HIS MAJESTY'S GOVERNMENT OF NEPAL

NEPAL ELECTRICITY AUTHORITY

FINAL REPORT
OF
FEASIBILITY STUDY
ON
ARUN-3 HYDROELECTRIC POWER DEVELOPMENT PROJECT

VOLUME I

MAIN REPORT

JUNE 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Kingdom of Nepal, the Japanese Government has decided to conduct a survey on Arun 3 Hydroelectric Power Development Project and entrusted the survey to the Japan International Cooperation Agency (J.I.C.A.). J.I.C.A. sent to Nepal a survey team headed by Mr. Shin-ichi Nojiri, Electric Power Development Co., Ltd., from February 1986 to March, 1987.

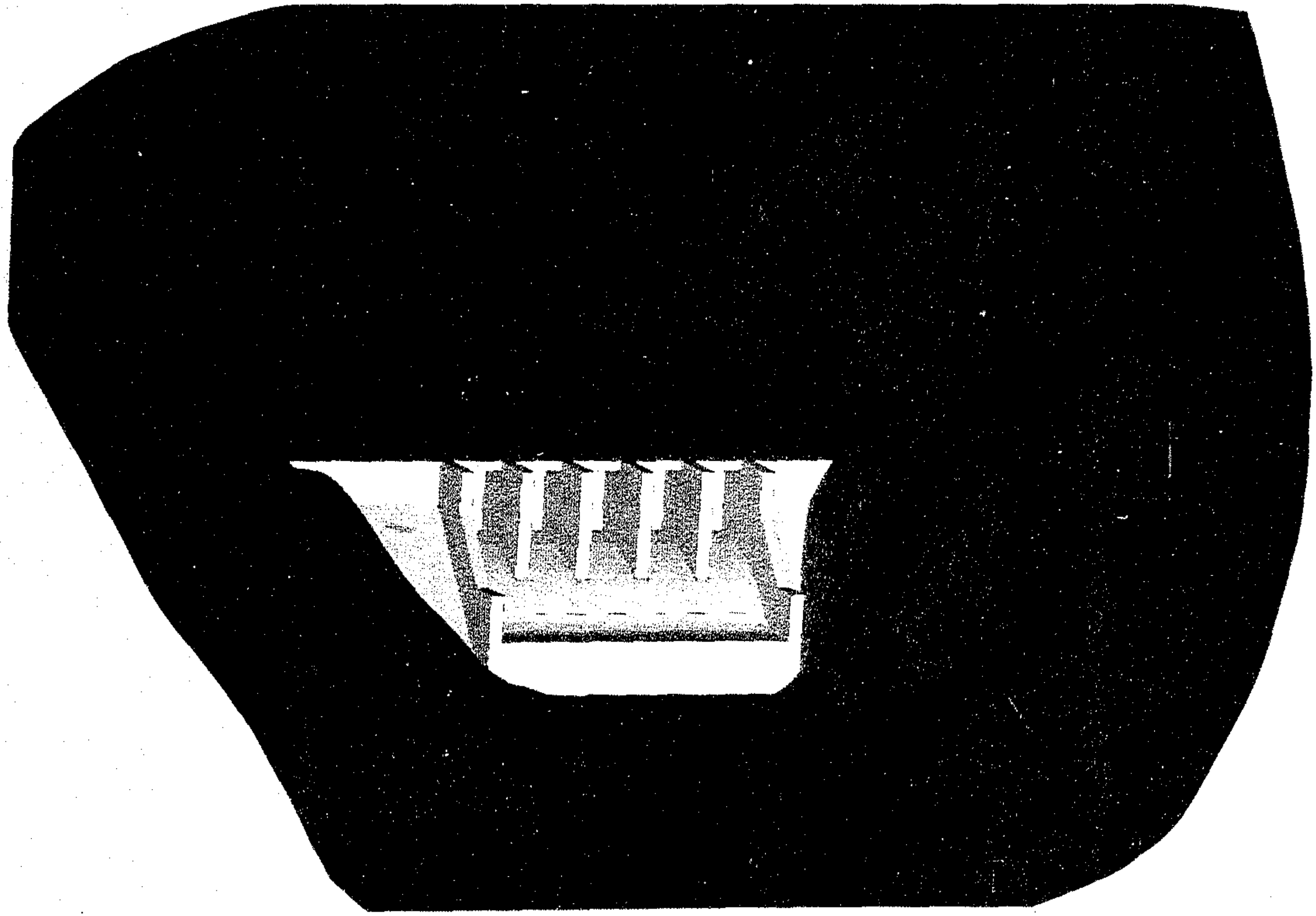
The team had discussions on the project with the officials concerned of the Government of Nepal and conducted a field survey in Arun River area. After the team returned to Japan, further studies were made and the present report has been prepared.

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

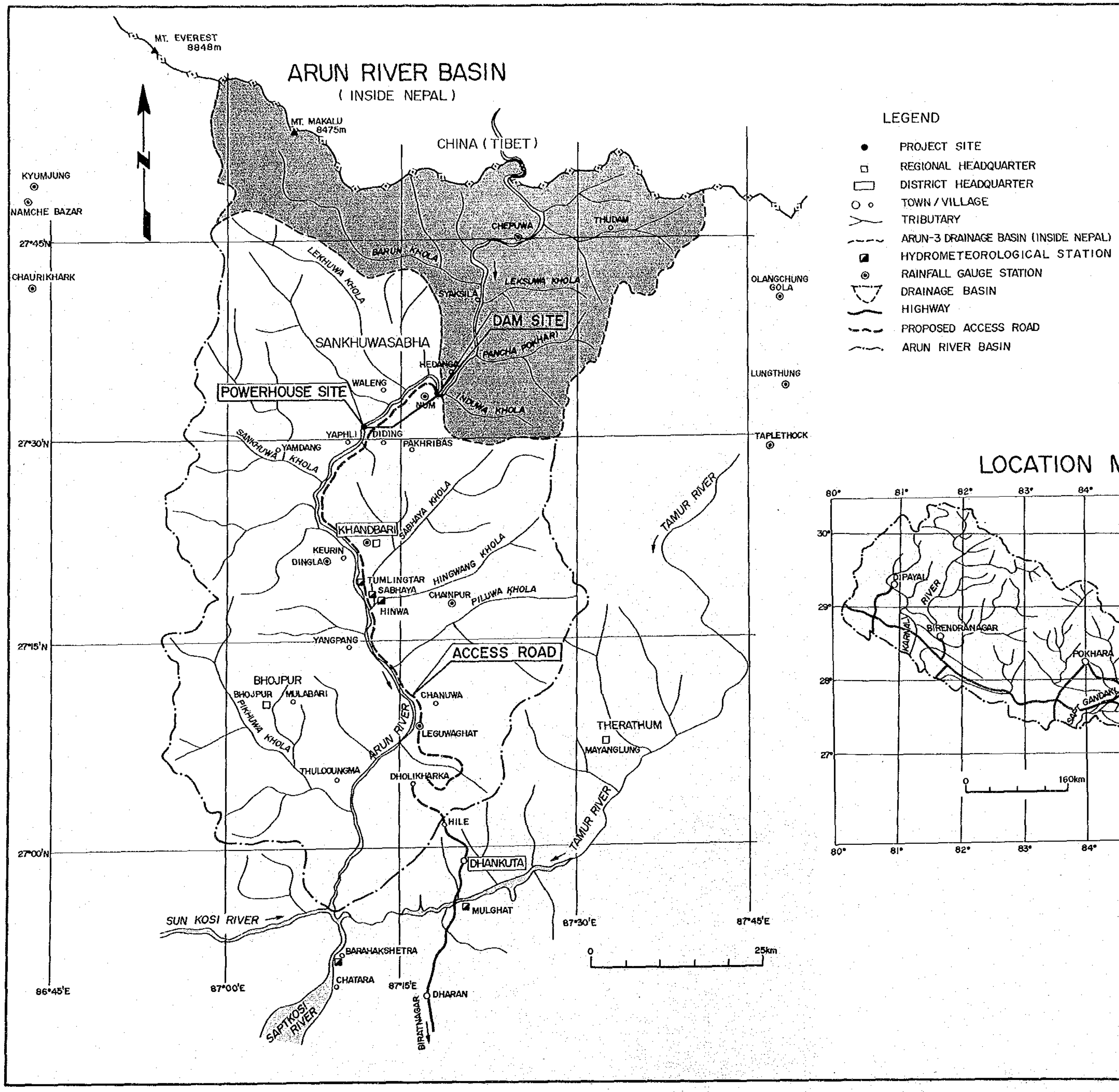
I wish to express my deep appreciation to the officials concerned of the Government of Nepal for their close cooperation extended to the team.

June, 1987

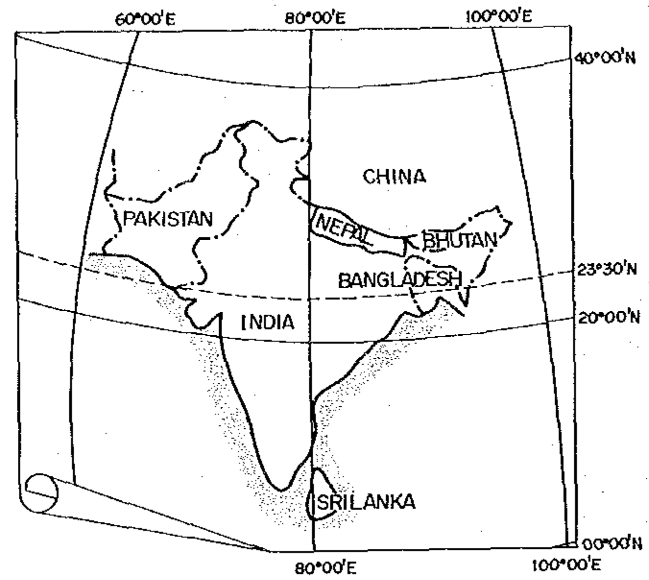
Keisuke Arita
President
Japan International Cooperation Agency



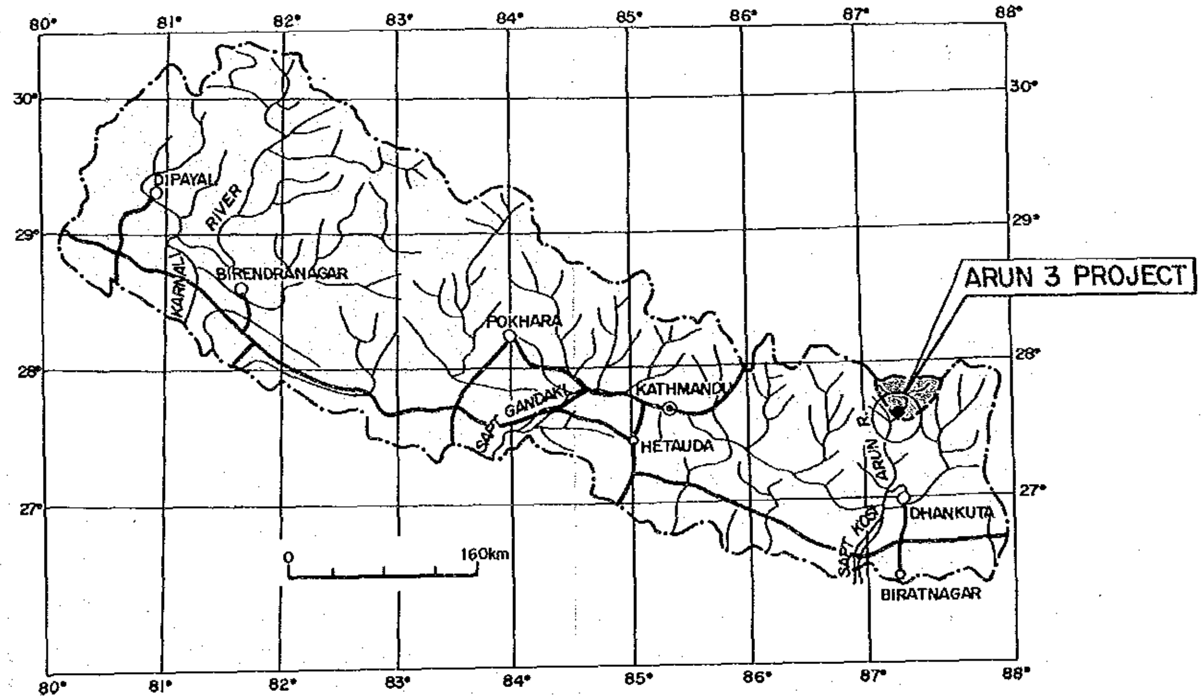
Bird eye view of Arun 3 Dam
(Drawn by Computer Aided Design System)



KEY PLAN



LOCATION MAP

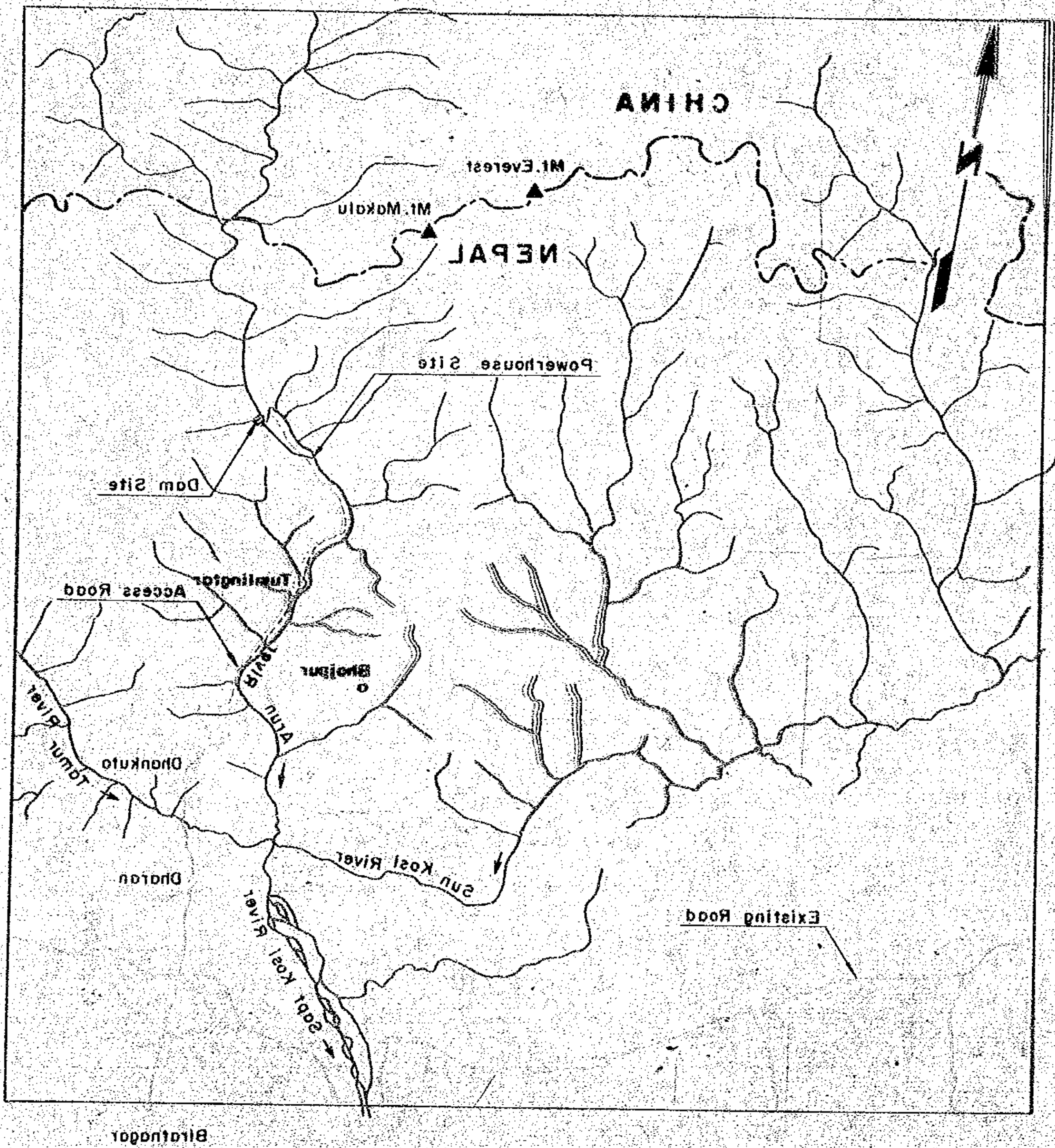


ARUN 3 HYDRO POWER PROJECT
FEASIBILITY STUDY

KEY AND LOCATION MAP

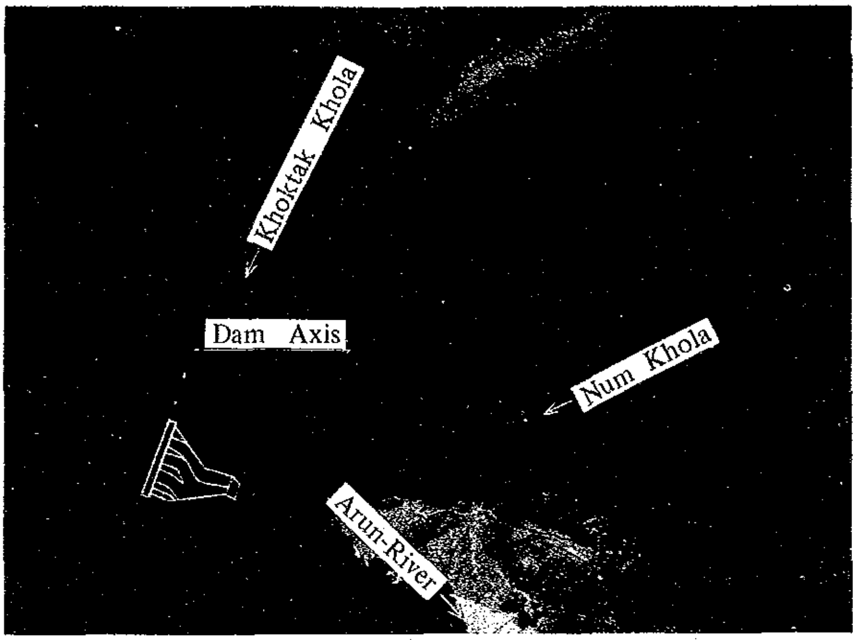
DWG. - 1	JUNE, 1987

LANDSAT Image of Arun River Basin
(Apr. 9, 1984)

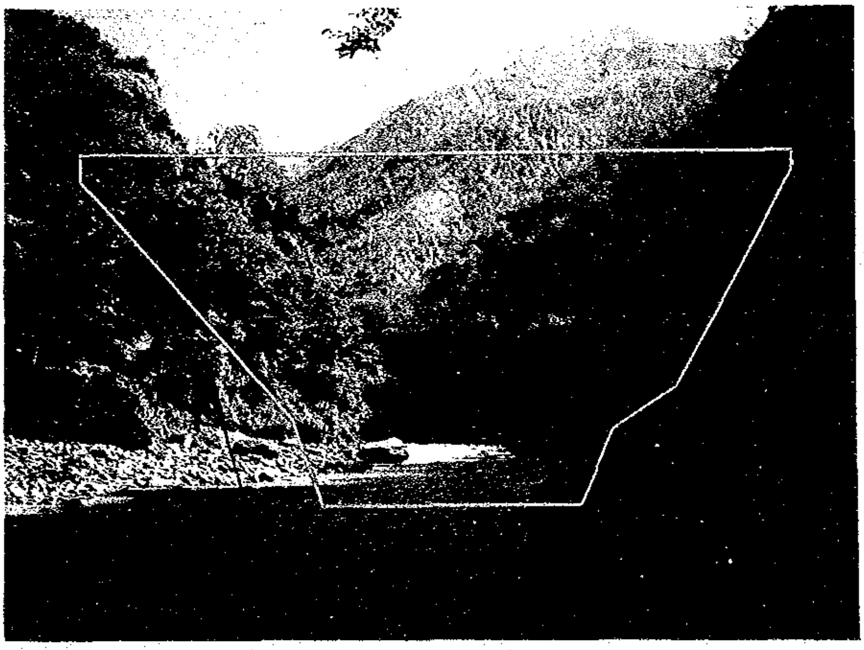


CHINA
NEPAL
N
Mt. Everest
Mt. Makalu
Powerhouse Site
Dam Site
Tumlingtar
Access Road
Bhojpur
Arun River
Tamur River
Dhankuta
Dharan
Sun Kosi River
Sapt Kosi River
Existing Road
Biratnagar

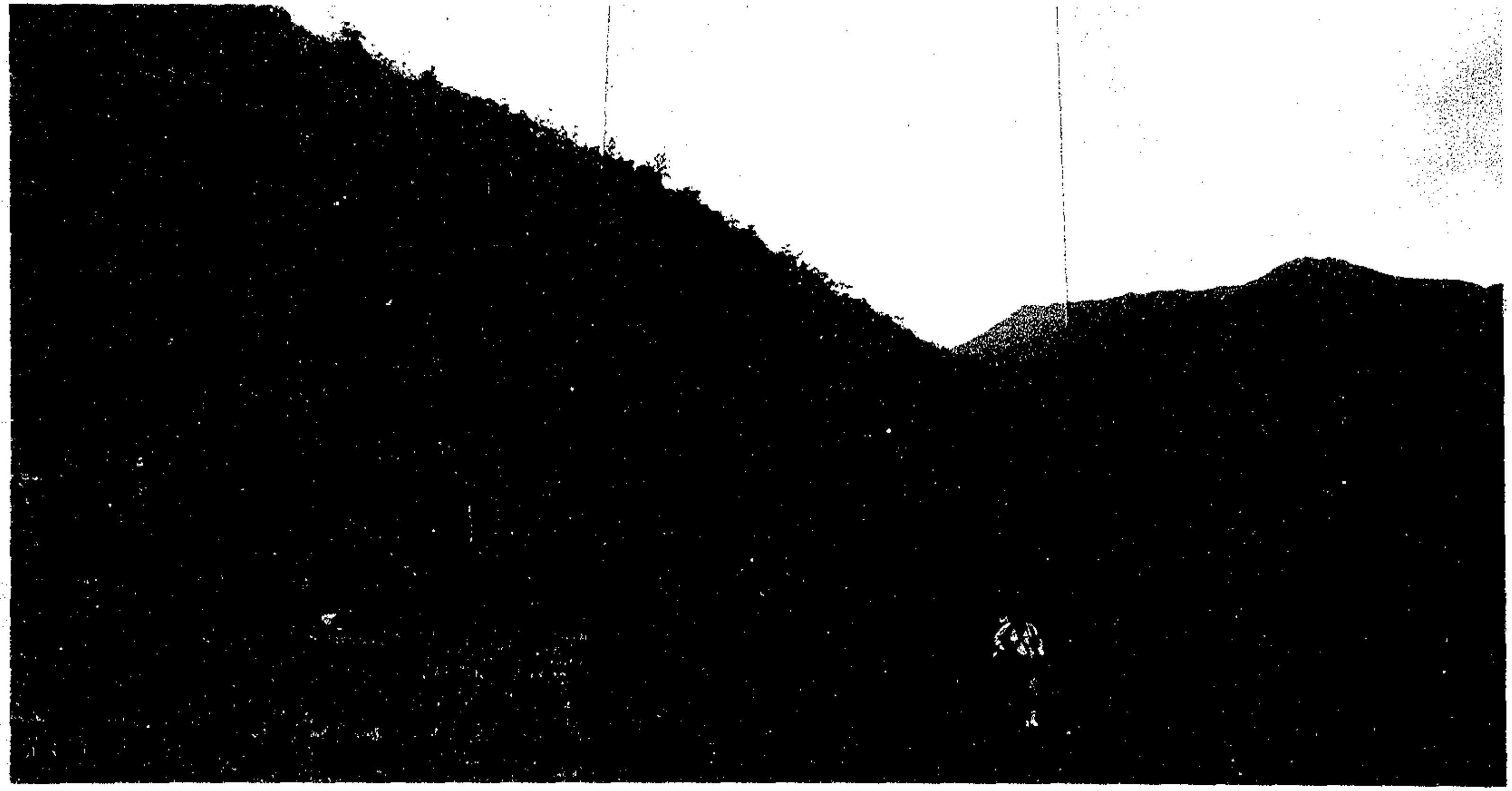
LANDSAT Image of Arun River Basin
(Apr. 9, 1984)



Arun 3 Dam Site
— Aerial view from Downstream —



Arun 3 Dam Site
— View from Downstream —



Powerhouse (Underground) & Switchyard Site
– View from Upstream –

CONTENTS

Page

CHAPTER 4. GEOLOGY

CHAPTER 5. HYDROLOGY AND METEOROLOGY

CHAPTER 6. ALTERNATIVE SCHEME

CHAPTER 7. OPTIMIZATION STUDY

SUMMARY

SUMMARY

This report concerns the Feasibility Study on the Arun 3 hydroelectric power development project and presents the results of the studies undertaken by the Japan International Cooperation Agency (JICA) over the period from February 1986 to April 1987. The general aspects of investigations and studies in respective fields in the report are summarized below.

1. Field Investigation

The extensive programme of field investigation was made in order to identify the geological condition of the project area, hydrology of the river at the dam site and to prepare the topographical map of the project area. The investigation programme including a total of 558 m of core drilling and 3.99 km of seismic prospecting at the related structures, ground survey covering an area of 593,000 m^2 was conducted and 1:500 scale maps of dam and powerhouse areas were produced. 1:5,000 scale map of the project area including headrace tunnel and reservoir areas and 1:10,000 scale map of access road linking the project area with the nearest road terminal Hile were also prepared on the basis of the existing aerophotographs of 1:20,000 scale. Rock mechanical test was carried out to acertain the mechanical properties of foundation rock. A geological map in the scale of 1:500 for dam and powerhouse areas and 1:5,000 map for headrace tunnel area were also prepared.

2. Geology

The geological formation of the entire project area consists of gneiss and micaschist with gneiss predominating. The proposed dam is located on the competent foundation rock composed of augen gneiss. Thickness of river deposit at the dam site is confirmed to be about 13 m. The rock foundation at the desanding basin is composed of augen gneiss with a low velocity zone across the central portion of the basin. The headrace tunnels pass through metamorphic rocks (augen gneiss and mica schist) with intrusion of granite.

At the Pikhuwa site, augen gneiss is widely distributed in the area including the surge tank and penstock route sites. Intrusion of deeply weathered granite formation occurs around the surge tanks of the Kaguwa site. Augen gneiss of good quality is distributed at both the Pikhuwa and Kaguwa powerhouse sites.

3. Hydrology

The Arun river has a catchment area of 29,310 km^2 at the dam site about 90% of which lies in the Tibetan region. Numerous glaciers and snow packed mountains serves as the source of feeding of this river, giving the river a high firm discharge throughout the year. The flood is usually generated by the monsoon rain which occurs from late June to late September, which does not coincide with the snow melting period.

The high base flow and comparatively low flood discharge create a favorable condition for designing the structure and yielding the benefit. The long term annual average discharge is calculated as 321 m^3/s. While the diversion discharge calculated on the basis of dry flood flows is estimated at 490 m^3/s. Owing to the fact that limited information is available for the greater part of the Tibetan catchment basin and also proper hazard potential of glacier lake outburst flood (GLOF) be presumed, it is considered proper to take the value of the probable maximum flood (PMF) instead of usual flood of 1,000 year return period for the design of structures such as spillway. The PMF discharge estimated at 7,700 m^3/s is considered enough for taking care of the uncertainties in the upper reach of the river.

In connection with GLOF, past records, mechanism, glacier lake distribution in the Arun river basin, etc. were investigated. Considering that the GLOF assumed at the Barun Khola would have the largest impact on the downstream structures compared with others in the Arun river basin, simulation analysis of prescribed GLOF was examined and the maximum flood discharge was estimated at approximately 7,200 m^3/s at the dam site.

4. Load Forecast

In the case that the Arun 3 project be implemented in succession to the Marsyangdi project which is being under construction, its optimum scale and development program shall agree with the trend of load demand in Nepal after 1994. The latest load demand forecast prepared by NEA and released in July 1986 is adopted as the basic condition for the study. The said load demand forecast for future twenty years is made by disaggregate method for the first five years forecast and trend method for the succeeding medium to long term forecast taking into consideration the industrial, agricultural and commercial development plan of Nepal, expansion plan of transmission and substation facilities, recent economic movement, etc. The above forecast is also cross-examined macrographically based on the growth rates of GDP and energy consumption per captia, the population growth rate, etc. and found to be adequate.

5. Comparative Studies on Alternative Layout

Different alternative schemes of the project are studied. In particular, two dam locations: upstream and downstream of the junction of the Khoktak Khola and Num Khola with the Arun river, two power systems: one with one intake, one headrace tunnel, one surge tank and another with two intakes, two headrace tunnels and two surge tanks, desanding basin of outdoor and underground types, and powerhouse of outdoor as well as underground types at two locations of Pikhuwa and Kaguwa are analyzed. The final scheme that came out of the study on the alternative schemes includes a dam of 65 m in height, two sets of intakes, desanding basins, headrace tunnels, surge tanks, penstocks and tailrace tunnels, and a powerhouse of underground type at the Pikhuwa site which are to be developed in two stages.

6. Optimization Study

Upon preparation of the cost estimates based on the preliminary designs in which all topographical and geological information obtained by the field investigations are fully incorporated and also the development program meeting the domestic load growth, the optimum scheme is examined with parameters such as the maximum power discharge, intake water level corresponding to the dam height and tailwater level corresponding to the powerhouse site. The results induced therefrom for two cases; single stage development to cope with domestic power demand only and two stage development in consideration of power export also, are as tabulated below.

	1st Stage (Without Export)	1st & 2nd Stages (With Export)
Intake water level (m)	840	840
Max. power discharge (m^3/s)	80	160
Max. output (MW)	201	402

Eventually, the optimum scheme of this project is the Pikhuwa power plant (1) with intake water level at EL. 840 m, the maximum power discharge of 160 m^3/sec and the maximum output of 402 MW, (2) to be developed in two stages.

Annual generating energy for the optimum scheme are summarized below.

Scheme	Installed Capacity (MW)	Generating Energy (GWh)		
		Firm	Secondary	Total
1st stage	201	1,721.6	0	1,721.6
1st & 2nd stages	402	1,863.2	1,097.1	2,960.3

The scheduled times of starting commercial operation of respective units are as shown below.

1st stage development scheme

Unit No. 1 (67 MW)	Jun. 1994
Unit No. 2 (67 MW)	Sep. 1994
Unit No. 3 (67 MW)	Sep. 1998

2nd stage development scheme

Unit No. 4 (67 MW)	Dec. 1998
Unit No. 5 (67 MW)	Mar. 1999
Unit No. 6 (67 MW)	Jun. 1999

7. Feasibility Design

The feasibility designs are undertaken based on every topographical and geological information obtained by the field investigations as well as the latest technical standard. Basic project features applied to the designs are intake water level at EL. 840 m, max. power discharge of 160 m^3/s and max. output of 402 MW as well as two headrace tunnels and 6 units of electrical equipment for facilitating two stage development. Both types of powerhouse construction; outdoor and underground types at both the Pikhuwa and Kaguwa sites, are studied and the underground type powerhouse at the Pikhuwa site is adopted from technical and economical point of view. As the type of the water turbine affects greatly on the design of powerhouse structure, the economic comparison between Francis and Pelton turbines is examined and the Francis turbine is finally adopted.

The main features of the Project are as shown below.

General Project Features

(1) Reservoir

Catchment area	29,310 km^2
Annual inflow	10,123 $\times 10^6$ m^3
High water level	EL. 842.00
Low water level	EL. 838.00
Flood water level	EL. 844.00
Available drawdown	4.00 m
Effective storage capacity	2.0 x 10^6 m^3
Dead storage capacity	4.5 x 10^6 m^3

(2) Diversion Tunnel

Length	354.50 m
Diameter	7.00 m (horseshoe)
No. of unit	1
Maximum discharge	490 m^3/s

(3) Dam (1st & 2nd Stages)

Type	Concrete gravity
Height	65 m
Volume	160,700 m^3

(4) Spillway

Gate type	Radial Gate
No. of gates	5
Size of gate	Width 12.0 m x Height 14.5 m
Discharge capacity	7,700 m^3/s

(5) Intake (1st & 2nd Stages)

Type	Vertical tower
No. of units	2

(6) Desanding Basin (1st and 2nd Stages)

Type	Underground (continuous flushing type)
No. of chambers	2
Width	20.00 m
Height	32.00 m
Length	110.00 m

(7) Headrace Tunnel

Type	Pressure tunnel
Length	11.354 km each
Excavated Diameter	7.00 m (circular for TBM)
"	" (horseshoe for CMB)
No. of units	1 (1st stage)
	1 (2nd stage)

(8) Surge Tank

Type	Orifice
Shaft diameter	14.00 m
Height	70.00 m
No. of units	1 (1st stage)
	1 (2nd stage)

(9) Penstock

Type	Embedded steel pipe
Length	376.74 m
Diameter	5.80 m - 2.30 m
No. of unit	1 (1st stage)
	1 (2nd stage)

(10) Powerhouse (1st and 2nd Stages)

Type	Underground
Width (Cavern size)	16.00 m
Length (")	120.00 m
Height (")	41.50 m
No. of units	3 (1st stage)
	3 (2nd stage)
Turbine	Francis (69 MW)
Generator	Vertical shaft, synchronized (79 MVA)
Main transformer	Indoor, oil immersed, water cooled (79 MVA, 13.8/220 kV)

(11) Tailrace Tunnel

Type	Pressure tunnel
Diameter	3.50 m (circular) - 5.80 m (horseshoe)
Length	272.00 m
No. of units	1 (1st stage)
	1 (2nd stage)

(12) Power Generation

Max. power discharge	80 m^3/s (1st stage)
	160 m^3/s (1st & 2nd stages)
Gross head	302 m
Effective head	288 m
Max. output	201 MW (1st stage)
	402 MW (1st & 2nd stages)

Annual energy	firm	secondary
1st stage	1,721.6 GWh	0.0 GWh
1st & 2nd stages	1,863.2 GWh	1,097.1 GWh

(13) Access Road

Length	115 km (Hile - Leguwa Ghat - Tumlingtar - P/H - D/S)

8. Transmission Line and Substation

The optimum scheme of transmission and substation facilities to be developed in stages corresponding to construction sequence of the Arun 3 power station, has been made up and outline of the facilities are summarized below.

The transmission line voltage has been selected as 220 kV, however, the operational voltage is to be provisionally 132 kV before No. 3 unit will have been put in service in September, 1998.

(1) Transmission Line

Arun 3 Switchyard - Dubi Substation	220 kV, 2 cct, 120 km
Dubi Substation - Dhalkebar Switchyard	220 kV, 2 cct, 146 km
Dhalkebar Switchyard - New Kathmandu Substation	220 kV, 2 cct, 120 km

(2) Substation/Switchyard

Dubi Substation (Expansion)	70 MVA x 3 (Transformer)
Dhalkebar Switchyard (Expansion)	25 MVA x 2 (Shunt Reactor)
New Kathmandu Substation (New Construction)	100 MVA x 3 (Transformer)

9. Total Construction Cost

The total construction cost estimated for the Arun 3 project is as shown below. The unit prices of materials and equipment are made up for the price level at June 1986.

	Foreign currency portion (US$)	Local currency portion (US$)	Total (US$)
1st stage scheme (201 MW)	328,561,000	55,830,000	384,391,000
1st & 2nd stage schemes (402 MW)	445,872,000	72,607,000	518,479,000

10. Construction Schedule

The Arun 3 project is to be constructed in two stages; the 1st stage development scheme and the 2nd stage development scheme. The 1st stage scheme is to develop the maximum output of 201 MW to cope with the domestic power demand, while the 2nd stage is to develop succeedingly another 201 MW taking also power export into consideration. The construction schedule of the 1st stage development scheme is set up aiming the start of commercial operation of unit No. 1 at June 1994 and the construction of the 2nd stage development scheme is to be started 4 years after commencement of construction of the 1st stage development scheme. The critical path of the project runs along the construction works of access road and headrace tunnel. The construction periods of the major works are as shown below.

(1) Supporting Facilities

Access road	Nov. 1987 - Oct. 1989 (1st phase)
	Nov. 1989 - Oct. 1991 (2nd phase)
Preparatory works	Nov. 1989 - Oct. 1990

(2) Reservoir Storage Facilities

Diversion tunnel	Nov. 1989 - Oct. 1990
Dam & spillway	Nov. 1990 - Feb. 1994

(3) Waterway

Desanding basin	Jan. 1991 - May 1994
Headrace tunnel	Nov. 1989 - May 1994 (No. 1)
	Jan. 1994 - Sep.1998 (No. 2)

(4) Powerhouse

Civil works — Jan. 1990 - May 1994

Electromechanical equipment

1st stage

Nov. 1990 - Jun. 1994 (No. 1)

Feb. 1991 - Sep. 1994 (No. 2)

Feb. 1997 - Sep. 1998 (No. 3)

2nd stage

May 1997 - Dec. 1998 (No. 4)

Aug. 1997 - Mar. 1999 (No. 5)

Nov. 1997 - Jun. 1999 (No. 6)

(5) Transmission Line

1st stage

Schedule 1 (Jun. 1994) 132 kV provisional operation

- Arun 3 P/S - Dubi S/S (220 kV, 120 km, 2 cct towers with 2 cct stringing)
- Dubi S/S - Dhalkebar S/Y (220 kV, 146 km, 2 cct towers with 1 cct stringing)
- Dhalkebar S/Y - New Kathmandu S/S (220 kV, 120 km, 2 cct towers with 1 cct stringing)

Schedule 2 (Sep. 1998) 220 kV operation of above schedule 1

2nd stage

Schedule 3 (Dec. 1998) 220 kV operation, power export is considered.

- Dubi S/S - Dhalkebar S/Y (220 kV, 146 km, 1 cct stringing)
- Dhalkebar S/Y - New Kathmandu S/S (220 kV, 120 km, 1 cct stringing)
- Dubi S/S - Importing country (220 kV, 2 cct towers with 2 cct stringing)

(6) Substations and Switchyard

1st stage

Schedule 1 (Jun. 1994) 132 kV provisional operation

- Dubi S/S (expansion of 220 kV equipment)
- Dhalkebar S/Y (expansion of 220 kV equipment)
- New Kathmandu S/S (New installation of 132 kV, 220 kV equipment)

Schedule 2 (Sep. 1998) 220 kV operation

- Dubi S/S (expansion of 220 kV equipment)
- New Kathmandu S/S (expansion of 220 kV equipment)

2nd stage

Schedule 3 (Dec. 1998) 220 kV operation, power export is considered.

- Dubi S/S (expansion of 220 kV equipment)
- Dhalkebar S/Y (expansion of 220 kV equipment)
- New Kathmandu S/S (expansion of 220 kV equipment)

11. Access Road

Two proposed routes are studied; Alternative A running through the populated centers such as Chainpur, Khandbari, and Alternative B running along the Arun river with the shortest length to the dam site from the end of the nearest motable road, i.e., Hile. Geological conditions along Alternative B is better in general, however, it has disadvantage that the bridge spans crossing the tributaries are comparatively long. In consideration of the requirement to complete the access road as early as possible, Alternative B having shorter length is selected also taking into account that Alternative B will serve for the rural development by construction of feeder roads to the populated centers.

12. Environmental Impact

The construction of the large sized project and long access road as involved in the Arun 3 project exerts, in general, a great influence on health and welfare of the inhabitants in the related area. According to the results of environmental assessment, however, it is judged that no harmful effects on the inhabitants as well as ecology in the project area will be produced. However, a limited amount of compensation and resettlement of the inhabitants will be necessary.

13. Project Evaluation

Results of the project evaluation for two stage development scheme are summarised below.

(1) Energy Cost

	Receiving End		Generation End	
	1st stage (201 MW)	1st & 2nd stages (402 MW)	1st stage (201 MW)	1st & 2nd stages (402 MW)
Construction Cost (10^6 US$)	384.4	518.5	280.9	392.0
Generated Energy (GWh)	1,635.5	2,816.2	1,721.6	2,960.3
Energy Cost (US Cent/kWh)	3.1	2.4	2.1	1.7

(2) EIRR and B/C

	EIRR	B/C
1st stage scheme (201 MW)	15.5%	1.5
1st and 2nd stage schemes (402 MW)	19.5%	2.1

(3) FIRR

	FIRR
1st stage scheme (201 MW)	10.8%
1st and 2nd stage schemes (402 MW)	14.9%

CONCLUSION AND RECOMMENDATIONS

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Conclusion

1. The total installed capacity of generating facilities of Nepal is 182 MW as of March, 1987. According to the load demand forecast released in July, 1986, the growth rate of future load demand is estimated at an average of 11.4 percent upto F.Y. 1993/94 and then 6.3 percent upto F.Y. 2005/ 06. In despite of rather low estimate mentioned above, it is still anticipated that the power supply capacity will come short in 1993/94, even the additional capacity of 113 MW to be generated by the projects under construction including the Marsyangdi power station (69 MW) being expected to be put in service in 1989 is taken into account. Since Nepal is endowed with abundant hydropower resources viable of economical construction, it is necessary to select the next hydropower development project urgently and proceed to construction of the same in order to avoid a situation of shortage in power supply capacity.

2. Since the Arun 3 hydroelectric power development project is capable of producing power of big capacity at low cost owing to abundant river discharge as well as high head available at the site, it can cope with the increasing domestic power demand over long period and also contribute to the national economy by possible power export of large scale. Further, it will serve with its stable power supply capability for promotion of light industries and for breakaway from dependance on wood as the domestic energy source, thus having considerable effects on the important national energy policies.

   While, it is indispensable to construct the access road over 115 km for implementation of the Arun 3 hydroelectric power development project and once this road is open for traffic service, it will produce immeasurable benefit for the local economy and welfare. Also it will provide apparently the favorable conditions for the future development of the projects existing in the upper Arun basin in series.

3. According to the load demand forecast of Nepal, additional capacities should be installed by June 1994. The way to fully and economically

utilize the hydropower potential endowed to this project is to carry out the large scale development considering power export. As the necessary arrangements related to power export are, however, not made yet at this time on both sides of the exporting and importing countries, the most realistic plan is to develop this project in two stages; the 1st stage development scheme to cope with the domestic load demand and the 2nd stage development scheme being the extension scheme considering power export.

The Arun 3 project mainly includes a concrete dam of 65 m in height, two headrace tunnels of 11.4 km in each length, underground type powerhouse, transmission lines of 386 km in total length, etc. and its development scale is 201 MW (3 units, 67 MW each) as the 1st stage development scheme and additional 201 MW (3 units, 67 MW each) as the 2nd, totalling 402 MW. The total energy production is estimated at 1,721.6 GWh and 2,960.3 GWh after completion of the 1st and 2nd stage development schemes, respectively.

4. The geological condition in the project area is favorable. Sound gneiss rock is widely distributed at the dam and powerhouse sites. Though the project involves desanding basin and powerhouse of underground type, there will be no particular technical problems in construction of these large sized caverns. While, mica schist distributing at the central part of headrace tunnel route is observed and it is important to identify its character for the future detailed designs and construction planning.

5. It must be well recognized that the construction schedule aiming at the start of commercial operation of the Arun 3 power station at June 1994 is considerably tight. Especially, the precondition for meeting the above schedule is that the access road should be open for transportation of construction materials and equipment by November, 1989 as the 1st phase work. The special considerations are needed in order to start the construction of access road at the end of rainy season, i.e., November 1987. It is considered that the access road can be completed within the above-stated period (1st phase) by advanced construction of pilot road followed by simultaneous works at 4 subdivided sections.

6. As to the construction schedule, unit No.1 of the 1st stage development scheme is to be operated in June 1994 being 4.5 years after the access road is open to traffic. Unit No.2 is also to be operated successively in order to secure the stability of power supply system, however, unit No.3 will be operated in September 1998 in line with the growth of domestic load demand.

While, construction of the 2nd stage development scheme is to be commenced 4 years (that will be sufficient for negotiation and fund arrangement) after commencement of construction of the 1st stage development at the end of 1989. The completion dates of the 1st and 2nd stage development schemes are scheduled to be September 1998 and June 1999, respectively.

In the event of stagewise development stated above, a part of facilities in the 2nd stage development scheme will be necessarily constructed simultaneously with execution of the 1st stage development. Namely, the respective structures of intake, desanding basin, powerhouse (excluding installation of equipment) and tailrace outlet are to be constructed as the unified ones to secure the safety of works and to avoid the increase in cost that will be further required when they are constructed separately.

7. The construction cost at the price level on June 1986 is as shown below.

	Foreign currency portion (US$)	Local currency portion (US$)	Total (US$)
1st stage scheme (201 MW)	328,561,000	55,830,000	384,391,000
1st & 2nd stage schemes (402 MW)	445,872,000	72,607,000	518,479,000

8. According to the project evaluation, economical internal rate of return (EIRR) and financial internal rate of return (FIRR) are calculated as shown below.

(1) Energy Cost

	Receiving End		Generation End	
	1st stage (201 MW)	1st & 2nd stages (402 MW)	1st stage (201 MW)	1st & 2nd stages (402 MW)
Construction Cost (10^6 US$)	384.4	518.5	280.9	392.0
Generated Energy (GWh)	1,635.5	2,816.2	1,721.6	2,960.3
Energy Cost (US Cent/kWh)	3.1	2.4	2.1	1.7

(2) EIRR and B/C

	EIRR	B/C
1st stage scheme (201 MW)	15.5%	1.5
1st and 2nd stage schemes (402 MW)	19.5%	2.1

(3) FIRR

	FIRR
1st stage sceme (201 MW)	10.8%
1st and 2nd tage schemes (402 MW)	14.9%

9. The construction of the large sized project and long access road as involved in the Arun 3 project exerts, in general, a great influence on health and welfare of the inhabitants in the related area. According to the results of environmental assessment, however, it is judged that no harmful effects on the inhabitants as well as ecology in the project area will be produced. However, a limited amount of compensation and resettlement of the inhabitants will be necessary.

10. It is concluded that 1st stage development (201 MW) is technically and economically feasible. If the project is further developed into 2nd stage (402 MW in total), the project will become much more economically attractive.

Recommendations

1. As Arun 3 project is found to be economically and technically attractive the proceeding with immediate implementation of the project is highly recommended.

2. Since it is essential to strictly observe the construction schedules of access road and headrace tunnel (which are on the critical pass) in order to start the commercial operation of unit No.1 in June 1994, the related preparatory proceedings and detailed designs have to be actively promoted.

3. In order to obtain the further detailed information that will be incorporated in the future detailed designs and construction activities, the following investigations have to be made as soon as possible.

   (a) Driving of exploratory adit along work adit in headrace tunnel

   Since mica schist is distributed widely in this area, further investigations are needed in order to obtain geological features at the place of tunnel route and also to obtain geotechnical information for detailed construction planning.

   (b) Additional test drillings around surge tanks

   In order to check the adequacy of surge tank locations and also to obtain the supplementary information for detailed designs, it is required to survey the geological conditions in more detail.

   (c) Driving exploratory adit reaching powerhouse cavern

   This exploratory adit is for obtaining detailed geotechnical information of rock around powerhouse and transformer caverns and the results are to be incorporated in the stability analysis of caverns as well as study on construction procedure.

(d) Other investigation works

Test drilling, seismic prospecting and topographic survey of 1/500 scale around the dam site, desanding basin, headrace tunnel, tailrace outlet, etc. are to be carried out to obtain the geological information in more detail, where deemed necessary.

4. In order to collect the additional hydrological data to be referred to the construction planning, it is necessary to make continuous measurement of river discharge at the upstream dam gauging station. Suspended load survey at this station is also required.

Further, it will also be necessary to augment the weather observations at the existing meteorological stations in the Arun river basin to obtain weather conditions to be referred especially during construction. New construction of meteorological stations in the area upstream of the dam site is desired.

5. To make further studies on GLOF, site reconnaissance at the glacier lake on the Barun Khola and data collection related to distribution and sizes of glacier lakes in Tibet are necessary.

6. It is necessary to actively undertake the studies on transmission, substation and telecommunication systems, especially of those itemized below, so that the schedules of these work components will be reasonably set out in line with the construction schedule of the Arun 3 project.

(a) Transmission line route between the Dhalkebar switchyard and the New Kathmandu substation.

(b) Location of the New Kathmandu substation and connection of same with the existing substations and expansion programme of the existing power supply system.

(c) Expansion plan of 132 kV transmission line in the western region.

(d) Formation of Supervisory Control and Data Acquisition (SCADA) system of NEA's power supply facilities including the Arun 3 power station.

(e) Formation of telecommunication system including its route between the Arun 3 power station and Kathmandu.

(f) Further studies on power supply system to set up, on the premise of the development of the Arun 3 project, the optimum overall system including transmission and subtransmission networks around Kathmandu and in the western region, SCADA system and telecommunication system.

CHAPTER 1 . INTRODUCTION

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1.1 Preface

This Final Report includes the results of the feasibility study works undertaken in the period from February 1986 to April 1987 on the Arun 3 hydroelectric power development project in Nepal as a part of technical cooperation of the Japan International Cooperation Agency (JICA). The Report is composed of the following three volumes.

Volume 1 Main Report
Volume 2 Access Road
Volume 3 Appendix

A part of the studies related to the access road is specially prepared in a separate volume at the request of the Nepal Electricity Authority (NEA). On the basis of Agreement signed by JICA and NEA dated 12 December 1985, the study on the access road by the Team is of preliminary design level using newly developed aerophotographic maps of 1/10,000 scale. However, the Field Report on the access road separately prepared by NEA on the basis of 1/5,000 scale aerophotographic maps was provided to the Team in November 1986 to further supplement those data and field information which the Team had already collected. The contents of the said Field Report are well incorporated in this Report.

1.2 History of Project

The Arun 3 hydroelectric project was identified in the course of the "Master Plan Study on the Kosi River Water Resources Development" conducted with the JICA's technical assistance from 1983 to 1985 and was accorded the highest priority for future further study. Recognizing the attractiveness of the project, NEA immediately carried out the prefeasibility study of the project and issued the report in October 1985. The findings of this study reconfirmed the technical and economical attractiveness of the project which led to the HMG's request to the Government of Japan in May 1985 to assist in carrying out the feasibility study of the project.

The Government of Japan agreed to provide assistance and instructed JICA immediately to duly consider the above. Upon careful investigations of the status of preliminary studies performed so far by NEA and the draft report of NEA's prefeasibility study, JICA dispatched to Nepal the preliminary study team composed of five (5) experts headed by Mr. H. Suzuki (then Head of Natural Resources Division, Mining & Industrial Planning and Survey Department, JICA) in November 1985. After their arrival in Nepal, the team undertook site reconnaissance, data collection, etc. and also had discussions with NEA. The Scope of Work (S/W) and appurtenant Minutes of Meeting (M/M) for the feasibility study on the Arun 3 hydroelectric power development project were then prepared, agreed finally on their contents and signed on December 12, 1985. In order to promote the study works contemplated in the above S/W and M/M, JICA proceeded in selection of the consultant firm and awarded the works to the joint venture of the Electric Power Development Company (EPDC) and the Chuo Kaihatsu Corporation (CKC), who subsequently transferred its service contract to the Chuo Kaihatsu Corporation, International (CKCI) on January 27, 1987, through prescribed documentary examination.

The study team organized in accordance with the above consultancy contract and headed by Mr. S. Nojiri immediately started the home study of the project background and was dispatched to Nepal for approximately one month from February 23 to March 25, 1986 to carry out the first site investigation works which include data collection indispensable for further studies in various fields, site reconnaissance and drafting of topographical, geological field investigation works. The study team was again dispatched for approximately three months from May 4, 1986 to carry out the second site investigation works which include further data collection, execution of the topographical, geological field investigations previously drafted, investigation of the existing power generation, transmission line and substation facilities, and aerial reconnaissance by helicopter of probable routes of access road and transmission line for this project.

All reference data collected during the above site visits and topographical and geological data obtained by the field investigation works were brought back to Japan and have been used for the succeeding study works in Japan. The study team has intensively executed various works such as analyses of these data and other study works indicated in the Scope of Work.

1.3 Object and Scope of Study

The object and scope of this study are indicated in detail in Chapters 2 and 3 of the Scope of Work agreed and signed by JICA and NEA on December 12, 1985.

1.4 Data

In order to undertake analyses and other studies for feasibility study of hydroelectric projects, it is necessary that all information such as topographic maps covering project area, hydrological and meteorological data, geological data, data for project cost estimation, economical and financial indications, etc. be fully furnished to the study team. As the abovementioned data necessary for analytical studies were not comprehensive at the time of commencement of this study, it was required to collect the existing data first and to execute the field investigation works immediately to clarify topographical and geological features of the project area. The main data collected in Nepal and those generated by the study team based on the field investigation activities are as described below.

1.4.1 Generated Data

(1) Aerophotographic Mapping

Aerophotographic maps of the area covering dam including reservoir to powerhouse and probable access road were prepared in 1/5,000 and 1/10,000 scales respectively, using aerophotographs of 1/20,000 scale obtained at the Topographic Survey Branch of the HMG/Nepal Department of Survey.

(2) Topographic Mapping by Ground Survey

As for topographic maps necessary for basic design of the main civil structures, estimating the work quantities, etc., topographic maps covering the dam area (dam, diversion tunnel, intake, desanding basin, etc.) and also powerhouse area (surge tank, penstock, powerhouse, switchyard, etc.) were prepared in the scale of 1/500.

(3) Levelling and Installation of Bench Marks

Levelling survey between dam and powerhouse sites was carried out and five bench marks were installed. The results of this levelling survey were properly referred to (1) aerophotographic mapping and (2) topographic mapping above.

(4) Geological Data

For undertaking feasibility designs in the feasibility study, geological investigation is of the great importance. This activity constituted a major part of the field investigation works and the results have been fully incorporated in making project layout and designs of the main structures. Field investigation works performed include geological reconnaissance in the area covering dam, waterway and powerhouse sites, seismic prospecting and core drilling. Mechanical test of rock specimens collected at the site were also executed.

(5) Sedimentation Data

During the first and second field investigations, water samples were taken from the Arun river and sediment load estimate was made on the basis of the laboratory test results of suspended solids contained in the said samples together with other documented data.

1.4.2 Available Data

(1) Hydrological and Meteorological Data

All the available hydrological and meteorological records at gauging stations and meteorological observatories existing in the Arun river basin and other neighbouring river basins were collected for enhancing the accuracy of analytical studies.

(2) Power Demand Forecast, Existing Power Supply Facilities and Transmission Network

Related data were collected as much as possible from the concerned divisions of NEA. On-site inspections of the existing power generation, transmission and substation facilities in Nepal (especially the area east of Kathmandu) were extensively carried out for facilitating the study works.

(3) Data for Cost Estimate

The study team collected data and documents of the similar projects constructed or being constructed in Nepal, procurement procedure of construction equipment/materials, costs for ocean freight and inland transportation through India and Nepal, local wage rates, etc. which are all necessary for project cost estimate.

(4) Data for Environmental Impact

(5) Data for Economical Analysis

Various statistic data, electricity tariff rates, etc. were collected in Nepal.

(6) Data List

List of the main data collected is shown in Table 1-1.

1.5 Study Works in Japan

From commencement of the feasibility study in February 1986, the following studies have been carried out in Japan.

(1) Analysis of hydrological data, estimate of power demand forecast and studies on the required future power supply system, and the studies on development scheme and optimum size of the project.

(2) Feasibility design of main civil structures including access road and power generation equipment as well as transmission and sub-station facilities, estimates of work quantities and construction cost, and studies on construction schedule.

(3) Economical analysis of the project, that is, evaluation of the project based on the economic internal rate of return (EIRR) and financial internal rate of return (FIRR) is carried out.

1.6 Personnel Involved in the Study

Members of JICA study team, senior officials and counterpart officers of HMG/N involved in the study are as listed below.

(1) Members of JICA Study Team

Mr. S. Nojiri	Team Leader	EPDC
Dr. T. Abe	Deputy Team Leader	CKCI
Mr. T. Tezuka	Hydropower Planning Engineer	EPDC
Mr. S. Tsunoda	Design Engineer	"
Mr. K. Mishima	Hydrologist	"
Mr. C. Itoh	Geotechnical Engineer	CKCI
Mr. R. Sugawara	Electrical Engineer	EPDC
Mr. M. Yabuki	Transmission Planning Engineer	"
Mr. S. Masumura	Economist	CKCI
Mr. K. Mori	Drilling Expert	"
Mr. T. Hirota	Seismic Survey Specialist	"

Mr. A. Matsunaga	Seismic Survey Specialist	CKCI
Mr. M. Shirota	"	"
Mr. K. Toyota	Survey Specialist	"
Mr. T. Watanabe	"	"
Mr. M. Kuriya	"	"
Mr. K. Komatsuya	"	"

EPDC: Electric Power Development Co., Ltd.

CKCI: Chuo Kaihatsu Corporation International

(2) Senior Officials and Counterpart Officers of HMG/N

NEA

Mr. H. M. Shrestha	Managing Director
Mr. L. M. Dixit	Director in Chief
Mr. R. C. Chaudhary	Director in Chief
Dr. J. L. Karmacharya	Director
Mr. H. O. Shrestha	Director
Mr. V. S. Shrestha	Director
Dr. M. R. Tuladhar	Director
Mr. O. P. Koirala	Director
Mr. D. B. Thapa	Joint Director
Mr. G. B. Shrestha	Joint Director
Mr. J. K. Maskey	Deputy Director
Mrs. A. Kayastha	Deputy Director
Mr. G. K. Shrestha	Deputy Director
Mr. S. P. Pradhan	Deputy Director
Dr. M. D. Joshi	Economist
Mr. K. P. Shrestha	Civil Engineer
Mr. B. K. Shrestha	Mechanical Engineer
Mr. D. Shrestha	Hydrologist

WEC

Mr. B. K. Pradhan	Executive Secretary
Dr. H. M. Shrestha	Executive Director
Dr. C. K. Sharma	Executive Director

DOR

Mr. S. B. Pradhanang	Chief Engineer
Mr. A. M. Tuladhar	Deputy Chief Engineer

DIHM

Mr. C. D. Bhatt	Director General

DS

Mr. A. B. Basnet	Director General
Mr. P. P. Oli	Assistant Director

Royal Nepal Army Rotary Wing Unit & VVIP

Helicopter Service

NEA : Nepal Electricity Authority, HMG/N
WEC : Water and Energy Commission, HMG/N
DOR : Department of Road, HMG/N
DIHM : Department of Irrigation, Hydrology & Meteorology, HMG/N
DS : Department of Survey, HMG/N
HMG/N : His Majesty's Government of Nepal

Table 1-1 List of Main Data Collected

(1) Master Plan Study Report on the Kosi River Water Resources Development, March 1985, JICA

(2) Prefeasibility Study Report, Arun 3 Hydroelectric Project Oct. 1985, NEA

(3) 1984 Generation Expansion Plan for Period 1984 to 1994, Report 3/2/170784/1/2, HMG D.E.

(4) 1985 Electric load forecast for period 1985 - 2004, Report 3/2/160485/1/2, HMG D.E.

(5) Electricity Load Forecast 1986 Report PD/SP/430416/1-2, NEA

(6) Longrun Marginal Costs of Electricity Generation in Nepal, Report 3/2/301284/1/2

(7) Transmission system look-ahead, Report for period 1984/85 to 1993/94, Report 4/1/060884/1/1, D.E.

(8) GLOF Bhote/Dudk Kosi, Aug. 4, 1985 Hydrological Studies of Nepal No.1.1, March 1985

(9) Preliminary Study of the Glacier Lake Outburst Flood (GLOF) Phenomenon in the Nepal Himalaya (Phase-I Interim Report), Draft, WEC, Nov. 1986

(10) Erosion and Sedimentation Process in the Nepalese Himalaya, ICIMOD, Occasional paper No.1 Aug. 1985

(11) Maps of Project Area 1/50,000

(12) Climate Records of Nepal

(13) Population Census 1981 and Other Statistical Data of Nepal

(14) Nepal Road Statistics and Others

CHAPTER 2. PRESENT STATE OF POWER INDUSTRY AND FUTURE DEVELOPMENT

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LIST OF TABLES

LIST OF FIGURES

CHAPTER 2. PRESENT STATE OF POWER INDUSTRY AND FUTURE DEVELOPMENT

2.1 Electric Power Industry in Nepal

The competent authority that controls and supervises the electric power industry in Nepal is the Nepal Electricity Authority (NEA), which is the undertaking of His Majesty's Government. On August 16, 1985, the then Department of Electricity (ED) of the Ministry of Water Resources (MWR) and the then Nepal Electricity Corporation (NEC) were amalgamated to form the Nepal Electricity Authority. Formerly, there was also the Eastern Electricity Corporation (EEC) which was affiliated in the above NEC in July 1982.

The Department of Electricity was the sole agency for planning and implementation of power generation and transmission facilities, and all the power supply facilities constructed by ED in Nepal were transferred to NEC (or EEC) for operation and maintenance, excluding those located in far-western region and operated by ED itself. NEC was responsible for operation and maintenance of those facilities connected with the power supply systems in the eastern, central and western regions as well as power export to and import from India at these regions. At present, all activities including planning and construction of projects, operation and maintenance of power facilities, administration, power distribution and collection of tariff are undertaken by NEA after affiliation of ED and NEA.

2.2 Energy Resources and Development Policy of Nepal

Though no fossil energy resources such as coal, petroleum, natural gas, etc. are found, Nepal is blessed with abundant hydropower resources and total potential is estimated to be 83,000 MW, the major parts of which are centered in the Karnali river basin (32,000 MW), the Gandak river basin (21,000 MW) and the Kosi river basin (22,000 MW). Out of the above, economically viable generating capacity is estimated approximately at 25,000 MW as reported by the Ministry of Water Resources. Nepal is ranked as one of the countries with very high hydropower potentials in the world, and the future development thereof is of paramount importance for economic growth of the country.

However, total installed capacity of hydroelectric power plants is 150 MW as of 1985 which is equivalent to merely 0.6% of the above mentioned economically viable hydropower potentiality. Though the hydropower generating facilities of 76.9 MW (target 129.9 MW and achievement rate of 60%) was completed during the period of the Sixth Plan (1980 - 1985), development activities are still tardy.

The annual power consumption per capita during the period of the Sixth Plan is of very low value of 22 kWh equivalent to approximately 2% of total energy consumption per capita. Current energy consumption per capita in Nepal is about 224 kg in terms of coal, 94% and 6% of which are by traditionally used firewood and petroleum product, respectively. Owing to this situation, forest depletion has been substantial and therefore, the conservation of remaining forest and reforestation have been the subjects of great importantce and also the change of energy source from firewood to the others is one of the major national policies.

In the Seventh Plan (1985 - 1990), intensive development of water resources, especially of hydropower projects and reinforcement of transmission line network to meet adequately the growth of energy demand are envisaged. The major items in the Plan related to development of hydropower supply facilities are construction of power plants with 106.6 MW installed capacity in total including the Kulekhani (32 MW), Marsyangdi (66 MW) and Andi Khola (5.1 MW) power stations, etc., new construction of transmission lines of 132 kV (728 km) and 33 kV (233 km) and expansion of the existing 33 kV (350 km) transmission line. As to the large scale hydropower development projects, investigation activities in the Sapt-Gandak and Sapt-Kosi basins are enumerated, especially giving priority to the feasibility study on the Arun 3 project and final study on the Sapt-Gandak project.

2.3 Present State of Power Industry

2.3.1 Existing Power Supply Facilities

The power supply system in Nepal is divided into the east, central, western, mid-western and far-western regions as shown in Fig. 2-1. At present, most of eastern and western regions and all of central region are connected with the Integrated Nepal Power System (INPS) by 132 kV trunk transmission lines, however, in some area not connected with INPS near the Indian border, power imported from India is being supplied by the local distribution lines.

The existing power generating capacity in Nepal as of March, 1987 is approximately 182 MW as shown in Table 2-1, out of which diesel power generating facility forms approximately 12% and the remaining part is hydropower generation.

Table 2–1 Existing Generating Facilities in Integrated System

Plant Name	Installed Cap. (MW)	Load-Carrying Cap. (MW)
Hydro:		
Sundarijal	0.64	0.64
Panauti	2.40	1.80
Pharping	0.50	0
Butwal	1.27	1.20
Pokhara	1.02	1.00
Trisuli	21.00	18.00
Sunkosi	10.00	5.80
Gandak Canal	15.00	8.40
Kulekhani I	60.00	60.00
Kulekhani II	32.00	26.40
Devighat	14.10	14.10
Seti	1.50	1.50
Sub-total	159.40	138.80
Diesel:		
Dhorsing	2.20	2.20
Patan	1.50	1.20
Mahendra	1.70	1.40
Bharatpur	0.50	0.50
Hetauda I	4.50	3.00
Hetauda II	10.00	10.00
Pokhara	1.00	1.00
Other Western	1.20	0.80
Sub-total	22.60	20.10
Total	182.00	153.60

Table 2-2 shows outline of the existing transmission lines. Voltages of transmission lines adopted in Nepal are 132 kV, 66 kV and 33 kV, while those adopted to distribution lines are 11 kV, 3.3 kV and 0.4 kV. Substations of 33 kV or higher are shown in Figs. 2-1 and 2-2, and the four main substations (Balaju, New Chabel, Siuchatar and Patan) are being operated in the load center, Kathmandu. The Thimi substation is being operated at 33 kV, which will subsequently rise to 66 kV in future.

Table 2–2 Existing Transmission Lines in Nepal (66 kV and Higher)

	Length (km)	Voltage (kV)	No. of Circuits
Trisuli-Balaju	29	66	2
Balaju-Siuchatar	7	66	2
Siuchatar-Kulekhani I	29	66	2
New Chabel-Devighat	33	66	2
Patan-Siuchatar	4	66	1
Patan-Sunkosi	57	66	1
Hetauda-Birgunj	44	66	2
Kulekhani I-Hetauda	16	66	2
Kulekhani II-Hetauda	7	132	1
Kulekhani II-Siuchatar	36	132	1
Hetauda-Bharatpur	80	132	1
Pokhara-Bharatpur	85	132	1
Bharatpur-Dumkibas	52	132	1
Dumkibas-Gandak	32	132	1
Dumkibas-Nepalgunj	253	132	1
Hetauda-Dubi	283	132	1

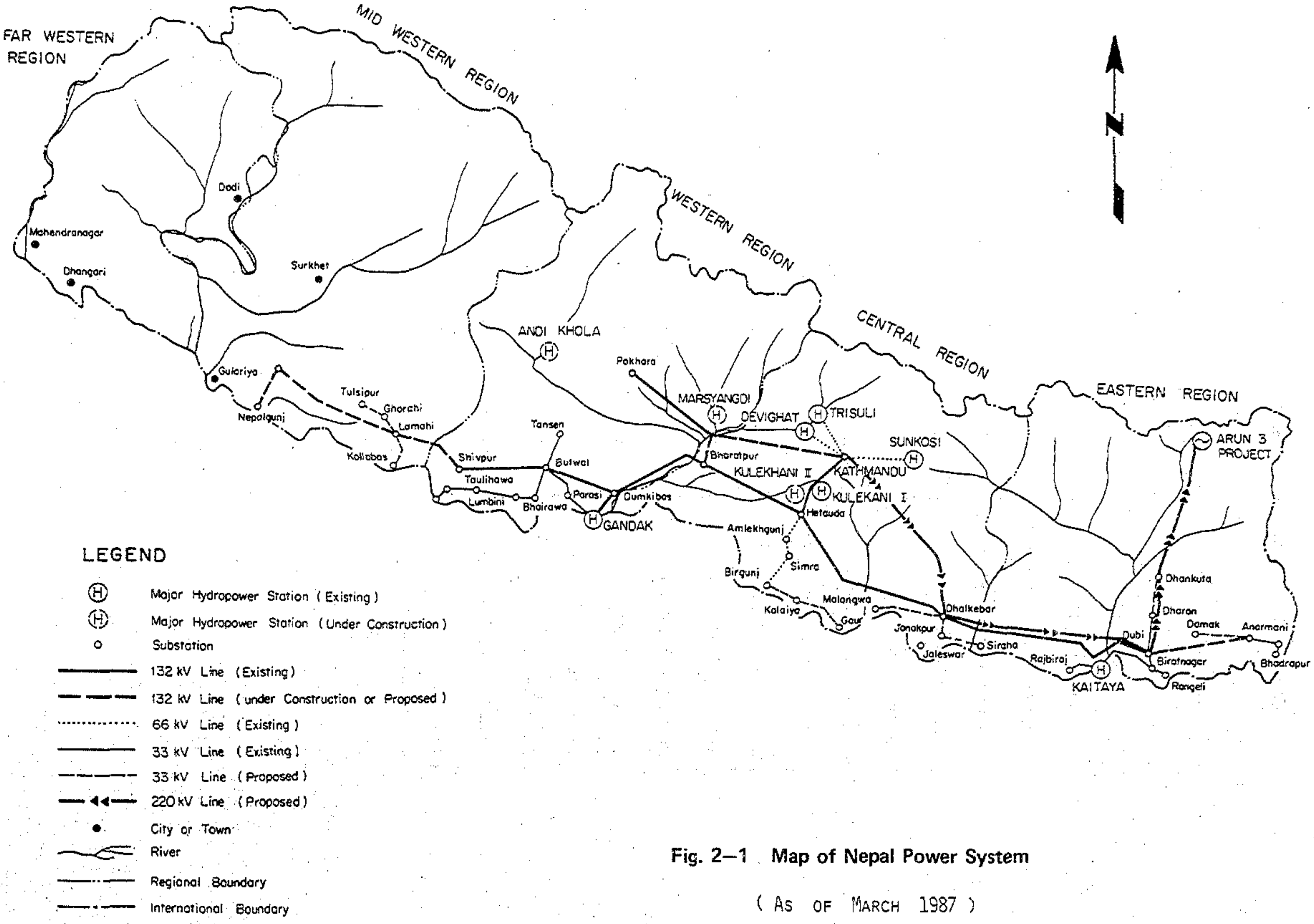
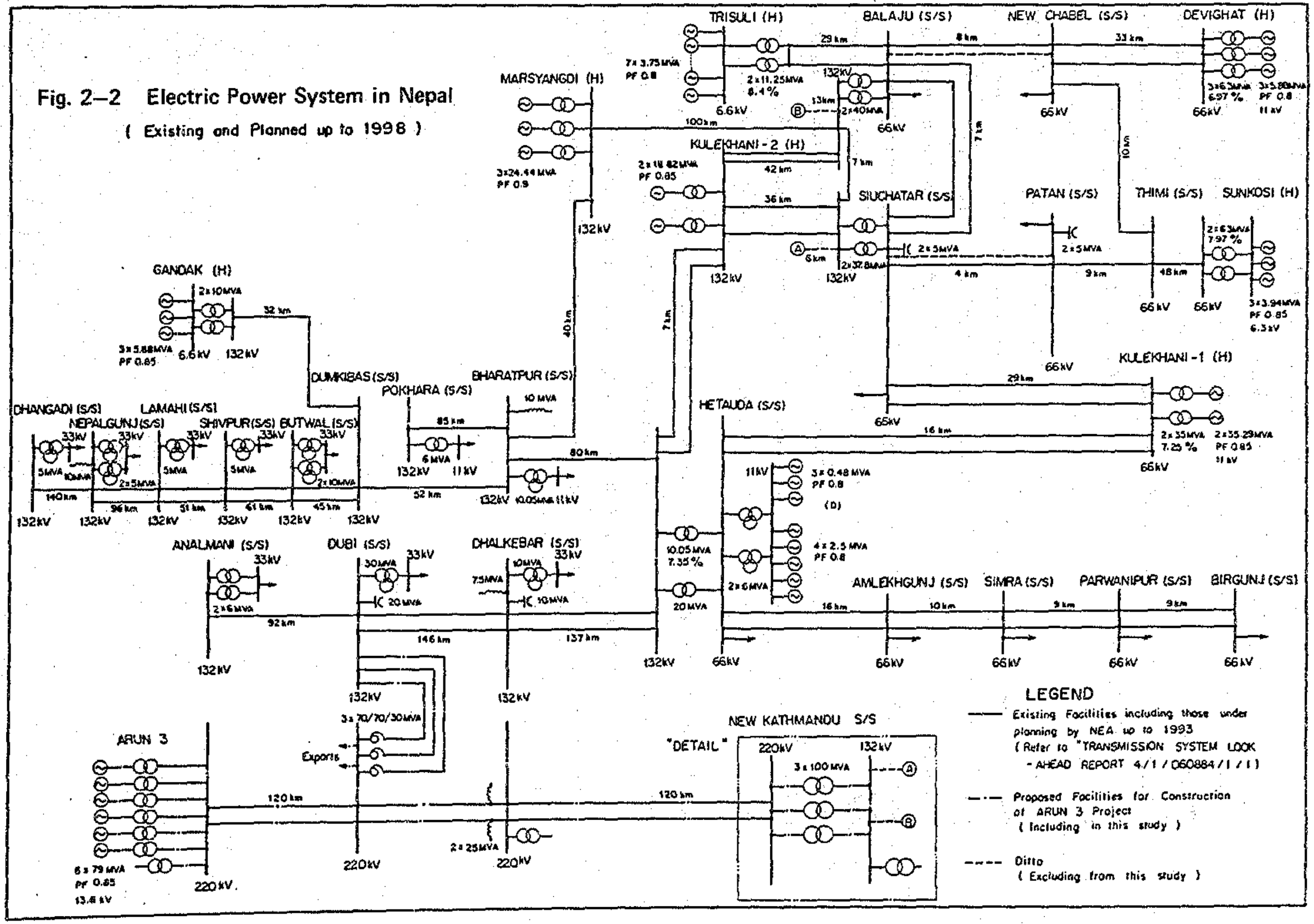


Fig. 2—1 Map of Nepal Power System

(As of March 1987)

Fig. 2–2 Electric Power System in Nepal

(Existing and Planned up to 1998)



2.3.2 Power Demand

As shown in Table 2-3, energy consumption in the whole Nepal is reported to be 365.2 GWh in the fiscal year 1983/84. Energy consumption and the peak load in the integrated system of Nepal are 298.8 GWh and 76 MW, respectively. The average growth rates of energy consumption in the whole Nepal and the integrated Nepal from F.Y. 1975/76 to F.Y. 1983/84 are 11.7% and 11.8%, respectively. In 1983/84, 74.8% of the total energy in the country was consumed in the central region, mainly in Kathmandu, and 13.4% in the eastern region wherein the Arun 3 project is located and this will be owing mainly to the industrial demand at Biratnagar. Further, 7.9% was consumed in the western region and 3.9% in the mid-western and far-western regions as referred to Table 2-4. Energy consumption by categories is indicated in Table 2-5. As observed therein, energy loss is taking very large portion of the total consumption. As for the pattern of energy consumption, domestic sector takes the largest share followed by industrial and commercial sectors in that order.

Nepal has close connection with India historically, geographically and economically, and interchange of electricity between two countries has been in force for long, though the amount of power imported from India has been exceeding that of power exported to India as shown in Table 2-6.

Table 2-3 Historical Energy Consumption and Peak Load

Fiscal Year	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	(Average)
Total Nepal (GWh)	150.226	165.380	186.379	211.951	228.578	231.170	269.116	345.021	365.244	
Growth Rate (%)	-	10.1	12.7	13.7	7.8	1.1	16.4	28.2	5.9	(11.7)
Integrated Nepal (GWh)	118.909	129.291	144.162	160.578	179.211	177.553	205.142	273.688	289.775	
Growth Rate (%)	-	8.7	11.5	11.4	11.6	-0.9	15.5	33.4	5.9	(11.8)
Integrated Peak (MW)	31.88	34.72	37.90	38.10	42.46	44.46	56.48	66.00	76.00	
Growth Rate (%)	-	8.9	9.2	0.5	11.4	4.7	27.0	16.9	15.2	(11.5)

Table 2–4 Energy Consumption in Each Region (1983/1984)

Region	Total Nepal (GWh)	
Central	273.155	(74.8%)
Western	28.884	(7.9%)
Eastern	49.046	(13.4%)
Mid-West	8.865	(2.4%)
Far-West	5.294	(1.5%)
Total	365.244	(100.0%)

Table 2–5 Energy Consumption in Each Sector (1983/1984)

Sector	Total Nepal (GWh)	
Domestic	101.411	(27.8%)
Industrial	78.342	(21.4%)
Commercial	48.215	(13.2%)
Irrigation & Water Supply	9.350	(2.6%)
Transport	1.463	(0.4%)
Street Light & Others	5.070	(1.4%)
Self Consumption	2.712	(0.7%)
Losses	118.681	(32.5%)
Total	365.244	(100.0%)

Table 2-6 Power Export and Import

Fiscal Year	Import (GWh)	Export (GWh)
1975/76	25.372	5.940
1976/77	29.141	6.116
1977/78	32.726	5.970
1978/79	40.626	6.160
1979/80	38.972	5.196
1980/81	45.070	3.765
1981/82	56.759	6.092
1982/83	63.291	8.922
1983/84	67.170	10.312

2.3.3 Fluctuation of Load

(1) Seasonal fluctuation

Monthly transition of daily peak load in F.Y. 1984/85 is shown in Fig. 2-3 and the maximum load takes place in winter (dry season) from December to March, while it declines in summer. The ratio of the minimum load to the maximum load on the day corresponding to the monthly maximum load is approximately 76%. The historical annual load factors from F.Y. 1975/76 to F.Y. 1984/85 are shown in Table 2-7 and the average load factor during the above 10 years is 45%.

Table 2-7 Historical Annual Load Factor in Interconnected Power System

Fiscal Year	Interconnected Energy Consumption (GWh)	Interconnected Peak Load (MW)	Load Factor (%)
1975/1976	118.909	31.88	42.6
1976/1977	129.291	34.72	42.5
1977/1978	144.162	37.90	43.4
1978/1979	160.578	38.10	48.1
1979/1980	179.211	42.46	48.2
1980/1981	177.553	44.46	45.6
1981/1982	205.142	56.48	41.5
1982/1983	273.688	66.0	47.3
1983/1984	289.775	76.0	43.5
1984/1985	302.000	79.7	43.3
Average			44.6

(2) Daily fluctuation

The daily load curve and load duration curve at the maximum peak load in F.Y. 1984/1985 (January, 1985) are shown in Fig. 2-4. As observed therein, daily peak loads take places at two times, breakfast time (8 to 9 o'clock a.m.) and dinner time (6 to 8 o'clock p.m.), and the daily maximum load at dinner time, showing typical load pattern for domestic use. Transition of daily load factors corresponding to the monthly maximum loads in 1984/85 are also shown in Fig. 2-3. The maximum load factor of 59.8% was recorded on the day of the maximum peak load in January 1985 and the average daily load factor per annum was approximately 54%. There is a trend that daily load factor becomes larger for larger load. The ratios of the minimum loads at midnights to the maximum loads on the days corresponding to the monthly maximum loads in 1984/85 are again shown in Fig. 2-3 and the annual average is approximately 35%, showing considerable declination at midnight.

Fig. 2–3 Monthly Transition of Daily Peak Load, Daily Load Factor and Ratio of Max. and Min. Load (July, 1984 to June, 1985)

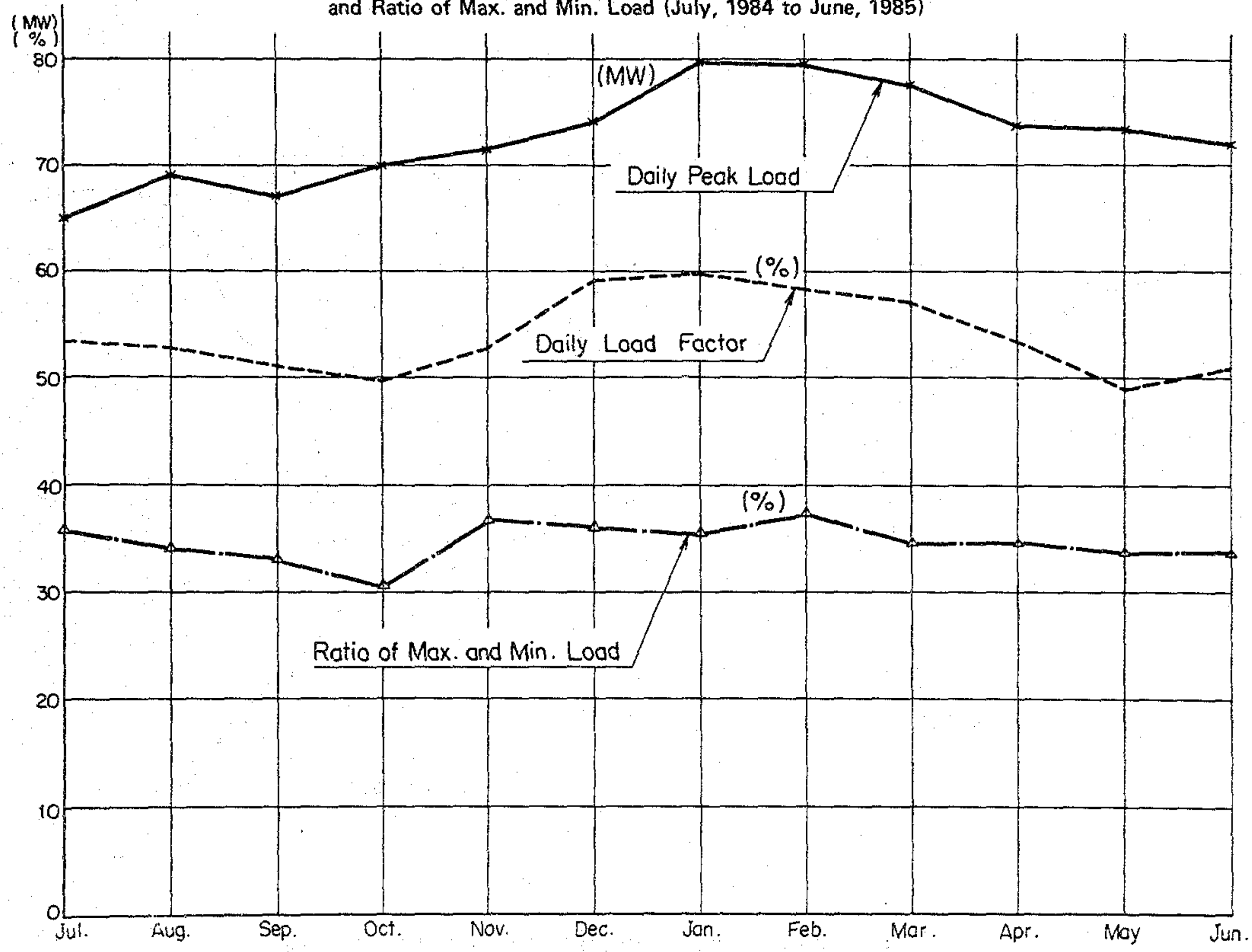
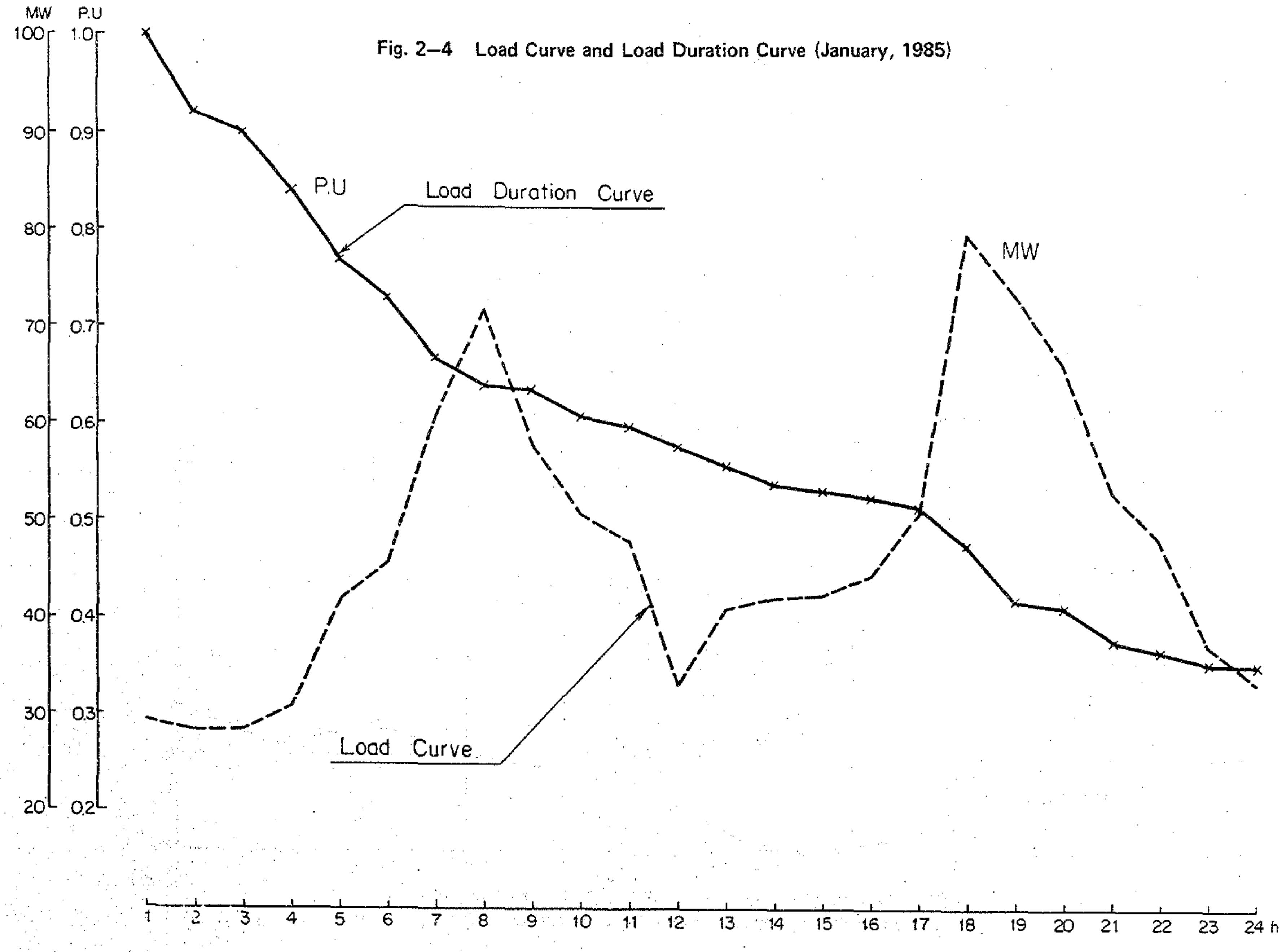


Fig. 2–4 Load Curve and Load Duration Curve (January, 1985)



2.4 Load Demand Forecast

2.4.1 Load Demand Forecast Applied to the Study

(1) Load demand of integrated power system of Nepal

Load demand forecast governs the study of the optimum development scheme in relation to timing and programming of implementation, project size, etc.

There are several demand forecasts released by NEA such as Report No. 3/3/080883/1/6 prepared by ED in 1983, that by the World Bank in 1984, Report No. 3/2/160485/1/2 and Report No. PD/SP/430416/1-2 by NEA in 1985 and 1986.

There was marked difference between the demand forecasts concluded in 1983 and 1985. The 1983 electric load forecast was based on the disaggregate method and the actual demand in electrical load was far less than the forecasted one.

The 1985 forecast was based on the trend analysis and lined to take into account previous large gap between anticipated and actual demands as well as the impact of tariff increase in twice in 1984/1985.

But owing to the expansion of transmission grid to Biratnagar and growth in domestic consumption because of reliable power supply, the increase in demand in F.Y. 1985/86 was registered to around 25% despite of the tariff increase, exceeding the load forecast in 1985.

Owing to the abovementioned fact, NEA released new load demand forecast in July 1986 with the assistance of the World Bank in order to minimize the difference between the forecasted and actual values. This load forecast was analyzed based on the disaggregate method for twenty years ahead taking the following factors into consideration.

* Future industrial, agricultural and commercial development plans
* Impact of tariff increase effected in 1983
* Transmission line expansion programme
* Economic movement in recent years

The optimum development scheme of new project is generally studied on the basis of the medium to long term load demand forecast. The above 1986 load forecast is considered reasonable, since the disaggregate method is applied for the first five years and the trend method for the medium to long term forecast based on correlation between industrial power demand and gross domestic product (GDP). Therefore, the 1986 load forecast prepared by NEA is adopted in this study for analyses of the related subjects (Table 2-8, Figs. 2-5 and 2-6). The 1986 load forecast is cross-examined as described in the succeeding paragraph 2.4.2 and found to be adequate.

In the meantime, the demand forecast involves electric power system losses due to transmission line, substation and distribution systems, that is, the adopted demand forecast means the estimated values required for generating capability.

Power losses in total power supply system, though they vary at respective regions, are currently reported to show large value of 30% in average and is anticipated to fall to 20% at F.Y.1993/94 when the Arun 3 project will be put in service. Though this problem is considered to be further improved gradually, power losses after F.Y.1993/94 in transmission lines and others (substations, distribution lines) are estimated at 5% and 15% respectively for the study.

Table 2-8 Power Demand Forecast of Interconnected System

F.Y.	Energy (MWh) ①	Growth Rate (%) ②	Energy (MWh) ③	Peak Load (MW) ④	Growth Rate (%) ⑤	Peak Load (MW) ⑥
1985/86	473,265			107.1		
1986/87	557,463	17.79		124.0	15.72	
1987/88	635,485	14.00	Same as ①	141.1	13.83	Same as ④
1988/89	709,666	11.67		157.7	11.76	
1989/90	786,968	10.89		177.4	12.47	
1990/91	869,838	10.53		196.3	10.67	
1991/92	946,014	8.76		213.3	8.65	
1992/93	1,038,096	9.73		233.8	9.60	
1993/94	1,121,543	8.04		251.8	7.68	
1994/95	1,204,242	7.37	1,307,172	269.5	7.04	293.0
1995/96	1,281,278	6.40	1,384,208	286.5	6.33	310.0
1996/97	1,357,804	5.97	1,460,734	303.6	5.97	327.1
1997/98	1,439,650	6.03	1,542,580	321.7	5.96	345.2
1998/99	1,524,850	5.92	1,627,780	340.7	5.89	364.2
1999/2000	1,613,312	5.80	1,716,242	360.5	5.80	384.0
2000/01	1,705,408	5.71	1,808,338	381.2	5.75	404.7
2001/02	1,801,269	5.62	1,904,199	402.9	5.70	426.4
2002/03	1,901,368	5.56	2,004,298	425.8	5.69	449.3
2003/04	2,005,319	5.47	2,108,249	449.8	5.63	473.3
2004/05	2,113,592	5.40	2,216,522	475.0	5.61	498.5
2005/06	2,225,748	5.31	2,328,678	501.3	5.54	524.8
2006/07	2,342,822	5.26	2,445,752	528.8	5.49	552.3
2007/08	2,464,883	5.21	2,567,813	557.6	5.44	581.1
2008/09	2,592,071	5.16	2,695,001	587.6	5.39	611.1
2009/10	2,724,526	5.11	2,827,456	619.0	5.34	642.5
2010/11	2,862,387	5.06	2,965,317	651.8	5.29	675.3
2011/12	3,005,793	5.01	3,108,723	685.9	5.24	709.4
2012/13	3,154,880	4.96	3,257,810	721.5	5.19	745.0
2013/14	3,309,784	4.91	3,412,714	758.6	5.14	782.1
2014/15	3,470,640	4.86	3,573,570	797.2	5.09	820.7

Note:
1. Load forecast after F.Y.2006/2007 which is not indicated in the latest demand forecast of July, 1986 is estimated on assumption that the demand growth rate will decline by 0.05% per annum for both energy consumption and peak load.
2. After F.Y.1994/1995, peak load is obtained by adding 23.5 MW to be exported through the interconnected system of Nepal as shown in above ⑥.
3. After F.Y.1994/1995, energy consumption of 102,930 MWh per annum for export which is obtained by application of annual load factor of 50% is added to the interconnected system of Nepal as shown in above ③.
4. Energy demand ③ and power demand ⑥ are adopted in this study.

(2) Peak demand forecast at main substations

Peak demand forecast at the main substations is prepared as shown in Table 2-9, on the basis of the records at the main substations shown in Report No. 4/1/060884/1/1: Transmission System Look-Ahead Report for Period 1984/85 to 1993/94 and also the above-mentioned load demand forecast of the integrated system of Nepal.

Table 2–9 (1/2) Projection of Power Demand Growth at Each Substation (MW)

Substation \ Fiscal Year	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
HETAUDA	2.852	3.245	3.627	4.08	4.514	4.905	5.377	5.791	6.739	7.13	7.523
	(2.709)	(3.083)	(3.445)	(3.876)	(4.289)	(4.66)	(5.108)	(5.501)	(6.402)	(6.773)	(7.147)
BIRGUNJ	4.836	5.502	6.15	6.918	7.655	8.318	9.118	9.82	11.427	12.09	12.756
	(4.594)	(5.227)	(5.842)	(6.572)	(7.272)	(7.902)	(8.662)	(9.329)	(10.855)	(11.485)	(12.119)
PARWANIPUR	1.984	2.257	2.523	2.838	3.14	3.412	3.74	4.028	4.688	4.96	5.233
	(1.884)	(2.144)	(2.397)	(2.696)	(2.983)	(3.242)	(3.553)	(3.827)	(4.453)	(4.712)	(4.971)
SIMRA	0.868	0.987	1.103	1.241	1.374	1.493	1.636	1.762	2.051	2.17	2.289
	(0.824)	(0.938)	(1.048)	(1.179)	(1.305)	(1.418)	(1.554)	(1.674)	(1.948)	(2.061)	(2.175)
AMLEKHGUNJ	0.496	0.564	0.63	0.709	0.785	0.853	0.935	1.007	1.172	1.24	1.308
	(0.471)	(0.536)	(0.599)	(0.674)	(0.745)	(0.81)	(0.888)	(0.956)	(1.113)	(1.178)	(1.242)
NEW CHABHIL	13.02	14.815	16.558	18.627	20.611	22.396	24.549	26.439	30.765	32.55	34.345
	(12.369)	(14.074)	(15.73)	(17.695)	(19.58)	(21.276)	(23.321)	(25.117)	(29.226)	(30.922)	(32.628)
BALAJU	18.6	21.165	23.655	26.61	29.445	31.995	35.07	37.77	43.95	46.5	49.065
	(17.67)	(20.106)	(22.472)	(25.279)	(27.972)	(30.395)	(33.316)	(35.881)	(41.752)	(44.175)	(46.611)
SIUCHATAR	23.436	26.667	29.805	33.528	37.1	40.313	44.188	47.59	55.377	58.59	61.821
	(22.264)	(25.334)	(28.315)	(31.852)	(35.245)	(38.298)	(41.978)	(45.21)	(52.608)	(55.66)	(58.73)
PATAN	11.408	12.981	14.508	16.32	18.059	19.623	21.509	23.165	26.956	28.52	30.093
	(10.837)	(12.332)	(13.782)	(15.504)	(17.156)	(18.642)	(20.434)	(22.007)	(25.608)	(27.094)	(28.588)
BHARATPUR	5.704	6.49	7.254	8.16	9.029	9.811	10.754	11.582	13.478	14.26	15.046
	(5.418)	(6.166)	(6.891)	(7.752)	(8.578)	(9.321)	(10.217)	(11.003)	(12.804)	(13.547)	(14.294)
POKHARA	2.976	3.386	3.784	4.257	4.711	5.119	5.611	6.043	7.032	7.44	7.85
	(2.827)	(3.217)	(3.595)	(4.044)	(4.475)	(4.863)	(5.33)	(5.741)	(6.68)	(7.068)	(7.457)
BUTWAR	6.944	7.901	8.831	9.934	10.992	11.944	13.092	14.1	16.408	17.36	18.317
	(6.596)	(7.506)	(8.389)	(9.437)	(10.443)	(11.347)	(12.438)	(13.395)	(15.587)	(16.492)	(17.401)
SHIVPUR	1.488	1.693	1.892	2.128	2.355	2.559	2.805	3.021	3.516	3.72	3.925
	(1.413)	(1.608)	(1.797)	(2.022)	(2.237)	(2.431)	(2.665)	(2.87)	(3.34)	(3.534)	(3.728)
DHALKEBAR	2.232	2.539	2.838	3.193	3.533	3.839	4.208	4.532	5.274	5.58	5.887
	(2.12)	(2.412)	(2.696)	(3.033)	(3.356)	(3.647)	(3.997)	(4.305)	(5.01)	(5.301)	(5.593)
DUBI	19.22	21.87	24.443	27.497	30.426	33.061	36.239	39.029	45.415	48.05	50.7
	(18.259)	(20.776)	(23.221)	(26.122)	(28.905)	(31.408)	(34.427)	(37.077)	(43.144)	(45.647)	(48.165)
LAMAHI	0.372	0.423	0.473	0.532	0.588	0.639	0.701	0.755	0.879	0.93	0.981
	(0.353)	(0.402)	(0.449)	(0.505)	(0.559)	(0.607)	(0.666)	(0.717)	(0.835)	(0.883)	(0.932)
NEPALGUNJ	4.092	4.656	5.204	5.854	6.477	7.038	7.715	8.309	9.669	10.23	10.794
	(3.887)	(4.423)	(4.943)	(5.561)	(6.154)	(6.686)	(7.329)	(7.893)	(9.185)	(9.718)	(10.254)
ANALMANI	0.992	1.128	1.261	1.419	1.57	1.706	1.87	2.014	2.344	2.48	2.616
	(0.942)	(1.072)	(1.198)	(1.348)	(1.491)	(1.621)	(1.776)	(1.913)	(2.226)	(2.356)	(2.485)
DHANGADI	2.48	2.822	3.154	3.548	3.926	4.266	4.676	5.036	5.86	6.2	6.542
	(2.356)	(2.68)	(2.996)	(3.37)	(3.729)	(4.052)	(4.442)	(4.784)	(5.567)	(5.89)	(6.214)
Total	124.000	141.091	157.693	177.393	196.290	213.290	233.793	251.793	293.000	310.000	327.091
	(117.793)	(134.036)	(149.805)	(168.521)	(186.474)	(202.626)	(222.101)	(239.200)	(278.343)	(294.496)	(310.734)

Note: Numeral with parenthesis means the loads excluding transmission line losses of 5%.

Table 2-9 (2/2) Projection of Power Demand Growth at Each Substation (MW)

Substation \ Fiscal Year	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08
HETAUDA	7.939	8.376	8.832	9.308	9.807	10.333	10.885	11.465	12.07	12.702	13.365
	(7.542)	(7.957)	(8.39)	(8.842)	(9.316)	(9.817)	(10.341)	(10.892)	(11.466)	(12.067)	(12.697)
BIRGUNJ	13.462	14.203	14.976	15.783	16.629	17.522	18.458	19.441	20.467	21.539	22.662
	(12.789)	(13.493)	(14.227)	(14.994)	(15.798)	(16.646)	(17.535)	(18.469)	(19.443)	(20.462)	(21.529)
PARWANIPUR	5.523	5.827	6.144	6.475	6.822	7.188	7.572	7.976	8.396	8.836	9.297
	(5.247)	(5.535)	(5.836)	(6.151)	(6.481)	(6.829)	(7.194)	(7.577)	(7.976)	(8.394)	(8.832)
SIMRA	2.416	2.549	2.688	2.832	2.984	3.145	3.313	3.489	3.673	3.866	4.067
	(2.295)	(2.421)	(2.553)	(2.691)	(2.835)	(2.987)	(3.147)	(3.315)	(3.489)	(3.672)	(3.864)
AMLEKHGUNJ	1.38	1.456	1.536	1.618	1.705	1.797	1.893	1.994	2.099	2.209	2.324
	(1.311)	(1.383)	(1.459)	(1.537)	(1.62)	(1.707)	(1.798)	(1.894)	(1.994)	(2.098)	(2.208)
NEW CHABHIL	36.246	38.241	40.32	42.493	44.772	47.176	49.696	52.342	55.104	57.991	61.015
	(34.433)	(36.328)	(38.304)	(40.368)	(42.533)	(44.817)	(47.211)	(49.725)	(52.348)	(55.091)	(57.964)
BALAJU	51.78	54.63	57.6	60.705	63.96	67.395	70.995	74.775	78.72	82.845	87.165
	(49.191)	(51.898)	(54.72)	(57.669)	(60.762)	(64.025)	(67.445)	(71.036)	(74.784)	(78.702)	(82.806)
SIUCHATAR	65.242	68.833	72.576	76.488	80.589	84.917	89.453	94.216	99.187	104.384	109.827
	(61.98)	(65.392)	(68.947)	(72.663)	(76.56)	(80.671)	(84.981)	(89.505)	(94.227)	(99.165)	(104.336)
PATAN	31.758	33.506	35.328	37.232	39.228	41.335	43.543	45.862	48.281	50.811	53.461
	(30.17)	(31.831)	(33.561)	(35.37)	(37.267)	(39.268)	(41.366)	(43.568)	(45.867)	(48.271)	(50.788)
BHARATPUR	15.879	16.753	17.664	18.616	19.614	20.667	21.771	22.931	24.14	25.405	26.73
	(15.085)	(15.915)	(16.78)	(17.685)	(18.633)	(19.634)	(20.683)	(21.784)	(22.933)	(24.135)	(25.394)
POKHARA	8.284	8.74	9.216	9.712	10.233	10.783	11.359	11.964	12.595	13.255	13.946
	(7.87)	(8.303)	(8.755)	(9.227)	(9.721)	(10.244)	(10.791)	(11.365)	(11.965)	(12.592)	(13.249)
BUTWAR	19.331	20.395	21.504	22.663	23.878	25.16	26.504	27.916	29.388	30.928	32.541
	(18.364)	(19.375)	(20.428)	(21.53)	(22.684)	(23.902)	(25.179)	(26.52)	(27.919)	(29.382)	(30.914)
SHIVPUR	4.142	4.37	4.608	4.856	5.116	5.391	5.679	5.982	6.297	6.627	6.973
	(3.935)	(4.151)	(4.377)	(4.613)	(4.86)	(5.122)	(5.395)	(5.682)	(5.982)	(6.296)	(6.624)
DHALKEBAR	6.213	6.555	6.912	7.284	7.675	8.087	8.519	8.973	9.446	9.941	10.459
	(5.902)	(6.227)	(6.566)	(6.92)	(7.291)	(7.683)	(8.093)	(8.524)	(8.974)	(9.444)	(9.936)
DUBI	53.506	56.451	59.52	62.728	66.092	69.641	73.361	77.267	81.344	85.606	90.07
	(50.83)	(53.628)	(56.544)	(59.592)	(62.787)	(66.159)	(69.693)	(73.404)	(77.276)	(81.326)	(85.566)
LAMAHI	1.035	1.092	1.152	1.214	1.279	1.347	1.419	1.495	1.574	1.656	1.743
	(0.983)	(1.037)	(1.094)	(1.153)	(1.215)	(1.28)	(1.348)	(1.42)	(1.495)	(1.574)	(1.656)
NEPALGUNJ	11.391	12.018	12.672	13.355	14.071	14.826	15.618	16.45	17.318	18.225	19.176
	(10.822)	(11.417)	(12.038)	(12.687)	(13.367)	(14.085)	(14.837)	(15.627)	(16.452)	(17.314)	(18.217)
ANALMANI	2.761	2.913	3.072	3.237	3.411	3.594	3.786	3.988	4.198	4.418	4.648
	(2.623)	(2.767)	(2.918)	(3.075)	(3.24)	(3.414)	(3.597)	(3.788)	(3.988)	(4.197)	(4.416)
DHANGADI	6.904	7.284	7.68	8.094	8.528	8.986	9.466	9.97	10.496	11.046	11.622
	(6.558)	(6.919)	(7.296)	(7.689)	(8.101)	(8.536)	(8.992)	(9.471)	(9.971)	(10.493)	(11.04)
Total	345.192	364.192	384.000	404.693	426.393	449.290	473.290	498.496	524.793	552.290	581.091
	(327.930)	(345.977)	(364.793)	(384.456)	(405.071)	(426.826)	(449.626)	(473.566)	(498.549)	(524.675)	(552.036)

Note: Numeral with parenthesis means the loads excluding transmission line losses of 5%.

2.4.2 Cross-examination of Adopted Load Demand Forecast

Adequacy of the load demand forecast adopted for this study as stated in 2.4.1 above is cross-examined by the following macroscopic method on the basis of variation of load demand corresponding to growth of the gross domestic product (GDP).

(1) Elasticity coefficient of GDP to the total power consumption in whole Nepal is to be first analysed based on growth rates of GDP per capita and energy consumption (kWh) per capita by this time and the prospective elasticity coefficient of GDP is to be then estimated. As shown in Table 2-10, the average value of elasticity coefficient of GDP from F.Y. 1975/76 to F.Y. 1981/82 is calculated to be 12.6 which is considered to be considerably large compared with those of the advanced countries. The elasticity coefficients of GDP adopted in this examination are assumed to be 5.0 and 3.0 for the periods from F.Y. 1985/86 to F.Y. 1994/95 and from F.Y. 1995/96 to F.Y. 2004/05, respectively, referring to the past records thereof and also to the general tendency that the growth of GDP is normally larger than that of energy consumption (kWh) resulting in smaller GDP elasticity.

(2) Secondly, the growth rate of GDP per capita in whole Nepal is assumed as described below. Though the average growth rate of GDP per capita for the period from F.Y. 1974/75 to F.Y. 1981/82 was 0.7% as shown in Table 2-10, it turned out to be 1.54% for the period of the Sixth Plan from F.Y. 1980/81 to F.Y. 1984/85, giving sound prospect to the recent economic situation of Nepal. The average growth rate of GDP per capita for the period of the Seventh Plan from F.Y. 1985/86 to F.Y. 1989/90 is estimated to be 1.8%. During the period from F.Y. 1984/85 to F.Y. 1990/91, the marked increase in load demand is expected because of new construction of industrial factories such as Hetauda Cement, Nepal Orind Magnesite, Laxmi Banaspati Ghee, Annapurna Textile, Bhrikuti Paper Industry, etc. However, Nepal is being troubled by the scarcity of foreign currency and its economic situation for holding high growth rate of GDP over a long period is not always optimistic.

Based on the above consideration, the growth rate of GDP per capita is assumed to be as below.

F.Y. 1985/86 - F.Y. 1989/90	2.0%
F.Y. 1990/91 - F.Y. 1994/95	1.5%
F.Y. 1995/96 - F.Y. 2005/06	1.0%

(3) Thirdly, the growth rate of energy consumption (kWh) per capita in the future is to be estimated based on the abovementioned growth rate of GDP multiplied by the elasticity coefficient of GDP to energy consumption, as shown in Table 2-11.

(4) Finally, the growth rate of energy consumption is to be estimated from the growth rate of energy consumption per capita multiplied by the population growth rate in whole Nepal, as shown in Table 2-11. The average population growth rate of 2.7% is first referred to the Report No. 3/2/160485/1/2 "1985 Electric Load Forecast for Period 1985 - 2004" prepared by NEA up to F.Y. 1994/95 and 2.5% is assumed thereafter as shown in Table 2-12.

(5) Peak load forecast is obtained on the basis of the above-stated estimate of energy consumption together with the annual load factor (Table 2-13). Though the record of the annual load factors is as shown in the preceding Table 2-7, there can be observed no particular relationship between load demand growth and annual load factor. Hence the constant load factor of 50% is adopted, assuming that the annual load factor will be more or less increased in the future.

Table 2–10 Historical Population, Energy Consumption and GDP Elasticity of Energy Consumption (GDP Values at 1974/1975 Price)

Fiscal Year		1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	Average /Year
GDP	(Million Rs)	16,571	17,300	17,822	18,607	19,048	18,606	20,158	20,926	
Total Energy Consumption	(GWh)	124.195	150.226	165.380	186.379	211.951	227.578	231.170	269.116	
Population	(Million)	12.834	13.176	13.526	13.886	14.256	14.635	15.024	15.424	
Per Capita GDP	(Rs)	1,291	1,313	1,318	1,340	1,336	1,271	1,342	1,357	
Per Capita GDP Growth Rate	(%) (1)	-	1.7	0.4	1.7	-0.3	-4.9	5.6	1.1	0.7
Per Capita Energy Consumption	(KWh)	9.68	11.40	12.23	13.42	14.87	15.62	15.39	17.45	
Per Capita Energy Consumption Growth Rate	(%) (2)	-	17.8	7.3	9.7	10.8	5.0	-1.5	13.4	8.8
Per Capita GDP Elasticity of Energy Consumption	(2)/(1)		10.5	18.3	5.7	-36.0	-1.0	-0.3	12.2	12.6

Table 2–11 Projection of Interconnected Energy Consumption Growth Rate

Fiscal Year	Per Capita GDP Growth Rate (%)	GDP Elasticity of Energy Consumption (per Capita Bases)	Per Capita Energy Consumption Growth Rate (%)	Population Growth Rate (%)	Energy Consumption Growth Rate (%)	Energy Consumption (GWh)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1985/86	2.0	5.0	10.0	2.7	13.0	473	473
1986/87	2.0	5.0	10.0	2.7	13.0	534	534
1987/88	2.0	5.0	10.0	2.7	13.0	604	604
1988/89	2.0	5.0	10.0	2.7	13.0	682	682
1989/90	2.0	5.0	10.0	2.7	13.0	771	771
1990/91	1.5	5.0	7.5	2.7	10.4	851	851
1991/92	1.5	5.0	7.5	2.7	10.4	940	940
1992/93	1.5	5.0	7.5	2.7	10.4	1,037	1,037
1993/94	1.5	5.0	7.5	2.7	10.4	1,145	1,145
1994/95	1.5	5.0	7.5	2.7	10.4	1,264	1,367
1995/96	1.0	3.0	3.0	2.5	5.6	1,335	1,438
1996/97	1.0	3.0	3.0	2.5	5.6	1,410	1,513
1997/98	1.0	3.0	3.0	2.5	5.6	1,488	1,591
1998/99	1.0	3.0	3.0	2.5	5.6	1,572	1,675
1999/00	1.0	3.0	3.0	2.5	5.6	1,660	1,763
2000/01	1.0	3.0	3.0	2.5	5.6	1,753	1,856
2001/02	1.0	3.0	3.0	2.5	5.6	1,851	1,954
2002/03	1.0	3.0	3.0	2.5	5.6	1,955	2,058
2003/04	1.0	3.0	3.0	2.5	5.6	2,064	2,167
2004/05	1.0	3.0	3.0	2.5	5.6	2,180	2,283
2005/06	1.0	3.0	3.0	2.5	5.6	2,302	2,405

Note: (3) = (1) x (2) (5) = (3) x (4)

(7) is obtained adding energy consumption of 103 GWh per annum to (6) for power export after F.Y. 1994/95.
Average growth rate of energy consumption from F.Y. 1985/86 to F.Y. 2005/06 is 8.5% p.a.

Table 2–12 Projection of Population Growth

Fiscal Year	Total Population (Mill)	Growth Rate (%)
1972 / 73	12.178	2.66
1973 / 74	12.502	2.66
1974 / 75	12.834	2.66
1975 / 76	13.176	2.66
1976 / 77	13.526	2.66
1977 / 78	13.886	2.66
1978 / 79	14.256	2.66
1979 / 80	14.635	2.66
1980 / 81	15.024	2.66
1981 / 82	15.424	2.66
1982 / 83	15.834	2.66
1983 / 84	16.255	2.66
1984 / 85	16.687	2.66
1985 / 86	17.131	2.66
1986 / 87	17.587	2.66
1987 / 88	18.055	2.66
1988 / 89	18.535	2.66
1989 / 90	19.028	2.66
1990 / 91	19.534	2.66
1991 / 92	20.054	2.66
1992 / 93	20.587	2.66
1993 / 94	21.135	2.66
1994 / 95	21.697	2.66
1995 / 96	22.239	2.50
1996 / 97	22.795	2.50
1997 / 98	23.365	2.50
1998 / 99	23.949	2.50
1999 / 00	24.548	2.50
2000 / 01	25.162	2.50
2001 / 02	25.791	2.50
2002 / 03	26.436	2.50
2003 / 04	27.097	2.50
2004 / 05	27.774	2.50
2005 / 06	28.468	2.50

Table 2–13 Projection of Interconnected Peak Load

Fiscal Year	Load Factor (%)	Peak Load (MW) (1)	(2)
1985 / 86		107	107
1986 / 87	50	122	122
1987 / 88	50	138	138
1988 / 89	50	156	156
1989 / 90	50	176	176
1990 / 91	50	194	194
1991 / 92	50	215	215
1992 / 93	50	237	237
1993 / 94	50	261	261
1994 / 95	50	289	312
1995 / 96	50	305	328
1996 / 97	50	322	345.5
1997 / 98	50	340	363
1998 / 99	50	359	382.5
1999 / 00	50	379	402.5
2000 / 01	50	400	423.5
2001 / 02	50	423	446
2002 / 03	50	446	470
2003 / 04	50	471	494.5
2004 / 05	50	498	521
2005 / 06	50	526	549

Note: (2) is obtained adding 23.5 MW to (1) for power export after F.Y. 1994/95.

2.4.3 Examination Result

Comparison of the load demand forecast released by NEA in 1986 and that induced from the trend method is shown in Fig. 2-5 (energy consumption) and Fig. 2-6 (peak load). In twenty years from F.Y. 1985/86 to F.Y. 2005/06, the average growth rate of load demand forecast by NEA is 8.3% while that estimated by trend method is 8.5% showing no substantial difference between the two. Hence, the load demand forecast released by NEA will be judged to be reasonable.

The trend method applied to cross-examination will not be adequate for short term load forecast, while, the load demand forecast by NEA is estimated on the basis of both the disaggregate and trend methods enhancing high reliability. It is, therefore, considered appropriate to adopt the forecast released by NEA for the study.

Fig. 2–5 Comparison of Projected Energy Consumption (Interconnected)
(Required for Generating Capability, Including Power System Losses)

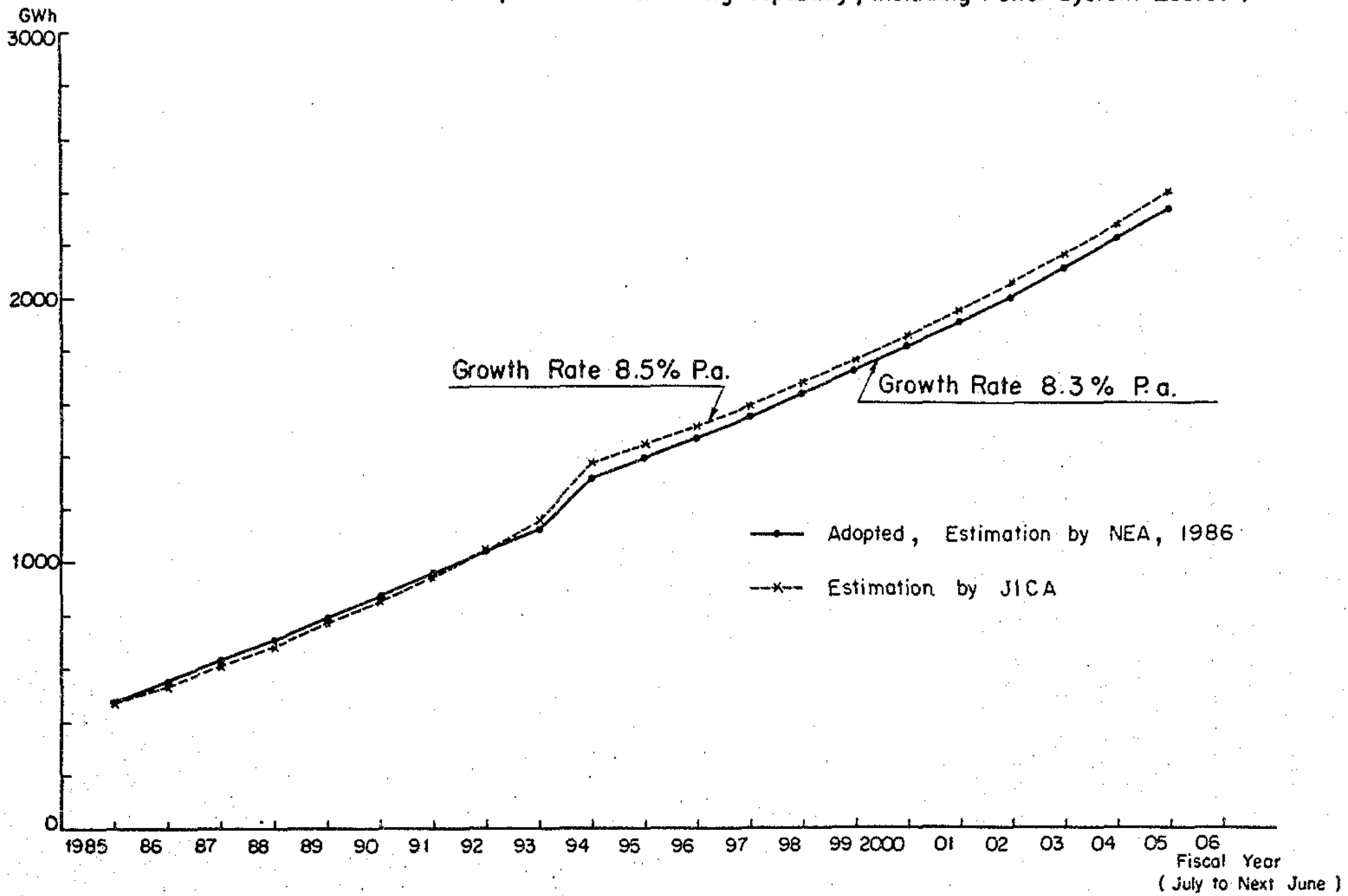
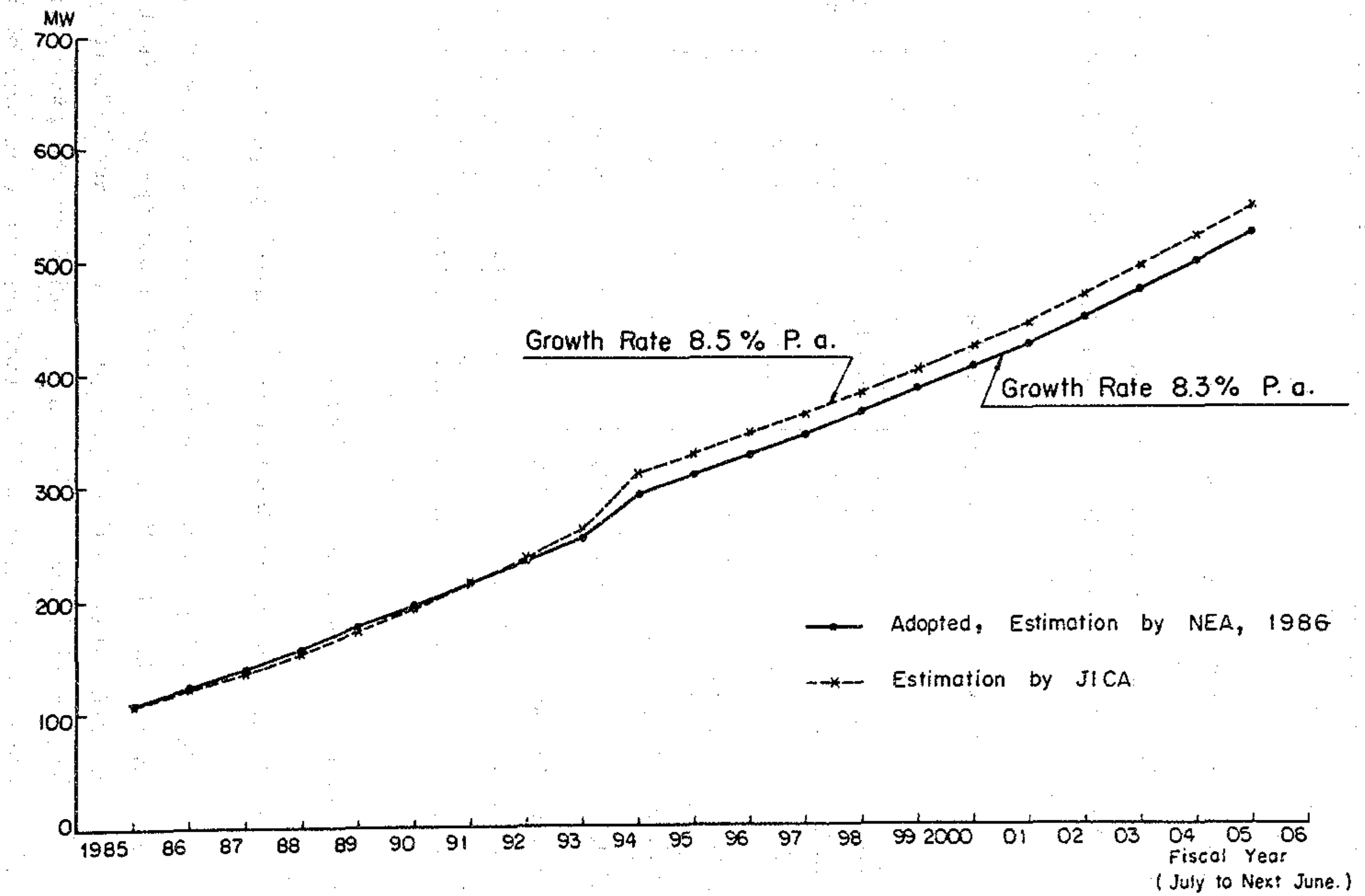


Fig. 2–6 Comparison of Projected Peak Load Demand
(Required for Generating Capability, Including Power System Losses)



2.5 Electric Power Development Program and Load Resources Balance

In order to examine the adequate development program as well as the optimum size of the Arun 3 project, load resources balance in kW and kWh is checked, based on the load demand forecast and the existing electric power development program.

2.5.1 Development Program before Arun 3 Project

According to the electric power development program prepared by NEA, the implementation program of new projects before the Arun 3 project is as shown in Table 2-14.

Table 2-14 Projected Generating Power Plants

New Project	In-Service Date	Installed Capacity (MW)	Load-Carrying Capability (MW)	Firm Energy (GWh/yr)
Existing INPS System		182.0	153.6	742
Kosi Canal Integration		6.8	6.7	31
Net Diesel Integration		0.5	0.5	2
Andhi Khola (Hydro)	Nov. 1987	5.1	6.3	41
Marsyangdi (Hydro)	Apr. 1989	69.0	73.9	312
Total		263.4	241.0	1,128

2.5.2 Development Plan of Arun 3 Project

(1) Basic concept of development of Arun 3 project

The Arun 3 project is being considered to be the top-rated project after the Marsyangdi hydropower project which is under construction. As observed in Figs. 2-7 and 2-8, it is required to commence the commercial operation of the first unit in June 1994 at the latest taking load resources balance of kW and kWh into consideration. Hence, it is necessary to carefully examine the schedules of the succeeding detailed designs, access road construction as well as the construction of the powerplant facilities in order to meet the above requirement.

The Arun 3 project will surely be the key power station to cope with the domestic load demand after the Marsyangdi hydropower station and further, its economic superiority will apparently make great stride when the power export of large amount is taken into consideration. However, the total capacity of power supply system in Nepal is rather small at present and the power interchange with the neighboring country is also on a small scale with predominant power import. Therefore, it will be important to firstly complete all the necessary arrangement for power export in the case of developing the project with power export.

In view of the above, it is realistic to develop the Arun 3 project in two stages as described below.

(i) 1st stage scheme ... Development of the optimum scheme to meet the domestic power demand

(ii) 2nd stage scheme ... Upon completion of the necessary arrangement for power export, development of the 2nd stage scheme equal to the above

(2) Development scale

As to the development scale of the Arun 3 project, it is desirable to utilize the hydropower potential endowed thereto upon careful studies of technical and economical aspects of the project.

As analyzed in Chapter 7, the maximum installed capacity of the project will be around 400 MW taking the possible power export in the future into consideration.

(3) Capacity and Number of Unit

It is general tendency that economic aspect is improved in proportion to large-scale unit size, while selection of appropriate unit size is to be made in consideration of power system capacity, power demand growth, marginal supply capability, effect on existing power system operation and so forth.

In this study, the maximum unit capacity of 20% of the total installed capacity is adopted, though it is somewhat on large side, taking into account the general tendency in countries having small total installed capacity. Since the total installed capacity is counted to be 263.4 MW after completion of the Marsyangdi project in 1989, the unit capacity of the new project equivalent to 20% of the total installed capacity including the new unit is calculated to be 66 MW approximately.

For selecting the optimum unit capacity, the unified unit capacity is considered to be most benefitial in view of functions in the system, simplified dimentions and layout, adaptable operation and maintenance as well as project economy. While, within the limit of maintaining adequate balance between the power supply system and the new power plant, the bigger unit capacity is apparently more economical. As obviously observed in Chapter 8, no particular problems will be expected from technical viewpoint through the power system analyses such as power flow and system stability, hence, it is judged adequate to install six units of 67 MW each for the Arun 3 project.

(4) Development schedule

The Arun 3 project is to be developed basically to meet the domestic power demand with the option of exporting the surplus powers which may exceed the domestic demand.

As observed in Chapter 7 in detail, the optimum development scale meeting the domestic load demand in Nepal only is 201 MW (unit Nos. 1, 2 and 3, 67 MW each) which is to be constructed as the first stage scheme. The second stage scheme is also 201 MW (unit Nos. 4, 5 and 6, 67 MW each) which will be developed with power export.

There will be another plan to develop the Arun 3 project with the total installed capacity of 402 MW in single stage, however, the most part of the generated power is to be transmitted for power export due to small domestic power demand in Nepal. This plan is considered not practical and eliminated from examination in the feasibility study.

(i) Generating facilities

(a) 1st stage development

The Arun 3 project is the key station in the power supply system and a shutdown of a unit due to accident or for maintenance purpose will greatly affect on the system operation. Therefore, after completion of the unit No.1, the succeeding unit No.2 shall be completed as soon as possible in order to keep the reliability of the power supply system. After completion of the unit No.1 and succeeding unit No.2 in June and September 1994 respectively, the marginal supply capability at shutdown of a unit is approximately 22% which is considered to be moderate for the NEA's power supply system which mainly relies upon a few number of power stations such as the Arun 3, the Marsyangdi and the Kulekhani projects. In view of the above, it is considered that two units shall be completed in 1994.

The development schedule resulting in adequate load resources balance and the least surplus power will be as shown in Figs. 2-7 and 2-8. As observed in these figures, the maximum power demand prevails over the maximum energy demand for scheduling the development programme.

The marginal supply capability at the completion of unit No. 3 is estimated to be approximately 8.6%.

(b) 2nd stage development

The development schedule of the second stage scheme which takes power export into consideration is as described below.

The time of starting commercial operation of unit No. 4 which is to be the first unit for power export is set at December 1998 that falls on completion year of unit No. 3, giving four years for necessary arrangement for power export after commencement of construction of the first stage scheme and further four years for construction of the second stage scheme up to completion of unit No. 4 installation. Thereafter units No. 5 and No. 6 are to be installed continuously at intervals of three months. The surplus power generated at the Arun 3 power plant in excess of the domestic power demand is to be exported and the amount of power that can be exported will be gradually decreased with the growth of domestic power demand. As shown in Fig. 2-7, the maximum and firm capacities available for power export in F.Y. 2001/02 is estimated at 201 MW and 153 MW, respectively.

Based on the above consideration, the scheduled online dates will be as shown below.

(1st stage scheme)

Unit No. 1 June 1994

Unit No. 2 September 1994

Unit No. 3 December 1998

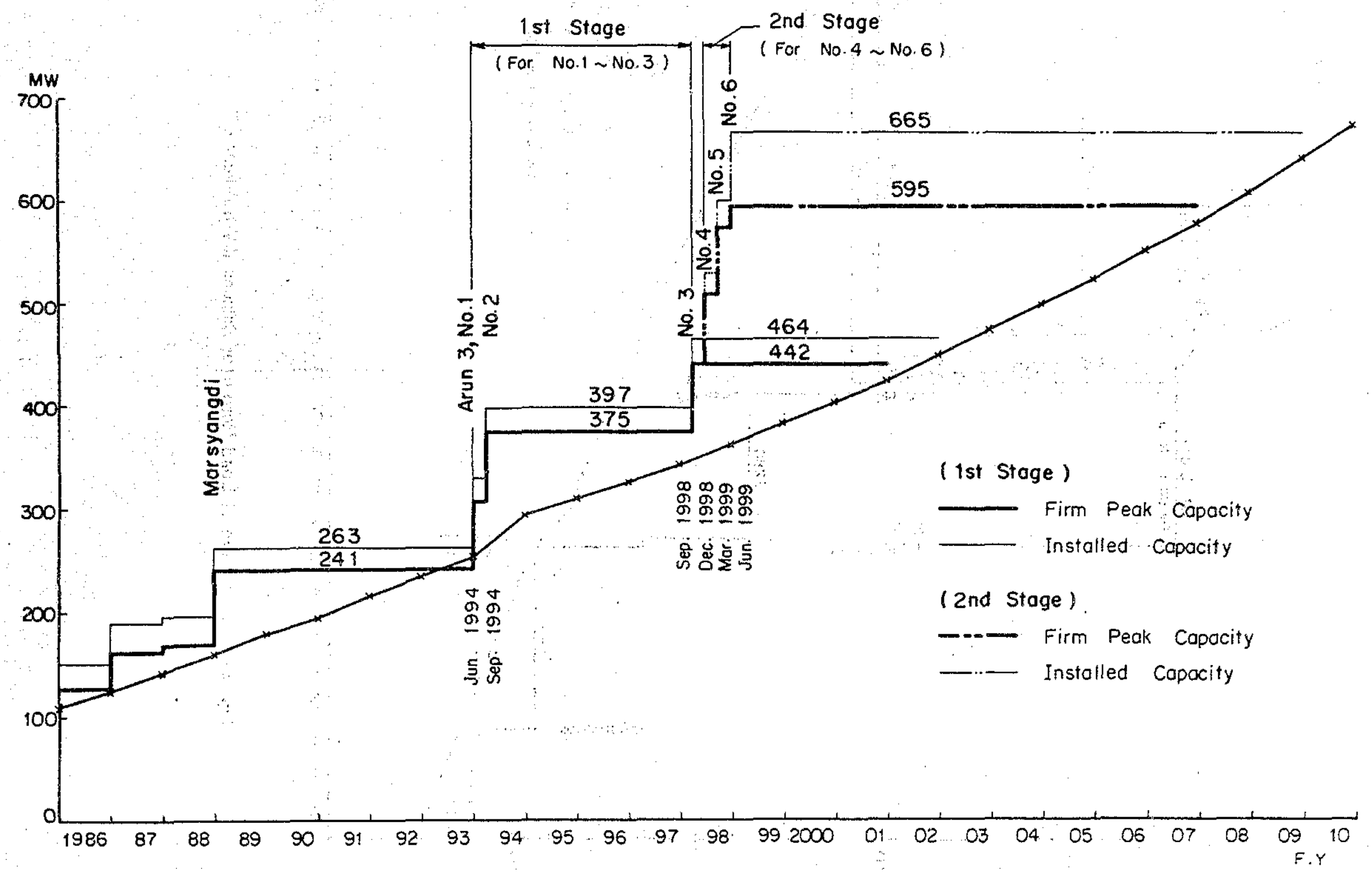
(2nd stage scheme)

Unit No. 4 December 1998

Unit No. 5 March 1999

Unit No. 6 June 1999

Fig. 2–7 Projection of Load Resources Balance (kW Balance)



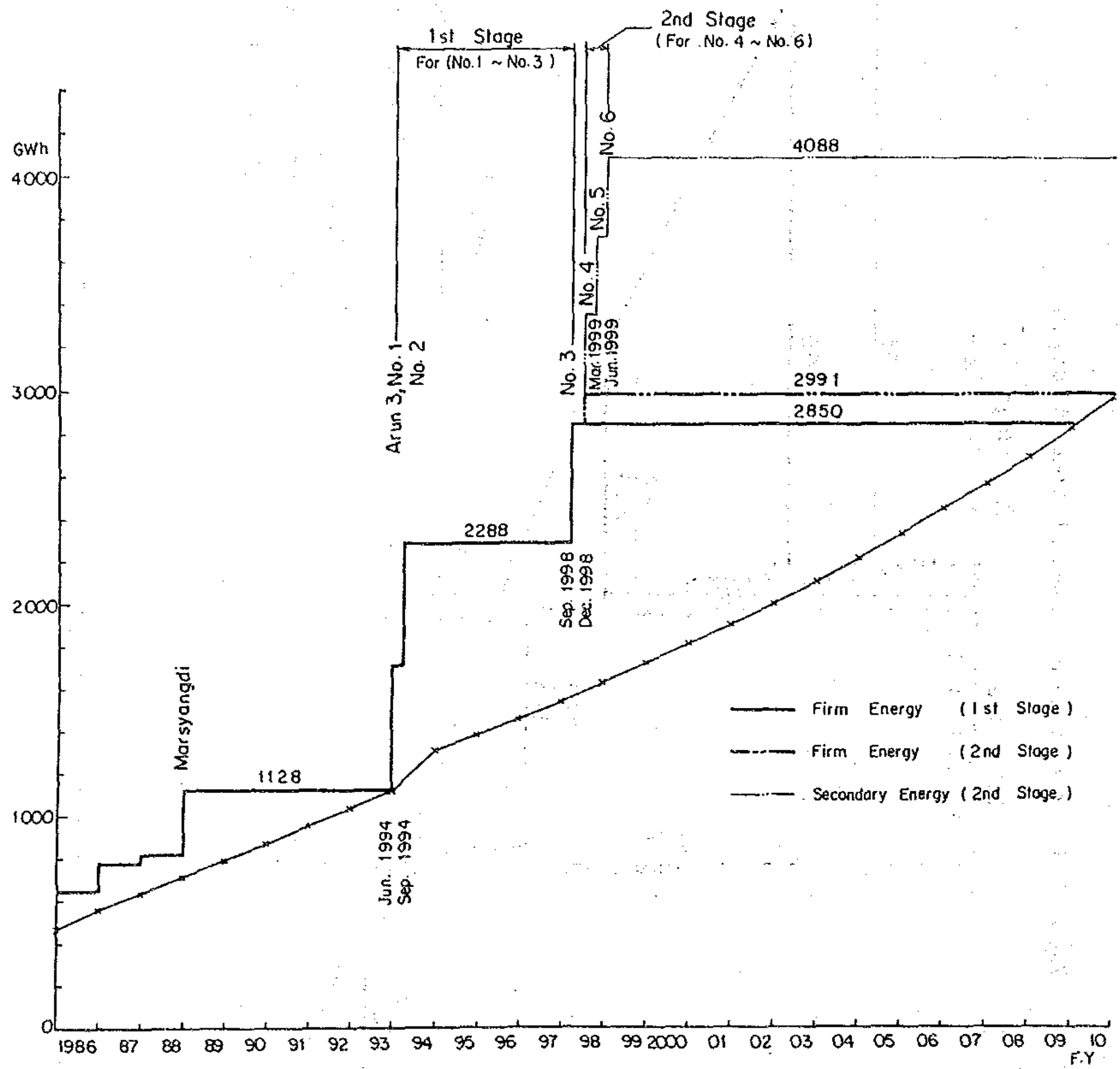


Fig. 2-8 Projection of Load Resources Balance (kWh Balance)

(ii) Trnasmission line and substation facilities

The development schedule of transmission line and substation facilities is as described in detail in Chapter 8, and the general development plan worked out in cooperation with the above-mentioned development schedule of generating facilities are as shown below.

(a) 1st stage

Schedule 1 (Jun. 1994)

(Transmission line)

Arun 3 P/S - Dubi S/S :
220 kV (120 km, 2 cct, 132 kV provisional operation)

Dubi S/S - Dhalkebar S/Y :
220 kV (146 km, 1 cct, 132 kV provisional operation)

Dhalkebar S/Y - New Kathmandu S/S :
220 kV (120 km, 1 cct, 132 kv provisional operation)

A few premises are made for making provision of transmission line cost to be charged to the Arun 3 project.

- 132 kV transmission lines connecting the New Kathmandu S/S and existing substations in Kathmandu are taken into account, namely, 1 cct to Balaju S/S and 1 cct to Siuchatar S/S, however, the cost therefor is not included in the study.

- At present, transmission line of 132 kV, 1 cct between the Hetauda S/S and the Dubi S/S is being operated, however, it is necessary to construct additional 1 cct line by the time when unit No.1 of the Arun 3 is put in service, however, the cost for this upgrading is not included in this study, because the upgrading should be a part of original transmission line expansion program by NEA and thereby it should not be charged to the Arun 3 project.

(Substation and switchyard)

Dubi S/S : Expansion of 220 KV S/S equipment
(132 kV provisional operation)

Dhalkebar S/Y : Expansion of 220 kV equipment
(132 kV provisional operation)

New Kathmandu S/S: New installation of 220 kV
(132 kV provisional operation)
and 132 kV equipment

Schedule 2 (Sep. 1998)

(Transmission line)

Operation voltage is stepped up to 220 kV.

(Substation and switchyard)

Dubi S/S : Expansion of 220 kV equipment
(transformer, etc.)
(220 kV operation)

Dhalkebar S/Y : (220 kV operation)

New Kathmandu S/S : Expansion of 220 kV equipment
(transformer, etc.)
(220 kV operation)

(b) 2nd stage

Schedule 3 (Dec. 1998)

(Transmission line)

Dubi S/S - Dhalkebar S/Y :
220 kV (146 km, 1 cct, 220 kV operation)

Dhalkebar S/Y - New Kathmandu S/S :

220 kV (120 km, 1 cct, 220 kV operation)

Dubi S/S - Importing Country :

220 kV (2 cct, Incremental cost for power export is quoted up to the boarder between two countries.)

(Substation and switchyard)

Dubi S/S	:	Expansion of 220 kV equipment (for 1 cct outgoing and 2 cct for power export)
Dhalkebar S/Y	:	Expansion of 220 kV equipment (for 1 cct incoming and 1 cct outgoing)
New Kathmandu S/S	:	Expansion of 220 kV equipment (for 1 cct incoming and one transformer)

2.6 Necessity of Implementation of Arun 3 Project

As observed in the above studies, the load resources in both kW and kWh will balance up to F.Y. 1992/93 in the case that the NEA's development plan will be proceeded as scheduled. However, it is anticipated that the supply capability of the total system will fall short of the required peak load and energy in F.Y. 1993/94, and it is considered necessary to put the Arun 3 project in operation at this stage, namely, the development of this project should be proceeded aiming the first operation of unit No. 1 in June 1994.