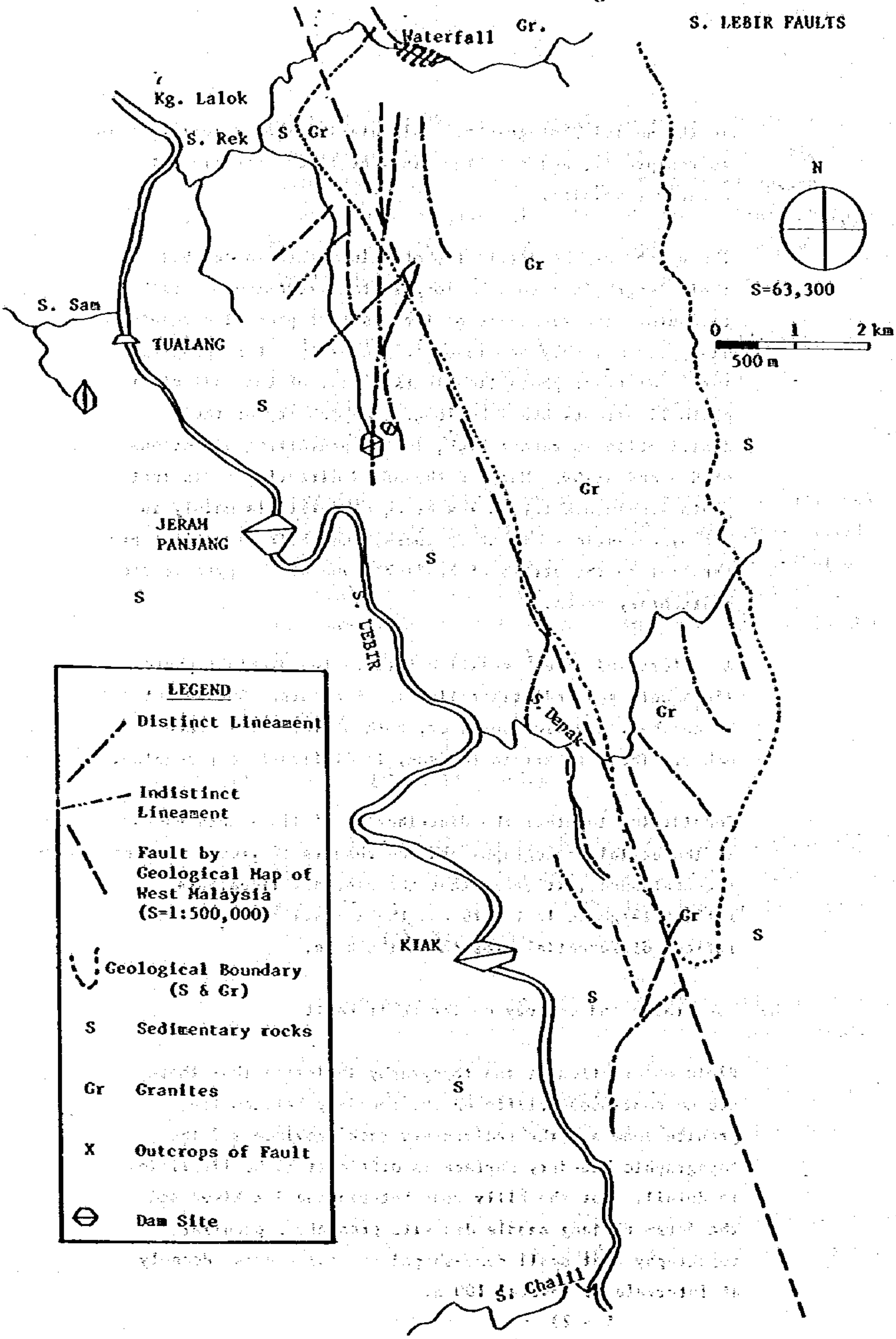
MALAYSIA

INTERIM REPORT
OF
FEASIBILITY STUDY
FOR
THE LEBIR HYDROELECTRIC POWER DEVELOPMENT PROJECT

MARCH 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 5-5 PHOTOLINEAMENT MAP
S. LEBIR FAULTS



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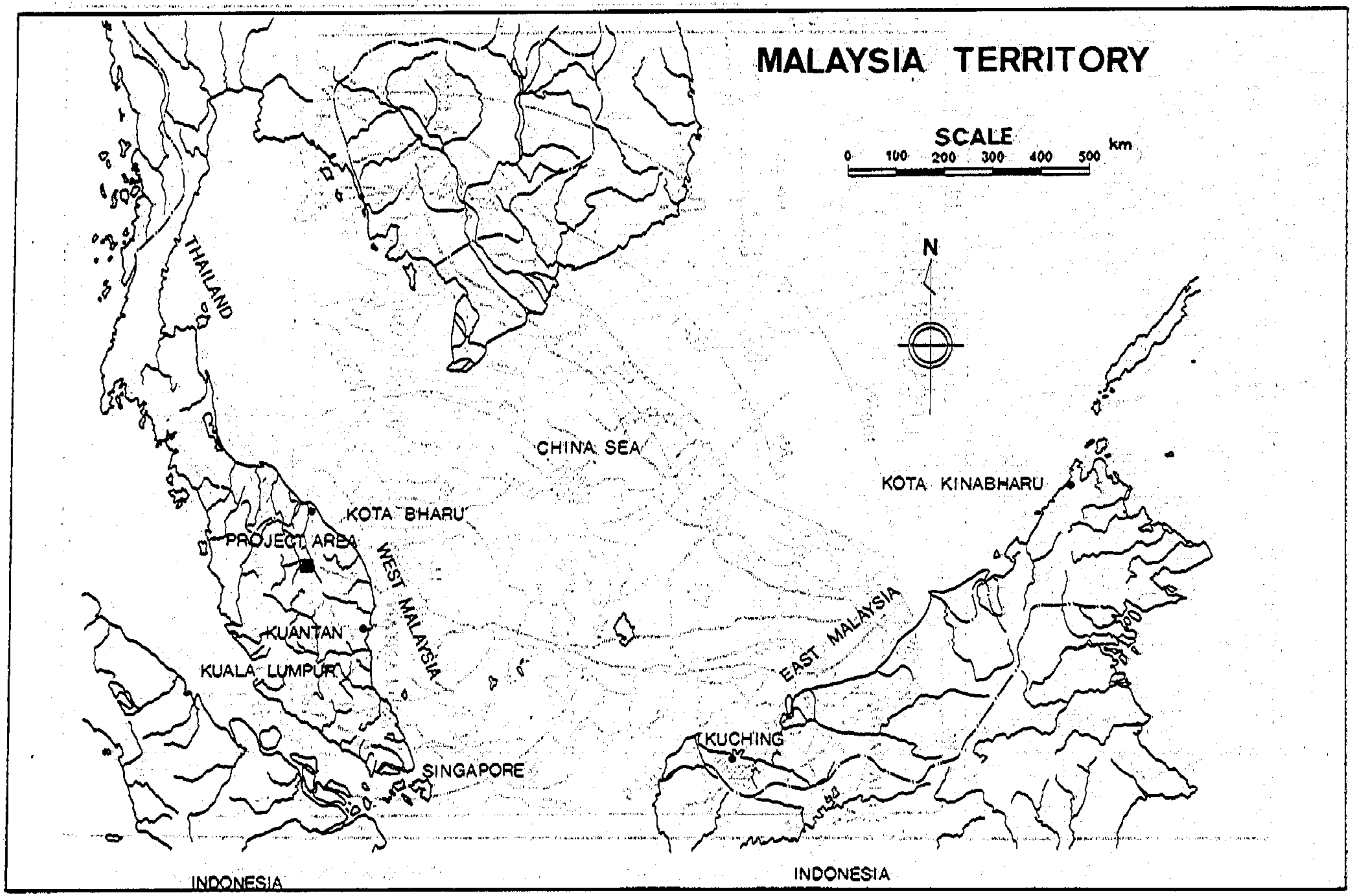
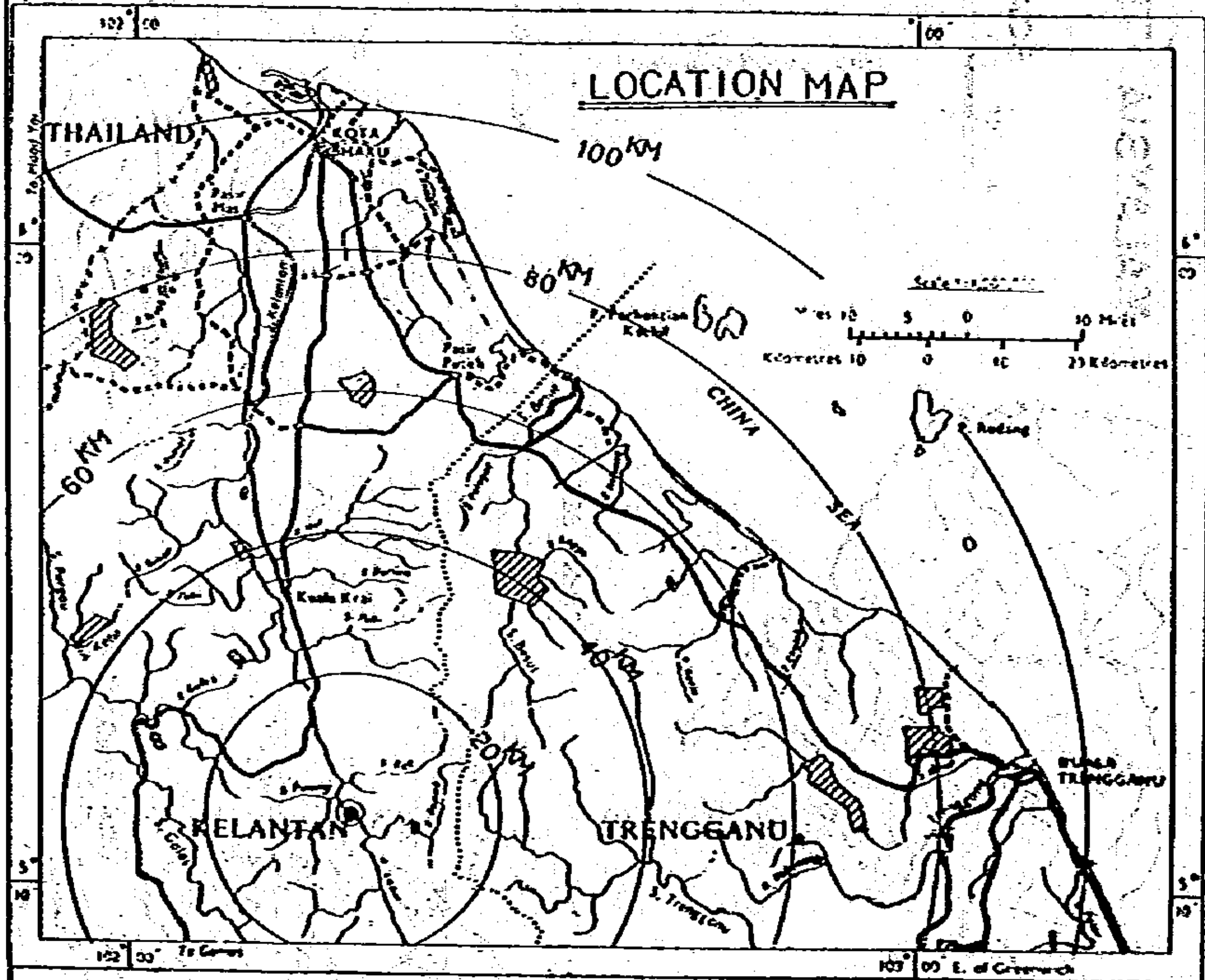
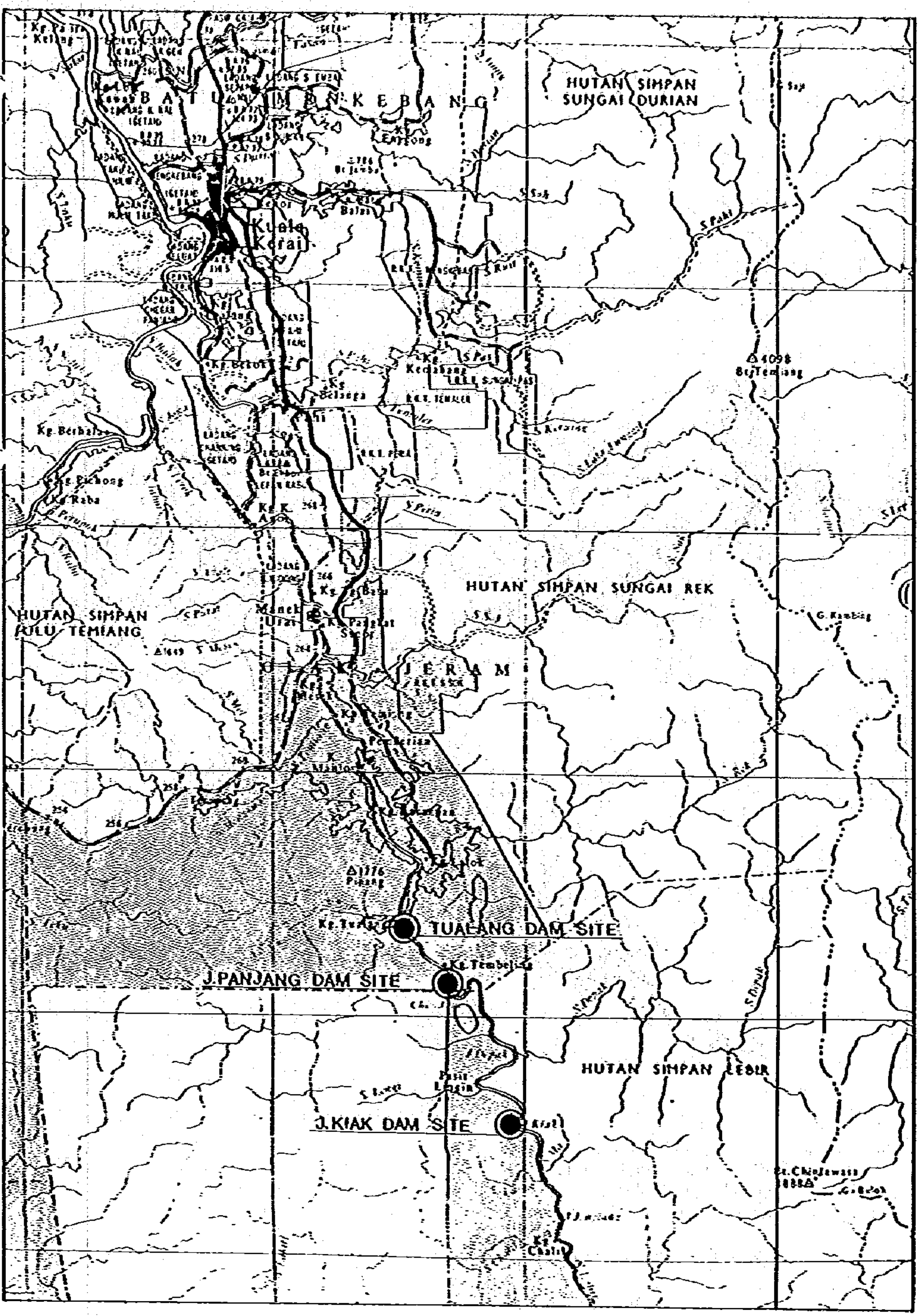
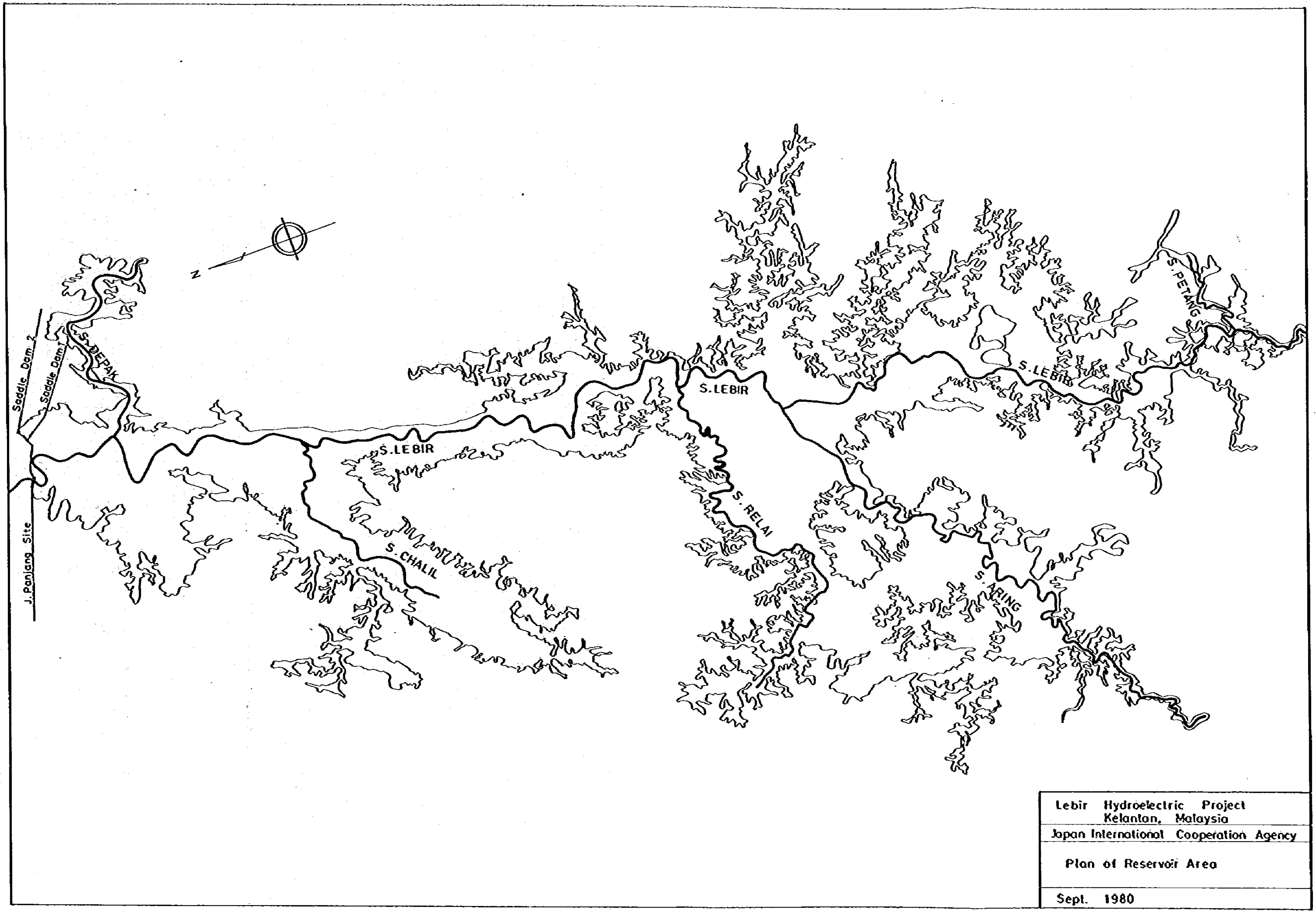

MALAYSIA TERRITORY
SCALE
0 100 200 300 400 500 km
N
THAILAND
CHINA SEA
KOTA KINABHARU
KOTA BHARU
PROJECT AREA
WEST MALAYSIA
KUANTAN
KUALA LUMPUR
SINGAPORE
EAST MALAYSIA
KUCHING
INDONESIA
INDONESIA



LOCATION MAP
THAILAND
KOTA BHARU
100KM
80KM
60KM
40KM
20KM
CHINA
SEA
Kuala Krai
KELANTAN
TRENGGANU
KUALA TRENGGANU
E. of Greenwich


HUTAN SIMPAN
SUNGAI DURIAN
BATU MENGKEBANG
Kuala
Krai
HUTAN SIMPAN SUNGAI REK
HUTAN SIMPAN
HULU TEMIANG
JERAM
TUALANG DAM SITE
J.PANJANG DAM SITE
HUTAN SIMPAN LEBIR
J.KIAK DAM SITE



Lebir Hydroelectric Project
Kelantan, Malaysia

Japan International Cooperation Agency

Plan of Reservoir Area

Sept. 1980

1. Introduction

1.1. Objective of Study

The objective of the Study is to carry out a feasibility study of the Lebir Hydroelectric Development Project on the Lebir River, a tributary of the Kelantan River flowing through the State of Kelantan in the Peninsular Malaysia.

This interim report presents the results of studies done at the Preliminary Investigation Stage which is designed to make a comparative analysis of the three (3) sites identified on the Lebir River, to select an optimum site and to program the detailed field investigation works on the optimum site which will be carried out at the Detailed Field Investigation Stage subsequent to the present stage.

1.2. Scope of Preliminary Investigation Stage

The study at the Preliminary Investigation Stage includes the following:

a) Collection of available data and information relevant to the project, concerning;

   i) Sociological and environmental problems

   ii) Present conditions and programs of the whole river basin development including flood control, water utilization, drainage and land development

   iii) Existing power facilities, load forecast, power source development program and financial and economic conditions

b) Site reconnaissance

i) Comparative study of previous and alternative plans of the project by means of the existing topographic maps 1:63,360.

ii) Site reconnaissance of the alternative dam sites to investigate the topographic and geological features of the dam sites, powerhouse sites, switchyards, quarry sites, and construction roads for the alternative sites.

iii) Siting of hydrological observation stations

c) Preliminary field investigation work

i) Topographic surveys of the proposed sites for main structures including alternative sites and reservoir area.

ii) Preliminary field geological investigations necessary for comparative study of the alternative sites, by seismic prospecting and drilling works.

iii) Investigation of riverbed materials

iv) Installation guidance of hydrological observation stations

v) Flood observation during the rainy season.

d) Optimization of development

i) Selection of the optimum site

ii) Optimization of the development size

iii) Programming of investigations to be carried out at the Detailed Field Investigation Stage

1.3. Outline of Field Operations at the Preliminary Investigation Stage

Immediately after the conclusion of an Agreement on the scope of work for the study between the leader of the JICA Study Team and the Malaysian Government, the study team started collection of available relevant data and information.

The Japanese experts in various specialties including dam, geology, hydrology, civil works, power system, power transmission, economics, environment and agriculture carried out various investigations in Kuala Lumpur and Kelantan for a period of five months from March, 1979 to August, 1979.

On the project site, seismic prospecting was carried out by a local contractor sublet by the Study Team under the technical supervision of the Team's expert from June, 1979 to August, 1979. Simultaneously, preliminary drilling works were carried out at the identified alternative sites of the project by a local contractor sublet by the Study Team under the supervision of the Team's drilling mechanic.

A team of surveyors made field operations from July, 1979 to September, 1979 to carry out levelling at the alternative sites and take aerial photographs of the reservoir area.

As far as flood observations are concerned, the Team's hydrologist was stationed on the site from November, 1979 to December, 1979 in the rainy season to gauge flood discharges.

1.4. Acknowledgements

We wish to acknowledge the grateful cooperation and assistance given during the preparation of this interim report. Instances of individual cooperation are too numerous to mention specifically,

however, the Study Team wishes to thank the following officials;

Director of Infrastructure, Economic Planning Unit, Prime Minister's Department

Staff of Infrastructure, Economic Planning Unit, Prime Minister's Department

Mr. Fong Thin Yiew, Chief Engineer (Civil/hydro), National Electricity Board

Staff of Mr. Fong Thin Yiew, Chief Engineer (Civil/hydro), National Electricity Board

Director of Economic Planning Unit, the State Government of Kelantan

The Study Team would like to express appreciation for the cordial spirit of various government authorities and agencies including;

Survey Department
Drainage & Irrigation Department
Agricultural Department
Geological Survey Department
Federal Land Development Authority
Federal Land Consolidation & Rehabilitation Authority
Games Department

2. Summary and Conclusions

2.1. Background of Project

The project site is located on the lower reaches of the Lebir River, about 100 km south of the City of Kota Bharu, Capital of the State of Kelantan on the north of the east coast of the Peninsular Malaysia and on the border with Thailand. The Project is designed to supply an increasing power load for the Peninsular Malaysia and to promote regional development in Kelantan by the development of water resources.

The formations in the project area consist of sedimentary rocks formed between the late Palaeozoic and the early Mesozoic Periods. Most of the sedimentary rocks are clastic rocks including shale and sandstone, and pyroclastic sedimentary rocks and sedimentary rocks including tuffs and cherts are also distributed at many places in the project area. The weathered bedrocks have two zones of heavily weathered zone and weakly weathered zone of soft rocks and/or cracky hard rocks. The thickness of the two zones is estimated to be about 15 m in the project area. Even the places where fresh rocks are exposed at the riverbeds have the two zones of weathered rocks at higher elevations on the slopes of both banks. The fresh rocks are hard and compact as shown by seismic wave velocities of 3 to 5 km/sec. which were recorded by the seismic prospecting survey team.

The geology of the project area is governed by a large tectonic line traversing the Peninsular Malaysia from NNW to SSE, in which granites underlie Mesozoic sedimentary rocks. The boundary between the granite rocks and the sedimentary rocks appears about 3 km east of the Lebir River and presents a fault zone about 1 km wide. But this fault zone is intermittent and each of the intermittent zones is short in the length. Accordingly, the fault zone is not so large nor serious that it will not pose a crucial problem to the construction of the dam.

The river discharge varies largely according to the season. The annual mean discharge at the Tualang Gauging Station is about 113 m^3/sec.; the discharge for a period of 7 months from February to August is lower than the annual mean value but it exceeds the annual mean value for a period of 5 months from September to January. In February, the monthly mean discharge is lowest (about 68 m^3/sec.), while in December, it becomes a monthly maximum with a mean discharge of 229 m^3/sec. which corresponds to 3.4 times as much as the monthly mean discharge in February. The river discharge for a period of 3 months from November to January forms about 42% of the annual discharge. In contrast, the river discharge for a period of 3 months from February to April corresponds to only 16% of the annual discharge.

The precipitation record observed at Lapan Kabu indicates that the mean annual precipitation is 2,720 mm, of which 1,120 mm occurs in the 3 months of the north-east monsoon season from October to December. This is 41 % of the annual precipitation.

The flood discharge in the river is affected by a precipitation intensity in the north-east monsoon season. The 200-year return period flood at Tualang was estimated by correlative analysis of the flood discharge estimated by the simulation method and the actual record of floods observed at the Guillemard Bridge. In this method, the abovementioned and its specific discharge were estimated to be about 5,800 m^3/sec. and 2.34 m^3/sec./km^2 respectively. The specific discharges of the same return period at Dabong and the Guillemard Bridge in the same river system, which were estimated on the basis of previous study data, are 2.09 m^3/sec./km^2 and 1.78 m^3/sec./km^2 respectively. The estimated specific discharge at the Tualang Gauging Station is higher than those estimated values at Dabong and the Guillemard Bridge, and is proportional to differences among the catchment areas at the Tualang Gauging Station, Dabong and the Guillemard Bridge. (See Fig. 6-8)

The Drainage and Irrigation Department of the Malaysian Government implements 5 drainage projects and 13 irrigation projects designed to alleviate flood damage on the coastal area in the State of Kelantan, to convert swamps there to farmland and to obtain irrigation water necessary to attain more agricultural productivity. These projects will not attain expected effects unless accompanied with improvements in agricultural policy and techniques including intensive agriculture and diversification of planting.

The discharge in the Kelantan River varies largely by season and year, and this results in adverse effects to the agricultural production in the Kelantan River basin. If it is kept in its current natural conditions, water necessary for the increasing water demand for irrigation and conservation of river flow will decrease, resulting in a decline in the progress of the agricultural improvement projects. The reservoir construction schemes including the Lebir Project which are tailored to regulate the river discharges and control floods, hold the key to the success of the irrigation and drainage projects in progress in the State of Kelantan.

The major part of the reservoir area for the Lebir Project is covered with thick forests. Only about 700 people in 120 families live in the reservoir area, and they are engaged in small-scale rubber plantations and farming. The main economic activities in the reservoir area are logging and prospecting of mineral deposits on a small scale. In July 1979, some land development schemes were projected in the proposed reservoir area, mainly in the complex farms of rubber or palm oil plantation. They are the Aring and Lebir Land Development Schemes at the upstream of the Lebir river projected by the Federal Land Development Authority (FELDA) and the Chalil Land Development Scheme around the Chalil river by the Kelantan State Land Development Authority (LKTN). Due consideration of these schemes will be required for the most appropriate development of the Lebir Hydroelectric Project.

The Gua Musang - Kuala Keral highway which is regarded as one of the priority infrastructure projects for regional development, was at construction stage in July 1979 when the field survey of the project was carried out. According to the detailed design, this highway route is aligned to bypass parts of the reservoir area, and a road bridge is to cross the river just on the Tualang Dam Site.

2.2. Identification of Alternative Sites

The Lebir River has a gentle gradient in the river profile. Because of this topographic feature, only dam type hydroelectric power stations can be developed on the river. The valley of the river is rather wide even in the upper headwaters. Potential sites for dam construction are limited in number by the topographic features of the river valley.

From topographic and geologic points of view, the following 3 sites have been identified for comparative studies.

2.2.1. Tualang Site

This site is located furthest downstream among the 3 sites. It is 3 km south of Kampong Lalok. The elevation of the riverbed at the dam site is 16 m above sea level. Both banks from the riverbed to Elevation 40 expose hard base rocks and present a V-shaped valley. As the elevation becomes higher, however, the ground surface exposes weakly weathered fractured rocks and heavily weathered lateritized rocks. At higher elevations, the gradient of the mountain slopes becomes gentle.

This site is narrowest in valley width among the 3 sites, and the volume of the dam required is estimated to be smallest. However, if a fill type dam is constructed on the site, a suitable site for the spillway is not available. Moreover, if the high water level of the reservoir is designed at more than Elevation 40, one saddle dam will be required for construction on the basin boundary with the Sam River, a tributary of the

Lebir River, on the left bank and another 2 saddle dams on the boundary between the Rek River basin and the Pedah River basin.

The catchment area at the Tualang Site is 2,480 km^2, and the gross storage capacity and area of the reservoir will be 4,500 million m^3 and 250 km^2 respectively, if the high water level is designed at Elevation 90. Even if the flood control to 1,000 year return period is made to cut the flood peak discharge of 4,500 m^3/sec. and to reduce the discharge after controlling to almost 50% of natural flood discharge, the surcharge depth will only reach 4.2 m by such flood control, and even if at the dry season such as 30 year return period, the water intake is done so as to keep capacity factor of at least more than 25%, the low water level in the surcharge will be only 9.5 m lower than the normal water level at that return period. In the latter case, the effective water head of 50.2 m can be obtained at the low water level. In the former case, the flood control capacity of the reservoir is estimated at approx. 1,620 x 10^6 m^3.

The ineffective discharge during floodtime is estimated to be only 2.6% of the mean annual inflow. The 10-year return period discharge during drought conditions was only 17 m^3/sec. but it will be increased to 80 m^3/sec. by the regulation of flow with the reservoir. This will make it possible to supply water of more than 63 m^3/sec. during drought periods.

The weathered zones lie deep under the higher elevation on the site. This will inevitably increase the excavation volume required for the dam foundation. Small-scale faults, although they are not serious, exist on the saddle dam site on the right bank. Seismic prospecting done on the saddle dam sites indicates the existence of some zones with a low seismic wave velocity.

2.2.2. Jeram Panjang Site

This site is located at the S-shaped bend of the river stream 3 km upstream of the Tualang Site. It located between the Tualang Site and the Jeram Kiak Site.

The riverbed on the site exposes base rocks, and the river stream has rapids, upstream and downstream of the site. The lowest elevation of the riverbed is 24.0 m above sea level which is higher by 8 m than that at the Tualang Site. Both banks on the site have gentle slopes with a gradient of 15° to 20°. The width of the valley on the site is wider than that on the Tualang Site. Geologically, exposure of base rocks is limited adjacent to the edges of the river stream and the majority of the banks is covered by laterite. But weathered zones at higher elevations on both banks are only 15 m thick.

The topographic feature of this site has a 110 m to 130 m high ridge standing out on the right bank. If a high fill type dam is proposed for construction, a suitable site for the spillway is available and a saddle dam will not be required for construction on the left bank, unlike the Tualang Site.

The catchment area at the dam site is decreased only by 6 km^2 compared to the Tualang Site. The gross storage capacity and area of the reservoir is 4,400 million m^3 and 247 km^2 respectively, which is almost the same as for the Tualang Site. If the high water level is designed at EL.90 m at the flood time, and if the same flood control as made to the Taulang site in Article 2.2.1. is done at such designed high water level, the surcharge water depth will be 6.2 m and the low water level at the dry season will be 10.7 m lower than normal water level. This shows that minimum and maximum effective water heads of 47.1 m and 57.8 m can be developed at this site.

2.2.3. Jeram Kiak Site

This site is about 9 km upstream of the Jeram Panjang Site. The valley on this site is widest, and the weathered zones of the base rocks are thickest. The catchment area on the site will be reduced to 2,290 km^2. While saddle dams will be required for construction for the development of the other 2 sites, a saddle dam will not be necessary for this site.

Base rocks are exposed on the edges of the river stream. The elevation of the lowest riverbed is 26.5 m above sea level which is highest among the 3 sites. The weathered zones on the site are deep, and the weathered zone on the right bank is 20 m or thicker.

If the high water level of the reservoir at the floodtime is determined at EL.90 m. The area of the reservoir will be 217 km^2 with its total storage capacity of 3,560 million m^3, which will indicate 21% reduction in comparison with the volume estimated in the case of Tualang site.

The topographies of the 3 sites and examples of layouts of dams and spillways used for comparative analysis are presented in Figs. 2-1-1 to 2-1-6.

2.3. Comparative Analysis of Alternative Sites

Several types and heights for a dam on each respective site were planned on the basis of the field investigations made at the Preliminary Investigation Stage, including topographic survey, seismic prospecting and drilling work. The costs of various plans of the dam on each respective site were estimated, according to the quantities computed from the layout plans. The costs thus estimated are presented in Tables 2-1-1 and 2-1-2.

These tables show that the construction cost of the dam on the Jeram Klak, which is estimated to produce the least benefit is most expensive and it cannot be reduced to a competitive level compared to the other 2 sites by changes in the design of the dam. The tables also show that if the main dam is of fill type, the dam construction on the Jeram Panjang site will be more economical, and that the construction of a concrete gravity main dam on the Tualang Site will minimize the construction cost of a dam. In comparison with both dam sites, Jeram Panjang Site will be more advantageous in case of large-scale dam where the high water level of the reservoir at the floodtime is fixed at EL.90 m, while, Tualang Site will be more economical in case of small-scale dam where the high water level is designed at EL.70 m. For the determination of priority of dam site, comprehensive study will be required in consideration of power benefit, flood control benefit, agricultural benefit, etc.

Following the above comparison in the construction costs of the dams, the cost-benefit analysis of the two alternative sites was carried out using the method described overleaf.

First, the alternative construction costs for each of the Tualang Site and the Jeram Panjang Site were estimated with the dam height and generating capacity varied. And the alternative outputs at each of both sites were computed with the maximum discharge varied on the basis of the 30-year monthly discharge record, maintaining the minimum plant factor at 25%. In the computation, the flood control benefit and the irrigation benefit in addition to the power benefit were taken into account. The irrigation benefit was assumed to accrue from a decrement of damage to the future agricultural production by the irrigation and drainage projects in progress on the coastal area, which will attribute to the water supply from the Lebir reservoir during drought periods and an increment in agricultural income owing to the introduction of ultimate crop patterns which will be accelerated by the water supply from the same reservoir during the drought period.

The correlation between the damages caused by actual floods at the coastal area and the flood peak discharge at the Guillemard Bridge was obtained to determine flood control benefit. In addition, the estimated flood peak discharges at the Guillemard Bridge with and without Lebir Dam were also obtained respectively by means of discharge model of Kelantan river system. The estimated flood damage mitigation by each probability flood discharge was calculated by dam controlling from the above correlation obtained.

These mitigated values were converted to the annual expected values calculated based on the non-excess probability of floods. These values were applied to the flood control benefit for the Lebir Dam.

Determination of the high water level of the reservoir will have the big influence on the land development schemes projected at the Aring, Lebir and Chalil areas. Therefore, deliberate adjustment with these schemes will be needed as the Lebir Project progresses in the near future. These factors, however, were not considered in benefit-cost analysis, because the schemes were still at the unofficial stage of project planning as of July 1979.

The Gua Musang - Kuala Kerai Highway is proposed to pass parts of the reservoir at the valleys of the Lakit River and the Bayol River which are the tributaries of the Chalil River. If the highway route is removed to higher elevation in the west, the inundation of parts of the highway will be avoided. Accordingly, the cost of removal was not included in this cost-benefit analysis. But the relocation of two road bridges and construction of a 3.6 km roundabout route will be indespensable for the construction of the dam at the Tualang Site. These costs were added to the cost for the Tualang Site.

Compensation for resettlement of the residents residing in the proposed reservoir, costs of relocation of the logging roads and losses of forests resulting from the inundation were not included in the cost of this study.

Table 2-2 presents the cost-benefit ratio and surplus benefit computed using the above method for each of the alternative development plans by site and development size.

2.4. Conclusions

The following are our conclusions on the selection of an optimum project site which is the objective of the Preliminary Investigation Stage.

a) The Jeram Panjang Site is the most recommendable site for further detailed studies among the 3 identified sites. The optimum plan of the project at Jeram Panjang is the construction of a 69.5 m high fill type dam with the reservoir high flood water level designed at EL.90. Required in association with the main fill type dam is the construction of two saddle dams on the right bank.

b) The annual energy production of the optimum plan at Jeram Panjang will be 426 GWh with a capacity factor of 32 %. Its maximum output and firm output will be 151 MW and 137 MW respectively.

c) An increment in the river discharge during the drought period will result from discharge regulation from the reservoir and will be about 63 m^3/sec. This will increase the agricultural production on the area downstream of the Jeram Panjang Site for an amount of M$14.2 million per annum.

d) With the construction of the dam at Jeram Panjang, an area of 100 km^2 out of the total project area for the Aring, Lebir and Chalil Land Development Projects will be submerged. A forest area of 150 km^2 will also be inundated.

e) The cost-benefit ratio of the optimum plan of the Jeram Panjang Project including only the power benefit is calculated to be 1.32 at a rate of interest of 8 %, and its cost-benefit ratio is increased to 1.63, if the agricultural benefit is taken into account. The internal rate of return of the optimum plan including the agricultural benefit is calculated to be about 13.0 %.

f) Expected annual cost benefit of the flood mitigation will be Malaysian Dollars 2.1 million. This cost benefit is equivalent to 35 percent of the damage in the case of without dam, it means that 1/3 of the past annual flood damage will be mitigated.

g) The discharge volume of the natural river in the dry season can be increased to 80 m^3/sec. by the discharge control effects of dam. This is equivalent to 80 percent of the demanded agricultural water for the coastal area in the dry season. This will have influence upon the agriculture, and promote the conversion of the ultimate crop and further development of agricultural improvement. Annual agricultural profit can be expected Malaysian Dollars 14.2 million as an income increase, if the agricultural improvement can be attained 6 years ahead.

h) The environmental impact caused by the construction project will be settled properly, if adequate measures are taken.

i) A technical problem remains on small-scale faults on the saddle dam site on the right bank. Great care should be given to the small-scale faults in further studies. Considering the fact that they were formed at an old era and receive relithification, they will not pose a serious problem to the project.

The above demonstrates that the project will be feasible technically and economically. Although the economics of the project are not so high, the project will bring many intangible benefits which will serve to increase the economics, if quantified.

Resettlement problems incidental to the creation of the reservoir will not be so serious. Other development projects in the project area are just before implementation but still at the stage of planning and design. The development of the project can be planned in the most effective manner, keeping a close coordination with those development projects.

The plan of the Jeram Panjang site development recommended at this stage is summarized in "Main Feature of Tualang and Jeram Panjang Site" following next page.

Main Feature

Item	Tualang	Jeram Panjang
1. Summary		
H.W.L.	90 m	90 m
N.W.L.	85.8 m	83.8 m
Type of Dam	Concrete Gravity	Rockfill Type
Dam Height	77.5 m	69.5 m
Type of Development	Dam-Conduit Type	Dam-Conduit Type
Catchment Area	2,480 km^2	2,474 km^2
Gross Storage Capacity of Reservoir	4,495 x 10^6 m^3	4,397 x 10^6 m^3
Effective Storage Capacity	1,576 x 10^6 m^3	1,563 x 10^6 m^3
Surcharge Storage Capacity	949 x 10^6 m^3	1,350 x 10^6 m^3
Maximum Water Surface Area of Reservoir	250 km^2	247 km^2
Gross Head	60.98 m	57.75 m
Effective Head	59.43 m	55.77 m
Maximum Discharge	320 m^3/s	320 m^3/s
Maximum Output	162 MW	151 MW
Firm Peak Output	151 MW	137 MW
Annual Generated Energy	455 GWh	426 GWh
2. Catchment Area	2,480 km^2	2,474 km^2
3. Stream Run-off		
Annual Average	113 m^3/s	113 m^3/s
Droughty Discharge	30.4 m^3/s	30.3 m^3/s
Flood (Return Period, 1,000 years)	9,700 m^3/s	9,700 m^3/s
4. Plant Discharge		
Maximum Discharge (for 6 hours of daily-peaking at least)	320 m^3/s	320 m^3/s
Firm Discharge	80 m^3/s	80 m^3/s
Firm Peak Discharge	320 m^3/s	320 m^3/s

Item	Tualang	Jeram Panjang
5. Head		
Normal Water Level	85.8 m	83.8 m
Low Water Level	76.7 m	73.1 m
Available Depth	9.1 m	10.7 m
Tailrace Water Level	24.82 m	26.05 m
Gross Head	60.98 m	57.75 m
6. Generating Plant		
Number of Plants	2	2
Maximum Output	162 MW	151 MW
Firm Peak Output	151 MW	137 MW
Annual Generated Energy	455 GWh	426 GWh
Plant Factor	32.06 %	32.21%
7. Reservoir		
Gross Storage Capacity	$4,495 \times 10^6$ m^3	$4,397 \times 10^6$ m^3
Effective Storage Capacity	$1,576 \times 10^6$ m^3	$1,563 \times 10^6$ m^3
Surcharge Storage Capacity	949×10^6 m^3	$1,350 \times 10^6$ m^3
Maximum Surface Area	250 km^2	247 km^2
8. Dam		
8.1. Main Dam		
Type	Concrete Gravity	Rockfill Type
Height	77.5 m	69.5 m
Crest Length	370 m	645 m
Dam Slope on the Upstream Side	0.1	1 : 2.2
Dam Slope on the Downstream Side	0.75	1 : 1.85
Dam Volume	495,000 m^3	4,579,000 m^3
Elevation of Dam Crest	93.5 m	93.5 m
8.2. Saddle Dam No. 1		
Type	Rockfill Type	Rockfill Type
Height	67.5 m	67.5 m
Crest Length	370 m	370 m

Item	Tualang	Jeram Panjang
Upstream Side Slope	1 : 2.2	1 : 2.2
Downstream Side Slope	1 : 1.85	1 : 1.85
Dam Volume	990,000 m^3	990,000 m^3
Elevation of Dam Crest	93.5 m	93.5 m
8.3. Saddle Dam No. 2		
Type	Rockfill Type	Rockfill Type
Height	33.5 m	33.5 m
Crest Length	220 m	220 m
Upstream Side Slope	1 : 2.2	1 : 2.2
Downstream Side Slope	1 : 1.85	1 : 1.85
Dam Volume	119,000 m^3	119,000 m^3
Elevation of Dam Crest	93.5 m	93.5 m
8.4. Saddle Dam No. 3		
Type	Rockfill Type	
Height	58.5 m	
Crest Length	700 m	
Upstream Side Slope	1 : 2.2	
Downstream Side Slope	1 : 1.85	
Dam Volume	2,524,000 m^3	
Elevation of Dam Crest	93.5 m	
9. Spillway		
Type	Gate Operation	Free Overflow
Width	62 m	160 m
Stilling Basin	Flat Apron Dissipator	Skijump Type
Gate Type	Radial Gate (10 m x 16 m)	-
Gate Number	5	-
10. Intake		
Type	Side Intake	Side Intake
Width	14.5 m	14.5 m

Item	Tualang	Jeram Pajang
Number of Units	2	2
Depth	30.5 m	33.5 m
Maximum Discharge	160 m^3/s	160 m^3/s
Maximum Velocity	0.8 m/s	0.8 m/s
Gate	Steel Roller Gate and Stop Log	Steel Roller Gate and Stop Log
11. Penstock		
Type	Stiffened Steel Penstock Covered Reinforced Concrete	Stiffened Steel Penstock Covered Reinforced Concrete
Number of Lines	2	2
Pipe Length	164.9 m	361.8 m
Internal Diameter	5.8 ∿ 4.5 m	6.2 ∿ 4.1 m
12. Power Station		
Type	Semi-Underground Type	Semi-Underground Type
Dimension	52 m x 28 m	52 m x 28 m
Foundation	Barrel Type	Barrel Type
13. Tailrace		
Type	Open Flow Channel	Open Flow Channel
14. Hydraulic Turbine		
Type	Vertical Shaft Francis Turbine	Vertical Shaft Francis Turbine
Maximum Output	81 MW	75.5 MW
Number of Units	2	2
15. Generator		
Type	3-Phase AC Generator	3-Phase AC Generator
Output	88,000 kVA/unit	82,000 kVA/unit
Voltage	13,200 V	13,200 V
Number of Units	2	2

3. Gathered Data

Most of the data and information used for the various kind of studies in this Report have been gathered by the Study Team during a period of March 1979 to August 1980, in cooperation with the relative authorities of Federal Government and the State of Kelantan, Malaysia. The gathered data and information include hydrological, meteorological, topographic, geological data, etc. In addition to these basic data, the Survey Team have collected other necessary data concerning land development, power transmission, financing, economics and agriculture. All gathered data are enumerated in the appendix.

The Study Team gathered during the Preliminary Investigation Stage the previous studies and data relevant to the project.

Number and location of stations show Fig. 3-1.

4. General Description of the Project

4.1. Location of the Project

The project is located on the lower reaches of the Lebir River, a tributary of the Kelantan River whose catchment area makes up 85% of the total area of the State of Kelantan bordering on Thailand.

The project site is about 230 km north-north-east of Kuala Lumpur, Capital of Malaysia and 100 km south of Kota Bharu, the State Capital.

The project site lies in the Ulu Kelantan District whose administrative center is Gua Musang. A city nearest to the site is Kuala Keral at the confluence of the Lebir River and the Galas River which is about 30 km north of the project site.

4.2. Topography of Project Site

On the south of the Kelantan River basin lies the Central Mountain Range with 1,000 m to 2,000 m high mountains, having Mt. Gunong Tahan as its peak summit. On the east side, the coastal mountain range including 1,000 m high mountains draws a line on the border with the State of Trengganu, and on its west the 500 m high mountain range divides the Kelantan River basin and the Golok River basin. Only the north is open to the South China Sea. The Kelantan River Basin encompasses an area 60 km from the east to the west and 130 km from the south to the north.

The Kelantan River system is divided into the mountainous part of the river basin and its plain. The mountainous part of the river catchment includes the Galas River basin, Pergau River basin and Lebir River basin. In the plain part of the river basin the name of the river is changed into the Kelantan River, after the Galas River and the Lebir River join, and the Kelantan River meanders gently over a wide alluvial plain and flows into the South China Sea near Kota Bharu.

The Lebir River flows in the east edge of the mountainous part of the Kelantan River System. It originates from the Taman Negara (the National Park) stretching over the northern foot of the Central Mountain Range. The Lebir River consists of the main stream, Aring River, Chalil River, Depak River and Sam River with a total catchment area of 3,400 km^2. On the east of its catchment area lies the Coastal Mountain Range, and the river basin is separated from the Galas River by a range of about 300 m high dome-shaped mountains on the west of the catchment area.

The Lebir River is very gentle in its riverbed gradient; on the lower reaches of 150 km out of the total stream length 200 km, the mean riverbed gradient is 1/4,500, the valley is wide, and the mountain slopes of both banks are very gentle.

The river flows down from the south-south-east to the north-north-west, almost in parallel with the Coastal Mountain Range with repeated small meanders. The river stream has rapids called "Jeram" in many places which are formed by the damming of exposed riverbed rocks. The velocity of the river stream between one rapid and another rapid is very slow, but only a few sand bars are developed on both banks. The direction of the river stream is consistent with a long synclinal axis of more than 500 km in length from Kota Bharu to Singapore out of the fold axis traversing the Peninsular Malaysia. The long synclinal axis consists mainly of sedimentary rocks formed from the late Palaeozoic era to the early Mesozoic era. The Coastal Mountain Range and the mountains on the west of the river basin which put the long synclinal axis in the middle consist of granite rocks which intruded in the Mesozoic. Judging from a mode of the distribution of rocks in the project area, the geological structure is presumed to belong to the Orogenic zone. In view of the fact that no Cenozoic stratum exists in the area, the time of the Orogenic movement was rather old and is considered to be the Variscan Orogeny age. The mountains in the area present a topographic feature of old age with rare precipitous slopes and the area has a wide alluvial coastal plain. This topographic feature indicates the mechanism of a cycle of erosion that the area became land in the Mesozoic era and its surface has been eroded for a long time.

Exceptionally to the general topographic feature as mentioned above, a gorge with rather steep slopes on both banks and a narrow valley continues for a distance of about 10 km from Jeram Kiak to Tualang via Jeram Panjang, which is about 50 km upstream of the confluence of the Galas River and the main stream of the Lebir River. The dam site for the project was located in this gorge.

4.3. Profile of the State of Kelantan

The State of Kelantan has a total area of 14,900 km^2, 75 % of which are forests. The coastal alluvial plain which forms 20 % of the total area is cultivated intensively.

The farming land including that in the mountainous area is about 3,200 km^2. The share of its agricultural product is rubber 45 %, aquatic rice 33 %, horticulture 18 % and palm oil 4 %.

The total population is estimated to be 840,000, 90 % of which live in a concentration on the northern coastal area. The wide mountainous area on the south is less populated. The density of population in the coastal area is 200 persons per km^2, while it is only 8 persons per km^2 in the Ulu Kelantan District on the southern part. Most of the people reside at kampong (villages) and only 15 % of the total population live in towns of more than 10,000 residents. The population of the state capital, Kota Bharu is

105,800, but the population of Pasir Mas, the second biggest city in the State, is 15,000 or less.

Malays form 92.4 % of the total population, Chinese 5.6 % and Indian and others 2.0 %.

The increase rate of population is 2.4 % per annum which is less than the 2.6 % of the mean rate of increase for the whole country. The remarkable pattern of the population problem is that outflow of the population to other states is very much large, attributable to small job opportunities inside the State. As a matter of fact, the statistics indicates that at least 55,700 persons emigrated to Singapore from 1957 to 1970.

The main economic activity in the State is agriculture; 38.9 % of G.D.P. of the State is agriculture, which is higher than the 24.8 % mean percentage for the whole country. The share of other manufacturing industries in the G.D.P. in the State of Kelantan is as low as 7.9 % which do not reach even half of 19.1 % of the average rate in the whole country. The agricultural population exceeds 62 % of the total population which is very much higher than the servicing job population of 28 % and the manufacturing industry population of 10 %. The farmland suffers from yearly flood damage. The farmers abide by traditional farming techniques with a low productivity dependent on natural rainfall. The rate of unemployment in the State is high and is said to be 8 % or more.

The per capita G.D.P. based on the 1970 price was M$463 in 1970, M$545.00 in 1975 and M$630.00 in 1978, with an annual rate of increase of 4 %. As compared with the mean value of G.D.P. in the whole country, the per capita G.D.P. in 1975 in the State of Kelantan was only 39 % of the mean per capita G.D.P. for the whole country and 38 % in 1978, which shows that the progress of the State of Kelantan is lacking.

The main reason for such less development is a historical condition that the State of Kelantan is less blessed with natural resources than the other states on the west coast and a focus was not highlighted on the development of this State. Geographically, it is located farthest from the economic centers of the country, including Kuala Lumpur. Counted as other reasons are the unstable economic base attributable to yearly floods, insufficiency of arable land restricted by soil conditions and topography, incompleteness of infrastructure for development including roads, harbours, and electric power supply, and ineffective farming methods resulting from dense cultivation of farmland on the coastal area.

The New Economic Plan of Malaysia drawn out in 1971 is aimed at eradicating poverty and the imbalance of wealth among the regions and races. Importance in the policy is given to the development of less developed states including the states on the east coast of the Peninsular Malaysia and the States of Sabah and Sarawak to better the income level of residents in those states. In order to achieve this objective, increase in income, expansion of job opportunities and an increase of social services are laid as the base for development planning.

The agricultural policy laid for the State of Kelantan seeks the improvement of agricultural productivity and a resultant increase of income would be achieved by flood control, diffusion of new agricultural techniques, introduction of improved seeds, application of fertilizer and improvements in the marketing of agricultural products. The development of the southern part of the State focuses attention on the expansion of farmland by land development works and an increase in traffic inside the State, and to other states, by construction of roads. The correlated industries to agriculture and forestry, mining and tourism are intended to be promoted for the development of manufacturing industries in the State.

The construction of a network of roads including the East-West Highway is planned so as to enlarge the infrastructure in order to attract the above manufacturing industries at Tanah Merah, Gua Musang and Penkalan Chepa. Improvements in transport, storage methods and sales markets are devised to facilitate smooth sales of agricultural products. The development policy of the State of Kelantan also includes the promotion of fisheries by an improvement in techniques of inshore fishing and marketing.

To facilitate the realization of the basic development policy of the State of Kelantan as mentioned above, many regional development projects are planned or being investigated or are being put in implementation. Particularly a master plan entitled "Kelantan River Basin Study" was completed in 1977 with technical assistance granted by the Government of New Zealand and approved in 1979 by the Malaysian Government. This study report provides a general guideline for the regional development.

This study report recommends that the goal for the economic development of the State of Kelantan is to alleviate periodic floods and develop abundant water resources for productive purposes. Periodic floods caused by heavy rains will become a minimum with the construction of a drainage system. Flood overflow will be mitigated by the construction of two reservoirs at Dabong and Lebir with embankments along both banks on the lower reaches of the Kelantan River.

The North Kelantan Rural Development Project is carried out on the Kelantan plain with IBRD finance. This project is designed to drain and irrigate the Lemal district on the left bank furthest downstream of the Kelantan River.

The Water Management Training Center which was constructed with technical assistance from the Japanese Government is in full activity.

The 13 irrigation projects proposed in the Kelantan River Basin Study are in contemplation for implementation by the Federal Government and the State Government of Kelantan (See Fig.4-1). The development schedule of those projects provided by the Malaysian Government is presented in Fig.4-2.

In the same report, the agricultural production is estimated to be 4.1 times as much as the present level, on the completion of the proposed projects. (See Table 4-1).

The extent of flood mitigation after the completion of the proposed projects is shown in Table 4-2. With the completion of the irrigation and drainage projects, the benefit will be increased by about 60 %.

In addition to those effects, the proposed projects will produce large social benefits including increases in the income of farmers and employment which will result in a break from the present low productivity.

4.4. Power Situation in Malaysia

4.4.1. Power Load and Supply in the Peninsular Malaysia

The power consumption in the Peninsular Malaysia in the fiscal year of 1977 to 1978 (Sept. 1977 to Aug. 1978) was 6,991 GWh.

The distribution percentage of power consumption was tin mining 14.53%, iron ore and bauxite mining 0.07 %, cement 3.03 %, commerce and industry 62.37 % and lighting and residential use 20.00%. The percentage of power consumption by tin mining was about 15 %, and it has decreased gradually. However, power consumption for industrial use has a tendency to increase.

The annual generated energy in the same period was 6,384 GWh, 94.9 % of which was generated by Public Utilities, about 0.7 % by generating facilities attached to tin mining and 4.3 % by generating facilities owned by other private companies. The distribution percentage of the generated energy was steam power 81.6%, diesel 7.3 % and 11.1 % hydro.

4.4.2. Power Load and Supply of NEB

The rate of growth of power demand supplied by National Electric Board has shown a high constant rate of about 14.1 % per annum except in the 1950's, 14.0 % in the 1960's, 13.7 % per annum for a period of 8 years from 1970 to 1978 and 11.2 % in a fiscal year of 1977 - 1978.

The units sold in a fiscal year of 1977 to 1978 by the National Electric Board were 5,929 GWh. The sent-out energy in the same fiscal year was 6,651 GWh, 97.4 % of which were sent out by NEB with the component percentages of steam power 82.9 %, diesel power 3.2 %, hydro 11.2 % and other 0.1 %, and 2.4 % by the Perak Electric Power Co.

Number of Consumers

At the end of the fiscal year for 1964 - 1965, which was the initial fiscal year of NEB after its inaugration, the number of consumers was 314,000, and it increased to 1,013,000 in the fiscal year for 1977 - 1978 which corresponds to about 3.2 times as much as the number of consumers in the first fiscal year. The fiscal years of 1976 recorded the respective remarkable growth rates of 19.2 % as compared to the number of consumers in the respective preceding years but after that the increase rates of this figure had kept on 10% level.

Energy Consumption per Consumer

Energy consumption per consumer in 1965 was 3,410 KWh, and it was increased to 5,859 kWh in a fiscal year of 1977 - 1978. In the 1950's the energy consumption per consumer was about 3,000 kWh, but in 1960's it revealed rapid increase. Annual average increase rate of energy consumption is shown as approx. 3.6% for the duration of 17 years from 1961/62 to 1977/78.

Classification of Sold Energy

55.7 % of the total sold energy in the fiscal year for 1977 - 1978 was for industrial use, 28.0 % commercial use, 14.2 % domestic use and 2.1 % other uses.

Power Rate per kWh

The mean power rate in a fiscal year of 1977 to 1978 was 10.84 cents/kWh. In the fiscal year for 1972 to 1973, the mean power rate was maintained at the minimum level of 7.53 cents/kWh but it has risen in a steep curve since the fiscal year for 1973 to 1974. Fig.4-3 shows that an increase in the power rate exceeds a rise in the consumers' price in recent years.

Power Demand by Region

The regional distribution of power demand and energy consumption per capita by region are presented in the following table.

Region / Item	Central Region	Northern Region	Southern Region	Eastern Region	Total
Sold energy (%)	40.7	38.0	16.7	4.6	100
Consumed energy per capita (kWh)	1,237	1,040	532	266	846 (Mean value)
Percent to mean value (%)	146	123	63	31	100

The majority of the power demand concentrates in the Central Region (40.7 %) and the Northern Region (38.0 %). The mean annual energy consumption per capita in the Peninsular Malaysia in a fiscal year of 1977 - 1978 was 846 kWh, and the annual energy consumption per capita in the Central Region was 1.46 times as much as the mean annual energy consumption while the Eastern Region occupies only 31 % of the mean annual energy consumption per capita.

Load Characteristics

a) Monthly Characteristics of Load

The monthly load in the Peninsular Malaysia has no seasonal variation and increases from the beginning of the year to the end of the year; the maximum load in the year appears in August which is the last month in the fiscal year. The monthly daily load curve in the Western Transmission Network which occupies a greater part of the power load is shown in Fig.4-4.

b) Daily Characteristics of Load

A typical daily load curve in the Western Transmission Network is shown in Fig. 4-5. This figure indicates that the load comes to the peak three times per day, at 11 am, 3 to 4 pm and 7 to 8 pm, and the maximum peak load appears at 11 am. It also shows that the base load corresponds to about 69.5 % of the peak load and the industrial load in the daytime shares a large weight in the load curve.

In contrast, a typical daily load curve in local areas supplied mainly by diesel engine generators is presented in Fig. 4-6. This figure shows that the peak load appears only one time at 8.00 pm and the base load is only 50 % of the peak load, because the lighting load at night shares a larger weight in the load.

The components of power supply capacity in a fiscal year of 1977 to 1978 were steam power 82.9%, diesel 3.2 %, and hydro 11.2 % owned by NEB, hydro 2.4 % owned by the Perak Electric Power Co., and others 0.2 %.

The supply capability of hydro power comes to a peak in October which is 1.75 times as much as the annual mean hydro power supply capability and comes down to the minimum in February which is equivalent to 0.62 % of the annual mean hydro power supply capability. Generally, the hydro power supply capability is above the mean value from October to January and comes down to lower of the mean value after February except May.

4.4.3. Generating Facilities

The generating capacity owned by NEB at the end of August, 1978 consists of thermal power 970 MW, hydro power 352.4 MW, diesel power 97.4 MW and gas turbine 20 MW which amount to 1,439.8 MW in total. Out of this total capacity, almost 95 % is inter-connected to the Western Transmission System. The main power stations are listed in Table 4-3. Annual increases in the generating capacity are shown in the following table.

Generating Capacities
(MW)

	Steam	Hydro	Diesel	Gas	Total
1971 - 72	420	265.4	39.6		725.0
1972 - 73	420	265.4	47.8		733.2
1973 - 74	540	265.4	48.9		854.3
1974 - 75	540	265.4	57.2		862.6
1975 - 76	850	265.4	72.5		1,187.9
1976 - 77	970	265.4	81.0		1,316.4
1977 - 78	970	352.4	97.4	20.0	1,439.8

4.4.4. Transmission and Substation Facilities

The transmission lines owned by NEB as of August, 1978 consist of 275 kV, 231 miles, 132 kV, 959.62 miles and 66 kV, 336.49 miles. As shown in Fig.4-7, the main power stations and substations on the west coast are interconnected with Kuantan on the east coast by a 132 kV transmission line. Electric power generated by the Port Dickson Steam Power Station is transmitted to Kuala Lumpur and Malacca on a 275 kV transmission line. Electric power generated by the Temenggor Hydro Power Station is transmitted to Papan by means of a 275 kV transmission line.

As of August, 1978, the number of substations owned by NEB is 5,264 and their capacity amounts to 8,146 MVA.

The yearly expansion of transmission and substation facilities of NEB is demonstrated in the following table.

Year	Transmission Route Length (mile)			Substation	
	275 kV	132 kV	66 kV	Number of substations	Transformer capacity (MVA)
1971 - 72	45.3	584.87	311.13	2,831	3,488
1972 - 73	45.3	607.14	311.13	3,047	4,323
1973 - 74	45.3	607.14	326.55	3,352	4,764
1974 - 75	98.0	613.84	333.47	3,133	5,277
1975 - 76	98.0	693.53	333.47	4,346	6,091
1976 - 77	137.0	894.65	338.97	4,760	6,752
1977 - 78	231.0	959.62	336.49	5,264	8,146

4.4.5. System Expansion Plan

The power load is forecast to increase by about 115 MW every year until 1980, about 200 MW annually from 1980 to 1981 and about 152 MW annually from 1982 to 1986.

To supply the increasing load, additional capacities of steam power 1,100 MW and hydro 592 MW, totalling 1,692 MW are planned for development by the end of August, 1986 (see Table 4-4).

This generation expansion plan is shown in Fig. 4-8. Keeping in pace with the generation expansion plan, a 275 kV interconnecting line linking Tanah Merah - Temenggor - Papan - Port Dickson - Malacca is scheduled to be placed in service by 1985. At the same time, an interconnecting transmission line connecting Tanah Merah - Kuala Trengganu - Kuantan - Awah Village will be completed. Thus, a trunk line in the Peninsular Malaysia will be linked by 275 kV or 132 kV transmission lines.

4.4.6. Role of the Lebir Hydroelectric Project

As far as the Lebir Project is concerned, NEB wants to have more precise data and information on the output of Lebir, particularly annual energy production and the firm capacity in a drought year. The economics of the Project is closely related to the annual energy production. But NEB is more concerned about the firm output of the project, in the light of a recent shortage in power supply caused by a severe shortage of water.

Electric power generated at Lebir is proposed to be transmitted to Tanah Merah and Kota Bharu. NEB plans the erection of a 275 kV transmission line between the power station and Tanah Merah, considering the future tie with the Nenggeri Power Station to be developed, following the Lebir one.

5. Geology

5.1. Topography and Geology of the Kelantan River Basin

Most of the mountain ranges, streams of main rivers, axis of a fold and the distribution of rock formations over the whole of the Peninsular Malaysia are toward northnorthwest to southsoutheast. The northnorthwest to southsoutheast direction is called hereinafter "N direction".

5.1.1. General Topography

(1) The topographic and geological section map of the Kelantan River Basin is shown in Fig.5-1. As shown therein, a large backbone mountain range on the eastern part and another backbone mountain range on the western part stretch in the N direction. An intermediate zone between both mountain ranges presents a hilly land of low elevation 40 km wide in the east to the west and 140 km long in the south to the north. This intermediate zone is called hereinafter "Central Hill Zone".

The Central Hill Zone continues southnorth over the Kelantan State and the Pahang State. A mass of mountains with elevation 1,000 m to 2,000 m lies on the boundary area between both states. The Kelantan River basin extends north of those mountains.

(2) The boundary between the coastal plain and the backbone mountains presents a distinct transition of the topography from the plains to the inclined land. The area on the north edge of the Central Hill Zone, on the boundary between the coastal plain and the Central Hill Zone presents an unclear topographic transition with less undulation and gentle slope.

(3) On the Central Hill Zone there exist alternatively dome-shaped small mountains and mountainous platforms. The elevation of summits of dome-shaped small mountains is 200 to 300 m and the elevation of mountainous platforms is less than 100 m. Those elevations are almost constant over the Central Hill Zone.

(4) The Central Hill Zone is almost level, if it is considered as a single block, and its general slope is very gentle. For instance, the elevation at Kuala Keral is about 20 m and the elevation of riverbed at the Lebir dam site is 18 - 27 m.

(5) The Lebir River flows along the east edge of the Central Hill Zone and the Galas River along its west edge. Both rivers meander but their streams tend generally toward the M Direction.

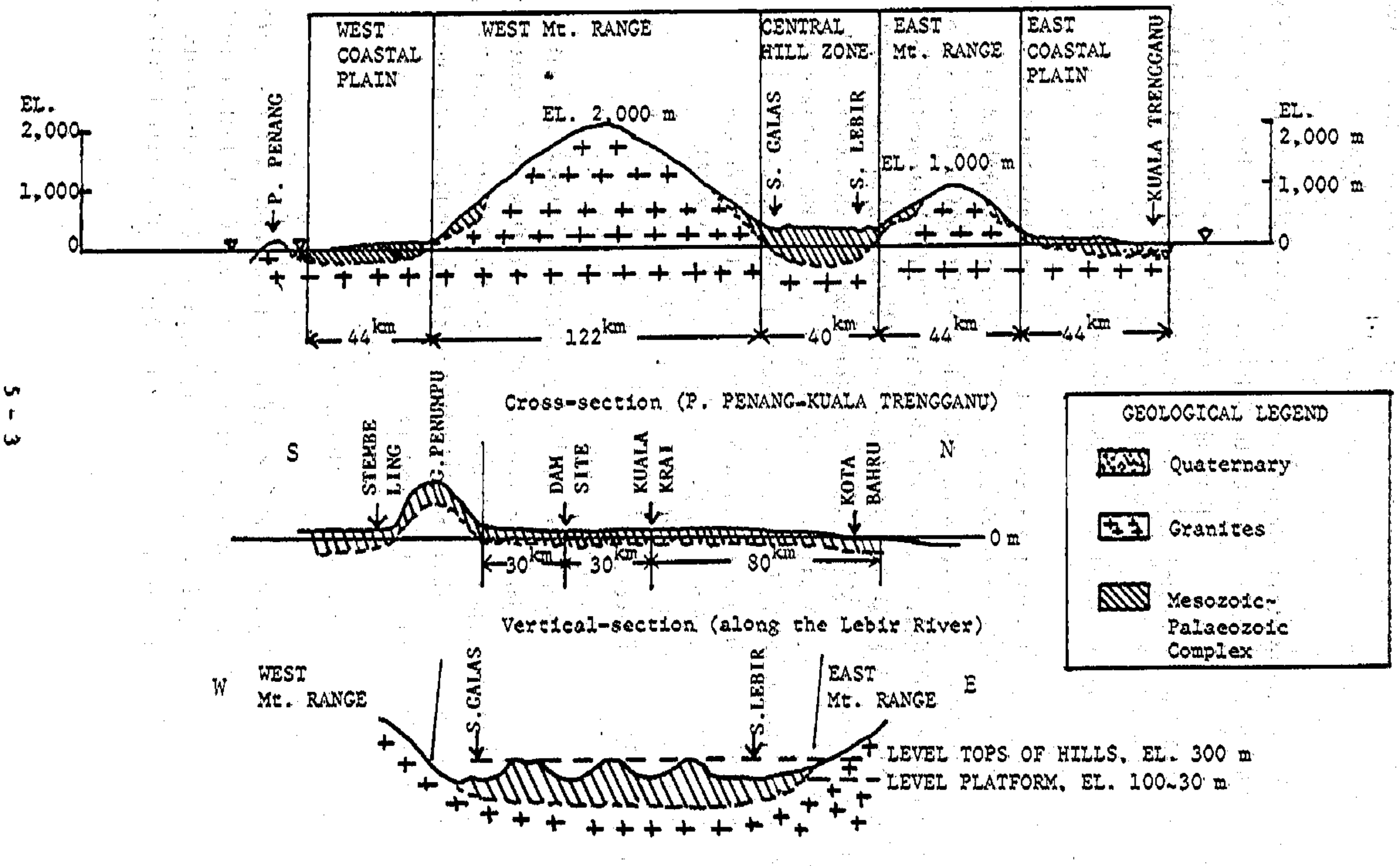
(6) The arrangement and distribution of tributaries of the Kelantan River are rather complicated and their watersheds are not clear. The directions of streams of tributaries meander but they tend generally toward the M Direction or the direction crossing the M Direction.

(7) The backbone mountain ranges have a gentle mountain slope.

5.1.2. General Geology

(1) The eastern backbone mountain range and the western backbone mountain range consist of granite rocks intruded during Mesozoic Period, and the Central Hill Zone consists of sedimentary rocks from the late Palaeozoic to the early Mesozoic Period. The sedimentary rock zone contains partly regional metamorphic rocks, pyroclastic rocks incidental to igneous activity and volcanic rocks. This shows that the geologic structure in the Kelantan River Basin is an Orogene. The period of Orogenic movement is considered to

Fig. 5-1 General Topographic and Geologic Maps in the Kelantan River Basin



(CENTRAL HILL ZONE) Schematic Profile

be the Variscan Orogeny period, because the Kelantan River Basin excludes completely any Cenozoic complexes.

(2) The constituent rocks in the Central Hill Zone are mainly clastic rocks including shales, slates, sandstones, and mudstones. Reflecting the Orogenic movement, the following non-clastic rocks are distributed in the Central Hill Zone.

a) Regional Metamorphic Rocks (the TAKU Schists)

Prevailing metamorphic rocks are distributed in a belt shaped 60 km from the north to the south and 10 km from the east to the west along the Kelantan River and on the left bank of the Lebir river. The TAKU schists consist of schists which are based on retrograde metamorphism and are green. Their bedding and schistosity tend generally in the N direction. The TAKU schists are distributed concentratedly in the above-mentioned area but they are also distributed in fragments near granitic rocks.

b) Quartzites

Cherts, hornfels and siliceous sandstones are called temporarily "quartzites". Quartzites are distributed widely on the northern edge of the Central Hill Zone, and they are also distributed in limited areas near the Lebir dam site.

c) Pyroclastic Sedimentary Rocks

Pyroclastic sedimentary rocks consist of tuffs, tuff breccias, agglomerates, and lavas which include acidic rocks and basic rocks. These rocks are distributed along the granite zone on both edges of the Central Hill Zone.

d) Limestones

Limestones are distributed intermittently in a lens-shape in a north-south direction almost in the center of the Central Hill Zone south of the TAKU schists area.

All those non-clastic sedimentary rocks are generally distributed in the N direction with a belt-shape.

(3) Geological Structure

The main fold axes are presumed to traverse the Peninsular Malaysia in the N direction. Out of these fold axes, a synclinal axis more than 500 km in length from Kota Bharu to Singapore lies almost in the center of the Central Hill Zone. The main fold axes are parallel at intervals of about 100 km. Accordingly, the geological structure in the Kelantan River Basin is governed by the synclinal axis from Kota Bharu to Singapore. In fact, there are no remarkable composite fold structures in the Kelantan River Basin because on anticlinal axis exists in the TAKU schists area. The beds over the whole area are inclined toward that single synclinal axis. But the dip of beds becomes steep or tends to be in an irregular direction in the adjacent areas to granite mass. The geology in the Kelantan River Basin is characterized in that the long and single synclinal axis governs the geological structure, small-scale folding structures are not developed well, and most of the area consists of a monoclinic structure.

In the Kelantan River Basin, there are few faults and fracture zones. Small-scale faults about 10 cm wide and 10 - 20 m long exist in some places, but they were formed at an old geological age and relithificated. There are a few large-scale faults more than 10 m wide and several km long in the Kelantan River Basin. A typical example is a fault distributed in the north-south or N direction on the boundary part between the granitic zone and the Mesozoic to Palaeozoic sedimentary rocks. This large-scale fault is hereinafter called temporarily "Lebir Fault". The Lebir Fault is a long tectonical fault distributed intermittently in a length of 60 km in the N direction. The results of reconnaissance indicate that the topographic revelation of the fault is very low and most of the visible faults and fracture zones are only 10 m wide and its scale is very much smaller than large-scale faults seen very frequently in Alpine Orogene.

On the 1/500,000 scaled geological maps (Geological Map of West Malaysia, 7th Edition published in 1973), a number of faults are drawn on the limestone zone in the Kelantan River Basin in addition to the Lebir Fault. Existence, scale, properties and activities of those faults are not known sufficiently.

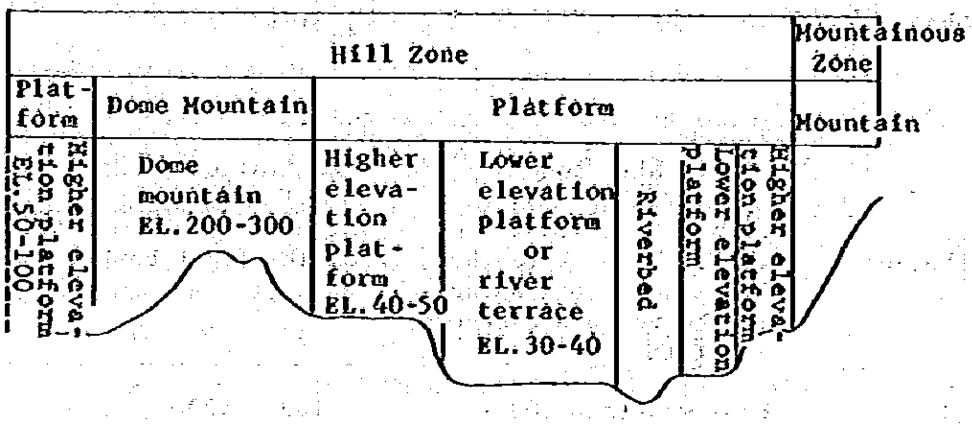
5.2. Topography and Geology of the Lebir River Basin

The topography and geology along the Lebir River have the same topographic and geologic features as for the Kelantan River Basin as mentioned before. In this Sub-section, detailed description is given about the topographic and geological features of about 20 km long section between the Rek River and the Chalil River.

5.2.1. Topography

(1) The area can be divided into the hill zone and the mountainous zone, and the hill zone can be divided further into dome mountain, platform, river terrace and riverbed. (See Fig. 5-2).

Fig. 5 - 2 Lebir River Basin Topographic Schematic Profile



Note: 1. The lower elevation platform and river terrace are on the same surface.

2. Small-scale lower elevation river terraces are scattered on the riverbed.

The river terrace (lower elevation platform) is distributed almost continuously but with an exception of some parts where the river terrace is not formed. The river terrace is located at a lower elevation than the platform, but the platform and river terrace on the places where the edge part of the platform leveled by erosion comes down to lower elevation are not different in the topography.

The topographic features of the hill zone and mountainous zone are shown in Table 5-1.

Table 5-1 Topography of Hill Zone and Mountainous Zone

	Hill Zone	Mountainous Zone
Area of distribution	From 2 km distant from the right bank to the left bank, continuing to the western backbone mountain	East of about 2 km distant from the right bank
Elevation	Dome mountain 100 - 300 m Platform 20 - 60 m	100 - 500 m
Topographic feature	The hill zone consists of dome mountain and platform with many undulations	The mountainous zone presents a mountain range without plain land and with less undulations
Meander of tributaries	The primary and secondary tributaries sharply.	The primary tributaries meander for a long distance, but the secondary tributaries meander for a short distance
Geology	All Mesozoic to Palaeozoic sedimentary rocks	Almost granitic rocks and partly Mesozoic to Palaeozoic rocks
Land use	Villages, farm land, rubber estates, and forests	Forests
Remarks	The hill land is located on the eastern edge zone of the Central Hill Zone	The mountainous zone is located on the western edge zone of the western backbone mountain range

(2) In the hill zone the main stream and tributaries flow gently with a riverbed gradient of less than 1/1,000.

(3) The dome mountain in the hill zone and the mountain in the mountainous zone which are located on the same elevation zone can be distinguished easily by the undulations of mountains, slopes of mountains and continuity of mountainous zones. This division is obviously distinguished in aerial photographs.

(4) The topographic feature of the hill zone is that platforms with an elevation of about 60 m and dome mountains with an elevation of 150 to 300 m are distributed intermittently. This topographic feature contributes to an increase in the reservoir storage efficiency and on the other side necessitates the construction of saddle dams.

(5) There exists no topography formed by surface changes resulting from landslides and landslips in the area. But there are few gullies caused by surface flow erosion on the edge part of the platform.

(6) On the main stream of the Lebir River there are rapids called "Jeram". No jeram exists downstream of the Kampung Lalok, but they are distributed rather densely in the river section from the Sam River to the Chalil River. The Jeram Panjung Site and the Kiak Site are located at the jeram. Riverbed rocks are exposed widely at the rapids.

(7) Cays are rarely formed at sharp meanders of the Lebir River. Although the Lebir River is a large river with a gentle slope and meanders, cays are scarcely formed on the river. Of course, the river stream flows in a full width of the riverbed. The riverbed rocks and cays at the rapids (Jeram) are exceptional for the shape of the riverbed.

(8) There are small-scale plains with a gentle slope on the left bank mountain on the Tualang Dam Site and on the mountain slopes or mountain peaks on both banks at the Jeram Panjang Dam Site. A number of similar small-scale plains are also there in other locations, but the density of their distribution is not so high. The formation mechanism of the small-scale plains on the mountain slopes is not clarified yet.

5.2.2. Geology

(1) Relation between the Topography and Geology.

The topography has a close relation with the geology. The following correlation between the topography and geology on this area is recognized.

a) The mountainous zone consists of granites, and the hilly zone consists of Palaeozoic and Mesozoic sedimentary rocks. The topographic difference between the mountainous zone and the hilly zone reflects a difference in lithologic character and crustal movement between the granites and the sedimentary rocks.

b) The topography of the hilly zone belongs to a stage of old age from a viewpoint of a cycle of erosion. This corresponds with the geological history mentioning that the zone did not suffer Alpine Orogeny and has undergone surface erosions after it turned into land in the Mesozoic Period.

c) There are so many places along the Lebir River where pyroclastic sedimentary rocks and volcanic rocks formed by igneous activity are distributed. These rocks are normally different in lithology and topography from the clastic sedimentary rocks. But we could not recognize a difference in topography between both kinds of rocks in the Lebir River Basin. This fact corresponds with the geological feature that the clastic sedimentary rocks and pyroclastic sedimentary rocks are alternations formed during a continuous geological period. In addition, the properties of both kinds of rocks are almost unified by metamorphism which took place after the sedimentation.

d) At the rapids, riverbed rocks are distributed over a considerably wide area and hard bedrocks are exposed along the side walls of the riverbed. The erosion surface of the riverbed rocks is scarcely curved but acute angled in a shape of teeth of a saw, which is apt to produce large breccias. The peculiar breccias are very hard and are produced only under the conditions that the thickness of a single bed is more than 20 cm but they are not formed in the shales. Included in the rocks at the rapids are many hornfels, agglomerates and quartzites which are considered to be related to intrusion of granites adjacent on the east mountaineous or igneous activity.

e) The stream directions of the Lebir River and its tributaries tend generally in the M Direction and perpendicular to the M Direction. The M Direction coincides with the strike of the beds. It seems that the differential erosion occurs directly corresponding to the bedding structure. In this meaning, the geological structure has a relation with the direction of river streams.

(2) Kinds and Lithologies of Distributed Rocks

The kinds of rocks distributed in the river basin include geosyncline clastic sedimentary rocks and many other kinds of rocks influenced by igneous activity and metamorphism. If types of distributed rocks are classified in detail, they are so much diverse by interposition of pyroclastic sedimentary rocks. The kinds of rocks distributed in the river basin are shown in Table 5-2. Normally, the kinds of rocks are expressed by small classification, but they are expressed by large or medium classification as the occasion demands.

Table 5-2 Classification of Rocks Distributed on the Middle Reaches of the Lebir River

Large classification	Medium classification	Small classification
Sedimentary rocks	Clastic rocks	Shales, Slates, Sandstones, Mudstones, Conglomerates and Quartzites
	Pyroclastic sedimentary rocks	Tuff breccias Lapilli tuffs Tuffs
	Chemical sedimentary rocks	Cherts
Metamorphic rocks	Regional metamorphic rocks	Green schists
	Contact metamorphic rocks	Hornfels
Granitic rocks	Granites	Granites

Note: [ ] rocks distributed over a wide area

Distribution of rocks

Generally, the granitic rocks are distributed on the mountainous zone, and the sedimentary rocks and metamorphic rocks are distributed on the hill zone. The sedimentary rocks are distributed on the mountainside and at the foot of the mountainous zone, pushed up by granites.

The pyroclastic sedimentary rocks are distributed over a comparatively wide area, if all the rocks distributed in a small area are added. Actually, pyroclastic sedimentary rocks are distributed in an area which is shown as clastic sedimentary rocks on the 1/500,000 scale Malaysia Geological Map.

The rocks which are distributed in a comparatively wide area out of the thirteen rocks classified in the small classification in Table 5-1 are shales, lapilli tuffs, tuffs, cherts and granites.

The green schists are exposed in a limited area near Klak but not distributed in other regions. In contrast, the hornfels are distributed in many places along the Lebir River main stream.

Lithology of Rocks

The clastic rocks and pyroclastic sedimentary rocks are considered to have been formed in a series in the same geological period. Both rocks alternate each other and intermediate rocks between both rocks, for example tuff mudstones and sandy tuffs exist in considerably large number.

North of the Chalil River there exist no lavas, although the area is in the pyroclastic sedimentary rock area. The lapilli tuffs and tuffs are hard and compact. Accordingly, they are easy to be misjudged as andesites or andesitic lavas by the naked eye. But they are confirmed by microscopic observation to be a kind of pyroclastic sedimentary rocks but not volcanic rocks such as lavas, rock veins and sheets.

Almost all kinds of clastic rocks are silificated and become hard and compact.

The pyroclastic sedimentary rocks, if they are fresh, are considerably hard and compact. The tuffs have a similar tendency, but they show a tendency that they become soft by weathering.

Most of the pyroclastic sedimentary rocks are dacitic. They are acidic rocks but they are rarely basic rocks.

In many cases, the rocks which contain tuffs present light bluish green. Some of them are pink.

There are many rocks whose kinds are difficult to be distinguished by the naked eye or which are given different rock names according to the standard adopted for classification. The following combinations are typical examples of different names but with the same properties.

Shales	-	Slates
Tuff brecclas	-	Lapilli tuffs
Tuffs	-	Tuffecious sandstones
Schists	-	Tuffecious shales
Hornfels	-	Quartzites - Cherts
Conglomerates	-	Tuff brecclas

Those combinations indicate that they are different kinds of rocks to each other but they are all hard rocks in terms of the strength of rocks. This is one of the features in the properties of rocks distributed in the Lebir River Basin.

(3) Exposure of Bedrocks

Fresh rocks or almost fresh rocks are exposed widely on the riverbed side walls or riverbeds and riverbed sides at the rapids (Jeram).

Fresh bed rocks are not exposed on the mountainsides nor the platform surface. On these areas there are few small rolling stones.

The mountainside slopes and platform surface are heavily weathered in principle. Soft rocks which are weakly weathered are exposed on many road cut surfaces and side walls of dales.

(4) Mode of Weathering of Baserocks

The mode of weathering of baserocks is as important for the construction of a dam as the petrological properties of the baserocks.

The weathered zone of baserocks is a two zone structure of heavily weathered zone and weakly weathered zone. The weakly weathered zone is divided into the soft rock zone and the hard cracky rock zone. The thickness of the heavily weathered zone varies depending on the topography and kinds of constituent rocks.

The basic mode of weathering as mentioned above is shown summarily in Table 5-3.

Table 5-3 Basic Mode of Weathering of Baserocks

Large Classification	Pattern	Small Classification	Facies	Seismic wave velocity (km/sec.)	Remarks
Rock weathered zone		Heavily weathered zone	Clay, gravel mixed clayey soil	0.3 - 0.5	
		Weakly weathered zone: Soft rocks (compact) or hard cracky rocks	Soft rock (compact), clayey soil mixed rock pieces	0.5 - 2.0	
Rock fresh zone		Fresh zone	Hard rock	2.0 - 5.0	Non-dehiscent rocks are included in fresh rocks

The respective thickness of the heavily weathered zone and weakly weathered zone varies with the slope point and the plain point. But the total thickness of rock weathered zone including both zones is almost the same throughout the whole surveyed area. It is about 15 m thick in a greater part of the river basin, and it reaches about 25 m on a wide plain surface near the Lebir River, for example Kiak. The above mentioned thickness was derived from the results of surface geological reconnaissance, drilling work and seismic prospecting carried out at the Preliminary Investigation Stage and is not a merely estimated value.

The weathered zone of the plain or gentle slope surface is thicker than the weathered zone in the steep slope zone.

The thickness of the heavily weathered zone on the mountainside slope is normally less than 5 m and not so thick.

The heavily weathered zone is lateritized in a major part of the river basin. It is reddish clay, but its colour tone is orange-coloured and pinky.

Thicker weathered zones underlie wider platform surfaces along the main stream of the Lebir River, for example the Kiak Site and the Tualang Village. The amount of the heavily weathered zone thickness in the weathered zone on the wider platform surface is high.

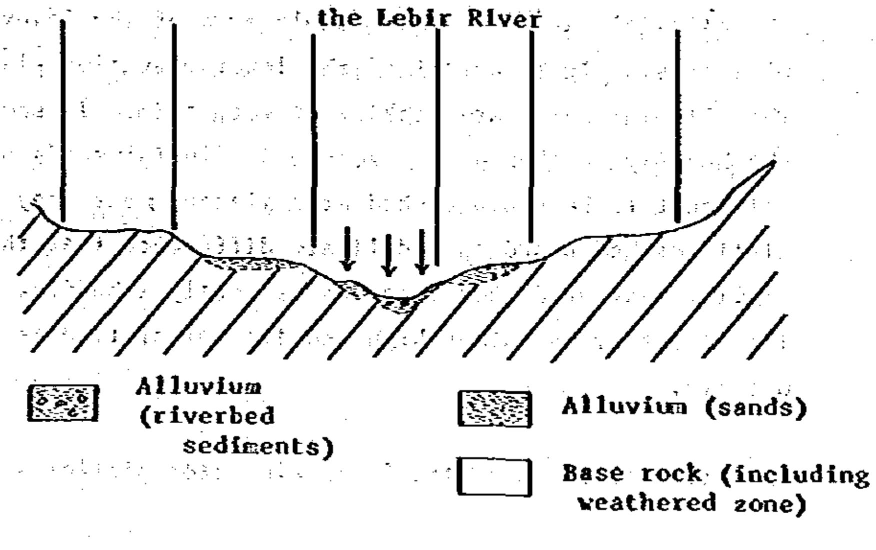
The weakly weathered zone of pyroclastic sedimentary rocks becomes a soft rock layer, in which no cracks take place and rock structures are kept considerably compact and form non-permeable layers. In contrast, hard rocks such as cherts and hornfels are easy to form hard cracky rocks as a weakly weathered zone, and some of them are semipermeable. The permeability of the weakly weathered zone is reflected in the water level of drilling holes.

There is a tendency that the weathered zone is a little bit thicker along the Lebir Fault.

(5) Alluvium (Unconsolidated Deposits)

The mode of distribution of alluvium along the main stream of the Lebir River is more complicated than the usual river.

Fig. 5-3. Conceptional Drawing of Alluvium along the Lebir River



The alluvium is classified into the present deposits, lower elevation platform deposits and river terrace deposits.

Fig. 5-3 shows a typical traverse in a schematic sectional drawing. There are so many areas to which this schematic drawing is applied. The platform is a part of the platform on the hilly zone. Near the main stream of the Lebir River the platforms are divided into the higher elevation platforms with elevation 40 to 50 m and the lower elevation platforms with elevation 30 to 40 m. The lower elevation platforms are sometimes submerged by large floods during the recent geological period. The terraces along the riverbed side are higher by several meters than the present riverbed surface. They have been affected very often by the river flow during the recent geological period. Accordingly, their scale is very small and they exist intermittently. Most of the ground surfaces of the higher elevation platforms are covered by the heavily weathered zone, and a small amount of the ground surfaces is covered by talus or, soil and sand washed away from tributaries. In principle, there is no alluvium on the ground surfaces of the higher elevation platforms.

The alluvium is deposited at lower levels than the lower elevation platforms. The alluvium consist of loose sands of uniform medium grain size which are considered as alluvium. The alluvial sands cover the whole area of the lower elevation platforms. In some part of the lower elevation platforms, the alluvial sands are lacking or very thin. In some cases, the heavily weathered rock zone and alluvial sands are difficult to be disinguished at a glance. But they can be distinguished based on a delicate difference that the heavily weathered rock zone leaves merely a bedding structure, its viscosity is rather high and its colour tone is not uniform.

The alluvial sands on the lower elevation platforms are estimated to be only several to 10 m thick over the whole area. The thickness of sediments on the terrace along the riverbed side is about 5 to 6 m. The above alluvial sands and sediments contain no gravels and have a peculiar facies consisting of sands without bedding.

The present river deposits consist mainly of sands, and gravel are distributed partially on cays. This gravel is smaller than fistsize. Exceptionally, angular boulders with a diameter of more than 1 m are accumulated on the riverbed on the left bank at the Jeram Panjang Dam Site. Those boulders are autochthonous and cannot be said to be the present river deposits.

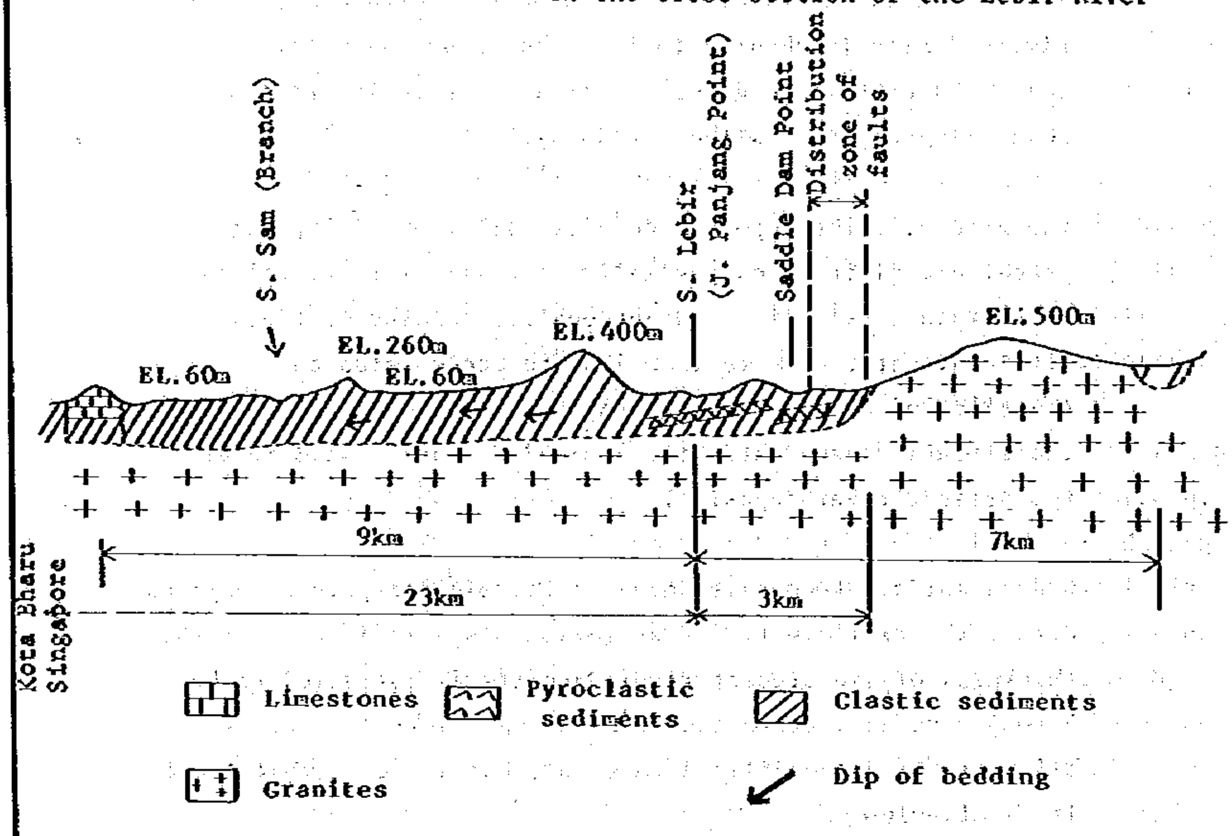
Ground surface reconnaissance and seismic prospecting carried out at the Preliminary Investigation Stage indicate that the thickness of the present river deposits is estimated to be 5 to 6 m on an average and 10 m in the thickest part. The diluvium was not confirmed to exist, but it seems that there is no diluvium.

(6) Geological Structure

a) Outline of Geological Structure

The geological structure in the Lebir River Basin is governed by the M Direction belt-shape structure. The outline of geological structure is shown herein by the geological structure section in the direction of east to west.

Fig. 5-4 Conceptional Drawing of Geologic Structure In the Cross-section of the Lebir River



Mesozoic to Palaeozoic sedimentary rocks overlie granites which constitute the batholith.

The Mesozoic to Palaozoic sedimentary rocks exist in the hilly zone and present platforms with elevation about 60 m and dome mountains with elevation 200 to 400 m. There are the same sedimentary rock formations as in the hilly zone, in the granite zone 7 km east of the Lebir River. The distribution elevation of these formations is higher by more than 10 m than in the hilly zone.

Most of the Mesozoic to Palaeozoic sedimentary rocks consist mainly of clastic rocks, for example shales. In a section 2 to 3 km wide between the Lebir River and the granite rock zone, pyroclastic sedimentary rocks formed by igneous activity and hornfels caused by contact metamorphism are distributed which present a diversification in the geological structure. Besides that, some limestone zones tending towards the N Direction are distributed about 80 km west of the Lebir River. Those clastic rocks, pyroclastic sedimentary rocks and limestones were formed in a series during the geosycline stage (the Variscan) and are not in uncomformity.

A section about 1 km west of the boundary between the granite rock zone and the sedimentary rock zone is a zone which may be named "A dense zone of faults with strikes". Here large-scale faults are more densely distributed than in the other areas. This group of faults have a fracture layer about ten to some tens of meters wide and 1 to 15 km long tending in the N direction. Even in this zone of many faults, sound rock zones not subject to fracture can be found easily.

b) Special Note of Geologic Structure

Only a long anti-clinorium in the N Direction exists 9 km west of the Lebir River as a fold axis, but the other large fold axes which can be illustrated in the geological maps are not in the area. The area is characterized in that no small fold axis structures are recognized. Accordingly, the geological structure presents a monoclinic structure inclined toward the west over almost the whole area.

Remarkable bedding structures have developed in the clastic rocks and pyroclastic sedimentary rocks.

The bedding strikes prevailingly toward the M Direction and dips toward the west. Many parts of the pyroclastic sedimentary rocks tend in N30E and 50-60°S direction. A tendency is observed that the beds are inclined sharply in a range of 50° - 90° from the Lebir River to the granite zone.

In the hard rocks including cherts and consolidated lapilli tuffs, joints with predominant directions parallel to or crossing the bedding plane have developed remarkably.

Apart from the Lebir group of faults the sedimentary rock members contain small faults 10 - 20 cm wide and several meters long. These small faults are thinly distributed and faults exist at an interval of every several 10 m. They are relithificated and have the same hardness as the marginal unfractured rocks.

(7) Lebir Fault

a) Outline of Photolineaments

The outline of lineaments obtained from aerial photographs of a section between the granite zone on the right bank and the sedimentary rock zone on the left bank is introduced hereunder (see Fig. 5-5).

The photo lineaments are rather densely distributed over a section 1 km wide between the boundry between the granites and sedimentary rocks and 1 km inside the sedimentary rock province. Only a few photo lineaments exist in the granite zone and along the boundary surface between both the rocks.

The photo lineaments can be divided into distinct lineaments and indistinct lineaments based on the degree of revelation in the aerial photographs. This distinction or indistinction is reciprocal, and even the distinct lineaments are not clearly revelated.

The number of the distinct photo lineaments is few but their length is 2 to 6 km long in the direction of north to south. The terminals of the distinct photo lineaments disappear suddenly or disappear gradually after changing into indistinct photo lineaments. Many of the indistinct photo lineaments are 1 km long. The density of their distribution is rather high, in two prevailing directions of N-S and NE-SW. Many of the NE-SW direction indistinct photo lineaments form a row at equal intervals mainly in the pyroclastic sedimentary rocks, and their directions are parallel to the strike of bedding plane of the pyroclastic sedimentary rocks.

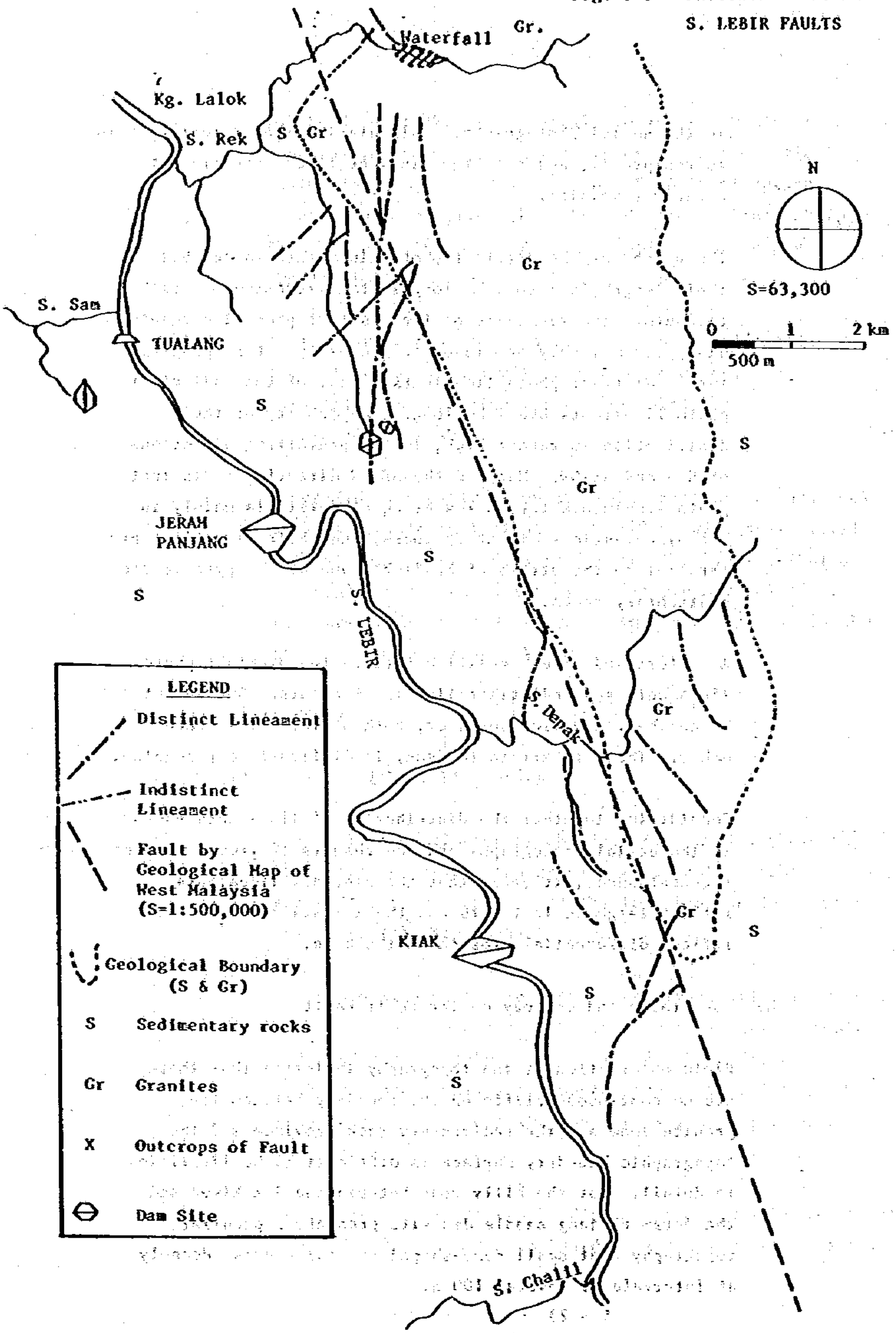
A "before and after" relation between the distinct photo lineaments and indistinct lineaments occurs. One is cut by another, and vice versa or, both of them cross each other. Thus, a certain tendency is difficult to recognize.

Considering together the distribution of lineaments shown in the aerial photographs and the results of ground surface reconnaissance, it seems that the distinct lineaments reflect large-scale faults and the indistinct lineaments reflect differential erosion on the beds.

b) Topography and Geology on the Lebir Fault

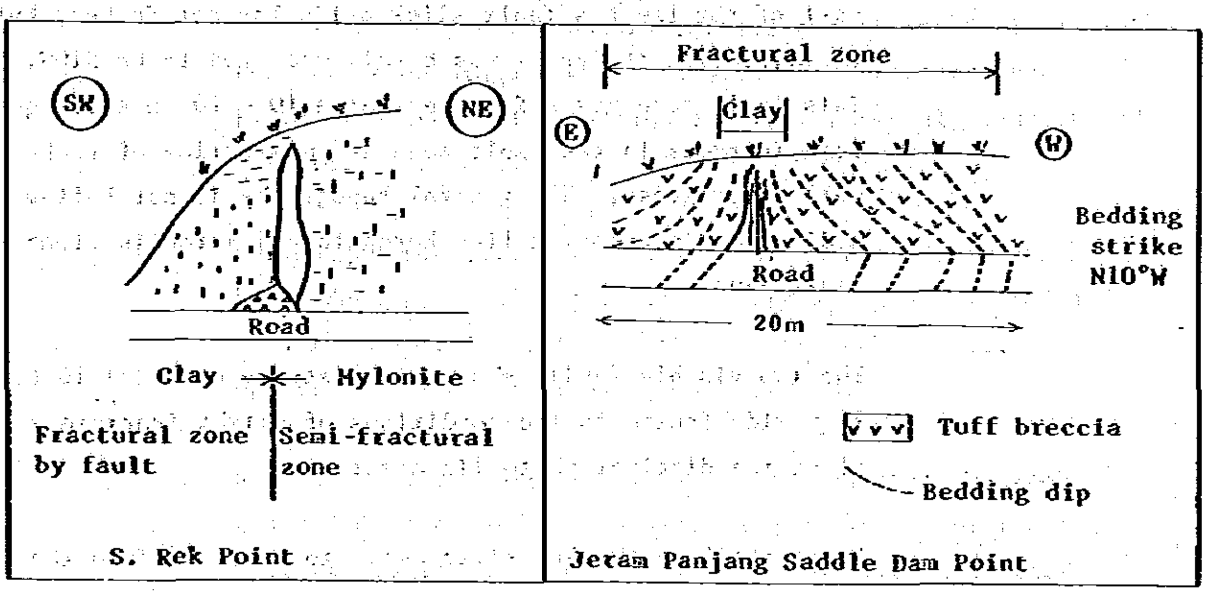
Field observation of the topography indicates that there are no continuous cliffs on the boundary between the granite zone and the sedimentary rock province and the topographic boundary surface is difficult to be identified in detail. But the hilly zone between the Rek River and the Jeram Panjang saddle dam site presents a peculiar topography that small dome-shaped mountains exist densely at intervals of several 100 m.

Fig. 5-5 PHOTOLINEAMENT MAP
S. LEBIR FAULTS



A distinct photo lineament exists in a length of more than 4 km from the south of a waterfall on the Rek River to the saddle dam site at Jeram Panjang. The exposure of visible faults on that lineament is shown in the following figure (see Fig. 5-6).

Fig. 5-6 Sketches of Exposed Faults



The fault exposed at the cut fact of the road on the right bank of the Rek River, does not show fault clay clearly, but it shows a clear fault slickenside in the direction of N30W and 85W. Its NE side consists of mylonite. The width of this fault is estimated to be more than 4 m, because the surface soil covers up the left side of this fault.

The fault on the saddle dam site at Jeram Panjang is exposed at the surface of the cutting of the sloping road connecting the first saddle dam with the 2nd saddle dam, and it is composed of tuffs, tuff breccias and tuffaceous conglemerates with distinguished bedding structure. As shown in the figure, the bedding changes sharply at an angle 55° to 90° toward the center of fault. The bedding structure and rock texture near the fault remain good and suffer from some fracturing. The fracture zones including small ones are about 20 m wide. In the center part of the fault a fault slickenside has not formed, but the direction of faults was barely measured to be N10W. This fault zone has a feature that a 10 - 20 cm thick quartz vein intrudes in the fault zone and weathering of rocks is well in progress. The general topography is not hollow like a ditch and not convex like kernbats and kerncols along the fault line.

The two visible faults show the existence of about 10 to 20 m wide faults in the conditions of slight fracture zones along the distinct photo lineament.

A waterfall on the Rek river seems to be related to the above mentioned fault case in these situations. But this waterfall is a steep slope of granite mass margine with a length of 500 m and a specific height of 50 m. It is not a waterfall formed by the fault.

The Rek River and the Depak River crosses the Lebir Fault and expose many crops on the riverbed. Accordintly, they are useful fields for clarification of the actual conditions of the Lebir Fault. The result of ground surface reconnaissance indicates that good rocks are exposed continuously in many places on the riverbeds of both rivers and any remarkable fracture zones could not be found there. There still remain, however, the possibility that the parts covered by surface soil and talus may be fracture zones.

There are observed no landslides nor landslips along the Lebir Fault. On the other hand, fault scarps, terminal facet, and peculiar bending of a group of stream courses are not seen along the Lebir Fault.

There are many cuttings of roads in the Lebir Fault belt. Seen on the cuttings of roads are only a few small faults and fracture zones without any shifting in either the vertical or horizontal plane along the length of fault. A seismic prospecting survey carried out at the Preliminary Investigation Stage shows that slow wave velocity zones in the longitudinal direction are rather densely distributed near the Lebir Fault.

No younger formations than the diluvium exist near the Lebir Fault. Accordingly, it is very difficult to judge from the outcrops of layers whether the Lebir Fault occurred in the quaternary period or not.

Near the Lebir Fault, there is a tendency that the rock weathered zones become thicker. The existence of fresh and unfractured rocks about 25 m beneath the ground surface was confirmed by drilling works done at this stage of study, which give a negative interpretation on the existence of large-scale faults or fracture zones.

Past records show that any large seismic activities did not take place in the Peninsula of Indo-china, the Peninsular Malaysia and Borneo Island. Accordingly, the Lebir River Basin is outside the seismic zone.

c) Location, Scale and Activity of the Lebir Fault

The Lebir Fault is deemed to exist judging from the photo lineaments recognized on aerial photographs, the exposure of faults on the lineaments and a knowledge of the geotectonics that many faults lie under sedimentary rocks near intruded granites in an Orogene.

The Lebir Fault belt is located in a zone 1.0 to 1.5 km toward the sedimentary rock province from the boundary surface between the granites and the sedimentary rocks.

The Lebir Fault tends generally in the N Direction, but the strike of each fault varies from the N direction to the north-south direction. Many faults do not exist densely over the Lebir Fault zone, but only one or two faults (fractured zone) exist(s) in the Lebir Fault zone.

The width and length of each of the faults including fracture zones on the side edge of the fault are about 20 m and less than several km respectively. Each of the faults less than several km long are distributed continuously or in the echelon over a length of several 10 km. In view of the fact that each of the faults does not contain fault clay, that it is not so seriously fractured, and that the photo lineaments are unclear, the Lebir Fault is distributed in a long distance but not large-scale and serious.

Generally, faults which were active after the diluvium are defined as active faults. Any diluvial and alluvial formations are not distributed near the Lebir Fault zone. It is very much difficult, therefore, to know from the outcrops whether the fault is active or not. However, the Lebir Fault is not considered active, in the light of that any ground surface movements including terminal facet, bending of stream courses, landslides and fault scarps are not observed, a degree of revelation of young topography including fault scarps is very much low, and the Peninsular Malaysia is not in the Alpine Orogene.