GOVERNMENT OF MALAYSIA

FEASIBILITY STUDY
SMALL SCALE HYDROELECTRIC POWER PROJECTS IN SARAWAK

VOLUME-IV
MAIN REPORT
FOR
FEASIBILITY STUDY
ON
MEDAMIT-2 HYDROELECTRIC POWER PROJECT

JULY 1988

JICA

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF REPORTS

Volume I	Main Report for Feasibility Study on Mukoh Hydroelectric Power Project
Volume II	Appendix for Feasibility Study on Mukoh Hydroelectric Power Project
Volume III	Data Book for Feasibility Study on Mukoh Hydroelectric Power Project
Volume IV	Main Report for Feasibility Study on Medamit-2 Hydroelectric Power Project
Volume V	Appendix for Feasibility Study on Medamit-2 Hydroelectric Power Project
Volume VI	Data Book for Feasibility Study on Medamit-2 Hydroelectric Power Project
Volume VII	Main Report for Identification of Small Scale Hydroelectric power Projects in Sarawak
Volume VIII	Appendix for Identification of Small Scale Hydroelectric power Projects in Sarawak

PREFACE

In reponse to the request by the Government of Malaysia, the Japanese Government decided to conduct a feasibility study on the Small Scale Hydroelectric Power Project in sarawak and entrusted the study to the Japan International Cooperation Agency.

JICA sent to Malaysia a study team headed by Mr. Yasuo Iwasaki, Nippon Koei Co Ltd., from August, 1986 to March, 1988.

The team had discussions with the officials concerned of the Government of Malaysia and conducted a field survey in the State of Sarawak.

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 Malaysia for their close cooperation extended to the team.

July,1988

Kensuke Yanagiya

Kensuke Yanagiya

President

JAPAN INTERNATIONAL

COOPERATION AGENCY

FEASIBILITY STUDY

SMALL SCALE HYDROELECTRIC POWER PROJECTS IN SARAWAK

Mr. Kensuke Yanagiya
President
Japan International
Cooperation Agency

July, 1988

LETTER OF TRANSMITTAL

We have the pleasure to submit herewith the Final Report for the Feasibility study on Small Scale Hydroelectric power Projects in Sarawak. The Study is consistent with energy diversification policy launched by the Fredral Government of Malaysia to the effect that the proposed hydroelectric power projects will contribute to the oil conservation.

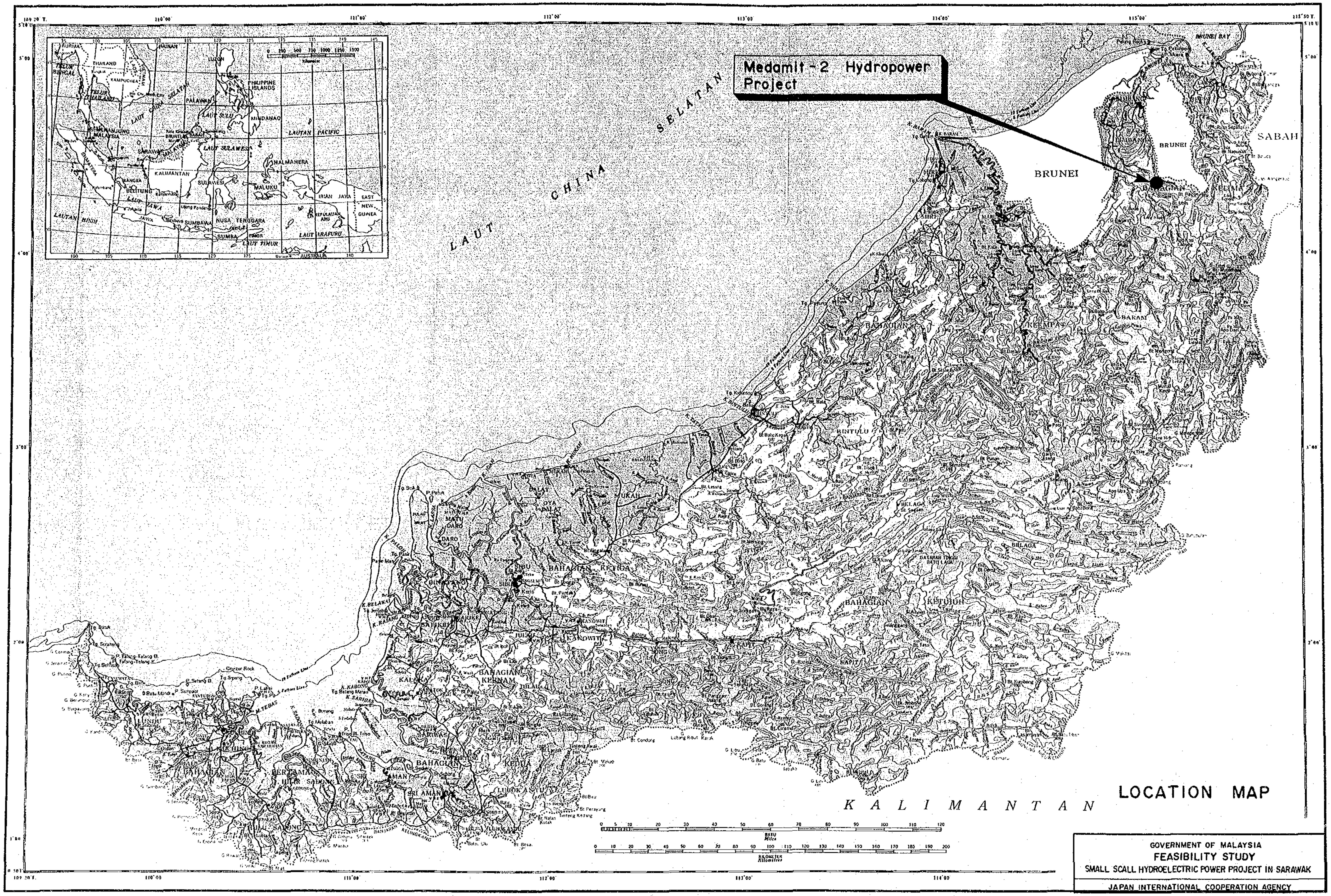
The eight Reports in total consist of the Feasibility Study on the Mukoh and the Medamit-2 small hydroelectric power projects, and the Study on site selection relating to optimal power development. The Feasibility Study Reports are the Main, the Supporting and the Data Book. The Study Reports on site selection relating to optimal power development are the Main and Supporting Report. The Main and Supporting Report contains study results and technical details respectively, and the Data Books are compiled by all data necessary for this study.

We would like to express our grateful acknowledgement to the personnel of your Agency, Ministry of Foreign affairs, Ministry of Industry and Trade, and Embassy of Japan in Malaysia as well as officials and individuals concerned of Malaysia for their kind assistance/advise extended to the Study Team. We sincerely hope that the study result would contribute to the future development of small scale hydropower project in Sarawak.

Yours Sincerely

Yasuo Iwasaki

Yasuo Iwasaki
Team Leader



LOCATION MAP

GOVERNMENT OF MALAYSIA
FEASIBILITY STUDY
SMALL SCALL HYDROELECTRIC POWER PROJECT IN SARAWAK
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SUMMARY

Background and objective of the study

1. Hydropower potential sites of a small scale development were, first of all, identified for the demand centres, Sri Aman, Sarikei, Limbang and Kapit. The selection of schemes to proceed into the feasibility study was carried out following the identification work. The Medamit-2 project for the Limbang demand centre was, then, selected as one of schemes to advance to the feasibility study.

2. The objective of this Volume IV together with Volumes V and VI is to formulate the optimal development plan of the Medamit-2 project and furthermore to assess the technical, economic and financial viability, taking into account power and energy requirements of the Limbang system until year 2010.

Limbang demand centre and Medamit-2 project site

3. Limbang, headquaters of Fifth Division of Sarawak and demand centre of the Medamit-2 project, is located near the estuary of the Limbang River and is placed between two split land areas of Brunei. This geographic character of Limbang results in a close relation with Brunei. In fact, a 30-minute travel from Limbang by speed boat makes possible to reach Bandar Seri Begawan, the capital city of Brunei.

4. Power demand in Limbang increased from 1,100 kW in 1980 to 2,500 kW in 1986, resulting in an average growth rate of 14.7%. This figure shows a higher growth rate compared with that of 12.9% in the whole of Sarawak.

5. The Medamit River originates from the Western slope of Mt. Pagon and flows down to the north-northwest direction along the border with Brunei (east). The Medamit River merges into the Limbang River at Medamit Village, after meandering some 50 km in the hilly areas. The proposed damsite of the Medamit-2 project is located in the middle reach of the Medamit River, some 20 km upstream from the confluence with the Limbang River. On the other hand, the powerhouse is situated at some 20 km upstream from Medamit village in the Limbang River. A diversion tunnel of 4,550 m long connects two sites.

Project site condition

6. The proposed project area is dominated by north-westerly striking ridges, with mostly steep ridges and mountain slopes. The Medamit River in the north and the Limbang River in the south flow parallel to these ridges. Terraces and gentle slopes are commonly covered by talus (slope wash) deposit, and some steep cliffs are found partly.

7. The project area is underlain by the Mulu Formation of Paleocene age, the Melinau Limestone Formation of Eocene to Miocene age and the Setap Shale Formation of Miocene age.

The Melinau Limestone Formation and the Setap Shale Formation, striking north-northwest and dipping toward northeast are differentiated by the unconformity.

8. The climate of Sarawak is classified into the tropical rain forest zone characterized by high moisture throughout the year. The northeast monsoon, which brings the rainy season, generally begins in the middle of October and lasts until the middle of April, while the southwest monsoon, which coincides with the dry season, prevails from the middle of April to the middle of October.

9. Annual rainfall in Sarawak is abundant, about 3,700 mm on an average, and about 30 to 40 percent of annual rainfall is expected in the dry season.

10. Long-term mean daily runoff at the project site with an catchment area of 186 km^2 is estimated at 15.0 m^3/sec. From the flow duration curve, dependable flow in the dry season is about 5 m^3/sec or so.

Power demand forecast

11. Power demand was projected by sector; domestic, commercial, industrial and public lighting sectors. Power consumption (energy sale) in the Limbang demand centre was estimated by totalling the consumption in each sector. Furthermore, energy generation and maximum demands were predicted based on the estimated power consumption. Following are the summary of demand forecast in the Limbang load centre:

Demand Forecast (Normal)

Year	Energy Consumption (MWh)	Energy Generation (MWh)	Maximum Power Demand (KW)	Annual Load Factor (%)
1984	8,083	9,462	1,912	56.5
1985	9,239	10,609	2,006	60.4
1986	10,212	11,596	2,502	53.0
1987	11,390	13,090	2,720	55.0
1988	12,570	14,450	2,840	58.0
1989	13,730	15,780	3,110	"
1990	14,960	17,200	3,390	"
1995	22,580	25,950	5,110	"
2000	31,110	35,750	7,290	56.0
2005	41,190	47,340	9,650	"
2010	54,020	62,090	12,660	"

12. The high and low cases of power demand were projected by changing the values for the electrification ratio in the domestic sector and growth rate of power consumption in the industrial sector, resulting in 10% and 15% higher power consumption in 2000 and 2005 respectively in the comparison of high and normal cases, whilst 10% and 12% lower power consumption in 2000 and 2005 respectively in the comparison of low and normal cases.

<u>Optimum development plan and installation timing</u>

13. An optimal development scale and timing of the Medamit-2 project was determined by searching the installation scale and timing of it in the optimal power development programme of a long time span.

14. Three alternatives were conceived for the hydropower development of the Medamit-2 project (refer to Figure 5.3). The basic development idea of those three alternatives is as follows:

Alt-1: A plan to create head for power generation with a dam and to have a powerhouse just at the dam toe.

Alt-2: A plan to increase head by shortening the river course largely meandered with a 300 m long headrace

Alt-3: A plan to divert water of the Medamit River to the Limbang River with a 4,550 m long headrace for creating head of 75 to 95 m.

The principal dimensions of these three alternatives are summarized as follows:

Unit:m

Alternatives	Alt-1	Alt-2	Alt-3
Full supply level	130.5 to 150	130.5 to 150	130.5 to 150
Minimum operating level	130	130	130
Tailrace level	114	110	56
Headrace tunnel length	0	300	4,550
Penstock length	40	40	230

15. Following were proposed to be optimal for the development of the Medamit-2 project as the results of optimization study:

Alternative plan	:	Alt-3
Full supply level	:	131.5 m
Minimum operating level	:	130.0 m
Tailrace water level	:	56.0 m
Type of dam	:	Concrete gravity
Headrace tunnel length	:	4,550 m

Penstock length	:	230 m
Plant discharge	:	8.9 m^3/sec
Firm discharge for power generation	:	4.5 m^3/sec
Maintenance flow to the Medamit River	:	0.5 m^3/sec
Peaking operation hours for firm discharge	:	12 hours
Rated net head	:	69.27 m
Maximum output	:	5.1 MW
Annual energy generation	:	36.1 GWh
Construction cost	:	M$59.0 million
Net benefit (capitalized)	:	M$4.4 million
EIRR	:	11.7%

16. The search for the optimal installation timing of the Medamit -2 project was made by shifting the installation year of the scale determined to be optimal (5.1MW) in the long-term installation programme. The study results to serarch the optimal installation timing are summarized as follows:

Installation year	Net benefit in 10% discount rate, M$ million	EIRR.%
1996	4.37	11.7
1997	4.63	11.9
1998	5.09	12.4
1999	5.02	12.7

The installation of Medamit-2 in 1998 gave the maximum net benefit of M$ 5.09 million. The variation of net benefit is, however, insensitive for the shift of installation year, and furthermore the Medamit-2 project keeps high viability in spite of shifting the installation year, so that earliest installation (1996) is recommended.

Basic design for main structures

17. The project involves the construction of a 19.5 m high gated intake dam on the Medamit River, intake structure feeding 8.9 m^3/sec into the waterway, a 4,554 m long headrace tunnel, a surge tank, a 227 m long penstock line, and a power plant with 5.1 MW installed capacity, for which the number of units was selected to be two units considering system reliability and maintenance of turbines and generators. The project would also include the construction of a 58 km long 33 kV transmission line to deliver the generated power to the Limbang substation.

18. The design was made at a feasibility study level, to the extent required for the purpose of estimating construction cost (refer to Figs. 6.1 to 6,5).

Construction schedule and cost

19. The construction of project is scheduled to extend over eight years from 1988 to 1995. First four years between 1988 and 1991 are required for the arrangement of construction finance, the selection of engineering consultant, the detailed engineering services and the tendering. Latter four years between 1992 and 1995 are required for the construction work of the project (refer to Fig. 7.1).

20. The construction cost for the Medamit-2 project was estimated to be M$58,959,262 in total, consisting of M$36,153,853 in foreign currency portion and M$ 22,805,407 in local currency portion. The annual disbursement of construction cost for foreign and local currencies was estimated as follows:

Year	Foreign currency (M$)	Local currency (M$)	Total (M$)
1991	337,180	674,452	1,011,632
1992	6,445,770	5,489,892	11,935,622
1993	8,790,400	6,049,969	14,885,369
1994	12,711,271	6,741,616	19,452,887
1995	7,869,222	3,804,478	11,673,700
Total	36,153,853	22,805,407	58,959,260

Economic and financial viability

21. The economic viability of the Medamit-2 project was discussed in the optimization study based on the future power expansion programme in the Limbang system. The economic viability for the optimal development scale of the Medamit-2 project was re-evaluated by assessing the valuation of goods in economic sense, conversion from financial cost to economic cost and so forth in more detail as follows:

Installation year	Net benefit (M$ million)	EIRR (%)
1996	4.37	11.7
1997	4.63	11.9
1998	5.09	12.4
1999	5.02	12.7

22. The discount rate of 10 percent was applied to estimate net benefit. Since net benefits are positive in all cases, the Medamit-2 project is economically viable.

The optimal installation time was identified to be 1998. The variation of net benefit is however insensitive for the shift of installation year and the project keeps high economic viability in terms of EIRR in spite of shifting the installation year, so that the earliest installation is recommended, namely year 1996.

23. Financial analysis discussed financial viability of the project and manageability of the implementing agency, SESCO, to repay foreign and local portion of investment costs or to finance local portion of them, if cost of the local portion is to be entirely funded by SESCO.

FIRR of the Medamit-2 project was calculated to be 8.4%. Since FIRR of 8.4% is higher than the local interest rate (7.5%) and foreign interest rate (4.0%), the Medamit-2 project is financially viable.

24. The manageability of SESCO to repay foreign and local loans was discussed by preparing the financial statements between revenue and interest plus repayment to be outlayed. In case that local cost is funded by the federal government (interest of 7.5%) and foreign cost is funded by soft loan (4%), the net cash flow turned to be positively in the commissioning year (1996) of the Medamit-2 project. Payment of interest during the first five years from 1991 to 1995 will be the amount order under financial manageability of SESCO, which is to be entirely covered by the internal cash generation. Therefore, the implementing agency will enjoy the favourable financial position under the operation of the Medamit-2 project within the maturity period.

In case that local cost is funded by SESCO itself and foreign cost is funded by soft loan, balance turned to be positive in the commision year(1996) of the Medamit-2 project. However, accumulated balance of local cost plus repayment of interest on foreign loan in 1996 entails financial matter of whether or not the amount order will be manageable under internal cash generation of SESCO. Consequently, as far as funding method is concerned, the case that local cost is funded by federal government, and foreign cost by soft loan is desirable.

Comparison studies of net cash flow and its accumulation between the system with all diesel and the Medamit-2 are also conducted under assumptions that oil price would increase according to IBRD's forecast or would be constant at 18 US$ per barrel. Despite of the assumptions, financial results turn out to be favourable condition in the system with the Medami-2.

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CHAPTER 1. INTRODUCTION

1.1 Background of Study

The State of Sarawak is located in the northern part of the Borneo Island with a latitude in a range from 1 to 5 North and a longitude from 110 to 115 East. The total land area is 124,450 sq. km. Alluvial and coastal plains mostly extend over its northwestern part and are intersected by numerous rivers flowing from hilly and mountainous hinterlands. The climate is classified into the tropical rain forest zone characterized by constantly moist days all the year round. Air temperature and relative humidity are normally high with little seasonal variation.

The abundant rainfall of 3,700 mm per annum on an average and suitable topography bring a great hydropower potential. Economically exploitable hydropower potential is estimated to be approximately 63,000 GWh per annum, corresponding to about 53 per cent of that of the whole of Malaysia.

The hydropower potential in the State of Sarawak however remains untapped, although Batang Ai Hydropower Project with installed capacity of 108 MW was completed in 1985 as the first major hydropower plant in the State of Sarawak.

In the State of Sarawak, public electricity is supplied by Sarawak Electricity Supply Corporation (hereinafter called SESCO) through a number of isolated power supply systems. The power generation mainly relies on diesel and gas-turbine. In 1984, SESCO operated the power plants with total installed capacity of 229 MW and produced the annual energy of 601 GWh as given in Table 1.1. Peak power demand and annual energy production increased at a growth rate of about 13 per cent per annum on an average during a 10-year period from 1975 to 1984. With the commissioning of Batang-Ai Hydropower Project, the total installed capacity and total energy generated by SESCO expanded to 352 MW and 704 GWh in 1985, respectively. In July 1986, SESCO operated 60 power plants as shown in Fig. 4.1.

The Government of Malaysia has established its energy policy for the period from 1986 to 1990 in the Fifth Malaysian Plan formulated in 1986. The Plan stresses the four-energy diversification strategy; namely, oil, hydro, gas and coal, aimed at ensuring reliability and security of supply, while reducing the dependence on oil in energy consumption. The objective of this strategy is primarily to utilize indigenous non-oil energy resources, particularly gas and hydropower. In line with the energy policy, SESCO has planned to harness the abundant hydroelectric resources in Sarawak in an attempt to reduce the over-dependence on fossil fuel for generation of electricity whenever possible and feasible.

The Fifth Malaysian Plan also refers to the energy policy of the State of Sarawak as follows:

> The energy generation capacity of SESCO will reach 1,600 GWh/year by 1990 compared with 704 GWh/year in 1985. The main project that will be implemented is the Ulu Ai Hydroelectric Project with a capacity of 54 MW. To identify potential projects worthy for implementation, several feasibility studies are planned to be undertaken. These include studies on small hydro projects for Sri Aman, Kapit, Sarikei and Limbang, and major hydro projects at Murum, Baleh and Belaga. As the single most capital-intensive component of the power sector development plan, which requires large capital outlay, the Bakun Hydroelectric project will be carefully assessed in terms of financial affordability and its impact on balance of payments prior to decision of its implementation.

In July 1984, the Government of Malaysia requested to the Government of Japan to extend a technical assistance on the feasibility study on small scale hydropower development for power supply to three (3) urban areas; that is, Sarikei, Sri Aman and Limbang. In response to this request, Japan International Cooperation Agency (hereinafter called JICA), the official agency responsible for the implementation of the technical cooperation programme of the Government of Japan, dispatched a contact mission to Malaysia during the period from January 24 to February 6, 1985 and carried out a reconnaissance survey for Sri Aman and Sarikei areas. During this reconnaissance survey, the Government of Malaysia further requested to JICA to add Kapit area as one of the objective areas.

JICA then dispatched again a preliminary survey mission to Malaysia during the period from October 8 to 27, 1985. The mission conducted a supplementary survey over Limbang and Kapit areas and discussed with the Government of Malaysia about the Scope of Works.

The Scope of Works of the Study was officially signed on the date of August 8, 1986 between Economic Planning Unit of Prime Minister's Department (hereinafter called EPU) and JICA. Immediately after, this Study was commenced on August 11, 1986.

1.2 Objective of Study

This report on the small scale hydroelectric power projects in Sarawak consists of eight volumes. Volume VII to VIII deal with identifying hydropower potential sites for the demand centres, Sri Aman, Sarikei, Limbang and Kapit, and selecting schemes to proceed into the feasibility study stage. In fact, Mukoh and Medamit-2 are selected as the schemes to advance to the feasibility study stage. Volumes I to VI deal with the feasibility study of Mukoh and Medamit-2 projects.

The objective of this Volume IV including Volume V and VI is to formulate the optimal development plan of the Medamit-2 hydroelectric power project selected as one of promising scheme to develop and furthermore to assess the technical, economic and financial viability, taking into account power and energy requirement of the Limbang power supply system until year 2010.

1.3 Work Progress

The feasibiltiy study of the Medamit-2 project was substantially initiated in May 1987 with a dispatch of JICA study team, based on the decision of steering committee meeting held at Kuching on January 21, 1987 for selecting the schemes to proceed into the feasibility study stage among five promising schemes selected for four load centres as discussed in Volume VII, Project Identification.

The investigation for the demand forecast, hydrological analysis and field survey such as topographic survey, seismic exploration, boring work and construction materials survey was commenced immediately after the arrival of JICA study team, and completed in September 1987 including the analysis.

The feasibility study mainly consisting of optimization of the project, feasibility level design of hydraulic structures, construction planning and cost estimates, and economic and financial analysis was carried out based on the results of field investigation. After the completion of field work for the feasibility study, the JICA study team returned to Tokyo for the preparation of Draft Final Report in the middle of December 1987.

A steering committee meeting was held on March 4, 1988 for discussing Draft Final Report submitted in advance. Incorporating the discussions for Draft Final Report, Final Report was prepared and submitted on July, 1988.

Through the field investigation and feasibility study stage, SESCO's counterparts participated in full and part time base and they engaged in data collection and supervision of field work as well as analysis.

1.4 JICA Study Team Members

Members of JICA Study Team participated in the Study are listed as follows:

Y.Iwasaki	Team Leader	Nippon Koei
K.Abe	Structural Design Engineer	Nippon Koei
T.Takenaka	Hydopower Planner	Nippon Koei
T.Udo	Soil Mechanical Engineer	EPDCI
Y.Inoue	Hydrologist/Computer Analyst	Nippon Koei
K.Miyajima	Electrical Engineer	EPDCI
T.Omori	Transmission Line Engineer	EPDCI
F.Sadohara	Geologist	EPDCI
H.Koizumi	Geophysicist	EPDCI
M.Yanase	Survey Expert	EPDCI
M.Sato	Construction Planner	EPDCI
M.Tada	Project Economist	Nippon Koei

CHAPTER 2 PROJECT AREA

2.1 Limbang Demand Centre

Limbang, headquaters of Fifth Division of Sarawak and demand centre of the Medamit-2 project, is located near the estuary of the Limbang River and is placed between two split land areas of Brunei. This geographic character of Limbang results in a close relation with Brunei. In fact, a 30-minute travel from Limbang by speed boat makes possible to reach Bandar Seri Begawan, the capital city of Brunei.

A high performance of timber industries, the second largest export earner following petroleum in Sarawak, in the region supports the prosperity of Limbang besides the geographic character of Limbang mentioned above. However, Limbang can be said to be a rather isolated area in Sarawak due to the lack of road network linked with other towns at this moment.

Limbang District, one of two districts in Fifth Division, has the population of 43,824 in 1980 for a land area of 3,978 km^2; that is, the area is populated with a density of 11.0 persons/km^2. Majorities of population live in the Limbang urban area and along the lower reaches of the Limbang River, and engage in the timber industries, trading and commercial activities besides agriculture.

Reflecting the situations mentioned above, power demand in Limbang has increased from 1,100 kW in 1980 to 2,500 kW in 1986, resulting in an average growth rate of 14.7%. This figure shows a higher growth rate compared with that of 12.9% in the whole of Sarawak.

2.2 Medamit-2 Project Site

The Medamit River originates from the western slope of Mt. Pagon and flows down to the north-northwest direction along the border with Brunei (east). The Medamit River merges into the Limbang River at Medamit village, after meandering some 50 km in the hilly areas.

Medamit-2 is the project to generate power using the head created by diverting water of the Medamit River to the Limbang River. The proposed damsite is located in the middle reach of the Medamit River, some 20 km upstream from the confluence with the Limbang River. On the other hand, the powerhouse is situated at some 20 km upstream from Medamit village in the Limbang River. A diversion tunnel of 4,550 m long connects two sites.

The existing roads, though the part between Medamit village and the project site is the logging road, are developed from Limbang to the project site. Moreover, since the improvement of existing roads is under way by the Public Works, the work for the access road will only be minimal.

2.3 Socio-economy

Major tribes and races in Sarawak are Malays, Melanaus, Ibans, Bidayuhs, other indigenous tribes, Chinese and others. According to the population census in 1980, ethnic majority is Ibans (368,000), followed by Chinese (360,000), Malays (248,800), Bidayuhs (104,900), Melanaus (98,800) and so on.

In the Limbang District, the population of other indigenous tribes is some 17,700 out of 43,824 (1980 census), followed by Malays of some 12,400, and Chinese of some 6,300, Ibans of 6,300 and so on. As mentioned in Section 2.1, majority of population live in the Limbang urban area and along the lower reaches of the Limbang River. The hinterland of the District is covered with dense forests and quite sparcely populated.

The primary product sectors in the District are agriculture and forestry. Agriculture is well developed along the alluvial plains extended in the lower reaches of the Limbang River. Major crops planted are rice and so on.

The District situated in the tropical rainforest is endowed with rich forest resources. The timber logging industry is the major source of revenue to the District and gives the largest job opportunity to the region.

CHAPTER 3 PROJECT SITE CONDITION

3.1 Location and Topography

Medamit-2 project area is located about 50 km south-southeast of Limbang town at the northern part of Sarawak. The proposed project area is dominated by north-westerly striking ridges, with mostly steep ridges and mountain slopes. The Medamit River in the north and the Limbang River in the south flow parallel to these ridges. Terraces and gentle slopes are commonly covered by talus (slope wash)deposit, and some steep cliffs are found partly.

Damsite is planned at the mouth of the gorge about 400 m downstream from the confluence with the Debarong River, a tributary of the Medamit River.

Medamit-2 project has three alternatives as discussed in subsequent Chapter 5 (refer to Fig. 5.3). Those three alternatives utilize the same dam.

Powerhouse of Alternative-1 plan is located on the right bank, immediately downstream from the damsite. The powerhouse of alternative-2 plan is situated on the left bank, about 400 m away from the damsite. The powerhouse of alternative-3 plan planning on alluvial terrace is located on the right bank of the Limbang River, 1.8 km from the Salidong tributary or about 4.5 km away from the damsite.

3.2 Geology

3.2.1 Regional geology

The project area is underlain by the Mulu Formation of Paleocene age, the Melinau Limestone Formation of Eocene to Miocene age and the Setap Shale Formation of Miocene age as shown in Fig. 3.1.

The Melinau Limestone Formation and the Setap Shale Formation, striking north-northwest and dipping toward northeast are differentiated by the unconformity.

Regional fault and local sheared zone in the project area were detected. About 5 m wide shear zone at the mouth of the Salidong River and faults along the damsite could be seen from the exposed outcrops.

The Melinau Limestone Formation consists of light grey and fine grained massive limestone with very thin (mm to cm thick) veins of quartz intercalated at the right bank of the Limbang

River near the project area.

The Setap Shale Formation occurred as intercalated form consists mainly of shale unit with minor light grey fine-grained sandstone unit.

Other than the type of rocks mentioned above as the bedrock, Quaternary terrace deposits, slope wash deposits and river gravel deposits along the rivers are distributed in a small scale.

3.2.2 Site geology

Medamit-2 project area consists of limestone, shale and sandstone units. The limestone is exposed in a scattered pattern at the slope of the right bank of the Limbang River near the powerhouse (alternative-3). Limestones which are light gray, fine grained hard and massive rest unconformably on an erodible basement of shale unit. Seepage through the surface of the unconformity is possible due to the fact that the limestone is soluble to form cavities. In the middle of penstock line and powerhouse of alternative-3 plan, limestone occurs in lenses form.

The shale unit distributed widely in the project area is slaty, folded, fractured, faulted and regionally metamorphosed. Fresh shale outcrops being grey to dark grey and hard occur as beds of about five centimeters intercalated with minor thin sandstone beds of two to three centimeters thick.

Right bank of the damsite, most of the waterway and powerhouse of Alternative-2 plan and headrace tunnel and the penstock line of Alternative-3 plan are sitting on the Setap Shale unit.

The sandstone unit was found as thin beds along the central part between the Medamit and Limbang rivers and as lenses near damsite. At the damsite, sandstone beds are gently dipping 30 to 40 towards downstream to right bank and intercalated with thin beds of shale. The sandstone being massive and hard, has two types of joints such as flat-lying opened joint and vertical joints.

Both sides of the sandstone highly sheared cracky and fault contact with the shale units could be seen about 30 m downstream from the dam axis on the left bank of the Medamit River.

The intake site of alternative-2 and 3 is mainly covered by sandstone.

3.2.3 Assessment on Engineering geology

The following conclusions of the foundation rock are based on the interpretation and evaluation of the geological investigations.

(1) Alternative-1 plan

a) Dam

Core drilling at three boreholes (BMe-1,2,4) and seismic prospecting at one line (Me-A line) were carried out at the damsite.

Foundation rock of the damsite is underlain by sandstone from left bank to lower part right bank through the riverbed, while Setap shale for the higher part of the right bank.

These rocks are judged to have enough bearing force to support the concrete dam. However, flat-lying joints dipping toward downstream are common in the massive sandstone. Furthermore, the permeability of sandstone varies from 1 to 32.5 in Lu-value, while 1 to 2.4 in Lu-value for shale.

Reinforcement such as grouting and rock bolts to reduce the permeability and to increase shearing force of the base rocks would be required before the dam is constructed. However, the extension of the high permeability zone is still unknown. A more detailed study will be required to confirm the stability and permeability of the area during the detailed design stage.

A fault running north-south is observed at the right bank. The dam is sitted entirely on the massive sandstone formation clear off the fault. Thus, it is unlikely that the fault will have any detrimental effect on the dam. However, clarification of this matter will be also required in the detail design stage.

b) Powerhouse

At right bank where powerhouse is situated, sandstone and shale were covered with terrace deposit and slope wash deposit of unknown thickness. However, normal thickness of these deposits at the proposed site is in the range of 5 to 8 m, judging from the topographic map and observation of outcrops along the river. Therefore the sandstone and shale at the site are suitable for the foundation of the powerhouse.

(2) Alternative-2 plan

a) Waterway

<u>Headrace</u>

Geology of the damsite and a section of the headrace tunnel, 50 m from intake, is underlain by sandstone intercalated with thinly bedded shales. Fault between the sandstone and shale extends in parallel or sharp angle to the tunnel where shale is covered. There is a high possibility of spring in sandstone area, since section of the tunnel would be constructed across the fault zone.

Surge tank and penstock line

Geology of the surge tank and penstock line is underlain with shales of which the rock condition is similar to the headrace tunnel area.

Foundation of surge tank and penstock line will be based on slightly weathered to fresh rock.

b) Powerhouse

Geology at the powerhouse site is Setap shale, the condition of which is similar to the headrace tunnel. Foundation of the powerhouse site will be based on the moderately weathered shale.

(3) Alternative-3 plan

a) Waterway

Headrace tunnel

Geology along the tunnel consists of sandstone and shale. The section from intake to 50 m of the tunnel mostly consists of sandstone intercalated with thin beds of shale. The rest is covered by shale interbedded with lenses of sandstone beds, and will be hard and tight due to the rock covering of 100 to 300 meters above the tunnel. However, sandstone in the section from the intake to 50 m of the tunnel forms a weak zone. Furthermore, the sandstone heavily jointed at about 110 m from the intake was caused by one of the main faults. Therefore, it will be possible to meet groundwater during construction.

It is recommeneded that more detail field investigation for the fault and joint spacing of sandstone should be carried out during the detailed design stage.

Surge tank and penstock line

Core drilling at two boreholes (BMe-5 and 6) and seismic prospecting at three lines (Me-D,E and F lines) were carried out at the surge tank and penstock line.

Foundation rock at the surge tank and penstock line area is underlain by shale and limestone having low velocity layer of 1,600 m/s, resulted from the unconformity and sheared zone commonly located at the boundary between these two rocks.

The surge tank site and penstock route are covered with highly weathered lateritic hard clayey to soft shale and limestone to the depth of 10 to 20 m. Foundation of surge tank will be based on the slightly weathered to fresh rock, while anchor blocks of penstock will be based on the weathered shale (SPT test shows over 50 blows in N-value).

It is recommended that more detailed field investigation to confirm the modulus of elasticity and deformation of soils and rocks by means of Borehole Jack Test and other suitable tests should be carried out during the detailed design stage.

Powerhouse

Core drilling at one borehole (BMe-7) and seismic prospecting at one line (Me-G line) were carried out at the powerhouse site.

From the result of water pressure test carried out in borehole BMe 7, the underlain limestone beds show a high permeable value.

Foundation rock at the powerhouse site is limestone covered by the terrace deposit of about 7 to 10 m thick. The terrace deposit should be removed to sound rock for the foundation of the powerhouse.

A high permeability of limestone may indicate cavernous conditions at the location of the powerhouse. These conditions although not detected during this study stage should be taken into consideration during the detailed design stage.

3.2.4 Seismicity

Sarawak is located outside the Circum-Pacific seismic zone and is situated on the Sudan Shield, a stable block where almost no recent activity or block tectonics have been recorded.

During the period of late Tertiary and Quaternary, extensive volcanism occurred in the folded Upper Tertiary strata of Central Sarawak. Volcanic eruptions and subsequent basaltic extensions built the Hose Mountain Range, the Usun Apau plateau and the Linau Balia plateau.

The youngest igneous rock in Western Sarawak is an andestic lava at Sematan, possibly of early Quaternary age. However, no volcanic activity has been detected recently in Sarawak, therefore, the possibilities of earthquake occurance are scarce.

Earthquake records in Sarawak are available in "MICRO-SEISMIC STUDY OF MALAYSIA AND ADJACENT AREA" prepared by Malaysia Meteorological Service, in which 17 events in Peninsula Malaysia, and 7 events in Sabah and 2 events in Sarawak during the period from 1896 to 1976 are recorded.

Two earthquake records in Sarawak are as follows.

a.	Year and Date	:	1958 June 30th
	Place	:	Kuching
	Intensity (MM Scale)	:	V
	Report of Damages	:	Two tremors reported, sleepers awakened
	Source	:	North Borneo News and Sabah Times Jesselton July 5, 1958 Sabah State Library
b.	Year and Date	:	1965 July 21
	Place	:	Niah and Bekenu, Sarawak, Forth Division
	Intensity (MM Scale)	:	IV
	Report of damages	:	Light tremors reported. Slamming doors and smashing window panes, nomajor damages
	Source	:	The Sarawak Tribune July 22 1965 Sabah State Library

Two earthquakes mentioned above occurred in the coastal region along the South China Sea, but no reports in inland area. For the sake of safety, it is prudent to assume that there is a possibility of earthquake occurence in inland area. The proposed horizontal ground acceleration of 0.05 g is therefore considered for Medamit-2 project. Indeed, in designing the Batang Ai, the seismic design coefficient (k) of k=0.05 was adopted, while k=0.15 for the Bakun project.

3.3 Hydrology and Meteorology

3.3.1 General features

The climate of Sarawak is classified into the tropical rain forest zone characterized by constantly moist days throughout the year. The northeast monsoon generally begins in the middle of October and lasts until the middle of April, while the southwest monsoon prevails from the middle of April to the middle of October. Since the southwest monsoon is generally weaker than the northeast one, the rainy season of Sarawak coincides with the period of northeast monsoon. The southwest part of Sarawak having the distinctive rainy and dry seasons is well affected by the prevailing of northeast monsoon, while the northeast part, especially in the vicinity of state boundary between Sabah and Sarawak, has no distinctive rainy and dry seasons because of the affection of southwest monsoon.

Annual rainfall in Sarawak is abundant, about 3,700 mm on an average, and about 30 to 40 per cent of annual rainfall is expected even in the dry season.

3.3.2 Meteorology

Meteorological data have been recorded for relatively longer period at four (4) stations under the control of Malaysian Meteorological Service (hereinafter called MMS).

The daily mean temperature is almost constant at about 26 C throughout the year, and the diurnal change of air temperature is 15 C from 20 C to 35 C. The mean relative humidity is also almost constant in a range from 85 per cent to 87 per cent, although there is a slight seasonal change.

Mean sunshine hour is 5.7 hours a day on an arithmetric average of the stations. It corresponds to annual sunshine hours of 2,080 hours.

Maximum surface wind speed of 31.8 m/sec was recorded at Kuching aerodrome on September 1964. However, wind is usually quite weak and mean surface wind velocity has been recorded in a range from 0.9 m/sec to 1.3 m/sec.

Evaporation data have been recorded at fourteen (14) stations under the control of MMS and Drainage and Irrigation Department (hereinafter called DID). Among the stations, Ukong is the nearest station from Medamit-2 site. The mean monthly evaporation at Ukong is almost constant throughout the year, ranging from 120 mm to 145 mm. Mean annual evaporation is 1,652 mm for the period from 1963 to 1977.

The Sarawak Hydrological Year Book for 1981 and 1982 published in 1986 contains the values of mean monthly rainfall recorded at 136 rainfall stations. The mean annual rainfall depth over Sarawak is estimated at about 3,700 mm for the past 20 years.

The wettest year was 1970 with annual rainfall depth of 4,310 mm, and the rainfall depth of 3,272 mm was recorded in 1972 which was the driest year.

Among 136 rainfall stations, Lubok Lalang is the nearest station to the Medamit-2 site. The mean annual rainfall is estimated to be 4,487 mm at the Medamit-2 site from the correlationship between Lubok Lalang and Ukong based on the data for 24 years from 1963 to 1986. The wettest year was 1967 with annual rainfall depth of 5,286 mm, while 1972 was the driest year with the depth of 3,751 mm.

3.3.3 Hydrology

(1) General

Streamflow measurements were carried out at 49 water level gauging stations in 1982 under the control of DID. Of these, 31 stations are automatic recorder stations while the remaining 18 are stick gauge stations. Most of the stations are, however, located along the major rivers having the catchment area of more than 1,000 km^2.

The mean annual basin loss is obtained by subtracting the mean annual runoff depth from the mean annual basin rainfall depth. The data of 15 selected river basins having the relatively longer period of rainfall and water level records show that the ratio of the mean annual basin loss to the mean annual basin rainfall depth varies in a range from 0.18 to 0.5.

(2) Low flow analysis

The flow duration curve at the intake site is used to determine the development scale of run-of-river type scheme. The flow duration curve is a figure to express discharges against their excess rates by arranging the daily runoff data in the numerical discending order.

However, none of water level gauging station is located along the Medamit River. In order to generate a series of daily runoff at the intake site, the tank model method is applied to the basin. The coefficients of tank model are calibrated on the basis of the low flow analysis of Kp. Git and Buan Bidi having a catchment area of 440 km^2 and 217 km^2 respectively as small as that at the intake site.

Three (3) flow duration curves in 1984, 1985 and 1986 are established on the basis of the daily rainfall records at Lubok Lalang. They are shown in Fig. 3.2.

A flow duration curve on a weighted average is obtained by assuming that the annual rainfall depth at Ukong rainfall station is normally distributed. Long-term mean daily runoff is estimated at 15.0 m^3/sec.

From the flow duration curve estimated for the Medamit River, the dependable discharge in the low flow season is about 5.0 m^3/sec.

(3) High flow analysis

Frequency analysis of rainfall depth at Long Semadoh, which is the second nearest rainfall gauging station to the intake site, is made for various durations and return periods. Three (3) methods, (i) Gumbel, (ii) Iwai and (iii) Log-Pearson Type III, are applied to verify the fitness to the plotting position of recorded data. The results show that significant difference is not observed in their values among the three (3) methods. Therefore, the results of Gumbel method which is adopted by DID in his publications are applied.

The average basin rainfall tends generally to decrease with the increase of catchment area. Although the development of depth-area-duration curve for each storm is required to estimate the conversion factor of point rainfall to average basin rainfall, the lack of sufficient data prevents the derivation of conversion factor by the statistical procedure. In the Study, the conversion factor of 0.95 is applied to estimate the average basin rainfall at the Medamit-2 site.

Depth-duration analysis is made on the basis of four (4) heavy rainfall data recorded at Kuching aerodrome so as to estimate the distribution of hourly rainfall. According to the data, the heavy rainfall occurs for the duration within 24 hours and has such characteristic that about 80 per cent of 24-hour rainfall depth concentrates in 15 hours after rainfall starts. These torrential showers are usually observed in the evening to next early morning. The average hourly distribution pattern is obtained as an arithemetic mean of four (4) heavy rainfalls.

Probable flood hydrographs at Batang Ai Project having a catchment area of 1,200 km^2 are referred for estimating the duration of design rainfall. The duration of direct runoff for various probable floods is roughly estimated at about 30 hours which correspond to the duration of heavy rainfall within 24 hours.

A unitgraph at the intake site is developed by the Nakayasu's synthetic unit hydrograph method. Initial rainfall loss is disregarded by assuming that the whole basin is saturated by antecedent rainfall, while the retention loss rate after the saturation is assumed to be constant at 2.5 mm per hour.

Probable flood peak discharges at the intake site are estimated at 542 m^3/sec, 595 m^3/sec and 648 m^3/sec for the return periods of 50, 100 and 200 years, respectively.

On the other hand, the powerhouse site is located in the middle reach of the Limbang River. Two (2) water level gauging stations along the Limbang River, namely, (i) Nanga Medamit and (ii) Insungai, have been managed by DID. In the Study, the data at Nanga Medamit are used, taking a relatively longer recorded period into consideration.

A flow duration curve at the powerhouse site is estimated on the basis of that at Nanga Medamit in proportion to their catchment areas. Annual mean daily discharge at the powerhouse site is estimated at 210 m^3/sec. The annual mean daily water level at the powerhouse site is also estimated at EL.55.740 m.

Probable peak discharge at the powerhouse site is estimated by applying the Creager's equation and the results of frequency analysis of annual maximum peak discharge at Nanaga Medamit. Probable flood peak discharges at the powerhouse site are estimated at 1,300 m^3 sec, 1,400 m^3/sec and 1,500 m^3/sec for the return periods of 50,100 and 200 years, respectively.

It is finally noted that the prediction of runoff was relied on the short records of rainfall and discharge data or was based on the data from other basins which may not be representative of the proposed project site due to lack of data. Meteo-hydrological observations are recommended to successively be carried out for enhancing the reliability of hydrological estimates.

3.3.4 Sedimentation and water quality

Although measurements on sedimentaton were carried out on June 23, 1987, data collected are still insufficient for the derivation of relationship between discharge and sediment volume.

The denudation rate of 1.0 mm per annum is adopted at the intake site on the basis of the results of study on Batang Ai and Bakun Hydroelectric Projects. The annual sediment flowing through the intake site is estimated at 0.19 million m^3.

Water quality of the Limbang River was analysed by the Agricultural Department in April 1974. The data show none of adverse effects on turbine and metal for hydropower use. Futhermore, water quality tests were also carried out in this study.

3.3.5 Right of way in water use

There is no habitant in the Medamit River basin upstream from the Medamit-2 site. Uppermost location of habitants is about 8.5 km downstream from the intake site, where people utilize river water for their drinking. Mandatory release of 0.5 m^3/sec would be required for ensuring their drinking water, if water of the Medamit River is diverted to the Limbang River for power generation.

The Medamit River is not used for the transport of logged timber. Further discussions on hydrology are referred to Appendix III of Volume V.

3.4 Construction Materials

3.4.1 Introduction

Major hydraulic structures for the project are such concrete structures as a concrete gravity dam, headrace tunnel, surge tank, powerhouse and tailrace. Concrete aggregates are therefore mainly discussed as construction materials. Aggregates required for such concrete structures are estimated to be some 43,000 m^3 in total; 28,000 m^3 for gravel and 15,000 m^3 for sand.

Reconnaissances to search the potential borrow pits for concrete aggregates were carried out in the vicinities of project area. Seven dunes consisting of sand and gravel were investigated as the candidate places of concrete aggregates; two in the Medamit River and five in the Limbang River. The location of seven potential areas is depicted in Figure 3.3.

Samples were also taken from the proposed quarry area located 0.1 km downstream of the dam site on the left bank.

3.4.2 Laboratory tests

During the field investigation, samples for laboratory tests were collected by digging test pits. Collected samples were brought to Kuching for carrying out such tests as sieve analysis, specific gravity and absorption and so on.

The technical specifications stipulated by American Society for Testing Materials, ASTM, for the laboratory test of concrete aggregates are applied to the samples collected from the borrow pits. The maximum size of coarse aggregates is 80 mm for laboratory tests.

The results of laboratory tests are summarized in Table 3.1. It can be said that sand and gravel in the Medamit River show the quality usable as concrete aggregates, although sand has slightly light specific gravity and slightly high absorption rate, and gravel contains some soft stones.

On the other hand, sand in the Limbang River shows the characteristics of light specific gravity, high absorption rate and high soundness rate mainly due to the reason that sand contains much organic matter as organic impurities show "not passed" in Table 3.1. In order to use sand in the Limbang River as concrete aggregates, it would therefore be necessary to wash it with clean water.

The gravel deposit contains some soft stones, but the result of abrasion test shows good quality, so that gravels in the potential borrow pits will be used as concrete aggregates.

The test result of the quarry samples are summarized in Table 3.1. The overall results indicate the suitability of the material as concrete aggregates.

3.4.3 Concrete aggregates

Table 3.2 shows the collectable amount of concrete aggregates, hauling distance and so on. Materials collected from two aggregate borrow pits in the Medamit River are conceived to be used as the concrete aggregates of dam, intake and a part of headrace tunnel. However, collectable amounts are not only limited, but also the deposits contain many cobbles and boulders with sand and gravel, even if the laboratory tests show the quality usable as concrete aggregates. Therefore, concrete aggregates required for the construction of dam, intake and a part of headrace tunnel will be quarried from the sandstone area located on the left bank just downstream from the dam. The suitability of sandstone as concrete aggregates is verified from the laboratory test for the quarry samples.

On the other hand, concrete aggregates required for the construction of a part of headrace tunnel, surge tank, powerhouse and tailrace will be collected from five aggregate borrow pits in the Limbang River due to sufficient deposit amount and easy accessibility. It is noted that since the many cobbles and boulders which are bigger than the suitable grain size as concrete aggregates contain in the deposits, it would be necessary to crush them for obtaining the required amount of concrete aggregates. In addition, although river bed deposits in the Limbang River are conceived to use for the concrete aggregates of dam concrete structure, a long hauling distance of 25 km in a hilly area is not economically justified. Further discussions on construction materials are referred to Appendix II of Volume V.

3.5 Environmental Aspect

3.5.1 General

Environmental impact associated with implementing major investment projects is a matter of increasing concern in Sarawak. With this view, an environmental study was carried out at this time as a part of the feasibility study on the Medamit-2 hydropower development project.

The objectives of the environmental study were first to clarify the existing conditions of the environment in and around the project site, particularly in the Medamit River basin, and secondly to assess possible environmental impact of the Medamit-2 project. The environment impact assessment as discussed below is only at a preliminary level, since the project is still at the relatively early planning stage.

3.5.2 Existing environmental conditions

Existing environmental conditions in the Medamit River basin were studied in many aspects, based on the existing data, reports, hearings and limited field survey. Aspects covered by the study are land use, economic activities, public health, water quality, vegetation, wildlife, fish and fisheries and natural conservation.

Land use and vegetation

Major parts of the Medamit River basin is covered with permanent forests. In Sarawak, permanent forests are majorly classified into three categories; forest reserves, protected forests and communal forests. The definition of each categories is simplified as follows:

Forest reserve	:	Permanent forest to reserve permanently for the benefit of the present and future inhabitants of the country.
Protected forests	:	Permanent forest to require protection of land and water, where the terrain or vegetation is of such a nature that intensive management in a protective forest is unlikely to be practicable.
Communal forests	:	Permanent forest to supply permanently the domestic needs of the specified community.

The forest in the Medamit River basin belongs to forest reserve, where logging is in full activities. The land of the Medamit-2 project area is reserved to the Government, and nobody may claim native customary rights for the development of the project, since activities of local dwellers lived at 8.5 km downstream from the project site are not extended to the project area.

Public health

Most of the diseases afflicting local people today are either infectious or due to poor nutrition. The most prevalent disease is malaria and tuberculosis, for which considerable cases are newly reported every year in the Limbang District.

The probable endemic disease affected by the hydro-electric development will be malaria. It will be free from the problem of spreading of schistosomiasis which is parasitic and water-borne disease known as bilharzia and is carried by aquatic snails, since the reservoir shore is not in a favourable condition for this disease.

Water quality

Water quality tests were carried out near the project site of the Medamit River as part of this project. The Medamit River shows clear colour without turbidity and highly dissolved oxygen concentration. However, the test shows slightly acid water probably due to a long time lapse from sampling to laboratory test.

The Medamit-2 project creates a man-made lake of a scale that water stored in it does not stay beyond a few days. Thus, the creation of new reservoir has not any adverse effect to water quality of the Medamit River.

Wildlife

There exist no available data on wildlife of the Medamit River basin. Hearings from the local people around the damsite indicate that the principal wildlives are as follows:

Mammals	Reptiles
Wild Boar	Snake
Barking Deer	Monitor Lizard
Mouse Deer	
Porcupine	
Slow Loris	
Gibbon	

Fish and fisheries

Fresh water fish in the Medamit River are semah, belidak, tengadak, baong and lajong. Those fish which are edible and a major protein source for local people have habit of local movement to the upstream reaches in wet seasons for seeking clean water.

3.5.3 Effects on environment

Possible impact of the Medamit-2 project to the environment is assessed at a preliminary level. Since it is only a preliminary assessment, possible effects are classified into following five ranks just to indicate if they would be beneficial, neutral or harmful to natural and human surroundings:

+H : high positive
+L : low positive
O : no effect or neglible effect
-L : low negative
-H : high negative

Environmental effects of the Medamit-2 project are assessed as summarized in Table 3.3. Low negative is assessed for sendimentation, vegetation, wildlife, and fish and fisheries. However, those effects may turn out to be neglible, if more detailed investigations are made into the existing conditions, and careful approaches are accordingly taken to the project implementation.

CHAPTER 4. POWER SUPPLY AND DEMAND

4.1 Organization of Power Sector

In the State of Sarawak, the Sarawak Electricity Supply Corporation (SESCO) is the sole agency to undertake the responsibility to supply electric power to consumers stably in line with the Ordinance established by the Government of Malaysia, and the Corporation is under statutory duty:

(1) to manage and work the electrical installations transferred to the Corporation by the provisions of the Sarawak Electricty Supply Corporation Ordinance, 1962 and such other installation and apparatus as may be acquired;

(2) to establish, manage and work such electrical installation as the Corporation may deem it expedient to establish;

(3) to promote and encourage the generation of energy with a view to promoting the economic development of Sarawak;

(4) to secure the supply of energy at reasonable prices; and

(5) to advise the Government on all aspects relating to the generation, transmission, distribution and use of energy in the State.

In addition, the Corporation has been implementing the rural electrification programmes throughout the State so as to raise the living standard of the rural people according to the Government policy.

4.2 Existing Power Supply System

4.2.1 Whole Sarawak

1. Power generating facilities

By the end of 1986, SESCO has constructed and operated 60 power stations, as shown in Fig. 4.1, with a total installed capacity of 364,624 kW in order to suit growing power demand, and the extension of the installed capacity from 1975 in major ten service areas is shown in Table 4.1.

The installed capacity at the end of 1986 has grown by 4.5 times compared with that in 1975. The generating facilities are comprised mainly of diesel engines as well as gas-turbine units. However, the first large scale hydropower station in Sarawak, Batang Ai, with an installed capacity of 108 MW (27 MWx 4 units) has been put into commercial operation in 1985.

The breakdown of generating types at the end of 1986 is shown below:

Breakdown of Generating Types

Diesel	Gas-turbine	Hydro	Total
50%	20%	30%	100%

Energy generated at the Batang Ai hydropower station is mostly consumed as base load in Kuching area. The gas-turbines are installed only in Kuching, Miri and Bintulu areas. In other load centres including Limbang and Kapit, the power supply relies on the respective diesel engine sets installed for each isolated grid.

2. Power transmission and distribution

In combination with the development of Batang Ai project, a 275 kV transmission line with a total length of 215 km was constructed. Its extension work to Sibu is now in progress as depicted in Fig. 4.2. SESCO has a further plan to extend the 275 kV transmission line to Bintulu, so that these interconnected transmission lines will constitute the main artery in the power system of Sarawak in near future.

Power is distributed with the voltage of 33, 11 and 6.6 kV, and power outlet used by consumers is normally wired with the rating AC 50 Hz, 3 phase/single, 400/230 V. According to SESCO's Annual Report in year 1983, a total length of the existing distribution lines is 3,757 km as detailed below:

Route Length of Distribution Network

(Unit:km)

Voltage	33 kV	11 kV	6.6 kV	400/230 V
Overhead Line	140	702	95	1,864
Underground Cable	22	474	114	346
Total	162	1,176	209	2,210

Most part of these distribution lines, except for river crossing and major town areas, are supported with wooden (Belian) poles.

4.2.2 Limbang area

1. Power generating facilities

As shown in Table 4.1, the installed capacity of Limbang power station at the end of 1986 was 3,585 kW in total, consisting of 8 diesel engine sets. An output of each generator is given in the single line diagram of Limbang system as shown in Fig. 4.3.

2. Distribution network

The existing distribution network consists of 11 kV, 6.6 kV and 400/230 V overhead line and underground cable with a step-down transformers in the range from 16 kVA to 1,000 kVA, and its route length at the end of 1983 is indicated below:

Distribution Network in Limbang

(Unit:km)

Voltage	11 kV	6.6 kV	400/230 V
Overhead Line	8.7	7.8	43
Underground Cable	4.8	9.7	5.7
Total	13.5	17.5	48.7

It is judged from the capacity of distribution transformers shown in the single line diagram that power supply is remarkably concentrated in the town areas.

4.3 Present and Historical Power Demand

4.3.1 Whole Sarawak

1. Energy generated and sold

The energy generated and sold in 1986 was 706.6 GWh and 568.6 GWh in the whole of Sarawak, and their historical data from 1975 are presented in Tables 4.2, 4.3 and Fig. 4.4. Taking the year 1980 as the base, the average growth rates of the energy generated and sold were 12.1% and 10.9% per annum, respectively, and those rates in four major cities of Sarawak are summarized as follows:

Average Growth Rate (1980-1986)

Service Area	Kuching	Sibu	Miri	Bintulu
Energy Generated	12.1%	7.7%	11.2%	25.6%
Energy Sold	9.8%	7.2%	9.9%	24.9%

It is clear from the above that Bintulu has been rapidly growing compared with others because of LNG production and industrial plants.

On the other hand, the system losses including station uses increased from 14.2% in 1980 to 19.5% in 1986.

2. Maximum demand

The maximum demand in 1986 was recorded at 141.4 MW in the whole of Sarawak. As its record from 1975 is indicated in Table 4.4, the maximum demand increased with 12.9% per annum.

The relation between the installed capacity and maximum demand is also given in Fig. 4.5, which shows much power supply reserve in 1985 onward by the installation of Batang Ai. The annual load factor in these six years is ranged from 51.2% in 1982 to 57.0% in 1986 as shown below:

Annual Load Factor (%)

Year	1980	1981	1982	1983	1984	1985	1986
Sarawak	55.1	54.1	51.2	54.7	55.0	56.1	57.0

3. Power consumption

Power consumption is in principle divided into four categories, i.e. (a) domestic, (b) commercial, (c) industrial and (d) public lighting, and its ratio for total power consumption of 568.6 GWh in 1986 (refer to Table 4.3) is listed below:

Power Consumption by Category in 1986

Category	Domestic	Commercial	Industrial	Lighting	Total
Ratio	30.2%	48.3%	20.2%	1.3%	100%

Power consumption by the commercial sector shares 48.3%, followed by the domestic sector of 30.2%.
Fig. 4.6 presents the historical data with regard to the power consumption by category in 1980, 1983 and 1986. The increase rate of power consumption in the commercial sector is 11.1% per annum for the period of 1980 to 1986, whilst 12.8% in the domestic sector, 8.4% in the industrial sector and 9.3% in the public lighting.

4. Number of consumers and power consumption per consumer

Table 4.5 shows the detailed description on transition of the number of consumers from 1975, and total consumers at the end of 1986 were recorded at 136,041. The average growth rate for the past six years was 11% approximately, and service areas with the higer rate than the average were Bintulu with 21.7% and Limbang with 12.0%. Annual power consumption per consumer in major cities and the proposed load centres of the project, Limbang and Kapit , is shown in Fig. 4.7.

A drastic increase of power consumption per consumer is recorded from the level of 2,000 kWh/year in 1975 to 6,700 kWh/year in 1986 in Bintulu due to LNG production and industrial plants. Large cities such as Kuching and Miri stay at the level of 5,700 kWh/year in 1986, whilst the demand centres of this project, Limbang and Kapit, are in the level of 3,500 to 3,800 kWh/year on the average.

4.3.2 Limbang area

1. Energy generated and sold

As given in Tables 4.2 and 4.3, the energy generated and sold in the proposed load centre, Limbang, was 11,596 MWh and 10,212 MWh in 1986, respectively. The average growth rates over the past six years were recorded at 13% per annum for generation and 13.6% per annum for energy sold, and both high values fully prove that the rapid economic growth is now in progress in the Limbang area in addition to the rural electrification plan.

System losses including station use were around 13% on average from 1980 in the system of Limbang.

2. Maximum demand

The maximum demand of 2,502 kW in year 1986 jumped up from 2,006 kW in 1985, representing an average annual growth rate of 24.7% (refer to Table 4.4). The relationship between the installed capacity and the maximum demand is illustrated in Fig. 4.8.

The average annual load factor from the year 1975 was 54.2% approximately, and the variation of annual load factor from the year 1975 is compared with that in Kuching and Miri in Fig. 4.9. Although the annual load factor in Limbang shows a rising tendency recently, it will fall in the range from 56% to 58% with an increase of the power system capacity.

3. Power consumption

Power consumed in each category from 1980 is described in Table 4.6, and consumption ratios of each category to the sold energy of 10,212 MWh in 1986 are as follows:

Power Consumption by Category in 1986

Category	Domestic	Commercial	Industrial	Lighting	Total
Ratio	28.6%	58.9%	11.8%	0.7%	100%

The average growth rate per annum over the past six years was 19.5% for the domestic sector, 8.7% for the commercial sector, 61.8% for industrial sector and 12.2% for public lighting, respectively.

The monthly variation of power consumption is given in Fig. 4.10, definitely showing seasonal pattern that the power consumption from December to March decreases due to climate. A daily load curve on May 25 (Mon) 1987 of Limbang is shown in Fig. 4.11. Daily load factor on that day was 77%.

4. Major consumers in Limbang

The share of power consumption by such major consumers as Limbang Trading Co., Transmitting, Hospital, Mircowave Station and Broadcasting Station was 20% of energy sold in early 1987, showing a falling tendency year by year.

5. Number of consumers

As stated in Subsection 4.3.1 (4), the number of consumers in Limbang area has increased with the high growth rate of 12% in comparison with other load centres. Following show the number of consumers by category at the end of 1986.

Number of Consumers in Limbang
(At the end of 1986)

Domestic	Commercial	Industrial	Lighting	Total
1,983	572	2	1	2,558

6. Power consumption per consumer for each category

It is summarized as shown below:

Power Consumption per Consumer of Limbang in 1986

	Domestic	Commercial	Industrial	Lighting
Annual energy (MWh)	2,922	6,014	1,206	70
Number of consumer	1,983	572	2	1
Energy per consumer (kWh)	1,474	10,514	603,000	-

The electrification ratio in the Limbang area is 37 % as of 1985.

4.4 Power Demand Forecast

4.4.1 Purpose

The purpose of the power demand forecast in this study is to ascertain the future demand in the proposed load centre to be connected with the planned small scale hydroelectric power project so as to set up the timing and scale of development of the project that would be most suitable.

4.4.2 Method

A macroscopic technique, which is the method to predict the growth of power demand by corresponding to that of gross domestic product, is normally applied to the power demand forecast of a long term, say 10 years.

However, it is almost impossible to apply the said technique to this study due to the reason that a close correlation cannot be found between power demand and economic activities in the isolated power system such as the proposed load centre.

In forecasting power demand, consumers are divided into four categories; domestic, commercial, industrial sectors and public lighting, and then the procedures mentioned below are applied to the power demand forecast for each category.

1. Domestic sector

The power demand of domestic sector is predicted by estimating the growth rate of two major factors of the electrification ratio and annual average power consumption per household. The procedures to estimate the growth rate of those factors are as follows:

- Firstly, population in the area is forecasted based on the Statistical Bulletin published by the Department of Statistics Malaysia and based on the population growth rate described in the Fifth Malaysia Plan 1986 - 1990.

- Secondly, the number of housesholds in the area is estimated based on the Statistical Bulletin.

- Thirdly, the electrification ratio is predicted based on the past trend in the area, referring to the trend of the electrification ratio in Kuching and Sibu.

- Fourthly, the annual average power consumption per consumer is estimated based on the past trend of the said consumption in the area referring its growth rate in Kuching and Sibu.

- Lastly, the power demand in the domestic sector is obtained by multiplying the number of households which will be supplied by SESCO by the annual average power consumption per consumer in the sector.

2. Commercial sector

The power demand of commercial sector is calculated by multiplying the number of consumers in the sector by the annual power consumption per consumer as estimated in the domestic sector.

The annual average power consumption per consumer in the commercial sector is estimated based on the past trend of the said consumption in the area, referring to the growth rate of the power consumption in such field of Kuching and Sibu.

3. Industrial sector

According to the power market survey by the JICA study team and answers to the questionnaire, there is no specific large industrialization programme in the Limbang area. Therefore, the power demand of the industrial sector is only predicted based on the past trend of the sector.

4. Public lighting

Power consumption to be used for the public (street) lighting is small compared with that of other sectors. Accordingly, the past trend of power consumption is applied to the calculation of power demand forecast in the street lighting.

The energy generation required to cope with the above mentioned power requirement is determined taking system loss rate and station use into consideration, and maximum demand can be obtained by the following formula:

$$\text{Maximum Demand (kW)} = A / 8{,}760 / B$$

where, A: Annual energy generation (kWh)
B: Annual load factor.

4.4.3 Previous studies on power demand forecast

1. Power demand forecast by SESCO

The recent power demand forecast upto year 2010 was made for seven major load centres, Kuching, Sibu, Miri, Bintulu, Sarikei, Sri Aman and Limbang as well as other load centres more than 50 by SESCO in 1986.
According to SESCO, demand was projected based on the past trend of power consumption by category, not counting any large individual load planned to be established in the industrial sector.

2. Power demand forecast by SAMA Consortium

Two study reports by SAMA Consortium and German Agency for Technical Cooperation Ltd. discuss the power demand forecast. Those are:

(a) Master Plan for Power System Development (Volume II Annexes), April 1981, and

(b) Recommendations for Sarawak Hydropower Development, February 1983.

The latter has been prepared in a manner to review the former master plan, wherein no remarkable difference between them is observed, and it was mentioned in the recommendations that the future power demand (energy sales) was forecasted based on a regression analysis of historical energy sold in the respective load centres in Sarawak.

4.4.4 Power demand projection for Limbang area

1. Power demand in domestic sector

Following are the basic data and criteria used in predicting the trend of population, the electrification ratio and the annual average power consumption per household in the captioned sector, which rely mainly on the Statistical Bulletin Sarawak, and data and information furnished by SESCO.

(a) Trend of population

According to the Statistical Bulletin Sarawak, the population in the major districts and the proposed load centres, Limbang and Kapit, are given as follows:

Population in Sarawak

(x 1,000)

District	1970	1980	Growth Rate (%)
Kuching	215	315	3.9
Sibu	98	139	3.6
Miri	58	101	5.7
Bintulu	39	58	4.0
Sarikei	34	44	2.6
Limbang	20	25	2.3
Kapit	30	38	2.4
Whole Sarawak	976	1,308	3.0

As seen from the Table above, the major cities including those newly industrialized, i.e., Bintulu, show the rapidly rising tendency of population.

In order to estimate the number of households in future, the population growth of Limbang area is presumed to be 3.0% in 1985, 2.5% in 1990 and 2.4% in 2000 and 2010 respectively, taking into account the rapid development of light industry as expressed in terms of power consumption in the industrial sector as shown in Table 4.6. The Fifth Malaysia Plan is also referred to estimate the future population growth rate.

(b) Prediction of electrification ratio in Limbang area

The electrification ratio in the year 1980 and 1985 for the proposed centre, Limbang, as well as major cities of Kuching and Sibu are as follows:

Electrification Ratio

Year	Limbang	Kuching	Sibu	(Kapit)
1980	20%	47%	51%	(5.5%)
1985	37%	64%	61%	(8.7%)

The electrification ratio in Limbang district is assumed to reach 45% in 1990, 55% in 2000 and 60% in 2010 respectively, reflecting the growth of electrification ratio from the past and the rural electrification programme to be implemented by SESCO in line with the Government policy.

(c) Number of households to be electrified by SESCO

The number of households to be electrified by SESCO is estimated as follows:

Number of Households to be Electrified by SESCO

Year	1980	1900	2000	2010
- Population (x 1,000)	25	32.8	41.2	52.7
- Estimated number of households	4,170	5,470	6,870	8,780
- Number of households to be electrified by SESCO	898	2,460	3,780	5,270

It is noted that the family number per household is estimated to be six persons from the Statistical Bulletin Sarawak 1984.

(d) Annual average power consumption per household

The annual average power consumption per household was 1.40 MWh (=2,181.096/1,560) in 1984, 1.52 MWh in 1985 and 1.59 MWh in 1986 respectively, according to the data collected by the team (refer to Table 4.7). The value of 1.59 MWh is then used as the base for the estimate of power consumption on the domestic sector.

Meanwhile, the growth rate of the annual average power consumption per household is estimated to be in the range of 4% per annum by referring to the historical growth rates in the Kuching and Sibu areas as shown in Table 4.8.

It is considered that the spread of such household appliances as television, refrigerator, air conditioner, electric fan and so on promotes the power consumption with a high growth rate and that the growth rate will drop after their spread.

(e) Energy requirement in domestic sector

Annual energy requirement in the domestic sector of Limbang district is summarized as shown below:

Annual Energy Requirement in Domestic Sector

Year	Energy (MWh)
1984	2,181
1985	2,507
1986	2,922
1987	3,394
1988	3,752
1989	4,153
1990	4,579
1995	6,624
2000	9,526
2005	12,176
2010	15,547

More details are shown in Table 4.9.

2. Power demand in the commercial sector

(a) Number of consumers in the commercial sector

The number of consumers in the commercial sector has a close relation with that in the domestic sector. Using the SESCO's historical data, the ratio of the number of consumers in the commerical sector to that in the domestic sector was analysed as follows:

Ratio of Number of Consumers in Commercial Sector
(Domestic = 100)

Year	Limbang	Kuching	Sibu
1980	37.0	23.3	23.9
1982	36.2	22.4	22.9
1984	31.1	(22.0)	(22.2)
1986	28.8	21.8	21.3

Note: Figures in parentheses show the estimated value. From the above, the ratios are assumed to be 28% in 1990, 27% in 2000 and 26% in 2010 respectively in consideration of scale of the Limbang district. The expected number of consumers in the commercial sector is therefore calculated at 690 in 1990, 1,020 in 2000 and 1,370 in 2010 respectively.

(b) Annual average power consumption per consumer in commercial sector

The annual average power consumption per consumer in the commercial sector was 9.57 MWh (= 4,727.352/494) in 1984, 10.26 MWh in 1985 and 10.81 MWh in 1986 respectively as shown in Table 4.7. The annual average power consumption of 10.81 MWh is taken as the base for predicting power consumption in the commercial sector.

Table 4.8 shows the growth rate of power consumption in the commercial sector of Kuching and Sibu. The growth rate in Limbang is estimated based on it as given below:

Growth Rate of Annual Average Power Consumption

Year	1990	2000	2010
Growth rate	3%	3%	2%

(c) Energy requirement in commercial sector

Energy requirement in the commercial sector of Limbang district is summarized as shown below:

Annual Energy Requirement in Commercial Sector

Year	Energy (MWh)
1984	4,727
1985	5,463
1986	6,014
1987	6,567
1988	7,220
1989	7,788
1990	8,348
1995	12,751
2000	16,657
2005	21,806
2010	27,921

More details are shown in Table 4.9.

3. Power demand in industrial sector

Power demand in the industrial sector is projected based on the past trend since there is no notable industrialization plan to be implemented.

Power consumption of 1,206 MWh in the year 1986 (refer to Table 4.6) is taken as the base and the following growth rates are applied in estimating power demand of the Limbang load centre:

Growth Rate and Energy Demand of Industrial Sector in Limbang

Year	1986	1990	2000	2010
Growth Rate	-	12%	9%	8%
Energy Demand (MWh)	1,206	1,894	4,704	10,156

4. Power demand of public lighting

It can be seen from Table 4.6 that the power consumption used for the lighting is as small as 0.7% of total power consumption in 1986. The power demand in the public lighting is therefore estimated based on the past trend, and