GOVERNMENT OF MALAYSIA

FEASIBILITY STUDY
SMALL SCALE HYDROELECTRIC POWER PROJECTS IN SARAWAK

VOLUME-VII
MAIN REPORT
FOR
IDENTIFICATION
OF
SMALL SCALE HYDROELECTRIC POWER PROJECTS
IN
SARAWAK

JULY 1988

JICA

JAPAN INTERNATIONAL COOPERATION AGENCY

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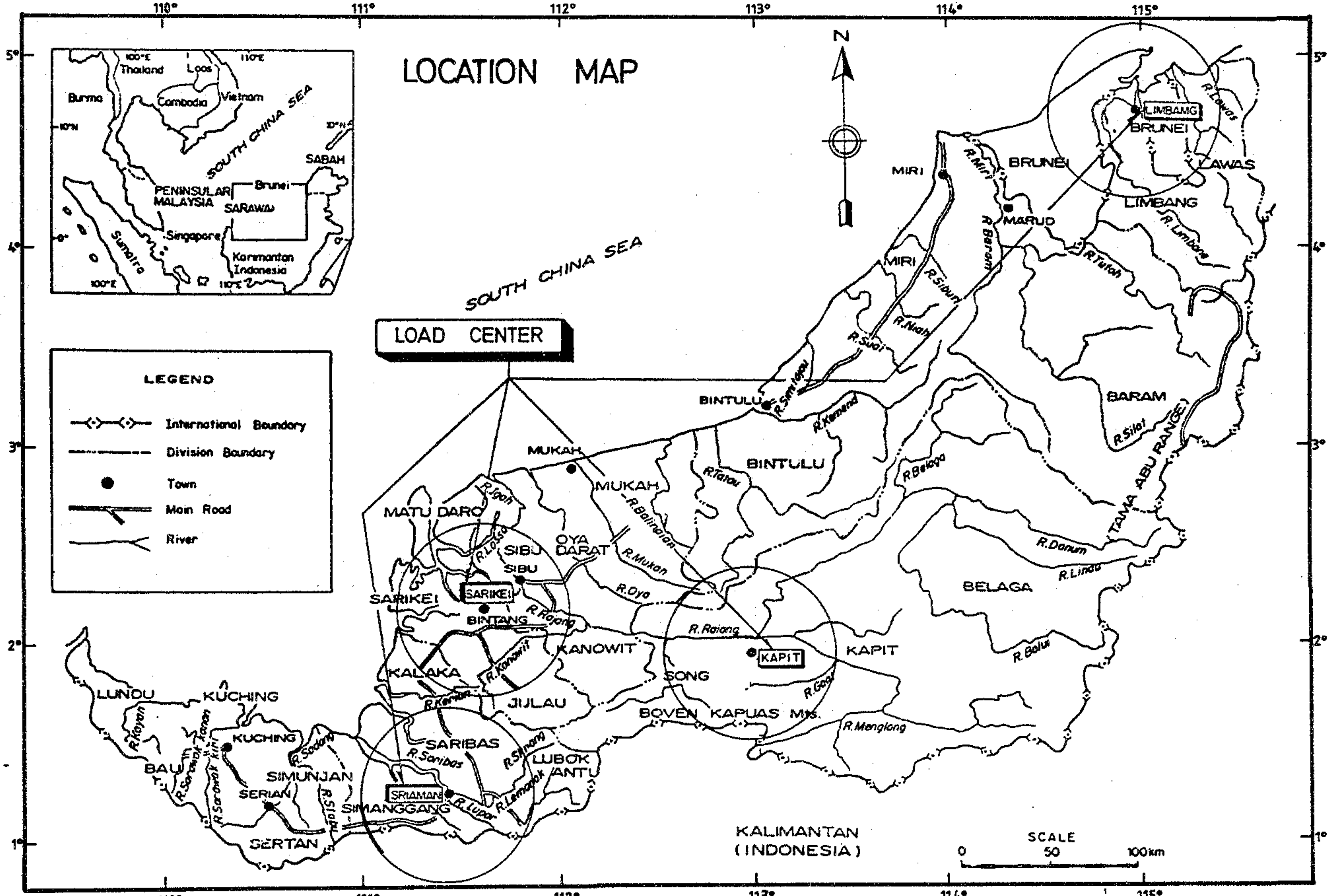
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Division Boundary
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SUMMARY

Objective and Schedule

1. The main objective of the study is initially to identify the potential sites for development of small scale hydroelectric power projects for supply of power to four (4) load centres viz.,

(i) Sri Aman
(ii) Sarikei
(iii) Kapit
(iv) Limbang

and subsequently to carry out the feasibility study for the site(s) evaluated to be promising.

2. The study is scheduled for a period of twenty-one (21) months from August 1986 to April 1988. It comprises the following three(3) stages:

(i)	Identification stage	Aug 1986 to Nov 1986
(ii)	Field investigation stage	Dec 1986 to Aug 1987
(iii)	Feasibility design stage	June 1987 to April 1988.

This Volume VII with the supporting reports of Volume VIII describes the outcomes of studies in the Identification Stage.

Activities during Identification Stage

3. A team of consultants for the study (the Study Team) was organized by Japan International Cooperation Agency (JICA) and commenced the study in Kuching at the beginning of August 1986.

During this Identification Stage (August to November 1986), the following studies have been carried out:

- Basic data collection and review
- Map study and field reconnaissance survey
- Low flow and flood analysis
- Hydropower computation and preliminary cost estimate
- Selection of attractive potential sites through screening evaluations.

Identification of Potential Sites

4. In total, twenty two (22) potential sites were identified in this study (See the attached figure for location of the sites). For these identified sites, power output calculation was made to estimate development scale in terms of power and energy outputs. The power output computation is based on hydrological data derived from the studies. The computed power output was used for evaluation of the schemes in the first screening, through which the candidate sites for field reconnaissance survey were determined.

Screening of Schemes

5. The first screening was made according to the predetermined screening criteria: the maximum output of 50 MW and minimum output of 2 MW in principle in view of the future power demand at each demand centre. Technical aspects revealed from the existing information were also taken into consideration.

6. The field reconnaissance survey was conducted for eleven (11) potential sites selected through the first screening. The survey was to confirm actual topography at the site including available head, geological condition, availability of construction materials, accessiblility and other technical conditions.

7. The second screening was to evaluate the sites from technical aspects such as topographical constraints, geological difficulties and availability of construction materials, mainly based on information obtained from the field reconnaissance. As the result seven (7) potential sites were retained at this screening evaluation. They comprise one (1) site for Sarikei load centre and two (2) sites each for Sri Aman, Kapit and Limbang load centres.

8. The preliminary cost estimate was then prepared for these seven (7) potential sites based on layout plan examined for each site. The estimated costs were reflected in the final comparison of sites at the third screening.

Candidate Sites for Subsequent Feasibility Study

9. As the third screening evaluation, relative merit of each hydropower scheme was examined in terms of present worth of cost streams, in comparison with that of alternative thermal power. Table S-1 shows five (5) schemes selected from the evaluation, one each for Sri Aman, Sarikei and Kapit load centres and two for Limbang load centre.

10. As seen in the Table, Sekrang-1 and Kanowit seem to be less attractive, while three schemes; namely Mukoh, Medamit-2 and Pasia, have been accorded favourable evaluation indices (e.g. 10.8%, 10.8% and 9.8% in terms of IRR, respectively). The latter three would therefore be the candidate schemes to be taken up in the next phase of study (feasibility study).

Principal features of the above three schemes are presented in Table S-2.

11. Following are preliminary recommendations at a technical level for making a decision in selecting the schemes as to proceed into the feasibility study by the Government of Malaysia and JICA:

(1) For Kapit load centre

Mukoh would be worthy of further investigation and study in view of the following factors accorded to this scheme:

Mukoh scheme

- Relatively high evaluation indices represented by EIRR of 10.8%
- Fair accessibility via a 6 km new road branched off from the existing logging road
- Location close to the Kapit load centre (25 km transmission line)
- No other technical constraint except for a minor difficulty in acquiring source of sand/gravel material.

(2) For Limbang load centre

Two schemes were proposed for Limbang area. Comparing the evaluated indices in Table S-1 as well as other relevant technical factors listed below, this study presumes that a preference for further study would be given to the Medamit-2 scheme.

Medamit-2 scheme

- Evaluation index is still within an acceptable level (EIRR = 10.8%). Development scale is appropriate to the size of present power market.
- Good accessibility to site (existing logging road passing close to the site)
- Moderate length of transmission line (60 km)
- No other specific difficulty foreseen.

Pasia scheme

- Potentiality of scheme is most attractive in terms of least cost energy producible
- Evaluation index assumed at the present demand level is within an acceptable range (EIRR = 9.8%), but involves some difficulties under present condition as listed below.
- Access over a long distance, via a 40 km logging road and a 20 km access road to be newly built, after branched from the existing public road
- A long transmission line of about 110 km, of which 20 km is in primary rain forest area without road for future maintenance along the line.

12. A steering committee meeting by the Government of Malaysia and JICA was held at Kuching on January 21, 1987 for selecting the schemes to proceed into the feasibility study stage among Mukoh, Medamit-2 and Pasia. Mukoh for the Kapit load centre and Madamit-2 for the Limbang load centre were then selected as the schemes to advance to the feasibility stage.

Table S-1 **EVALUATION INDICES OF POTENTIAL SITES**
(Schemes selected for Each Load Centre)

Load Centre Site	Sri Aman SEK-1	Sarikei K'WIT	Kapit MUKOH	Limbang MED-2	 PASIA
Type of development	RES	RES	RUN	RUN**	RUN
Installed capacity (MW)	11.8	25.1	1.94	4.49	12.4
Dependable output (MW)	11.8	25.1	1.94	4.49	8.5
Annual energy (GWh)					
- Primary	51.9	112.9	16.7	19.3	72.0
- Secondary	3.0	10.9	0	17.4	34.9
Total	58.9	123.7	16.7	36.7	106.9
Construction cost (M$million)	117.6	270.9	21.3	51.1	86.0
Energy cost (M¢/kWh)	27.0	27.6	16.1	17.6	10.1
Net present value* (B-C) (M$million)	-44.5	-105.2	+1.0	+2.3	-1.1
B/C*	0.75	0.66	1.04	1.03	0.99
IRR (%)	5.5	5.0	10.8	10.8	9.8

Note: 1. SEK-1: Sekrang-1 K'WIT : Kanowit
MED-2: Medamit-2

2. RES : Reservoir type development
RUN : Run-of-river type development

3. * : Discount rate : 10% per annum
** : Planned as a run-of-river scheme with regulating pondage.

4. Energy cost: On basis that all energy is consumed.

TABLE S-2 **PRINCIPAL FEATURES OF SELECTED PONTENTIAL SITES**

DESCRIPTIOIN	PONTENTIAL SITE		
	MUKOH	MEDAMIT-2	PASIA
Load centre	KAPIT	LIMBANG	LIMBANG
Power development type	Run-of-river	Run-of-river with regulating pondage	Run-of-river
Distance from load centre (km)	25.0	45.0	61.0
River basin (intake)	S. Mukoh	S. Medamit	S. Pasia
(powerhouse)	S. Mukoh	S. Limbang	B. Trusan
Catchment area (sq.km)	292	186	177
Average runoff (cms)	26.5	14.0	13.0
Peak discharge (cms)	7.4	7.8	5.3
Firm discharge (cms)	7.4	3.9	3.6
Riverbed elevation(El;m)	77	134	674
Full supply level (El;m)	80	147.2	677
Tail water level (El;m)	45	70	366
Gross head (m)	35	77.2	311
Power output (peak) (MW)	1.94	4.49	12.4
" (firm) (MW)	1.94	4.49	8.5
Diversion weir			
- Height (m)	7	21	6
- Crest length (m)	60	102	40
Headrace (m)	1,660	4,400	3,800
Penstock (m)	40	130	950
Turbine/generator (MW)	2nos.x 0.97	2nos.x 2.25	2nos.x 6.2
Access road (km)	6	1	20
Transmission line			
- Length (km)	25	60	110
- Capacity (kV)	33	66	66
Land compensation (ha)	Nil	Nil	Nil

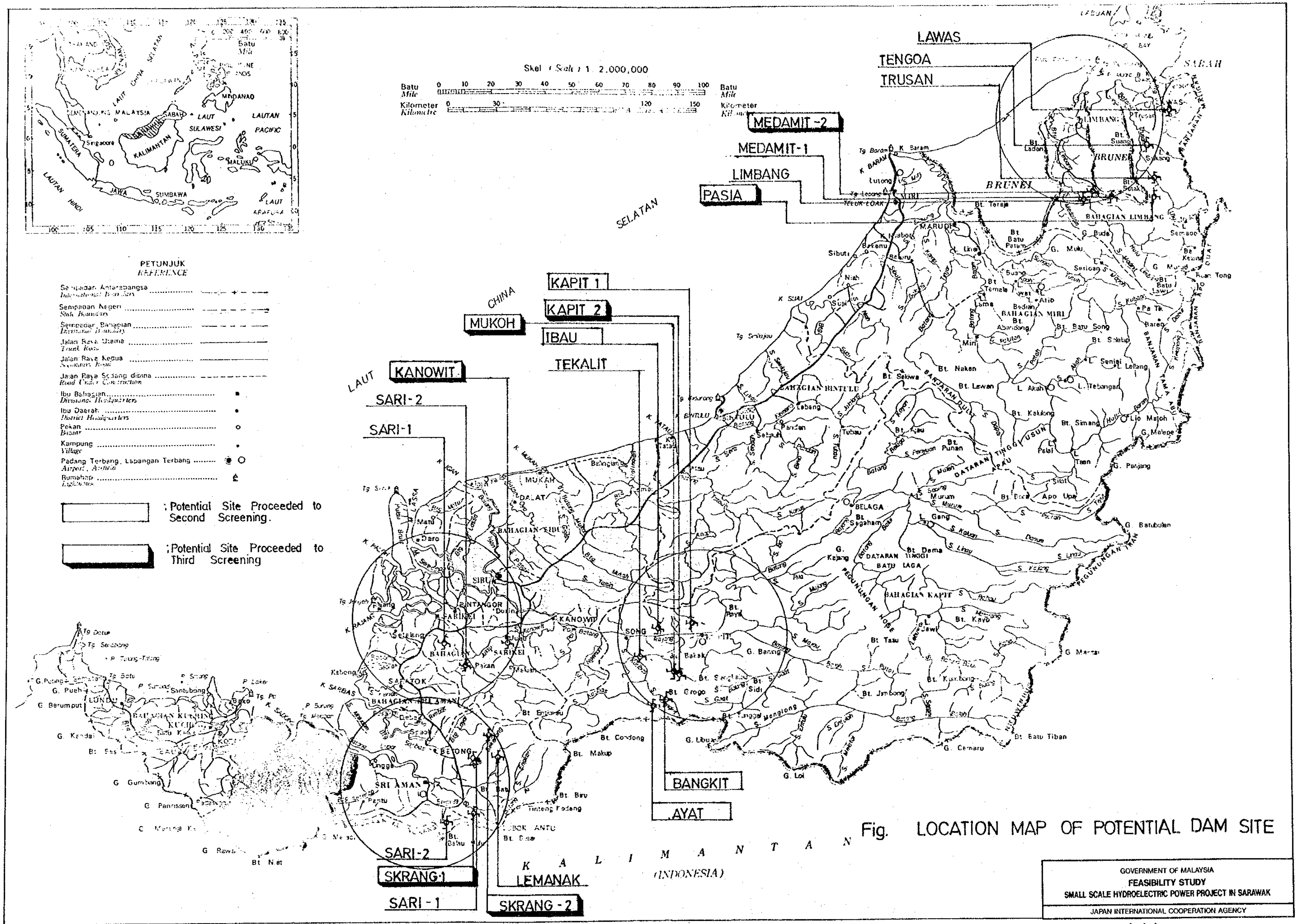

Fig. LOCATION MAP OF POTENTIAL DAM SITE

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ABBREVIATIONS

(1) Domestic Organization

DID	:	Drainage and Irrigation Department
EPU	:	Economic Planning Unit of Prime Minister's Department
GSD	:	Geological Survey Department
L&S	:	Land and Survey Department
MMS	:	Malaysian Meteorological Service
SESCO	:	Sarawak Electricity Supply Corporation
SPU	:	State Planning Unit

(2) International and Foreign Organization

JICA	:	Japan International Cooperation Agency
WMO	:	World Meteorological Organization

(3) Others

B	:	Benefit
C	:	Cost
CA	:	Catchment Area
cms	:	Cubic Meter per Second
Dia.	:	Diameter
EIRR	:	Economic Internal Rate of Return
El.	:	Elevation above mean sea level
Eq.	:	Equation
Fig.	:	Figure
FSL	:	Full Supply Level
GDP	:	Gross Domestic Product
GWh	:	Gigawatt Hour
H	:	Height or Water Head
HVAC	:	High Voltage Alternate Current
HVDC	:	High Voltage Direct Current
Km	:	Kilo Meter
KW	:	Kilowatt
KV	:	Kilo Volt
M	:	Meter
M¢	:	Malaysian Cent
M$	:	Malaysian Dollar
Max	:	Maximum
MCM	:	Million Cubic Meter
Min	:	Minimum
mm	:	Millimeter
MOL	:	Minimum Operating Level
MVA	:	Mega Volt Ampere
MW	:	Megawatt
O&M	:	Operation and Maintenance
PMF	:	Probable Maximum Flood
PMP	:	Probable Maximum Precipitation
RWL	:	Rated Water Level
Ref.	:	Reference
TWL	:	Tail Water Level

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 northeastern part and are intersected by numerous rivers flowing from hilly and mountainous hinterlands in the southwest. 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 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.1.1.

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

The objective of the Study is to formulate the optimum development plan for small scale hydroelectric power projects to the following selected areas:

(i) Sri Aman
(ii) Sarikei
(iii) Limbang
(iv) Kapit

and assess the technical, economic and financial viability and feasibility of these projects, taking into account the pattern of derived long term streamflow series, the predicted future power and energy requirements until the year 2010 and the economics of alternative generation methods.

1.3 Study Area

The study area comprises the surrounding areas of Sri Aman, Sarikei, Limbang and Kapit.

1.3.1 Sri Aman area

Sri Aman, headquarters of the Second Division of Sarawak, is located on the Batang Lupar about 85 km upstream from the sea and 192 km from Kuching. The land area of Sri Aman District is about 4,406 sq.km and a total population was 69,871 in 1980. The installed capacity and total generated energy in electricity in 1984 were 3,104 KW and 10,074 MWh, respectively.

1.3.2 Sarikei area

Sarikei, headquarters of Sixth Division of Sarawak, is located on the Batang Rajang about 40 km upstream from the sea and 150 km northeast from Kuching. The land area of Sarikei District is about 1,715 sq.km and the total population was 43,957 in 1980. The installed capacity and total generated energy in electricity in 1984 were 4,875 KW and 10,735 MWh, respectively.

1.3.3 Limbang area

Limbang, headquarters of Fifth Division of Sarawak, is located on the Sungai Limbang about 10 km upstream from the sea and 700 km northeast of Kuching. The land area of Limbang District is about 3,978 sq.km and the total population was 25,223 in 1980. The installed capacity and total generated energy in electricity in 1984 were 2,535 KW and 9,432 MWh, respectively.

1.3.4 Kapit area

Kapit, headquarters of Seventh Division of Sarawak, is located on the Batang Rajang about 200 km upstream from the sea and 300 km east-northeast from Kuching. The land area of Kapit District is about 15,597 sq.km and the total population was 38,429 in 1980. The installed capacity and total generated energy in electricity in 1984 were 1,164 KW and 4,209 MWh, respectively.

CHAPTER 2. STUDY PROCESS AND APPROACH

2.1 Study Stages

The study is scheduled to be carried out for a period of twenty-one (21) months from August 1986 to April 1988 through the following three (3) stages:

(1)	Identification stage	August 1986 - November 1986
(2)	Field investigation stage	December 1986 - August 1987
(3)	Feasibility design stage	June 1987 - April 1988

(1) Identification stage

The identification stage covers a 4-month period from August to November 1986. Its main works are to identify potential sites in the vicinity of the respective objective areas and to select an optimum development site for each objective area among the potential sites based on the review of previous studies, field reconnaissance, and economic comparative study. The Government of Malaysia will then determine the best site(s) (hereinafter called the Selected Site(s)) in consultation with JICA which will be subjected to subsequent field investigation and feasibility study. Upon decision of the Selected Site(s), detailed investigation programme and technical specification will be prepared for various field survey and investigation works.

This Volume VII with the supporting report of Volume VIII covers an output of this study stage.

(2) Field investigation stage

The field investigation stage is to carry out such field survey and investigation works as topographic survey, geological investigation, seismic prospecting, construction material survey including laboratory test, establishment of stream gauge station(s) and stream flow and sediment transport measurements for the feasibility study on the Selected Site(s). Such survey and investigation will be carried out in accordance with the field investigation programme and technical specifications by local firms selected through competitive bids by SESCO. The JICA study team will provide technical guidance together with the SESCO's counterparts for the respective works. In addition, the JICA study team will carry out the power market survey, reconnaissance on environment, meteo-hydrological analysis, etc. The field investigation stage will cover a 9-month period from December 1986 to August 1987, out of which initial 5-month period is for bidding and contract awarding by SESCO.

(3) Feasibility design stage

The feasibility design stage will be commenced in June 1987 and be completed in April 1988 upon submission of a final report. The draft final report will be submitted to SESCO in 2-month advance in February 1988. Main works during this stage are to conduct the feasibility design of the project facilities, cost estimate, construction planning, preparation of construction time schedules, and economic and financial analyses.

General flow of the Study is shown in Fig.2.1.

2.2 Study Approach

2.2.1 Load demands in each study area

It is foreseen that a huge amount of investment and a long period would be required to realize the power generation expansion programme formulated by the Master Plan for Power System Development. In meantime, SESCO contemplates to develop small scale hydroelectric projects, which would possibly be identified in the proximity of relatively large load centres in order to reduce reliance on the high cost diesel. This study focusses to identify an optimum site for each selected load centre and to verify technical and economic feasibilities of the optimum sites.

The Scope of Works sets forth that;

"Selection of one optimum site, among the potential sites, which meet the existing and forecast load demand for each of the four selected area viz. Sri Aman, Limbang, Sarikei and Kapit shall be made"(refer to Item (4)-(a) of Clause III).

According to data available so far, the present and forecasted load demands are as follows:

(Units: MW in peak and GWh in energy)

Load Centre	1985 Peak	1985 Energy	1990 Peak	1990 Energy	2000 Peak	2000 Energy	2010 Peak	2010 Energy
Sri Aman	2.0	10.2	3.4	17.1	8.6	42.4	17.0	83.3
Limbang	2.0	10.6	3.2	16.5	7.0	34.9	12.4	61.8
Sarikei	3.0	13.4	5.0	23.0	13.0	60.0	27.0	126.4
Kapit	1.2	5.0	1.6	6.8	2.5	11.0	4.2	18.0

Note: (1) The 1985 figures are of actual records.
(2) Forecasted energy is expressed in terms of energy generated.

Source : SESCO's latest forecast

2.2.2 Screening of schemes

In order to select an optimum site for each objective load centre, the relative merit of sites was evaluated through multi-stage screening process. The screening process comprises three (3) stages. The number of the potential sites is reduced successively at each screening process, however, the contents and profundity of study are increased.

The first screening aims at choosing such potential sites that would be subject to field reconnaissance. The second screening is mainly based on the results of field reconnaissance survey, which would be carried out placing emphasis on technical aspects in particular to observe whether or not the scheme involves any difficulty. The third screening is the final step to define the optimum site for the objective load centres among the sites scrutinized through the first and second screening procedures. The screening at this stage is dependent on the several economic indices.

2.3 Work of Site Identification

2.3.1 Identification of potential sites and screenings

A general work flow of this Identification Study stage is shown in Fig.2.2. Outlines of major activities are stated below. Details of finding from the studies are presented in succeeding Chapters.

(1) Data preparation

Data and information other than those previously collected by the JICA's contact and preliminary survey missions will be additionally collected and reviewed. They include;

(a) Topography

- Topographic maps on the scale of 1 to 50,000
- Trigonometric stations and bench marks

(b) Geology

- Geological maps covering the Study Area
- Previous investigation reports including the results of core boring, soil mechanics test, rock test, etc. in the vicinity of the Study Area
- Previous investigation reports on landslide and fault
- Earthquake records

(c) Meteo-hydrology

- Meteo-hydrological records in and around the Study Area

- Sediment transport and deposit records in and around the Study Area

- Water quality records in and around the Study Area

(2) Identification of potential sites

The potential sites are firstly identified on the basis of map study and their technical soundness is then evaluated from the veiwpoints of topographic and geological conditions and availability of meteo-hydrological data. Several potential sites are identified for each objective load centre.

(3) Preliminary hydrological analysis

Hydrological analysis for the potential sites is preliminarily made using the available meteo-hydrological data. The specific aims are as follows:

(a) Assessment of hydrological and meteorological data and selection of applicable data to the potential sites,

(b) Analysis of daily runoff sequence at selected water level gauging stations,

(c) Estimation of representative dimensionless flow duration curve and dimensionless storage draft curve to be applied to the potential site,

(d) Assessment of the evapotranspiration amount for the potential sites,

(e) Estimation of mean annual runoff for the potential sites, and

(f) Assessment of the sediment load for the potential sites.

(4) Preliminary power output calculation

Power output potential at each site is then computed based on scheme layouts preliminarily examined in the map study and hydrological information derived above.

(5) First screening evaluation

The first screening aims at choosing such potential sites appeared to be worthy of subsequent field reconnaissance. The criteria for the first screening consist of the following four (4) items;

(a) Remoteness of proposed sites

(b) Influence on waterborne traffic

(c) Power output potential

(d) Compensation and resettlement requirement.

(6) Field reconnaissance

The field reconnaissance is carried out basically for all the potential sites which have passed the first screening evaluation. The purpose of field reconnaissance is to observe the site condition for the following particulars:

- Confirmation of location

- Transportation and accessibility

- Geological condition of surface

- Availability of construction materials

- Streamflow condition

- Any particular difficulties which may be involved.

(7) Preliminary flood analysis

Flood analysis is to estimate the design floods for preliminary planning of spillway and river diversion works for each potential site. The probable flood hydrographs for various return periods are established by the synthetic unitgraph method. The probable maximum flood (PMF) is also derived for each potential site examined in the second screening.

(8) Second screening evaluation

The second screening is to examine social and technical problems involved in the scheme, mainly based on the results of the field reconnaissance. As far as no serious problem is observed, the potential sites are further passed to the third screening.

2.3.2 Selection of optimum site

(1) Basic layout plan

Preliminary layout plan is prepared for all potential sites which are passed to third screening by applying unified design criteria. The findings through site reconnaissance are also incorporated in the layout planning. The development scheme will be either of the following types:

(a) Run-of-river type development

(b) Reservoir type development.

(2) Power output calculation

Power output for each potential site is re-calculated incorporating the findings in the field reconnaissance, in particular power head available at the site.

Annual energy output calculation for the third screening should include the secondary energy. The annual total energy, which consists of firm and secondary energies, is examined for nine alternative cases varying dam height and maximum discharge in case of reservoir type development. While in case of run-of-river type development, the annual energy is estimated varying the plant factor.

(3) Project cost estimate

Cost estimate is made based on data derived from basic layout plan and cost data such as unit prices of respective work items of the similar projects in Sarawak. General consumer price index and construction price index of the reinforcement bars and cement since 1979 are applied to adjust the unit costs to 1986 price level.

Work quantities applied to the cost estimates are calculated either from layout drawings or using the quantity formulae as appropriate.

Total construction cost is estimated in Malaysian dollars by summing up cost of major project components including compensation and land acquisition.

(4) Hydropower benefit

The study assumes that the benefit of hydropower accrues from saving in costs of the most-likely thermal alternative.

(5) Third screening evaluation

An optimum site for each objective load centre is determined taking into account the following parameters:

(a) Power generation cost per KWh

(b) Net benefit (B-C)

(c) Internal rate of return (IRR).

CHAPTER 3. BASIC STUDY DATA

3.1 Previous Studies on Hydropower Development

The identification of potential hydropower development sites much owes to the previous power development studies. Brief outlines of the previous studies are summarized hereunder.

(1) Colombo Plan, Hydro-Electric Survey, Sarawak, Report on Preliminary Survey, March/April, 1962

The study was conducted during the period from March to April, 1962 under assistance from Australia, aiming at establishing a programme on collecting and recording of necessary data for use at a later stage in planning of the development of the considerable hydroelectric potential in Sarawak.

Theoretical hydroelectric potential in Sarawak is estimated to be approximately 192,000 GWh, of which roughly 20 per cent could economically be developed. Nineteen sites were preliminarily studied and they were finally classified into 3 categories; uneconomic (7 sites), marginal (9 sites) and economic (3 sites).

(2) Batang Ai Hydroelectric Project, Feasibility Report, December 1978, Snowy Mountains Engineering Corporation

This report sets out the best form of development of the Batang Ai Hydroelectric Project together with the physical features and the economics of the recommended plan. The salient features of the recommended plan are as follows:

River	:	Batang Ai
Main and Lima Saddle Dams		
Type	:	Rockfill with concrete face
Crest elevation	:	El.116.0 m
Maximum height	:	85 m
Volume of embankments	:	5.3 MCM

Saddle Dams		Height	Volume
Sebangi (earthfill)	:	26 m	0.3 MCM
Bakatan (earthfill)	:	40 m	1.3 MCM
Pan (earthfill)	:	minor structure	
Sekabo (earthfill)	:	minor structure	

Reservior		
Catchment area	:	1,200 sq. km
Average annual inflow	:	121 cms
Full supply level (FSL)	:	EL 108 m

Minimum operating level (MOL)	:	EL 98 m
Gross storage at FSL	:	2,380 MCM
Active storage	:	750 MCM

Power Station		
Number and rated capacity of unit	:	4 x 23 MW
Average annual energy output	:	580 GWh
Capacity at MOL	:	84 MW.

The construction of the Batang Ai Hydroelectric Project was successfully completed in 1985 and the power generated by the project is being supplied to Kuching through a 275 kV transmission line.

(3) Preliminary Survey of Hydro-Electric Potential, Sarawak, December 1977 (Revised January 1979), SESCO

The study was carried out with a veiw to locating large potential hydropower sites and to formulating a national policy to develop abundant hydropower reserves. All major rivers are investigated e.g. S. Sarawak, B. Saribas, B. Mukah, B. Rajang, S. Trinjar, S. Tuthoh, B. Baram, S. Limbang, S. Trusan and B. Lawas. Forty-two hydroelectric schemes are identified, all of which are of reservoir type development. Their total output amounts to 10,870 MW.

(4) Preliminary Investigation of Mini-Hydroelectric Potential of Sarawak, February 1980, SESCO

In order to attain successful implementation of Rural Electrification Programme, development of mini hydro schemes with installed capacity of 5 kW to 1,000 kW is regarded in this investigation.

Throughout Sarawak, 320 possible mini hydro schemes are so far identified on the basis of map study, of which 60 sites are considered highly favourable for feasibility study.

(5) Master Plan for Power System Development, April 1981, German Agency for Technical Cooperation Ltd.

The study was conducted during the period from December 1979 to March 1981 and its main objectives were set forth below:

- Master plan for the power system development in Sarawak, with main emphasis on the survey of hydroelectric potential,
- Feasibility study of the best hydroelectric project and associated high-voltage direct current (HVDC) transmission line to Peninsular Malaysia.

Systematic power demand forecast was elaborated up to the year 2010 over Sarawak, Peninsular Malaysia, Sabah, Singapore, Brunei and Kalimantan in view of marketing the Sarawak's excess hydroelectric power.

The hydroelectric survey over Sarawak identified 155 possible projects, ranging from 26 MW to 4,590 MW in terms of installed capacity. All the possible sites are considered to be developed with storage type with maximum dam height and their power output is calculated at a plant factor of 0.5. Various technical and economic assessment was worked out and finally eleven sites are selected to be most promising properly from the engineering viewpoint. Out of the eleven promising sites, six sites are located in the Upper Rajang River Basin. The most optimum power expansion programme is determined to be formulated in accordance with the Power Demand Scenario "H", which comprises Sarawak, Sabah and the HVDC supplies to Peninsular Malaysia. The programme includes such hydroelectric projects as Raja 284 (Midi Pelagus), Balu 037 (Bakun), Muru 40 and Bela 010, all located in the Upper Rajang River basin. Salient features of the proposed hydroelectric projects are as follows:

Description	Pelagus	Bakun	Muru 40	Bela 010
River	Rajang	Balui	Nurum	Belaga
Reservior				
Ave. annual inflow (cms)	2,000	1,560	310	230
Full supply level (El;m)	57	228	531	188
Active storage (MCM)	3,000	27,100	6,000	6,800
Surface area at FSL(sg.km)	380	730	210	390
Power Station				
Mean Net head (m)	37	159	291	112
Installed Capacity (MW)	770	2,580	940	260
Guaranteed Output (MW)	710	2,260	790	240
Energy output (GWh)				
Firm	4,900	17,200	6,500	1,800
Non-firm	500	900	100	-
Total	5,400	18,100	6,600	1,800
Cost				
Capital Cost (million M$)	1,480	2,690	1,080	730
Energy cost (M$)	0.041	0.023	0.023	0.053

(6) Mini-Hydro Project, (Sabah and Sarawak), Final Report, May 1982

This study comprises full feasibility studies of mini-hydro potential in the States of Sabah and Sarawak and detailed design and costing of 20 mini-hydro projects. Development scale of mini-hydro is limited within a range of 50 to 1,000 kW. In total 48 possible sites were firstly identified in Sarawak. Within Sarawak, the under-listed 10 mini-hydro schemes are finally selected:

Scheme Code	Name	Division	Gross Head (m)	Installed Capacity (kW)
1003	Sebako	1	117	2 x 300
1006	Lundu	1	238	1 x 300
1008	Semadang	1	34	2 x 100
2002	Batu Lintang	2	10	2 x 50
3004	Wong Silau	3	4	2 x 75
4009	Kejin	4	146	2 x 200
5004	Kalamuku	5	277	2 x 500
5011	Mediou	5	49	1 x 150
5019	Saliban	5	35	2 x 95
7001	Giam	7	66	1 x 75

Out of the above schemes, Kalamuku, Sebako, and Lundu schemes have been realized and Batu Lintang, Semadang and Saliban schemes are under construction.

(7) Bakun Hydro-Electric Project, Feasibility Report, November 1983, German Agency for Technical Cooperation Ltd.

The study was carried out following to the "Master Plan of Power System Development". The main features of the proposed project are as follows:

River	:	Batang Balui
Reservoir		
Catchment area	:	14,750 sq. km
Average annual inflow	:	1,440 cms
Maximum water level (MWL)	:	El.230.6 m
Full supply level (FSL)	:	El.228.0 m
Minimum operating level (MOL)	:	El.175.0 m
Gross storage below MWL	:	45,400 MCM
Active storage	:	27,500 MCM
Surface area at MWL	:	710 sq. km

Main Dam	
Type	: Concrete arch with double curvature
Max. height	: 204 m
Crest length	: 1,100 m
Concrete volume	: 3.9 MCM
Power Station	
Number and unit capacity	: 8 x 300 MW
Average annual energy output	: 18,000 GWh
Power Transmission Line	
Sarawak-Sabah-Kalimantan interconnection	:- 132 kV with 95 km long, - 275 kV double circuit with 450 km long - Two parallel 500 KV single circuit, 665 km long
Sarawak-West Malaysia interconnection	- 400 kV HVDC overhead lines with 675 km long - Four HVDC submarine cables each 375 MW capacity and 325 km long - 400 KV HVDC overhead lines, with 325 km.

(8) Preliminary Appraisal of Ulu Batang Ai Hydro-electric Project, May 1984, SESCO

In order to meet the medium term power demand for Kuching prior to the commissioning of Bakun Hydro-electric Project, developemnt of Batang Ai basin is envisaged.

The Master Plan for Power System Development has pointed out seven possible hydroelectric projects in the Upper Batang Ai basin. Economic comparison among the seven projects was elaborated and as the result, it was recommended that feasibility study of Ulu Batang Ai Project be undertaken as soon as possible.

3.2 Topography and Geology

3.2.1 Topographic maps

Topographic maps of the State of Sarawak are under the control of Land and Survey Department (hereinafter called L&S).

The topographic maps available for the study area are listed below:

	Area	Scale	Nos. of sheet
1	Whole Sarawak	1:2,000,000	1
2	- do -	1:1,670,000	1
3	- do -	1:1,000,000	1
4	- do -	1: 500,000	4
5	Study Area	1: 50,000	45
	- Sarikei and Sri Aman areas		(16)
	- Limbang area		(13)
	- Kapit area		(16)
6	Study Area	1: 10,000(*)	10

(*) Topographic maps on the scale of 1 to 10,000 are being prepared by L&S.

3.2.2 Previous geological studies

Regional geology of the State of Sarawak is referred to "The igneous rocks of Sarawak and Sabah" and its attached geological maps on a scale of 1 to 50,000 published by Mr.H.J.C.Kirk in 1968.

Sarawak is located in her most part on the belt of the Northwest Borneo Geosyncline, or the Sibu and Miri Zones. The rocks older than the Upper Cretaceous are cropped out only in the Kuching Area west from the Lupar River in West Sarawak. Geological structures are strongly controlled by the trend of the geosyncline and the arcuate zones of the craton in the areas of Northwest Borneo Geosyncline and West Sarawak.

Development of Northwest Borneo Geosyncline started in the late Cretaceous. Initial sediments of shales, siltstones, sandstones, greywackes and conglomerates, with cherts and ophiolitic rocks are developed north of the Lupar River.

Main parts of the Northwest Borneo Geosyncline are represented by the provinces of the Rajang Group in Central Sarawak and the Crocker Formation and others in Sabah. The Rajang Group is extensively developed in and around the Rajang River basin in more than 170 km wide belt, composed of hard sandstones, shales, siltstones and slates with some conglomerates and limestones of Upper Cretaceous of Eocene.

The Sibu Zone, the northern belt adjacent to the Kuching Zone, is the core of the Northwest Borneo Geosyncline, consisting of the Upper Cretaceous to Eocene flysch with the Miri Zone which is composed of areno-argillaceous and calcareous sediments formed in shallow sea environment during the period of Miocene to Pliocene.

3.2.3 Seismicity

Since the Seismological Division was set up in 1973 under the Malaysian Meteorological Service (hereinafter called MMS), four (4) seismological stations have been established to monitor earthquake activities in and around Malaysia.

Before 1973, information on earthquake and tremors were solely based on news reports and some published articles. Out of a total of about 5,000 earthquakes for the period from 1900 to 1976, about 1,000 were located over the Peninsular Malaysia region, while the rest were in Sabah and Indonesian Borneo island.

MMS concluded the macro-seismic study on the State of Sarawak as follows;

> "Sarawak is considered seismically stable. There were only a few cases of slight tremors recorded in this state."

3.3 Meteorology and Hydrology

3.3.1 Meteorological data

Most of the meteorological data are collected principally by MMS. The service of MMS operates five (5) first-order climatological stations at Kuching, Sibu, Bintulu and Miri Airports and Sri Aman. Sri Aman station has been newly established in 1982. Elements measured are wet and dry bulb temperatures, relative humidity, barometric pressure, surface and upper winds, evaporation, rainfall and hours of sunshine.

3.3.2 Hydrological data

The collection of hydrological data has been mainly carried out by Drainage and Irrigation Department (hereinafter called DID).

DID was established in 1967 from a branch of the Public Works Department. As of March 1986, there are 143 functioning rainfall stations of which 64 have recording gauges, 21 evaporation stations and 51 functioning water level stations of which about half are automatic recording stations, under the control of DID. DID also carries out regular discharge measurements at about the half of water level stations for the establishment of stage-discharge relationship. The small number of sediment samplings has been made. A considerable amount of the basic hydrological data compiled by DID has been stored in the computerized data bank.

3.4 Socio-economy and Power System

3.4.1 Socio-economic data

Socio-economic data were mainly collected based on the Fifth National Plan published in 1986 and Annual Statistical Bulletine Sarawak, 1984 published by the Department of Statistics.

The population in Sarawak was 1.31 million in 1980 Census and the average annual growth rate was 3.0% between 1970 to 1980. The population density rose from 7.8 persons/sq.km in 1970 to 10.5 persons/sq.km in 1980. The population in 1990 was estimated to grow at the average annual growth rate of 2.5%. The projected population is 1.75 million in 1990.

Gross domestic product (GDP) grew from M$2,980 million in 1980 to M$4,652 million in 1985 in factor cost at 1978 constant price with the annual growth rate of 9.3 per cent. Per capita GDP in 1985 was M$3,085 in 1980 in factor cost at 1978 constant price with the average annual growth rate of 6.1% between 1980 and 1985. The mining and quarrying sector grew rapidly at 14.9% which is the highest in Malaysia. The per capita GDP is estimated to grow at 2.7% per annum by 1990, higher than the national average of 2.4%.

Major land use patterns in 1984 were forest land of 94,376 sq. km, grassland of 800 sq.km, annual and perennial crop land of 4,700 sq.km, shifting cultivated land of 18,500 sq.km and miscellaneous land of 6,100 sq. km.

There existed 151,600 hactre of paddy cultivation areas in 1983/84 consisting of wet paddy field of 76,500 hactre. Domestic production of rice in 1983/84 was 200,400 tons, being composed of wet paddy rice of 149,200 tons and hill paddy rice of 51,200 tons, which covered 71.3% of the total rice consumed in the State of Sarawak.

Exports of goods and commodities from the State of Sarawak had been growing steadily over the years. The major export items include petroleum products, forestry products and agricultural products. Since 1983 export of LNG constituted a new important agricultural products. Since 1983 export of LNG constituted a new important export item. Imports of goods are in general growing over the years in line with the expanding needs of the population and development requirements. In 1984, the balance of trade was registered a surplus of M$4,111 million; that is, import of M$3,538 million and exports of M$7,649 million.

Consumer price index has been increased with annual rate of 4.1% on an average between 1980 and 1984. The consumer price index consists of two main index; namely, food and durable goods. The former was 121.1 and the latter was 112.9 at December 1984 from a designated period from 1980, which equals 100.0. The consumer price index in 1984 is listed below:

Consumer Price Index in 1984 (1980 = 100.0)

Description	Weight	Index
A.0 Food	43.8	122.5
Food at home	(40.7)	(120.9)
Food away from home	(3.1)	(142.9)
A.1 Beverages and Tobacco	3.8	142.3
A.2 Clothing and Footwear	4.0	112.9
A.3 Gross Rent, Fuel and Power	19.3	128.0
A.4 Furniture, Furnishing and Household	5.2	113.4
A.5 Medical Care and Health Expences	1.1	118.5
A.6 Transport and Communication	12.4	124.5
A.7 Recreation, Entertainment, etc.	5.5	106.9
A.8 Miscellaneous Goods and Services	4.9	117.4
	100.0	122.5
B.0 Durable Goods	11.4	112.3
B.1 Semi-durable Goods	6.2	111.6
B.2 Non-durable Goods	53.8	122.8
B.3 Services	28.6	128.5
	100.0	122.5

3.4.2 Power supply system in whole Sarawak

In the State of Sarawak, the Sarawak Electricity Supply Corporation (SESCO) has been responsible for supplying due power energy to the consumers in line with the Ordinance established by the Government of Malaysia. The power supply to a number of the isolated demand centres is mainly generated by the diesel engines as well as gas-turbine units. However, the first large scale hydropower station in Sarawak, Batang Ai, with the installed capacity of 108 MW, consisting of 4 units, has already been put into the commercial operation in 1985.

Data with regard to the SESCO's existing power facilities and the situation of the power market by the end of 1985, which are collected in this identification study stage are summarized as follows:

(1) Power generating facilities

By the end of 1985, SESCO has constructed and operated a large number of power stations with total capacity of 348,699 kW so as to suit with growing power demand, and its progress from 1982 in major ten service areas is described below:

Installed Capacity in Sarawak

(Unit:kW)

Service Area	1982	1983	1984	1985
1. Kuching	77,414	91,548*	103,324*	210,908*
2. Sibu	31,560	31,560	31,560	47,560
3. Miri	32,150	31,050	41,950	41,950
4. Bintulu	22,991	20,664	20,376	19,776
5. Sarikei	3,295	4,415	4,415	4,415
6. Sri Aman	2,474	2,534	2,534	4,184
7. Limbang	2,535	2,310	2,535	3,585
8. Kapit	1,054	1,254	1,164	2,363
9. Marudi	954	879	943	1,280
10. Lawas	655	786	1,775	1,775
Total (For Whole Sarawak)	183,646	196,599	221,518	348,699

Remarks :

1. *Inclusive of Batang Ai
2. These readings do not include generating units which have been retired.
3. Source : As per SESCO Annual Report (commercial office).

On the other hand, the breakdown of generating schemes as of March 31st, 1986 is as shown below:

(a)	Diesel	:	51%
(b)	Gas-turbine	:	21%
(c)	Hydro	:	28%
(d)	Total	:	100%.

The energy generated at Batang Ai hydropower station is consumed mostly as base load in Kuching area. Gas-turbine energy has been supplied to Kuching, Miri and Bintulu areas only. The remaining areas including the selected four load centres have been supplied the power from respective diesel-engine generator 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 has been constructed at the same time, and it will become a part of the main artery in the power system of the Sarawak in near future.

For power distribution, it is provided with the voltage of 33 kV, 11 kV and 6.6 kV, and power outlet used by consumers is normally wired with the rating of AC 50 Hz, single/3 phase, 230/400 V. According to SESCO Annual Report for the year of 1983, a total length of the existing distribution lines is as shown in Table 3.1.

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

(3) Energy generated and sold

Tables 3.2 to 3.4 present the situation of electric supply services under the operation of SESCO.

As shown in the above tables, an average growth rate of the energy generated and sold over the past five years was 13.1% and 11.8% per annum, respectively. Details of the energy generated and sold, the installed capacity and maximum demand are shown in Appendix VIII of Volume VIII.

In 1985, a total value of system losses and station uses was 123,696 MWh which corresponds to 18.8% of the annual energy production. Annual load factor in whole Sarawak was 56%.

(4) Power consumption

The power consumption is classified into three major categories, i.e. Commercial and Industrial, Domestic and Public Lighting uses, and their shares are given in the Annual Statistical Bulletin, Sarawak, 1984 as follows:

(a)	Commercial and Industrial use	:	70%
(b)	Domestic use	:	29%
(c)	Public lighting use	:	1%
Total		:	100%.

Number of consumers is approximately increasing annually at a rate of 11-12% as shown in Table 3.5.

(5) Private power sector in Sarawak

There are a few private power sectors as listed in Table 3.6. However, the power supplies are limited to the operation of their own factories.

3.4.3 Present situation of study areas

The present situation of the selected four load centres, i.e. Limbang, Kapit, Sarikei and Sri Aman, is as follows:

(1) Power supply

As stated in the above Sub-section 3.4.2, the power supply to these centres relies only on diesel engine generating units. The average growth rate of Limbang, Kapit, Sarikei and Sri Aman for past five years up to 1985 was 14.2%, 16.5%, 11.1% and 9.6%, respectively. The distribution network consists of 11 kV overhead line and underground cable with step down transformers ranging from 16 kVA to 1,000 kVA.

Appendix VIII of Volume VIII contains a single line diagram and typical daily load curve of each demand centre. It is understood from the single line diagrams concerned that the consumption is remarkably concentrated in the city areas.

(2) Major consumer in the selected four load centres

The share of power consumption by major customers such as factory, water pump station, broadcasting and etc. is between 20% and 30%, and name of major consumers and their monthly power consumption (kWh) are presented in Table 3.7.

(3) System losses and station uses

According to the operation records of Limbang and Kapit power stations, the captioned losses have been clarified as shown in Table 3.8.

From the table, the percentage of station uses and system losses is 3.1% and 10.4% respectively in Limbang, and 3.9% and 6.4% respectively in Kapit.

(4) Fuel and lubricating oil consumption

Table 3.9 gives fuel and oil consumption records at Limbang and Kapit power stations during a period from 1983 through 1986.

From the table, it is calculated that fuel and lubricating oil consumptions per kWh in Limbang were 0.30 litre and 0.0047 litre respectively, and 0.30 litre and 0.0024 litre in Kapit, respectively.

The fuel used by Limbang and Sarikei is light oil and that by Sri Aman and Kapit is diesel oil. The lubricating oil used is either Rimula X-30 or Rotela 30.

Fuel cost per energy generated (kWh) of gas, diesel and light fuel is estimated from the SESCO statistical data as follows;

(a) Gas : 5 M cent/kWh
(b) Diesel oil : 18 M cent/kWh
(c) Light oil : 12 M cent/kWh

(5) Engine maintenance schedule

The maintenance of engine is carried out periodically in accordance with running hour criteria which consist of three steps as mentioned below:

(a) Lub. oil change
 in Limbang : every 1,200 - 2,000 hours
 in Kapit : every 800 - 1,500 hours

(b) Top overhaul
 in Limbang : every 4,500 hours
 in Kapit : every 3,000 - 6,000 hours

(c) Complete overhaul
 in Limbang : every 18,000 hours
 in Kapit : every 12,000 - 15,000 hours.

In the top overhaul, items to be inspected are piston ring, piston, big end bearing and cylinder liner, etc. and these plus main bearing are disassembled and checked thoroughly during the complete overhaul. Generally, time necessary for the latter work is approximately 7 - 10 days.

3.4.4 Power expansion programme

(1) Generating facilities

SESCO intends to install more than 100 generating units with an output capacity of 63,022 kW in total by the end of 1991, and these units are mostly gas turbines and diesel engines. The plan also includes 3 mini-hydropower stations with a total capacity of 450 kW. Further 3 mini-hydropower schemes have been planned as a role of the Rural Electrification Programme to be realized within the period of Fifth National Plan.

Details of the power expansion programme up to year 1991 and the relationship between the said programme and the forecast peak demand are shown in Table 3.10 and Fig.VIII.13 of Appendix VIII (Volume VIII). In the selected four load centres, the expansion of supply capacity is scheduled in Limbang and Kapit, while no addition is planned in Sarikei and Sri Aman.

(2) Transmission line and switching station/substation expansion

In conjunction with Batang Ai Hydroelectric Project, a 275 kV transmission line connecting between the project and Kuching has already been constructed and now under operation.

As shown in Fig.VIII.14 of Appendix VIII (Volume VIII), a separate HVAC line is scheduled to be extended from the Batang Ai power station to Sibu area, and its construction work including the associated switching stations and substations will be completed by the end of March 1988. In this connection, the selected load centres of both Sri Aman and Sarikei are planned to be linked with this HVAC system within a few years.

Also Fig.VIII.15 of Appendix VIII (Volume VIII) outlines the SESCO's power system with HVDC lines of 400 kV in consideration of the development of huge scale hydro-electric projects in future.

3.4.5 Industrialization programme in the study areas

Following show presently proposed schemes for industrialization in the four load centre areas:

Area	Proposal	Approx. Loading
Sri Aman	Mainly Shophouses	1 MVA
Sarikei	Shophouses, army camp, School	1.5 MVA
Kapit	Housing, Shophouses	500 kVA
Limbang		(845 kVA)

Source : SESCO Planning Section

The figure in brackets was informed by the regional office. No rapid growth in power consumption by this sector is foreseen.

3.4.6 Rural electrification programme in the study area

According to information from SESCO, the rural electrification programme will cover the following consumers:

Area	1986	1987
Sri Aman	714 Applicants at 0.25 kW per applicant i.e 178.5 kW	12.75 kW
Sarikei (+ Bintangor)	250 Applicants at 0.25 kW per applicant i.e 62.5 kW	48.5 kW
Limbang	45 Applicants at 0.25 kW per applicant i.e 11.25 kW	7.75 kW
Kapit	None	None

CHAPTER 4. IDENTIFICATION OF POTENTIAL SITES

4.1 General

Previous studies carried out so far by SESCO have identified approximately 14 hydropower potential sites in the Study areas. In addition to these sites, the Study attempts to identify newly other potential sites within areas of 50 km radius from the objective load centres.

The identification of potential sites was made based on the topographic maps in a scale of 1 to 50,000 with the minimum contour intervals of 100 feet, making reference to the results of the previous studies and taking a view of topographic condition.

4.2 Type of Power Development

The potential sites are broadly classified into run-of-river type and reservoir type. Both types are further sub-divided as follows:

(1) Run-of-river type development

- (1a) Run-of-river scheme with a single intake
- (1b) Run-of-river scheme with an inter-basin water diversion intake

(2) Reservoir type development

- (2a) Single dam scheme
- (2b) Dam plus waterway scheme

A schematic diagram of power development is shown in Fig. 4.1.

4.3 Method and Criteria for Map Study

In order to attain a consistent map study, uniform criteria were established. The following guidelines are applied to the map study.

4.3.1 Selection/identification of site

The selection/identification of sites should consider various factors which vary at each location and river stretch. The potential sites are selected in line with the following basic criteria :

(1) The location of potential site would be limited in area within 50 km distant from the objective load centre at the furthest in consideration of avoiding excessive cost for transmission line,

(2) In order to secure an economic viability, the potential site should be facilitated with a good accessibility, and

(3) The potential site should not involve serious compensation and resettlement problems.

Furthermore, principal factors to select a development type are given as follows:

(1) Run-of-river type

The scheme consists of a diversion weir, a sand sediment pondage, a non pressure tunnel, head tank and penstock to a powerhouse at a lower elevation. The potential site is conceived in the river stretches of steep gradient or in places where relatively rich discharge is expected to be available.

(2) Reservoir type

The potential damsite is selected at a location in narrow gorge or at a place of closed topography with steep sloped banks. The gradient of river upstream of the potential damsite is reasonably gentle, preferably with an open plane topography in the upper area to get a larger reservoir capacity.

As for the dam plus waterway scheme, it is proposed in river streches where both the run-of-river and reservoir type schemes are mutually conceived in the following cases:

(a) topography of the proposed intake site is suitable for construction of a medium to high dam

(b) steep river gradient in stretches downstream from the potential damsite.

4.3.2 Power scale

The potential site should satisfy the maximum output of 50 MW and minimum output of 2 MW in principle in view of size of power demand up to year 2010 at each load centre.

4.3.3 General layout plan

After identification of potential site which is estimated to have output in a range between 2 MW and 50 MW, a preliminary layout plan was examined for each potential site on the topographic maps in a scale of 1 to 50,000.

The planning at this study stage is to extract the following information from the maps:

(a) axis of dam/diversion weir
(b) reservoir surface
(c) waterway route
(d) location of surge tank/head tank
(e) location of powerhouse.

In addition to the preparation of preliminary layout of the scheme, routes of access road and transmission line were also examined.

4.4 Identified Potential Sites from Map Study

The map study has revealed 21 potential sites as listed below:

Load Centre	Damsite		Development Type
Limbang	1.	Lawas	Reservoir type
	2.	Tengoa	"
	3.	Trusan	"
	4.	Medamit-1	Inter-basin water diversion Run-of-river
	5.	Medamit-2	Inter-basin water diversion Run-of-river/Reservoir type
	6.	Limbang	Reservoir type
	7.	Pasia	Inter-basin water diversion Run-of-river
Kapit	8.	Kapit-1	Reservoir type
	9.	Kapit-2	"
	10.	Ibau	"
	11.	Bangkit	Reservoir and waterway
	12.	Tekalit	Reservoir type
	13.	Ayat	Run-of-river/Reservoir and waterway
Sarikei	14.	Kanowit	Reservoir type
	15.	Sari-1	"
	16.	Sari-2	"
Sri Aman	17.	Sria-1	Reservoir type
	18.	Sria-2	Run-of-river
	19.	Sekrang-1	Reservoir type
	20.	Sekrang-2	"
	21.	Lemanak	"

Some of the potential sites are mutually alternative. The preliminary general layout plans are shown on Appendix-I of Volume VIII together with reservoir area-storage curves and river profiles.

CHAPTER 5. PRELIMINARY HYDROLOGICAL ANALYSIS

5.1 Climate and Meteorology

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 less vigourous than the northeast one, the rainy season of Sarawak coincides with the period of northeast monsoon.

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

Meteorological data have been recorded for relatively longer period at four (4) stations under the control of Malaysian Meteorological Service (hereinafter called MMS). The location and altitude of the stations are summarized below:

No.	Name of Station	Location		Altitude	Established
		Latitude	Longitude	(a.m.s.l.)	
1.	Kuching aerodrome	01 29'N	110 20'E	21.7	1954
2.	Sibu aerodrome	02 20'N	111 50'E	7.5	1968
3.	Bintulu aerodrome	03 12'N	113 02'E	3.1	1968
4.	Miri aerodrome	04 20'N	113 59'E	17.0	1968

Mean, maximum and minimum temperatures are shown in Fig. 5.1. The daily mean temperature is invariable at about 26 C throughout the year, and the variation of temperature depends upon the diurnal change. The mean relative humidity is also almost constant in a range from 85% to 87% as shown in Fig. 5.2 although there is a slight seasonal change.

Mean sunshine hour is 5.7 hours per day on an arithmetic avarage of the stations. It corresponds to annual sunshine hours of 2,080 hours. Mean monthly pattern of sunshine hour is shown in Fig. 5.3.

Maximum surface wind speed of 31.8 m/sec was recorded at Kuching aerodrome on September 1964. The mean surface wind velocity has been recorded in a range from 0.9 m/sec to 1.3 m/sec. Maximum surface wind speed recorded in each month is shown in Fig. 5.4.

5.2 Meteorological Analysis

5.2.1 Isohyetal map

The Sarawak Hydrological Year Book 79-80 published in 1984 contains the latest values of mean monthly rainfall recorded at 143 rainfall stations. The isohyetal map of mean annual rainfall depth is shown in Fig.5.5. The mean annual rainfall depth over Sarawak is estimated at about 3,700 mm for the past 18 years.

The wettest year is 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.

The distribution of mean monthly rainfall given in Fig. 5.6 shows that there is a distinctive rainy season from October through February in Divisions I to IV, VI and VII, while in the Division V the monthly rainfall is evenly distributed all the year round.

5.2.2 Evaporation

Evaporation varies generally with altitude. In Sarawak, the pan-evaporation data shown in Fig.5.7 are available at places of relatively low elevation at Kuching, Sibu, Bintulu and Miri aerodromes, compared with elevation of most of potential sites. In the Study, therefore, the evaporation data at 105 stations in Peninsular Malaysia, which include the data at equivalent altitudes similar to that of potential sites, are used.

The annual evaporation amount varies from 1,500 mm at mean sea level to 950 mm at El.1,600 m as given below:

Annual Evaporation Amount

Elevation (m)	0	100	200	400	800	1,200	1,600
Amount (mm/yr)	1,500	1,400	1,380	1,290	1,150	1,050	950

The relationship between evaporation and elevation is shown in Fig. 5.8.

5.3 Monthly Steamflow Data

5.3.1 Selection of monthly streamflow data

Streamflow measurements have been carried out at 50 water level gauging stations by DID. Monthly streamflow of the potential sites is estimated referring to representative gauging stations over Sarawak. The representative gauging stations are selected from the stations having a catchment area between 100 and 1,000 sq.km and a recording period of more than 10 years. The selected water level gauging stations are listed below:

Station Name	River Name	Catchment Area (sq.km)	Period of Record (yrs)
Serian	Btg.Sadong	941	18
Kg. Git	Sarawak Kiri	425	10
Pk. Buan Bidi	Sarawak Kanan	217	10

Monthly streamflow data of the above stations are used for a simulation study of the preliminary development scale for each potential site. The first-order Markov process is applied to extrapolate runoff from the existing data, since the recording period at each station is rather short. The generatd streamflow data comprised of the actual and extraporated data are used for the simulation study.

5.3.2 Mean annual basin loss

The mean annual basin loss is obtained by subtracting the mean annual runoff depth from the mean annual basin rainfall depth. The data on 15 selected river basins 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 as given in Table 5.1.

5.3.3 Estimation of mean annual runoff

As mentioned in Section 5.2.1, an isohyetal map of annual rainfall depth was drawn up for the whole basins in Sarawak. The mean annual rainfall is computed for the potential sites based on the isohyetal map.

The evapotranspiration for each catchment is estimated from Fig. 5.8 as described in Section 5.2.2 after deriving their average basin height. The annual runoff depth is calculated by subtracting annual evapotranspiration amount from the mean annual rainfall depth. The ratio of the runoff depth to the annual rainfall depth varies in a range from 0.54 to 0.66 as given in Table 5.2. The table also shows the estimated runoff volume at 21 potential sites.

5.4 Flow Duration and Storage Draft Curves

The flow duration and storage draft curves at each selected water level gauging station are obtained based on the generated streamflow data. The flow duration curve is used to determine a development scale of run-of-river type while the storage draft curve is used for reservoir type.

The flow duration curve is a figure to express discharges against their excess rates by arranging the monthly runoff data in the numerical descending order. Table 5.3 and Fig. 5.9 show that adopted flow duration curve prepared as an arithmetic mean of three water level gauging stations at Serian in the Btg. Sadong, Kg. Git in the S. Sarawak Kiri and Pk. Buan Bidi in the Sarawak Kanan. The flow duration curve is expressed in the dimensionless form; namely, the ordinate is denominated by mean discharge. The flow duration curves at the potential sites are obtained by multiplying the mean discharge at each potential site.

The storage draft curve is a diagram to show a relationship between the draft rate and the required active storage volume in the reservoir. The preperation of storage draft curve was made by simulating the continuity using the generated monthly streamflow data.

Table 5.4 and Fig. 5.10 show the adopted storage draft curve as an arithmetic mean of the curves drawn for aforementioned three gauging sites. The non-dimensionalization of the curve was made by dividing by annual inflow volume in ordinate and average discharge in abscissa, respectively. The required active storage volume on the curve represents the volume for the draught year with the recurrence interval of 25 years.

5.5 Sediment Yield Analysis

Sediment load measurement is being carried out by DID. The data collected so far, however, is rather limited.

Sediment yield analysis is made to estimate sediment volume which deposits in a reservoir during a project life. The sediment volume is usually estimated by means of daily streamflow data and sediment-discharge rating curve. In this study, however, the sediment volume of the potential damsites was estimated on the basis of estimated surface denudation rate, since the measurement record of sediment load in the objective areas is insufficient in number to establish the sediment-discharge rating curve.

The estimation of denudation rate is based on the study results of Batang Ai and Bakun hydroelectric Projects. The denudation rates for the above Projects are listed below:

Denudation Rate

Project	C.A. (sq.km)	Deposit Vol. (MCM)	Denudation Rate (mm/year)
Batang Ai	1,200	1.25/year	1.0
Bakun	14,750	380/50 year	0.5

The denudation rate of 1.0 mm/year is adopted in this study.

CHAPTER 6. PRELIMINARY POWER OUTPUT CALCULATION

6.1 General

Power output calculation is carried out preliminarily for the identified twenty-two (22) potential sites; namely, seventeen (17) potential sites conceived for reservoir type development and five (5) potential sites for run-of-river type development. Some of the potential sites are mutually alternative.

The installed capacity of each potential site is computed by the following equation:

$$Pmax = 9.8 \times Qmax \times He \times Ef \quad \text{(Eq.6.1)}$$

where, Pmax : installed capacity (kW)
Qmax : maximum plant discharge (cms)
He : net rated head (m)
Ef : combined efficiency of water turbine and generator

6.2 Development Scale Alternatives

6.2.1 Run-of-river type development

Since streamflow data for the potential sites are not sufficiently available, a flow duration curve is established based on the annual rainfall, evapotranspiration and dimensionless flow duration curve as described in CHAPTER 5. The maximum plant discharge is preliminarily determined at this study stage assuming a plant factor of 0.5.

6.2.2 Reservoir type development

The regulated outflow of a reservoir varies with active storage capacity of reservoir. For the development scale alternatives, three different storage capacities are selected with due attention to characteristics of dimensionless storage draft curve as described in CHAPTER 5. The initial value of draft rate, which means the rate of firm discharge to annual average discharge, is set at 0.78. The draft rates of 10% higher and 10% lower than the initial value are also examined to estimate storage capacity.

In case the storage capacity for initial value of draft rate is beyond the topographical maximum storage capacity, the draft rate is adjusted to a lower figure corresponding to its capacity.

For each storage capacity alternative, three different dam heights are examined for comparison as follows:

Case	Full Supply Level	Min. Operating Level
1	Topographically max. FSL (Highest full supply level)	Drawdowned level at a given active storage below FSL
2	Intermediate level between FSLs of Cases 1 and 3	Same as the above
3	Lowest FSL at a given active storage above MOL	Lowest allowable MOL at 3 m above sediment level (Lowest minimum operating level)

To enable a uniform comparison among the development scale alternatives, a plant factor of 0.5 is assumed for all the cases of reservoir type development. The schematic diagram for the development scale alternatives is shown in Fig. 6.1.

6.3 Power Calculation Criteria

To estimate the power output with a uniform basis for all the potential sites, plant discharge, operating level and head are determined by placing criteria as summarized below:

(a) Run-of-river type

PLANT DISCHARGE		
Firm discharge	Qf	Qf is assumed to be equivalent to 95% discharge on flow duration curve.
Dependable peak	Qd	Qd is obtained assuming a load factor of 0.5, in case the head pondage will have a diurnal regulating capacity.
Maximum plant discharge	Qp	Qp is estimated based on the plant factor of 0.5.
OPERATING LEVEL AND HEAD		
Normal operating level	NOL	NOL is set at 3 m above riverbed elevation.
Gross head	Hg	Hg is obtained subtracting tail water level from NOL.
Net head	Hn	Hn = 0.9 x Hg Hn is determined assuming the head loss is equal to 10% of Hg.

(b) Reservoir type

PLANT DISCHARGE		
Firm discharge	Qf	Qf is interpolated on dimensionless storage draft curve. Reservoir capacity is preliminarily determined based on a 1/25 draught year.
Maximum plant discharge	Qp	Qp = Qf / PF where, PF : plant factor of 0.5
OPERATING LEVEL AND HEAD		
Full supply level	FSL	As determined in Subsection 6.2.2
Minimum operating level	MOL	As determined in Subsection 6.2.2
Rated water level	RWL	RWL = 2/3 (FSL - MOL) + MOL where, FSL : full supply level for each case MOL : min. operating level for each case
Gross head	Hg	Hg = RWL - TWL where, TWL : tail water level
Net head	Hn	Hn = 0.9 x Hg Hn is determined assuming the head loss is equal to 10% of Hg.

6.4 Power Output Computation

The results of power output calculation are given in Appendix-II (Volume VIII) - Inventory of Potential Sites for the First Screening.

CHAPTER 7. FIRST SCREENING

7.1 General

The first screening aims at choosing the potential sites which appear to be worthy of conducting field reconnaissance for further examination of the scheme.

The criteria at the first screening evaluation consist of the following items;

(1) Remotenesss of the site
(2) Influence on waterborne traffic
(3) Power output
(4) Compensation and resettlement problem.

7.2 First Screening Elimination

7.2.1 Remoteness of site

The objective load centres except Kapit are all located in the coastal areas, while the hydroelectric schemes are, in most cases, exploitable in mountain area. In such small scale hydroelectric development as is examined in the present case, transmission line cost is one of major cost components affecting power generation cost to a great extent. Relative attractiveness of the scheme would decrease if the potential site is located far from the objective load centre.

Three (3) potential sites; namely, Lawas, Tengoa and Trusan, were eliminated because of long transmission line required for these schemes to avoid crossing through neighbouring country Brunei.

7.2.2 Influence on waterborne traffic

Although trunk and feeder roads are gradually stretching within Sarawak, waterborne traffic is traditionally the most popular and economical means of transportation, both along the coast and up the rivers. The construction of dam across the river or decrease of water depth would cause mal-effect on waterborne traffic or the construction of navigation facilities would involve additional investment, resulting in expensive power generation cost. An evaluation of the sites was made in this respect. The evaluation has revealed that most of the potential sites are located on tributaries having relatively small catchment and such potential sites may not cause inconvenience in waterborne traffic. Although several potential sites are located on the navigation route, circumtances are not so much severe that the construction of the dam is absolutely impossible.

On the other hand, there is logging activity in and around catchment area of several potential sites. The logging roads available thereat could be used as a mean of access for the project.

7.2.3 Power output

The optimum potential site should satisfy the existing and future power demand of the objective load centre. The lower and upper limit criteria are, therefore, predetermined as listed below:

Load Centre	Lower Limit (MW) Year 1995	Upper Limit (MW) Year 2010
Sri Aman	5.9	20.0
Sarikei	8.2	32.4
Limbang	5.0	15.0
Kapit	2.2	5.2

The minimum output is determined corresponding to the 1995 demand taking into account a lead time and construction period for hydroelectric scheme, while the maximum output is defined as the 2010 power demand plus 20 per cent allowance.

As a result, Four (4) potential sites; namely, Sria-1, Sria-2, Sari-1 and Sari-2, were eliminated because of the smaller output than the minimum limit, and one (1) potential site; Limbang, was eliminated because of the bigger power output than the maximum limit.

Two sites, Lemanak and Tekalit, involve the construction of high dams of more than 50 m in height, which would be apparently excessive for development of small hydropower of 5 to 15 MW class. Accordingly, these two schemes were also ruled out at this stage.

7.2.4 Compensation and resettlement

Potential sites involving serious compensation and resettlement should be eliminated mainly from the viewpoint of possible social problem. A preliminary evaluation of compensation and resettlement requirement was attempted based on topographical maps in a scale of 1 to 50,000. However, no definite assessment could be obtained for most of the potential sites owing to scarce information made available on the maps. Further assessment was therefore left to the findings in field reconnaissance survey.

7.3 Schemes Passed to Second Screening Evaluation

Twenty-one (21) potential sites except for Mukoh (refer to the subsequent section, 8.1) were screened according to the first screening criteria stated above. The results of first screening are summarized below:

Load Centre	Potential Site	First Screening Criteria		Schemes Passed to 2nd Screening
		Remoteness	Power Output	
Limbang	1. Lawas	X	O	
	2. Tengoa	X	O	
	3. Trusan	X	O	
	4. Medamit-1	O	O	
	5. Medamit-2	O	O	O
	6. Limbang	O	X	
	7. Pasia	O	O	O
Kapit	8. Kapit-1	O	O	O
	9. Kapit-2	O	O	O
	10. Ibau	O	O	O
	11. Bangkit	O	O	O
	12. Tekalit	O	X	
	13. Ayat	O	O	O
Sarikei	14. Kanowit	O	O	O
	15. Sari-1	O	X	
	16. Sari-2	O	X	
Sri Aman	17. Sria-1	O	X	
	18. Sria-2	O	X	
	19. Sekrang-1	O	O	O
	20. Sekrang-2	O	O	O
	21. Lemanak	O	X	

None of the potential sites was eliminated by the screening criteria on waterborne traffic. The screening criteria on compensation and resettlement are verified during field reconnaissance survey.

Medamit-1 and Medamit-2 are located closed each other, the former being at 5 km upstream of the latter. The development scales of two schemes are almost same. Of two, Medamit-1 was less favourable compared with Medamit-2 taking into account accessibility and transmission line length. The field reconnaissance survey for Medamit-1 will therefore be carried out in case that Medamit-2 is found to be unfavourable from the viewpoint of second screening criteria.

Accordingly, ten (10) potential sites, Medamit-2 and Pasia for Limbang area, Kapit-1, Kapit-2, Ibau, Bangkit and Ayat for Kapit area, Kanowit for Sarikei area, and Sekrang-1 and Sekrang-2 for Sri Aman area, were retained as the candidate sites for field reconnaissance survey.

CHAPTER 8. FIELD RECONNAISSANCE

8.1 General

Out of twenty-one (21) potential sites, ten (10) potential sites were selected for reconnaissance survey according to the first screening criteria. During the field reconnaissance survey in Kapit area, one additonal potential site of Mukoh was identified. The selected ten (10) and additional one (1) potential sites for the field reconnaissance survey are listed below:

Load Centre		Damsite	Development Type
Limbang	1	Pasia	Inter-basin water diversion run-of-river
	2	Medamit-2	"
Kapit	3	Kapit-1	Reservoir
	4	Kapit-2	"
	5	Ibau	"
	6	Bangkit	Reservoir and waterway
	7	Ayat	Run-of-river/reservoir and waterway
	8	Mukoh	Run-of-river
Sarikei	9	Kanowit	Reservior
Sri Aman	10	Sekrang-1	Reservoir
	11	Sekrang-2	"

8.2 Field Reconnaissance Survey

The field reconnaissance survey was carried out considering the following seven (7) main reconnaissance objectives:

(i) Topography
(ii) Geology
(iii) Construction materials
(iv) Accessibility
(v) Land compensation and resettlement
(vi) Present water use condition, and
(vii) Transmission line.

The summary sheets of field reconnaissance survey are attached in APPENDIX-III (Volume VIII).

Power output capacity of the eleven (11) sites was then re-examined incorporating the findings from reconnaissance survey. The results are presented in Appendix IV (Volume VIII). together with items newly identified through field reconnaissance.

8.3 Geological Condition

8.3.1 Regional geology

Geologically, the State of Sarawak can be divided into two distinct regions;

(a) The Sunda Shield which occurs west of the Batang Lupar covering the west part of Sarawak. Sri Aman load centre is located on the mid-stream of the Batang Lupar.

(b) The North West Borneo Geocycline which extends along the northern flank of the Sunda Shield covering all the area on the east of Batang Lupar.

All the eleven (11) potential sites passed to the second screenig are located on the North West Borneo Geocyncline. Sri Aman and Sarikei are located on the west thereof. Kapit is located in the central part thereof. Limbang is located in the east thereof.

The development of the North West Borneo Geocyncline, started in the late Cretacious period with slaty facies, consists of phyllite, slate and graywacke. The potential sites for the Sri Aman load centre scatter in this area.

The main development of the Geocyncline is represented by the deposition of the Lower Tertiary Rajang Group in central Sarawak consisting mainly of the hard quartzitic sandstone, graywackes, siltstones and slaty rocks. The potential sites for the Sarikei and Kapit load centres scatter in this area.

Lower Tertiary Sediments of time-equivalents to the Rajang Group crop out also in the Middle Baram Valley as well as in the head-waters of the Limbang and Trusan Rivers, and particularly in the Subis and Melinau areas which are characterised by massive limestone bodies. The potential sites for the Limbang load centre scatter in this area.

The deposition apparently ceased in mid-Tertiary in Central Sarawak and at the same time the sedimentary rocks were subjected to strong folding, faulting and uplifting. The major structure trend lines conform closely to the crescent shape of the geocyncline axis running roughly north-south in the Baram area.

The Rajang Group consists of the Belaga Formation of Stage I, II, III and IV formed during the upper Cretaceous and the Lower Tertiary. The Setap Shale Formation and Meligan Formation are formed after the Rajang Group.

8.3.2 Geological condition in objective area

(1) Sri Aman area

The Sekrang-1 and Sekrang-2 potential sites are located in the middle reach of the Batang Sekrang which is a tributary of the Batang Lupar.

Geology along the Batang Sekrang is dominantly slaty facies which consists of slate and graywacke of Stage I of the Belaga Formation of the Rajang Group. The deposition of their rocks started in the upper Cretacious.

(2) Sarikei area

The Sarikei load centre is located in the lower reach of the Batang Rajang. The Kanowit potential site is located in the upper reach of the Sungai Kanowit which is a tributary of the Batang Rajang.

Geology in the upper reach of the Sungai Kanowit is slaty facies which consists of phyllite, slate and argillite of Stage II of the Belaga Formation of the Paleocene-lower Eocene.

(3) Limbang area

The Medamit-2 potential site is located on the Sungai Medamit which is a tributary of the Sungai Limbang. The power-house is located on the Sungai Limbang.

Geology along the Sungai Medamit is dominantly shale of the Setap Shale Formation. Geology along the Sungai Limbang is the lower stratum of the Setap Shale Formation consisting of limestone. The deposition of the Setap Shale Formation is started in the Oligocene-Miocene of the Tertiary.

The Pasia potential site is located on the Sungai Pasia which is a tributary of the Batang Trusan. Geologically, the mountain situated between the Sungai Pasia and the Batang Trusan consists of graywacke and thin shale of the Meligan Formation of the Miocene.

(4) Kapit area

The Ayat, Bangkit, Kapit-2 and Mukoh potential sites are located in the southern region of the Batang Rajang. Geology in the southern region consists of slate, graywacke and their alternation of Stage II of the Belaga Formation.

The Kapit-1 and Ibau potential sites are located in the northern region of the Batang Rajang. Geology in the northern region consists dominantly of slate of Stage III of the Belaga Formation of the middle-upper Eocene.

Site geology of each potential site and general geological map of each objective area are summarized in Appendix V (Volume VIII).

CHAPTER 9. PRELIMINARY FLOOD ANALYSIS

9.1 Rainfall Analysis

9.1.1 Selected rainfall stations for potential sites

There are 143 functioning rainfall stations as of March 1986 in Sarawak, of which 64 are automatic recording stations and the remaining 79 are manual stations. However, none of the rainfall stations having long recorded data is located in the catchment areas of the potential sites.

In the Study, the rainfall stations nearest to the potential sites or characterized by the most similar hydrological condition to the potential sites are selected as listed below:

Load Centre	Potential Site		Rainfall Station		
			Name	Latitude	Longitud
Limbang	1	Pasia	Long Semadoh	4 13'N	115 35'E
	2	Medamit-2	Long Bilong	4 22'N	114 56'E
Kapit	3	Kapit-1	Kapit P.W.D.	2 01'N	112 56'E
	4	Kapit-2	Nanga Bangkit	1 46'N	112 38'E
	5	Ibau	Song	2 01'N	112 33'E
	6	Bangkit	Nanga Bangkit	1 46'N	112 38'E
	7	Ayat	"	"	"
	8	Mukoh	"	"	"
Sarikei	9	Kanowit	Kanowit W/W	2 06'N	112 09'E
Sri Aman	10	Sekrang-1	Riddan	1 13'N	111 42'E
	11	Sekrang-2	"	"	"

The location of selected rainfall stations and the period of records are shown in Figs. 9.1 and 9.2, respectively. The annual maximum 1-day, 2-day, 3-day and 5-day rainfall depths for the stations are given in Tables 9.1 to 9.7.

9.1.2 Frequency analysis

Frequency analysis of rainfall depth is made for various durations and return periods. The analysed rainfall durations are 1, 2, 3 and 5 days for return periods of 2, 5, 10, 20, 50, 100 and 200 years.

Three (3) methods; that is, (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 of frequency analysis on rainfall depth are given in Tables 9.8 to 9.10 and Figs. 9.3 to 9.6.

The above results show that there is no much difference in their values among three (3) methods. Therefore, the results of Gumbel method which is adopted by DID in his publications are applied to the further studies.

9.1.3 Conversion factor to average basin rainfall

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 for the potential sites has prevented the derivation of conversion factor by statistical procedure. In the Study, the conversion factor recommended by DID is applied to estimate the average basin rainfall for the potential sites. The conversion factor is shown in Fig. 9.7.

9.1.4 Depth duration analysis

"Sarawak Hydrological Year Book" published by DID for the period from 1963 through 1980 does not contain hourly rainfall data at the selected rainfall stations. Thus, the heavy rainfall data at Kuching are adopted to estimate the distribution of hourly rainfall.

The four (4) heavy rainfall data are adopted in the Study as listed below:

No.	Period		Amount
	From	To	(mm)
(1)	Jan. 8, 1971	- Jan. 9, 1971	355
(2)	Jun. 22, 1972	- Jun. 23, 1972	247
(3)	Dec. 24, 1973	- Dec. 25, 1973	198
(4)	Dec. 28, 1975	- Dec. 29, 1975	193

According to the above data, the heavy rainfall occurs for the duration within 24 hours and has such characteristic that about 80 per cent of 24-hour rainfall concentrates in 15 hours after rainfall starts. These torrential showers were usually observed in the evening to early morning.

The average hourly distribution pattern as shown in Fig. 9.8 is obtained as an arithmetic mean of the above four heavy rainfalls. The ratio of every 3-hour rainfall to 1-day rainfall is estimated as follows:

Duration (hr)	Accumulated (%)	Ratio (%)
0 - 3	9.7	9.7
3 - 6	24.4	14.7
6 - 9	40.0	15.6
9 - 12	60.5	20.5
12 - 15	82.3	21.8
15 - 18	89.5	7.2
18 - 21	95.3	5.8
21 - 24	100.0	4.7

9.1.5 Design rainfall

Probable flood hydrographs at Batang Ai Project (catchment area is 1,200 sq. km) are referred for estimating the duration of design rainfall.

According to the Batang Ai Project, the probable flood hydrographs for the various return periods of 2, 10, 20, 50, 100 and 200 years were estimated on the basis of the observed five (5) flood hydrographs at the dam site. 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. This suggests that an assumption of 24-hour storm would reasonably be on a conservative side for smaller catchments at the potential sites under consideration.

The design rainfall depths for the potential sites are, therefore, developed for the duration of 24 hours by the following equation:

$$R24 = CF \times RF \quad \text{(Eq.9.1)}$$

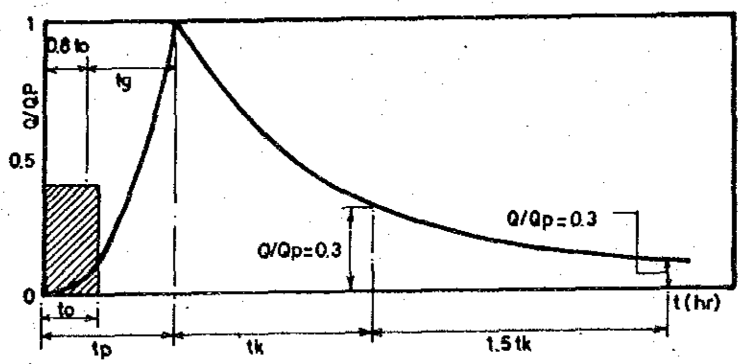
where, R24: design rainfall depth for the duration of 24 hours
CF : conversion factor of point rainfall to average basin rainfall
RF : 1-day probable point rainfall depth.

Design rainfall at the potential sites is divided into eight by every 3 hours on the basis of depth duration analysis in Subsection 9.1.4. The design rainfalls at the potential sites are summarized in Tables 9.11 to 9.14.

9.2 Flood Analysis

9.2.1 Derivation of unitgraph

A unitgraph at the project site is developed by Nakayasu's synthetic unit hydrograph method. The unitgraph is derived by the following procedures:



(1) Lag time of peak discharge

$tg = 0.5 + 0.058L \quad (L<15\ km)$ . . . .(Eq.9.2)

$tg = 0.21 \times L\ \exp(0.7) \quad (L>15\ km)$ . . . .(Eq.9.3)

where, tg : lag time of peak discharge (hr)
L : river channel length (km)

$tk = 0.47\ (\ A\ L\ )\ \exp(0.25)$ . . . . (Eq.9.4)

where, tk : recession time period from the time of peak discharge to 30 per cent of peak discharge (hr)
A : catchment area (sq. km)

(2) Time of concentration

$tp = T1 = 0.8to + tg$ . . . .(Eq.9.5)

$t1 = T2 = tp + tk$ . . . . (Eq.9.6)

$t2 = T3 = tp + tk + 1.5tk$ . . . . (Eq.9.7)

(3) Peak discharge

$Qp = A\ Ro\ /\ [\ 3.6\ (0.3\ tp + tk)\ ]$ . . . . . (Eq.9.8)

where, Qp : peak discharge (cms)
Ro : unit effective rainfall (mm)

(4) Unitgraph

- Rising limb

$$Qr = (t / tp) \exp(2.4) \quad (0<t<tp) \ldots\ldots (Eq.9.9)$$

- Recession limb

$$Qr = 0.3 \exp[(t-tp)/tk] \quad (T1<t<T2) . (Eq.9.10)$$

$$Qr = 0.3 \times 0.3 \exp[(t-T2)/1.5tk] \quad (T2<t<T3) . (Eq.9.11)$$

$$Qr = 0.3 \times 0.3 \times 0.3 \exp[(t-T3)/2tk] \quad (t>T3) \ldots (Eq.9.12)$$

The values required to obtain a unit hydrograph are summarized below:

Potential Site	River	Catchment Area (sq.km)	River Length (km)
Pasia	S.Pasia	177	29.0
Medamit-2	S.Medamit	186	38.0
Kapit-1	S.Menuan	101	19.5
Kapit-2	S.Benuang	220	20.0
Ibau	S.Ibau	163	23.0
Bangkit	S.Bangkit	167	14.0
Ayat	S.Ayat	59	9.5
Mukoh	S.Benuang	292	25.0
Kanowit	S.Kanowit	1,331	65.0
Sekrang-1	B.Sekrang	508	68.5
Sekrang-2	"	360	45.0

9.2.2 Loss rate

Initial rainfall loss is disregarded by assuming that the whole basin is saturated by antecedent rainfall, resulting in the estimate of a conservative side. While the retention loss rate after the saturation is assumed to be constant at 2.5 mm per hour.

The rate of 2.5 mm per hour as retention loss is estimated on the basis of other hydroelectric projects in Sarawak and Peninsula Malaysia as listed below:

Retention Loss Rate of Rainfall

Project	Location	Catchment Area (sq. km)	Loss Rate (mm/hr)
Klang Gates Dam	P.Malaysia	74	5.1
Jor Dam	"	123	7.2
Batang Ai	Sarawak	1,200	3.0
Pergau Dam	P.Malaysia	1,290	2.5
Temengor Dam	"	3,400	2.5
Kenyir Dam	"	4,580	2.5
Bakun	Sarawak	14,750	4.0

The retention loss rate generally tends to increase with the increase of catchment area. Therefore, the minimum retention loss rate of 2.5 mm per hour is adopted in view that most of potential sites in the Study are located in the steep-sloped mountainous area with relatively small catchment and that future logging activities will lead to reduce its retention loss rate.

9.2.3 Flood hydrograph

Probable flood hydrographs are calculated under the following conditions:

(1) A unitgraph is obtained by the Nakayasu's synthetic unit hydrograph method.

(2) Design hyetographs of 24-hour duration for various return periods are applied to synthesize the hydrographs.

(3) Retention loss rate of 2.5 mm per hour is subtracted from the design hyetograph to estimate rainfall excess.

(4) Base flow is assumed to be equivalent to the annual average discharge.

The probable flood hydrographs at the potential sites are shown in Figs. 9.9 to 9.19. The peak discharges, flood volumes and their specific discharges are summarized in Tables 9.15 and 9.16.

9.3 Probable Maximum Flood

9.3.1 Probable maximum precipitation

Probable maximum precipitation, PMP, is defined as the theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin at a particular time of year.

PMP for all durations and sizes of area in a specific basin is usually determined by several types of storms. For example, thunderstorms are very likely to cause PMP over an area smaller than about 1,000 sq. km for durations shorter than 6 hours, but controlling values for longer durations and larger areas will be derived invariably from general storms. For short durations, thunderstorms can produce more heavily than general storms, but they are relatively short-lived, and individual storms cover relatively small areas. General storms, although they often include thunderstorms, produce less intense rainfall on an average, but their longer life and greater areal coverage result in greater rainfall amounts for the duration of more than 6 hours and for large areas.

In fact, this longer life and greater areal coverage of storm during January - February 1963 resulted in the unprecedented flood over the coastal area of Sarawak. These storms were mainly brought to Sarawak by the northeast monsoon which blows across the South China Sea from October to the end of February. According to the rainfall records, these storms occurred sequentially with the periodicity of 4 and 5 days.

There are several methods applied to the derivation of PMP such as the theoretical methods and Hershfield's statistical methods. The lack of sufficient meteorological data prevents the derivation of PMP by the former method. The latter method was statistically developed for the catchment area within 1,000 sq. km.

The magnitudes of PMP for heaviest 24 hours are estimated by the Hershfield's method and are also compared with those in other hydroelectric projects in Sarawak and Peninsular Malaysia as listed below:

Project name		Catchment area (sq. km)	Maximum 24-hour rainfall (mm)	maximization factor
Potential Sites				
Pasia	(Limbang)	177	385	2.69
Medamit-2	(")	186	543	2.41
Kapit-1	(Kapit)	101	513	2.64
Kapit-2	(")	220	427	1.76
Ibau	(")	163	541	2.97
Bangkit	(")	167	431	1.76
Ayat	(")	59	440	1.76
Mukoh	(")	292	422	1.76
Kanowit	(Sarikei)	1,331	495	2.36
Sekrang-1	(Sri Aman)	508	495(*)	1.76
Sekrang-2	(")	360	495(*)	1.74

Other Hydroelectric Projects

Batang Ai	(Sarawak)	1,200	580(3-day)
Kenyir	(P.Malaysia)	2,600	470
Bakun	(Sarawak)	14,750	280
Pelagus	(P.Malaysia)	21,020	210

(*) The value at Kanowit is applied because of an extraordinary results.

These 24-hour maximum basin average precipitations are 1.74 to 2.97 times more than the 100-year probable basin average rainfall depth. PMP for other durations of 2, 3 and 5 days is also obtained multiplying the maximization factor of 1.74 to 2.97 by the 100-year probable basin average rainfall for the respective durations as given in Table 9.17.

For the 5-day PMP, its hyetograph is arranged to produce the most critical flood on the basis of the standard procedures of the U.S. Weather Bureau, and the depth-duration relationship is applied to the heaviest 24 hours assuming that the thunderstorm develops. PMP hyetographs for the potential sites are given in Table 9.18.

9.3.2 Probable maximum flood

Probable maximum flood (PMF) is dervied by the synthetic unit hydrograph method as described in Section 9.2. PMF for each potential site is calculated under the following conditions:

(1) The unitgraph is defined by the Nakayasu's synthetic unit hydrograph method.

(2) A PMP hyetograph for 5-day duration is applied to synthesize the hydrograph.

(3) Retention loss rate of 2.5 mm per hour is subtracted from the PMP hyetograph to estimate rainfall excess.

(4) Base flow is assumed to be equivalent to the annual average discharge.

The PMF hydrographs for the potential sites are shown in Figs. 9.20 to 9.30, and their peak discharges are summarized below:

Load centre		Potential site name	Catchment area (sq.km)	Peak disharge (cms)	Specific discharge (cms/sq.km)
Potential Site					
Limbang	1	Pasia	177	1,052	8.5
	2	Medamit-2	186	1,592	8.6
Kapit	3	Kapit-1	101	890	8.8
	4	Kapit-2	220	1,480	6.7
	5	Ibau	163	1,392	8.5
	6	Bangkit	167	1,220	7.3
	7	Ayat	59	477	8.1
	8	Mukoh	292	1,923	6.6
Sarikei	9	Kanowit	1,331	7,950	6.0
Sri Aman	10	Sekrang-1	508	3,385	6.7
	11	Sekrang-2	360	2,578	7.2
Other Hydroelectric Projects					
	1	Batang Ai	1,200	8,700	7.3
	2	Kenyir	2,600	13,000	5.0
	3	Bakun	14,750	44,400	3.0
	4	Pelagus	21,020	42,500	2.0

The magnitude of PMF is also evaluated referring to the following Creager's equation:

$$q = 46 \times C \times A \exp(b) \quad \text{(Eq.9.13)}$$

$$b = 0.864 \times A \exp(-0.048) - 1 \quad \text{(Eq.9.14)}$$

where, q : specific discharge in cub.ft/sec/sq.mile
A : catchment area in sq. mile
C : coefficient depending upon the characteristic of the basin.

The envelope curve for C = 100 gives the general trend of all the world maximum flood records with a few exceptions, while it is known that the maximum floods recorded in a region covering Malaysia, Indonesia and Thailand correspond to the envelope curve for C = 34.

According to other projects in Sarawak and Peninsular Malaysia, the envelope curve for more than 100 gives their specific discharges for PMF. On the other hand, those for the potential sites give their specific discharges in a range from C = 34 to C = 100 except for the case of Kanowit as shown in Fig. 9.31.

CHAPTER 10. SECOND SCREENING

10.1 General

The field reconnaissance survey was carried out for eleven (11) potential sites including one (1) additional potential site identified during the field reconnaissance survey for Kapit area. These eleven (11) potential sites in total were evaluated based on the second screening criteria. As far as there is no serious problem on social, topographic or geological conditions, the potential sites will be passed to third screening.

10.2 Second Screening Elimination

10.2.1 Geological assessment

Surface geological reconnaissance was extensively executed to observe general geological and tectonic features, possibility of land sliding, degree of weathering, existence of faults, etc. on damsite, waterway and powerhouse as well as reservoir area. Those sites, which impose serious geological problems, are ruled out.

10.2.2 Accessibility

Most of the potential sites are not accessible by surface road at present, although logging roads are available for some potential sites. Access roads are planned based on road extension programme under the Fifth National Plan by the Government, taking into account availability of existing logging road.

10.2.3 Present water use

The implementation of hydroelectric projects sometimes causes an adverse effect to the present river water use for irrigation, industry and domestic water supply, navigation and scenery. Particularly, in case of interbasin water diversion scheme, impacts for the present water use may be large. In these respects, present water use was investigated in the upstream and downstream reaches from the proposed site to identify any foreseeable problem.

10.2.4 Availability of construction materials

From topographic, geological and climatological points of view, dam would be designed in either concrete type or rock-fill type. Availability of embankment materials and concrete aggregates would be one of dominant factors for economical construction of major civil structures, in particular for dam. Field reconnaissance was conducted to identify the location of borrow or quarry sites and to examine the quality of construction materials available there.

10.3 Schemes Passed to Third Screening Evaluation

Field reconnaissance survey revealed the actual condition of eleven (11) potential sites. As a result, four (4) potential sites were eliminated based on the second screening criteria as summarized below, and detailed comments for each site are described in Appendix III (Volume VIII):

Load Centre	Potential Site	Screening Criteria			
		Geology	Access	Water Use	Materials
Limbang	1 Medamit-2	O	O	O	O
	2 Pasia	O	O	O	O
Kapit	3 Kapit-1	X	O	X	X
	4 Kapit-2	O	O	O	O
	5 Ibau	O	O	X	X
	6 Bangkit	-	-	-	-
	7 Ayat	-	-	-	-
	8 Mukoh	O	O	O	O
Sarikei	9 Kanowit	O	O	-	O
Sri Aman	10 Sekrang-1	O	O	O	O
	11 Sekrang-2	O	O	O	O

Actual topographic condition of Bangkit and Ayat sites was found to be different from that informed in the map study and to be unsuitable for power scheme. These sites were therefore eliminated from further studies. Finally, seven (7) out of eleven (11) potential sites were selected for the third screening.

CHAPTER 11. BASIC LAYOUT PLAN AND PRELIMINARY COST ESTIMATE

11.1 General

Preliminary project cost is estimated for all the seven potential sites selected by the second screening. Basic layout is firstly drawn on maps in a scale of 1/10,000 enlarged from the original maps in a scale of 1/50,000 (refer to Appendix VI of Volume VIII). The basic dimensions of principal structures are determined on the 1/10,000 scale maps. The work quantitites are calculated for a representative development scale at each potential site. The work quantities for alternative development scales are calculated by means of computerized quantity formulas of which the quantity output is modified by adjustment factors obtained through the actual quantity calculation made for the representative development scale.

Unit prices of construction work are estimated based on cost data from the existing hydropower projects of Batang Ai and Batu Lintang as well as the cost estimates for the Bakun Project and other overseas projects.

Principal features of the major structures at each potential site are shown in Table 11.1. Results of the preliminary cost estimate are shown in Appendix-VII (Volume VIII).

11.2 Basic Design Criteria

11.2.1 Dam and waterway

(1) Storage dam

In the study at this identification stage, dam type is selected taking account of topographic and geological conditions prevailed at the site as well as availability of the dam construction materials. As the result, rockfill dam type is selected for all the reservoir type development schemes.

Topographical features of the damsite are surveyed at the site by measuring the riverbed width and crest length at the possible maximum dam height. Average excavation depth is assumed based on the site reconnaissance survey on geology.

The dam volume is calculated by the following equation, assuming a composite trapezoidal valley profile with varying slopes between the maximum dam height and the riverbed:

$VD = 1.1 \times DH^2 \times CL$

where,

VD :	Volume of rockfill dam	(m^3)
DH :	Dam height estimated by adding 4 m above full supply level (FSL)	(m)
CL :	Dam crest length	(m).

(2) Diversion weir for run-of-river scheme

A typical design assumed herein is a concrete diversion weir with a fixed overflow weir. The volume of dam concrete including that of all associated structures is estimated by the following formula:

$VDW = 0.347 \times DH^2 \times CL$

where,

VDW :	Volume of diversion weir	(m^3)
DH :	Height of diversion weir	(m)
CL :	Length of weir including abutments	(m).

The dam crest elevation is assumed to be 3 m above FSL.

(3) Diversion tunnel

Pressure tunnel type is assumed for a diversion tunnel. The inner diameter of tunnel is calculated by the following equation assuming the maximum diameter of 7.0 m:

DIAD = 0.291 x (QDF/NBR)

where,

DIAD :	Inner diameter of diversion tunnel	(m)
QDF :	River diversion design flood	(cum/sec)
NBR :	Number of diversion tunnels	(Nos.).

(4) Headrace tunnel

Headrace tunnel is assumed to be pressure tunnel type for reservoir development type, while non-pressure type for run-of-river development type. In case of run-of-river development type, horse-shoe shape tunnel is designed assuming the maximum velocity of 3.0 m/sec and the minimum inner diameter of 1.8 m.

(5) Penstock line

Exposed penstock line is considered as a typical layout of penstock line. Inner diameter of the penstock line is calculated assuming the mean velocity of 6 m/sec and 7 m/sec for effective heads of less than 150 m and more than 150 m, respectively.

11.2.2 Access road

Permanent access road is built for use during the construction and after completion. Assumptions made herein are :

- Access road is connected from the existing or planned all-season public road or logging road passing nearby the potential sites.

- The cost of new access road is borne by the hydropower project. The existing public road will be kept maintained to an acceptable grade by other agency before and during the construction period.

The length of access road is measured on 1:50,000 maps.

11.2.3 Turbine and generator

(1) Calculation of power output

The power output of each identified site is calculated by a formula below:

$$P = 9.8 \times Q \times He \times Ef$$

where,	P	:	Power output (kW)
	Q	:	Plant discharge (cms)
	He	:	Effective head acting on turbine (m)
	Ef	:	Combined efficiency of turbine and generator = 0.85.

(2) Selection of turbine type and application range

Based on the available head and flow rate, the turbine type is preliminarily planned from Table 11.2 and Fig. 11.1 as follows:

(a)	Vertical Shaft Francis Turbine	:	Sekrang-2, Medamit-2 and Pasia
(b)	Kaplan Turbine	:	Sekrang-1, Kanowit, Mukoh and Kapit-2

(3) Selection of generator type

The generator suitable for the small-scale hydroelectric project is classified into two types; induction generator and synchronous one. The induction generator has advantages of low cost, simple and sturdy structure, easy maintenance, etc., while it also has disadvantage of being unable to operate independently, incurring a large rush current at the time of parallel connection with an electric power system and supplying only a leading current.

For these reasons, it will be necessary at time of the subsequent feasibility stage to select the type of generator after careful study of operation of the generator and the conditions of electric power system to which the generator will be connected. A comparison of the synchronous generator and induction generator is shown in Table 11.3 for reference.

It is at moment planned that generators at all the sites are of synchronous type.

11.2.4 Transmission line system

A voltage of 11 kV has been used in SESCO's distribution network in the selected four load centres at present. In connection with the 275 kV transmission line expansion programme, however, a new substation with voltage of 33 kV will be constructed in Sarikei and Sri Aman respectively within a few years.

The transmission voltage of 33 kV and 66 kV is applied for the basic design considering the transmission length and installed capacity.

Each identified hydropower station is assumed to be connected to the existing power station and/or the planned substation directly.

(1) Carrying capacity of transmission line

Allowable carrying capacity means maximum load level to be transmitted without any trouble and/or fault.

(2) Transmission line route

The route of transmission line from the identified hydropower station to the existing power station and/or the planned substation is planned on a map of 1:50,000 scale, taking account of general topogrphical features observed in field reconnaissance. The length of the line is then measured on the same map.

11.3 Preliminary Cost Estimate

11.3.1 Basic approach

Preliminary cost estimate is made based on unit price basis. The estimated cost is expressed in Malaysian dollars at 1986 price level with a foreign currency exchange rates of US$1.0 = M$2.6.

The estimate is made for the following separate itmes:

(a) Dam, waterway and power plant (Power development)
(b) Access road
(c) Transmission line including a substation
(d) Land acquisition and compensation.

Results of the preliminary cost estimate are shown in Appendix-VII (Volume VIII).

11.3.2 Power development cost

Work quantities at each potential site are calculated based on the basic design prepared for the representative development scale. The work quantities for the alternative development scales are obtained basically by means of computerized quantity formulas in the "Criteria for cost estimation for the planning of hydropower development project" established by the Ministry of Trade and Industry in Japan. The quantity output by the computer programme is adjusted in accordance with the actual quantity calculation made for the representative development scale.

Cost is then estimated by multiplying unit prices predetermined for each work item.

11.3.3 Access road

A unit price of access road is estimated at M$135,000/km in relatively flat areas, M$260,000/km in hilly land and M$400,000 to M$450,000/km in mountainous areas, respectively.

11.3.4 Transmission line and associated substation equipment

In estimating the unit price of transmission line to be constructed between the proposed hydropower station and the associated substation, voltage of 33 kV or 66 kV is taken into consideration. Using data from SESCO for reference, the unit price is estimated at M$72,000/km and M$160,000/km for 33 kV and 66 kV, respectively. For lines in mountainous areas where access is difficult, a higher rate is applied.

The cost of equipment to be installed at the receiving end is included in the construction cost of the line.

11.3.5 Land acquisition and compensation

Land acquisition and compensation costs for the potential sites are estimated at M$1,500/ha referring to cost data obtained from the Batang Ai hydropower project. Lands to be submerged and to be resettled were estimated based on information extracted from map and collected at time of field reconnaissance.

CHAPTER 12. POWER DEMAND FORECAST

12.1 Previous Studies by SAMA

The following two reports deal with in certain detail power demand forecast for the whole Sarawak including the major load centres;

(1) Master Plan for Power System Development (Volume II Annexes), April, 1981, SAMA Consortium

(2) Recommendations for Sarawak Hydropower Development, February, 1983, SAMA Consortium.

The latter has been prepared in a manner to review the former master plan, wherein no notable difference between them is observed. The latter report examined forecast in two cases, i.e. minimum and medium forecasts, until the year 2000 for the whole Sarawak, which are summarized below:

Case	Peak Demand in Year 2000 (MW)	Average Growth Rate per Annum	
		1980 - 1990	1990 - 2000
Minimum	600	14.1%	8.2%
Medium	1,075	26%	3.7%

12.2 Aggregate Peak Demand Forecasted by SESCO

According to the data provided by SESCO, peak power demand up to year 2000 and 2010 for the whole Sarawak is estimated at 469 MW and 860 MW, respectively taking an average growth rate of 7.3% per annum into consideration. As for the selected four load centres, the forecasted value in 2010 is as follows:

Description	Load Centre			
	Sarikei	Sri Aman	Limbang	Kapit
Peak Demand (MW)	27.0	16.9	12.4	4.1
Average Growth Rate per Annum(%)	9.1	8.9	7.3	5.0

Power demand growth curves projected by SAMA and SESCO in each load centre are shown for Figs.IX.1 and IX.2 of Appendix IX (Volume VIII).

12.3 Power Demand Forecast Applied to This Study

Of the above two forecasts, SESCO's projection seems to represent more updated figures in view of coincidence with actual records in recent years. Accordingly, this study will be at moment based on demand projections prepared by SESCO.

Further detailed demand forecast will be prepared for the finally selected demand centres during the subsequent feasibility study stage.

CHAPTER 13. ALTERNATIVE POWER SOURCES

13.1 Type of Alternative Power Plants

In view of size of the identified hydropower schemes, ranging between 3 MW and 27 MW, the thermal power alternative would be either of the following:

(1) Diesel power plant

(2) Gas-turbine power plant.

At this identification study stage, it is assumed that the diesel plant would be the most likely alternative, leaving a further examination during the next feasibility study stage.

13.2 Cost of Alternative Power Plants

The capital and running costs of diesel power plant are estimated so as to measure the hydropower benefit, which is used for preliminary evaluation of the proposed small-scale hydropower scheme.

13.2.1 Capital cost

The said cost is estimated based on the conditions as mentioned below:

(1) Cost estimation will be based on a price level prevailing in the middle of 1986.

(2) All major items of the plant and equipment are supposed to be imported from outside Malaysia. Taxes, such as custom duties and import taxes, are not included in the capital cost.

(3) Associated costs, such as physical contingencies, engineering fee, etc. will be counted in, but no price escalation and interest during construction will be considered.

Based on the prices in current international market, unit construction cost of the diesel power plant is estimated as follows:

500	-	1,000 kW	:	3,200 M$/kW
1,000	-	2,000 kW	:	2,600 M$/kW
2,001	-	3,000 kW	:	2,360 M$/kW.

13.2.2 Fuel and O&M cost

The fuel costs are assumed based on the SESCO's statistical data of fuel oil as described in Chapter 3.

On the other hand, operation and maintenance costs are also estimated in terms of either a ratio to the construction cost or unit cost per generation of kWh.

Values and figures used in the evaluation are presented in the succeeding Chapter 14.

CHAPTER 14. THIRD SCREENING

14.1 General

Seven (7) potential sites have been passed to a further study in the third screening. The seven (7) potential sites are:

Load Centre	Potential Site	
Sri Aman	SEKRANG-1	SEKRANG-2
Sarikei	KANOWIT	
Kapit	MUKOH	KAPIT-2
Limbang	PASIA	MEDAMIT-2

A revised power output calculation was made for nine (9) and six (6) cases of alternative development scale for reservoir and run-of-river type development, respectively, to examine an optimum scale at each site.

The development scale of each potential site is determined placing the following criteria:

(1) A development scale is in principle to be the scale giving the lowest kWh cost (cost of generation per kWh)

(2) This study envisages a power development plan up to year 2010. In case the development scale defined in (1) above is larger than the power demand level in 2010, a scale equivalent to the latter is regarded to be the maximum development at the site.

Relative attractiveness of each site is then examined in comparison with costs of alternative thermal power (herein assumed to be diesel plant). The comparison was made in terms of present worth of cost streams on economic cost basis over a time span of 50 years after the hydropower is installed.

14.2 Evaluation of kWh Cost

14.2.1 KWh cost index

The kWh cost at each potential site is calculated for all installed capacity alternatives derived from the power output calculation. Annual energy is calculated for firm and secondary energy output. At this evaluation stage, the secondary energy is assumed to be worth at 50% of the firm energy for equitable comparison of various schemes having different firm and secondary energies. Result of the kWh cost index obtained is illustrated in Figs. 14.1 and 14.2. The potential economic development scale which gives the minimum kWh cost is shown in Table below:

Load Centre	SRI AMAN		SARIKEI	KAPIT		LIMBANG	
Potential Site	SEK-1	SEK-2	K'WIT	MUKOH	KAPIT-2	PASIA	MED-2
Development Type	(RES)	(RES)	(RES)	(RUN)	(RES)	(RUN)	(RUN)
Installed Capacity (MW)	11.8	21.3	25.1	1.94	8.0	25.9	4.6
Dependable Peak Output (MW)	11.8	21.3	25.1	1.94	8.0	8.5	2.0
Annual Energy Output (GWh)	54.9	95.3	123.7	16.7	40.2	189.0	36.6
Plant Factor (%)	50	50	50	100	50	80	86
Construction Cost (million M$)	117.6	217.0	270.9	21.3	83.8	120.0	48.1
M ¢/kWh*	27.0	28.6	27.6	16.1	26.4	11.6	22.7

Remarks : SEK-1: SEKRANG-1 MED-2: MEDAMIT-2
SEK-2: SEKRANG-2 (RES): Reservoir development type
K'WIT: Kanowit (RUN): Run-of-river development type

* : The figures represent hydro energy cost on the basis that all part of primary energy and 50% of secondary energy are saleable.

The above index value of M¢/kWh indicates that some of the proposed sites seem to be marginal, compared with the current average power rate of M ¢ 30/kWh, although they represent the rate per "firm energy + 0.5 x secondary energy".

14.2.2 Selection of development scale for comparison

Applying the criteria given in Section 14.1 above, installed capacity for the potential sites is selected as follows:

(Unit: MW)

	SEK-1	SEK-2	K'WIT	MUKOH	KAPIT-2	PASIA	MED-2
Demand in 2010	17.0	17.0	27.0	4.2	4.2	12.4	12.4
Optimized scale*	11.8	21.3	25.1	1.94	8.0	26.2	4.6
Installed capacity selected for further analysis	11.8	17.0**	25.1	1.94	4.2**	12.4**	4.6

Note: * Optimized in terms of lowest kWh cost (See 14.2.1 above)
** Determined to be equivalent to power demand level in year 2010.

14.3 Evaluation of Project Viability

Economic viability of the proposed projects is evaluated in terms of comparing the present worth of costs of hydropower and alternative thermal power.

14.3.1 Hydropower costs

The cost for realization of the projects is estimated firstly on financial cost basis including costs of engineering service, land acquisition/compensation and physical contingency. All the costs are estimated in Malaysian dollars at the mid-1986 price level with a foreign exchange rate of US$1.0 = M$2.6. The estimated construction cost of seven schemes is shown in Table 14.1.

(1) Cost disbursement schedule

The construction work period is assumed to be three and four years for run-of-river type and reservoir type projects, respectively. It is assumed herein for comparison of schemes on a common basis that the construction work will be started in 1991 on the basis of the following schedule of preconstruction activities:

- Feasibility study : Up to April 1988
- Financing arrangement : 1 year up to March 1989
- Detailed design : 15 months up to mid 1990
- Tender and contracting : 6 months up to end 1990