construction of the open-air type powerhouse is commenced by excavation works. Excavation will be performed with conventional construction equipment such as bulldozers, back hoes, dump trucks and so on.

Construction of the penstock line will start after the excavation of powerhouse is completed at the level of the penstock line. Excavated rocks will be hauled from the powerhouse site. Subsequently installation of penstock steel pipes and placement of buckfill concrete will start.

After the excavation of powerhouse, concrete placement will be carried out for substructures by concrete pumps and a crawler crane with concrete buckets. Following the construction of substructure, the construction of superstructure and roofing will be started for the installation of overhead crane. Following the concrete placement to the substructure, draft tube installation and the second concrete placement to the draft tubes, an overhead travelling crane is scheduled to install the casings, turbines and generators.

Construction of the tailrace will be performed in parallel with the construction of powerhouse. The construction schedule of LR-1 is shown in Figure 6.2.9.

(2) Cost estimate

Construction costs for LR-1 are estimated on the basis of the preliminary design. Unit prices of each work item are established by considering local conditions, available construction materials and suitability of the construction method and by referring to similar projects in Nepal. The construction cost is estimated in US Dollar. Cost estimate was made based on the prices at the end of March, 1993 by applying an exchange rate of US$ 1.00 to Rs. 46.65.

Construction costs are divided into direct construction cost and indirect construction cost. The direct construction costs are the cost for general items and preparatory works, civil works, metal works, generating equipment, transmission lines and substation equipment. On the other hand, the indirect construction costs are the ones required for land acquisition and compensation, administration expenses, engineering services and contingencies.

Direct cost

Costs for general items comprise the costs for bond and insurance of works. Costs for preparatory works are composed of the costs for temporary buildings, water supply system, electric power supply system, telecommunication system, provision of medical facilities, operation of medical services, inland transportation, testing laboratory and temporary access roads. The cost for the general items and preparatory works of LR-1 is estimated at 10 % of the sum of civil works.

Cost estimates of civil works are based on unit prices, which are prepared by counting cost for labour, cost for the procurement of primary construction materials such as cement, reinforcement bars, steel pipes, etc. and equipment, and contractor's overhead expenses and profits. Other important factors besides the unit prices are the geological conditions for excavation works, and the haul distance between construction sites and borrow areas to collect concrete aggegates and embankment materials.

Unit prices of each work item are estimated in accordance with the above conditions as shown in Table 6.2.3. Costs necessary for civil works are estimated by multiplying the work quantity obtained from the preliminary design by the respective unit prices.

Indirect cost

All the work required for land acquisition and compensation will be carried out by the Nepali Government not to cause a delay to the project implementation schedule, and those costs include the costs required for the acquisition of the reservoir area and construction areas, transmission line routes, and road alignment. Land acquisition and compensation costs are estimated at 5 % of direct cost for the LR-1 reservoir type scheme.

Administration expenses are estimated at 1 % of direct construction cost. Costs of engineering services, which are necessary for the feasibility study and the detailed design including the preparation of tender document, are estimated at 7 % of the sum of direct construction cost.

Physical contingencies are provided to cope with unforeseen physical conditions, the rate of which, is assumed at 15 % of the sum of direct construction cost. Based on the above, total construction cost of LR-1 is estimated at US$ 142,934,764, a detailed breakdown of which is shown in Table 6.2.3.

6.2.4 Economic Evaluation

Economic viability of the scheme is assessed by calculating the return (benefits) gained by selling generated energy for the investment (costs) required for the construction of facilities. Assumptions and conditions applied for the economic evaluation are referred to Section 6.1.4.

The result of economic evaluation for LR-1 shows a net benefit of US$ 2.3 million for a discount rate of 10 % and EIRR of 10.2 %. Thus, LR-1 is judged to be viable in economic terms. A cash flow for the evaluation is given in Table 6.2.4.

6.3 SR-3 Scheme (Seti River)

6.3.1 Plan Formulation

(1) General

SR-1 is one of four priority schemes selected in the hydropower sector. This scheme aims to develop hydropower generation by taking advantage of a gross head of about 180 m available in the upper reaches of the Seti River.

The studies of this plan formulation are mainly focussed on searching for the optimal layout plan based on 1 to 20,000 scale topographical maps and the optimal installed capacity. The results of these studies are mentioned below :

(2) Layout alternatives

In planning the waterway route, a main constrain was to cross the Kachali Khola, which requires a sufficient earth cover over the headrace tunnel. Taking into consideration the topographic conditions, following two alternatives were examined to select the optimal layout (refer to Figure 6.3.1).

Alternative-I

This is a plan to develop hydropower with a 9,200 m long waterway, which detours the Kachali Khola. An open-air type powerhouse is situated about 2 km downstream of the Sangur Khola. Full supply level (FSL) in the upper pondage and tail water level (TWL) are set at EL. 1,250 m and EL. 1,070 m respectively, resulting in a gross head of 180 m for power generation.

Alternative-II

This is a plan to construct an open-air type powerhouse in the vicinity of outlet of the Kachali Khola. The waterway with a length of about 6,000 m is arranged with two curves for the work adits required for the construction of headrace tunnel. Full supply level (FSL) in the upper pondage and tail water level (TWL) are set at EL. 1,250 m and EL. 1,125 m respectively, resulting in a gross head of 125 m for power generation.

The above two alternatives are compared in economic merits as summarized in Table 6.3.1, in which principal features of these two alternatives are also shown. Alternative-I with a long waterway has a higher EIRR, and therefore is selected as the optimal waterway route for SR-3.

(3) Alternatives for installed capacity

As the second step, the optimization study for installed capacity was carried out by changing the operation hour for firm discharge. Following three are proposed as alternatives:

Case	Operation Hours	Design Discharge (m3/sec)	Installed Capacity (MW)
Alternative-I	8 hours	39.6	56.4
Alternative-II	12 hours	26.4	37.6
Alternative-III	16 hours	19.8	28.2

The results of economic evaluation are summarized as given in Table 6.3.2, showing the maximum EIRR of 11.0 % for 8-hour peaking operation. Thus, SR-3 is proposed to develop with an installed capacity of 56.4 MW.

6.3.2 Basic Design

(1) General

This Section describes the basic design concepts and main features for the principal structures of the proposed SR-3 scheme. The design was made in a master plan study level to provide the information on whether the scheme should proceed to the next feasibility study.

SR-3 aims at hydropower generation by harnessing about 180 m gross head available in the Seti River. An intake dam is provided downstream of the confluence of the Bauli Gad and the Seti River lying about 400 m downstream of Chainpur town. A power station is located about 12 km downstream of the intake dam along the Seti River.

As a result of the optimization study to determine the development scale of the project, principal features of SR-3 are worked out as follows:

- Full supply level (FSL)	:	EL. 1,250.00 m
- Tail water level (TWL)	:	EL. 1,070.00 m
- Gross head	:	180 m
- Maximum plant discharge	:	39.6 m^3/sec
- Peaking operation hours	:	8 hours
- Installed capacity	:	56.4 MW.

A general layout of the scheme is shown in Figures 6.3.2 and 6.3.3. Following are the discussions for the basic idea of respective structural components.

(2) Intake site

SR-3 is a run-of-river type, and therefore an intake dam with a desanding basin is designed at the intake site of the Seti River. A general plan of the intake is shown in Figure 6.3.4.

The intake dam lying downstream of the confluence of the Seti and Bauli rivers is a low overflow crest gate-controlled structure with dimensions of 35 m in height and about 400 m in width. The dam installs six tainter gates designed for 200-year probable flood with a peak discharge of 6,465 m^3/sec. Each of the gates is 13 m wide and 15 m high. The concrete piers separating the gate bays are 5 m wide. The profile and the typical cross section of the intake dam are shown in Figure 6.3.5.

The crests of the dam and the weir are set at EL. 1,255.00 m and EL. 1,238.00 m, respectively.

At the right end of the spillway, a sand flush gate, 10 m wide and 5 m high, is provided so that flushing through the sluice can be done for both the normal and flood flow conditions. Sand and gravel which are deposited in the forebay during the low flow season can be flushed through the sluice before a large amount of materials accumulates and blocks the trashracks in the intake.

The desanding basin is located in the right abutment. Proper operation of the sand trap facilities is one of the most vital elements for the smooth operation of such a run-of-river type plant as SR-3. Principal dimensions of the desanding basin are determined to trap particles of less than 0.2 mm in diameter, being 150 m long with two sub-basins of 11 m wide and 11 m deep.

(3) Waterway

The waterway for power generation will be composed of an intake, a headrace tunnel, a surge tank and a penstock line as shown in Figure 6.3.3. The waterway route is selected so as to minimize its length including work adits and to ensure adequate earth cover over the headrace tunnel. In particular, special attention is drawn for crossing the Kachali Khola.

The intake is located at the end corner of the desanding basin. A caterpillar gate will be installed in the intake gate shaft. The headrace tunnel with a circular section is 8,800 m long for the distance between the intake and the surge tank as shown in Figure 6.3.2. The tunnel will be concrete-lined for the whole length to reduce friction losses. The alignment of tunnel is determined from the topographic point of view. For the construction of the headrace tunnel, three work adits will be provided, the location of which is determined not so as that the tunnel length between both the entrances exceeds 4.0 km at maximum from the time required for the construction.

The penstock line consists of an upper horizontal tunnel, an inclined tunnel and a lower horizontal tunnel. The lower horizontal tunnel is bifurcated 20 m upstream of the powerhouse with the spherical branch. A total length of the penstock pipe is approximately 400 m between the surge tank and the powerhouse.

(4) Power station

The power station is planned to be an open-air type in the right abutment of the Seti River, consisting of a powerhouse and an outdoor switchyard. The powerhouse will house two units of vertical synchronous generators and Francis type hydraulic turbines.

The powerhouse consists of a machine room, an erection bay and control rooms. The dimensions of the powerhouse are determined essentially from the size of turbines and generators and from the area and height required for erecting and installing the generating equipment. The basic arrangement for the powerhouse is shown in Figure 6.3.6.

Two draft gates are provided just downstream of the powerhouse. The outdoor switchyard is located at the side of the powerhouse lying in the right bank of the Seti River. The switchyard is planned to accommodate a main transformer and switchgear equipment.

(5) Others

Check dams are designed at the upstream end of backwater about 4.2 km and 1.3 km upstream of the intake in the Seti River and in the Bauli Gad, respectively. The purpose is to prevent inflow of rather large gravel and bolder into the intake dam. The debris upstream of the check dam must be taken out in the dry season.

A permanent access road to the intake and the powerhouse will be newly constructed by branching off from the road between Khodpe and Chainpur. The length of new road is estimated at more or less 5 km, whilst the length of upgrading is about 263 km.

Power generated from the plant will be supplied to the national grid by extending the transmission line from the outdoor switchyard to the Dadeldhura-Dipayal-Silgadhi transmission line under construction. The length to be required for the extension is expected at some 59 km.

6.3.3 Construction Plan and Cost Estimate

(1) Construction plan

Intake dam, intake and desanding basin

An intake dam is constructed by half-river closure method taking into consideration rather wide riverbed at the site. Immediately after the monsoon season, an upstream cofferdam will be constructed in the right abutment in order to commence the construction of the right-half portion of the intake dam.

After making a dry space in the right-half of the river, foundation excavation for its part will start, and then foundation treatment works of curtain grouting and consolidation grouting will be made. Following the grouting works, concrete placement will be carried out by a crawler crane with buckets. After the completion of the right-half of the intake dam, the remaining left-half will be constructed by releasing flood water from the right-half. Batcher plant and aggregate plant are provided in the left abutment.

Installation of tainter gates will be commenced after the completion of center piers of the intake dam. The intake and desanding basin are constructed at the same time when the right-half of the intake dam is constructed.

Headrace tunnel and surge tank

The headrace tunnel is about 8,800 m long with a circular section. Three work adits will be constructed prior to the construction of headrace tunnel. No. 3 work adit, located near the surge tank, is planned to be utilized for the construction of the surge tank and the penstock line.

Tunnel excavation works are recommended to apply a full-face attack method for driving tunnel, whilst hauling of broken rocks will be done by the rail method. Six tunnel faces are planned to be attacked simultaneously using six sets of crew.

For concrete lining works, a full circular method is recommended to apply, and four sets of sliding steel forms with a travelling needle beam will be provided. Following the completion of concrete lining works at each section, backfill grouting and consolidation grouting works will be commenced.

Powerhouse, penstock and tailrace

Construction of the open-air type powerhouse is commenced by excavation works, which will be performed by using such conventional construction equipment as bulldozers, back hoes, dump trucks and so on.

After excavation, concrete placement will be carried out for the substructures of powerhouse by concrete pumps and a crawler crane with concrete buckets. Following the substructure, construction of the superstructure and roofing will start for the installation of overhead crane. Following concrete placement to the substructure, draft tube installation and second concrete placement to the draft tubes, an overhead travelling crane is scheduled to install the casings, turbines and generators.

Construction of the penstock line starts after the excavation of powerhouse is completed at the level of the penstock line. Excavated rocks will be hauled from the powerhouse site. Subsequently installation of penstock steel pipes and placement of backfill concrete will start.

Construction of the tailrace will be performed in parallel with the construction of powerhouse.

The construction schedule of SR-3 is prepared as shown in Figure 6.3.7, requiring five years for the completion.

(2) Cost estimate

Construction costs for SR-3 are estimated on the basis of the preliminary design. Unit prices of each work item are estimated by considering local conditions, available construction materials and suitability of the construction method and by referring to similar projects in Nepal. A currency used for the estimate of construction cost is US Dollar. The cost was estimated based on the prices at the end of March, 1993 by applying an exchange rate of US$ 1.00 to Rs. 46.65.

Construction costs are divided into direct construction cost and indirect construction cost. Direct construction costs are the cost required for general items and preparatory works, civil works, metal works, generating equipment, transmission lines and substation equipment. On the other hand, indirect construction costs are the ones required for land acquisition and compensation, administration expenses, engineering services and contingencies.

Direct cost

Costs for general items comprise the costs for bond and insurance of works. Costs for preparatory works are composed of the costs for temporary buildings, water supply system, electric power supply system, telecommunication system, provision of medical facilities, operation of medical services, inland transportation, testing laboratory and temporary access roads. Costs for the general items and preparatory works of SR-3 are estimated at 12 % of the sum of civil works by the following reasons :

- Basic rate is 10 %.
- Plus 1 % because the site is rather far from the East-West Highway

- Plus 1 % because of cost increase due to long waterway requiring more expensive temporary facilities such as air supply, water supply, electric supply, temporary access roads and so on.

Cost estimates of civil works are based on unit prices, which are prepared by counting cost for labour, cost for the procurement of such primary construction materials as cement, reinforcement bars, steel pipes, etc. and equipment, and contractor's overhead expenses and profits. Other important factors besides the unit prices are the geological conditions for excavation works, and the haul distance between construction sites and borrow areas to collect concrete aggregates and embankment materials.

The unit prices of each work item are estimated in accordance with the above conditions as shown in Table 6.3.3. Costs necessary for civil works are estimated by multiplying the work quantity obtained from the preliminary design by the respective unit prices.

Indirect cost

All the work required for land acquisition and compensation will be carried out by the Nepali Government not to cause a delay to the project implementation schedule, and those costs include the costs required for the acquisition of the inundation areas and construction areas, transmission line routes and road alignment. Since SR-3 is a run-of-river type, costs required for land acquisition and compensation are estimated at 1 % of direct cost.

Administration expenses are estimated at 1 % of direct construction cost.

Costs of engineering services, which are necessary for the feasibility study and the detailed design including the preparation of tender document, are estimated at 7 % of the sum of direct construction cost.

Physical contingencies are provided to cope with unforeseen physical conditions, the rate of which, is assumed at 15 % of the sum of direct construction cost. Based on the above, the total construction cost of SR-3 is estimated at US$ 141,987,150, a detailed breakdown of which is shown in Table 6.3.3.

6.3.4 Economic Evaluation

Economic viability of the scheme is assessed by calculating the return (benefits) gained by selling generated energy for the investment (costs) required for the construction of facilities. Assumptions and conditions applied for the economic evaluation are referred to Section 6.1.4.

The result of economic evaluation for SR-3 shows a net benefit of US$ 11.3 million for a discount rate of 10 % and EIRR of 11.0 %. Thus, SR-3 is judged to be viable in economic terms. A cash flow for the evaluation is given in Table 6.3.4.

6.4 CR-2 Scheme (Chamliya River)

6.4.1 Plan Formulation

(1) General

CR-2 is one of four priority schemes selected in the hydropower sector. This scheme aims to develop hydropower generation by taking advantage of a gross head of about 140 m available in the upper reaches of the Chamliya River.

The studies of this plan formulation are mainly focussed on searching for the optimal layout plan based on 1 to 20,000 scale topographic maps and the optimal installed capacity. The results of these studies are mentioned below :

(2) Layout alternatives

In planning the waterway route, a main constrain is to cross the Bhel Gad, which requires a sufficient earth cover over the headrace tunnel. Taking into consideration the topographic conditions at the site, following two alternatives were examined to select the optimal layout as shown in Figure 6.4.1.

<u>Alternative-I</u>

This is a plan to develop hydropower with a 4,900 m long waterway, which detours the Bhel Gad. The intake dam site is in a gorge suitable for constructing a several-ten-meter high dam. Full supply level (FSL) in the intake dam and tail water level (TWL) are set at EL. 930 m and EL. 790 m respectively, resulting in a gross head of 180 m for power generation. It is noted that displacement of people will not be raised as a social environmental issue, even if a several-ten-meter high dam is built, due to the topographic condition of narrow and steep gorge at the site.

Alternative-II

This is a plan to construct an intake dam downstream of the Bhel Gad. Since the intake dam site lies in a rather wide valley, an intake weir with a low height is preferable in terms of construction cost. Full supply level (FSL) for the intake weir and tail water level (TWL) are set at EL. 880 m and EL. 790 m respectively, resulting in a gross head of 90 m for power generation.

The above two alternatives are compared in economic merits as summarized in Table 6.4.1, in which principal features of these two alternatives are also shown. Alternative-I with a long waterway has a higher EIRR, and therefore is selected as the optimal waterway route for CR-2.

(3) Alternatives for installed capacity

As the second step, the optimization study for the optimal installed capacity was carried out by changing the operation hour for firm discharge. Following three are proposed as alternatives:

Case	Operation Hours	Design Discharge (m^3/sec)	Installed Capacity (MW)
Alternative-I	8 hours	21.7	24.1
Alternative-II	12 hours	14.5	16.0
Alternative-III	16 hours	10.9	12.0

The results of economic evaluation are summarized as given in Table 6.4.2, showing the maximum EIRR of 10.3 % for 8-hour peaking operation. Thus, CR-2 is proposed to develop with an installed capacity of 24.1 MW.

6.4.2 Basic Design

(1) General

This Section describes the basic design concepts and main features for the principal structures of the proposed CR-2 scheme. The design was made in a master plan study level to provide the information on whether the scheme should proceed to the next feasibility study.

CR-2 aims at hydropower generation by harnessing about 140 m gross head available in the Chamliya River. As a result of the optimization study to determine the development scale of the project, principal features of CR-2 are worked out as follows:

- Full supply level (FSL)	:	EL. 930.00 m
- Tail water level (TWL)	:	EL. 790.00 m
- Gross head	:	140 m
- Maximum plant discharge	:	21.7 m^3/sec
- Peaking operation hours	:	8 hours
- Installed capacity	:	24.1 MW.

A general layout of the scheme is shown in Figures 6.4.2 and 6.4.3. Following are the discussions for the basic idea of respective structural components.

(2) Intake site

CR-2 is a run-of-river type, and therefore an intake dam with a desanding basin is designed at the intake site of the Chamliya River. A general plan of the intake is shown in Figure 6.4.4.

The intake dam is a high overflow crest gate-controlled structure with the principal features as follows:

- Crest elevation of the dam	:	EL. 935.00 m
- Crest elevation of the weir	:	EL. 915.00
- Height of the dam	:	65 m
- Width of the dam	:	200 m.

The dam installs four tainter gates designed for 200-year probable flood with a peak discharge of 6,409 m^3/sec. Each of the gates is 14 m wide and 15 m high. The profile and the typical cross section of the intake dam are shown in Figure 6.4.5.

At the right end of the spillway, the sand flush gate with a dimension of 10 m wide and 5 m high is provided so that flushing through the sluice can be done for both the normal and flood flow conditions. Sand and gravel which are deposited in the forebay during the low flow season can be flushed through the sluice before a large amount of materials accumulates and blocks the trashracks in the intake.

The desanding basin is located in the right abutment. Proper operation of the sand trap facilities is one of the most vital elements for the smooth operation of such a run-of-river type plant as CR-2. Principal dimensions of the desanding basin are determined to trap particles of less than 0.2 mm in diameter, being 110 m long with two sub-basins of 8 m wide and 8 m deep.

(3) Waterway

The waterway for power generation will be composed of an intake, a headrace tunnel, a surge tank and a penstock line as shown in Figure 6.4.3. The waterway route is selected so as to minimize its length including work adits and to ensure adequate earth cover over the headrace tunnel. In particular, special attention is drawn for crossing the Bhel Gad.

The intake is located at the end corner of the desanding basin. A caterpillar gate will be installed in the intake gate shaft. The headrace tunnel with a circular section is 4,300 m long for the distance between the intake and the surge tank as shown in Figure 6.4.2. The tunnel will be concrete-lined for the whole length to reduce friction losses. The alignment of the tunnel is determined from the topographic point of view. For the construction of the headrace tunnel, two work adits will be provided, the location of which is determined not so as that the tunnel length between both the entrances exceeds 4.0 km at maximum from the time required for the construction.

The penstock line consists of an upper horizontal tunnel and an open penstock portion. The lower horizontal portion of the open penstock is bifurcated 20 m upstream of the powerhouse with the spherical branch. A total length of the penstock pipe is approximately 600 m between the surge tank and the powerhouse.

(4) Power station

The power station is planned to be an open-air type in the right abutment of the Chamliya River, consisting of a powerhouse and an outdoor switchyard. The powerhouse will house two units of vertical synchronous generators and Francis type hydraulic turbines.

The powerhouse consists of a machine room, an erection bay and control rooms. The dimensions of the powerhouse are determined essentially from the size of turbines and generators and from the area and height required for erecting and installing the generating equipment. The basic arrangement for the underground powerhouse is shown in Figure 6.4.6.

Two draft gates are provided just downstream of the powerhouse. The outdoor switchyard is located at the side of the powerhouse lying at the right bank of the Chamliya River. The switchyard is planned to accommodate a main transformer and switchgear equipment.

(5) Others

A check dam is designed at the upstream end of backwater in the Chamliya River. The purpose is to prevent inflow of large gravel and bolder into the intake dam. The debris upstream of the check dam must be taken out in the dry season.

A permanent access road to the powerhouse and the intake will be newly constructed by branching off from Baitadi-Darchula road under construction. The length of new road is estimated at about 10 km.

Power generated from the plant will be supplied to the national grid by extending the transmission line from the outdoor switchyard to the Kanchanpur-Dadeldhura transmission line under construction. The length to be required for the extension is expected 74 km.

6.4.3 Construction Plan and Cost Estimate

(1) Construction plan

Diversion tunnels and intake dam

River diversion for the construction of intake dam is planned to be carried out by the diversion method. A full-face attack method is applied for the tunnel excavation. Rocks will be drilled by drill jumboes, and broken rocks will be loaded by side-muck loaders into dump trucks. After the completion of tunnel excavation, concrete lining works will be performed by means of steel sliding forms and concrete pumps.

Succeeding the completion of diversion tunnels, the upstream cofferdam will be constructed at the beginning of the dry season, and river water will be diverted into the diversion tunnels. Plug concrete will be placed for the closure of the diversion tunnels after the completion of intake dam.

After the completion of diverting the Chamliya River water into the diversion tunnels, foundation excavation of the intake dam will start with bulldozers, back hoes and dump trucks, and then foundation treatment works of curtain grouting and consolidation grouting will be made for the intake dam from the gallery provided inside of it. After that, concrete placement will be carried out by a cable crane with buckets. Batcher plant, crushing plant and aggregate plant are provided at the right abutment. Installation of tainter gates will be commenced after the completion of centre piers of the intake dam.

Desanding basin and intake

The intake and the desanding basin are constructed at the same time together with the intake dam. However, concrete will be placed by crawler crane with buckets.

Headrace tunnel and surge tank

The headrace tunnel is about 4,300 m long with a circular section. Two work adits will be constructed prior to the construction of the headrace tunnel. No. 2 work adit, located near the surge tank, is planned to be utilized for the construction of the surge tank and the penstock line.

Tunnel excavation works are recommended to apply a full-face attack method for driving tunnel, whilst broken rocks will be hauled by the rail method. Four tunnel faces are planned to be attacked simultaneously using four sets of crew.

For concrete lining works, a full circular method is recommended to apply, and four sets of sliding steel forms will be provided. Following the completion of concrete lining works at each section, backfill grouting and consolidation grouting works will be commenced.

Powerhouse, penstock and tailrace

Construction of the open-air type powerhouse is commenced by excavation works, which will be performed by using such conventional construction equipment as bulldozers, back hoes, dump trucks and so on.

After excavation, concrete placement will be carried out for the substructures of powerhouse by concrete pumps and crawler crane with concrete buckets. Following the substructure, construction of the superstructure and roofing will start for the installation of overhead crane. Following concrete placement to the substructure, draft tube installation and second concrete placement to the draft tubes, an overhead travelling crane is scheduled to install the casings, turbines and generators.

Construction of the penstock line starts with the open excavation, which goes downward from the upper horizontal tunnel portion of the penstock line. Subsequently installation of the penstock steel pipes and placement of second-stage concrete will be made.

Construction of the tailrace will be performed in parallel with construction of the powerhouse.

The construction schedule of CR-2 is prepared as shown in Figure 6.4.7, requiring four years for the completion.

(2) Cost estimate

Construction costs for CR-2 are estimated on the basis of the preliminary design. Unit prices of each work item are estimated by considering local conditions, available construction materials and suitability of the construction method and by referring to similar projects in Nepal. A currency used for the estimate of construction cost is US Dollar. The cost was estimated based on the prices at the end of March, 1993 by applying an exchange rate of US$ 1.00 to Rs. 46.65.

Construction costs are divided into direct construction cost and indirect construction cost. Direct construction costs are the cost required for general items and preparatory works, civil works, metal works, generating equipment, transmission lines and substation equipment. On the other hand, indirect construction costs are the ones required for land acquisition and compensation, administration expenses, engineering services and contingencies.

Direct cost

Costs for general items comprise the costs for bond and insurance of works. Costs for preparatory works are composed of the costs for temporary buildings, water supply system, electric power supply system, telecommunication system, provision of medical facilities, operation of medical services, inland transportation, testing laboratory and temporary access roads. Costs for the general items and preparatory works of CR-2 are estimated at 11 % of the sum of civil works by the following reasons :

- Basic rate is 10 %.

- Plus 1 % because the site is rather far from the East-West Highway.

Cost estimates of civil works are based on unit prices, which are prepared by counting cost for labour, cost for the procurement of such primary construction materials as cement, reinforcement bars, steel pipes, etc. and equipment, and contractor's overhead expenses and profits. Other important factors besides the unit prices are the geological conditions for excavation works and the haul distance between construction sites and borrow areas to collect concrete aggregates and embankment materials.

Since the foundation rocks are relatively hard, the unit prices for open and underground excavation are estimated to be US$ 1.00 and 2.00 more expensive than those of other schemes.

The unit prices of each work item are estimated in accordance with the above conditions as shown in Table 6.4.3. Costs necessary for civil works are estimated by multiplying the work quantity obtained from the preliminary design by the respective unit prices.

Indirect cost

All the work required for land acquisition and compensation will be carried out by the Nepali Government not to cause a delay to the project implementation schedule, and those costs include the costs required for the acquisition of the inundation areas and construction areas, transmission line routes, and road alignment. Since CR-2 is a run-of-river type, costs required for land acquisition and compensation are estimated at 1 % of direct cost.

Administration expenses are estimated at 1 % of direct construction cost.

Costs of engineering services, which are necessary for the feasibility study and the detailed design including the preparation of tender document, are estimated at 7 % of the sum of direct construction cost.

Physical contingencies are provided to cope with unforeseen physical conditions, the rate of which is assumed at 15 % of the sum of direct construction cost. Based on the above, total construction cost of CR-2 is estimated at US$ 69,446,046, a detailed breakdown of which is shown in Table 6.4.3.

6.4.4 Cost Evaluation

Economic viability of the scheme is assessed by calculating the return (benefits) gained by selling generated energy for the investment (costs) required for the construction of facilities. Assumptions and conditions applied for the economic evaluation are referred to Section 6.1.4.

The result of economic evaluation for CR-2 shows a net benefit of US$ 1.4 million for a discount rate of 10 % and EIRR of 10.3 %. Thus, CR-2 is judged to be viable in economic terms. A cash flow for the evaluation is given in Table 6.4.4.

7. ELECTRICITY SUPPLY IN THE STRATEGIC AREAS

7.1 Jumla Strategic Area

The Jumla strategic area includes three VDC, Chandannath, Mahatgaun and Depalgaun, as shown in Figure 7.1.1. Electric power in the area is at present supplied by a small hydro plant (Jumla) with an installed capacity of 200 kW. Electric power demand was projected by year 2013, which is the target year of this master plan study, for assessing electric power to be developed in the strategic area as follows :

Unit: kW

Demand	1991	1995	2000	2005	2010	2013
Domestic	229.5	250.2	278.4	308.7	341.7	362.7
Industrial and Commercial	88.3	87.6	97.4	108.0	119.6	126.9
Public	45.9	50.0	55.7	61.7	68.3	72.5
Total	363.7	387.8	431.5	478.4	529.5	562.1

Domestic electric demand was projected on basis of following procedures :

(a) Population by year 2013 was estimated on basis of 10,075 persons in year 1991 for the area and its annual increase rate of 1.04%, which is an average value in the district.

(b) The number of persons in a household was assumed at 5.6 based on the 1991 population census.

(c) Power load for domestic use was assumed as follows :

Lighting : 200W per household
Heating : 1,000W per household.

The number of households to use electricity as a heating source was assumed at 10% of the households with electric supply.

(d) Electrification ratio of 42.5% measured in the Bagmati area was assumed to stand for the ratio in the area and to increase with a rate of 0.5% a year, resulting 53.5% in year 2013.

Industrial and commercial demands, consisting of cottage industry, mills (rice, flour, saw and so on) and shops, were assumed at 35% of domestic demand by referring to the load forecast carried out for the rural electrification programmes of Manma and Dunai (Ref. IV-1 and 2).

Street lighting, administrative load, school use and airport lighting are grouped in the public demand, which was assumed at 20% of domestic demand by referring to the load forecast carried out for Manma and Dunai.

As mentioned above, the area has an installed capacity of 200 kW. The balance of 362.1 kW is required to be developed by year 2013 to meet the electric power demand in the area. Power sources will be sought in the upper reaches of the Tila River as discussed in the subsequent Section 8.4, Jumla Area.

7.2 Surkhet Strategic Area

The municipality and the VDCs which belong to the Surkhet strategic area are Birendranagar (municipality), Uttraganga and Latikoili as shown in Figure 7.2.1. The area at present receives electric power supply not only from the national power grid (refer to Figure 2.2.1) but also from the small hydropower plant (Surkhet) with an installed capacity of 345 kW.

Electric power demand in the strategic area was projected by year 2013 for assessing the capacity of electric power to be developed as follows :

Unit: kW

Demand	1991	1995	2000	2005	2010	2013
Domestic	947.1	1,189.8	1,578.0	2,087.1	2,753.1	3,247.5
Industrial and Commercial	331.5	416.4	552.3	730.5	963.6	1,136.6
Public	189.4	238.0	315.6	417.4	550.6	649.5
Total	1,468.0	1,844.2	2,445.9	3,235.0	4,267.3	5,033.6

The base to estimate domestic electric demand in the area was as follows :

Population in year 1991	:	38,627 persons
Annual increase rate of population	:	4.5 %
Number of persons in a household	:	5.2 persons/household.