GOVERNMENT OF MALAYSIA

FEASIBILITY STUDY REPORT

ON

LEBIR DAM PROJECT

EXECUTIVE SUMMARY

MARCH 1989

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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Table of Contents

EQUIVALENTS AND ABBREVIATIONS

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Measurement

1 - milli-micron (um)	= 1 x 10^{-9}m
1 - meter (m)	= 3.2808 feet
1 - feet (ft)	= 0.3047 meter
1 - kilometer (km)	= 0.6214 mile
1 - mile	= 1.6093 kilometers
1 - acre	= 4,046.85 m^2
1 - hectare (ha)	= 10,000 m^2
1 - square mile	= 2.58985 km^2
1 - cubic meter (m^3)	= 35.316 cubic feet
1 - liter (1)	= 0.2642 U.S.gallon
1 - U.S.gallon(gal)	= 3.785 liters
1 - barral (bbl)	= 158.987 liter
1 - million cubic meter (MCM)	
1 - gram (g)	= 0.00220 pound (1b)
1 - kilogram (kg)	= 1,000 gram
1 - metric ton (ton)	= 1,000 kilogram
1 - kilo volt (KV)	
1 - kilo volt-ampare (KVA)	
1 - kilowatt (KW)	= 1.341 horsepower
1 - kilowatt (KW)	= 1,000 watt
1 - megawatt (MW)	= 1,000 kilowatt
1 - kilowatt-hour (KWH)	= 3,412.1 BTU
1 - gigawatt-hour (GWH)	= 1,000,000 kilowatt-hour
1 - terawatt-hour (TWH)	= 1,000 gigawatt-hour
1 - British thermal unit(BTU)	= 2.931 x 10^{-4} kilowatt-hour
1 - million British thermal unit(MBTU)	= 1,000,000 British thermal unit
1 - cubic meter per second (m^3/s, m^3/sec or cms)	
1 - lugeon (Lu)	= 11/min/m/10kgf/cm^2
1 - kilogram per square centimeter (kg/cm^2)	= 14.1935 pound per square inch (psi)
1 - meter in aqua (mAq)	

Domestic Organization

Drainage and Irrigation Department	DID (JPT)
Department of Statistics	DS
Deparment of Environment	DOE
Department of Forestry	DOF
Ecnomic Planning Unit	EPU
Federal Land Development Authority	FELDA
Federal Land Consolidation and Rehabilitation Authority	FELCRA
Geological Survey Department	GSD
Institute of Medical Research	IMR
Jabatan Orang Asli	JOA
Jabatan Kerja Raya	JKR(PWD)
Kelantan Agriculture Development Authority	KADA
Kelantan South Land and Regional Development Authority	KESEDAR
Ministry of Agriculture & Cooperation	MOAC
Ministry of Finance	MOF
National Electricity Board	NEB (LLN)
Public Works Department	PWD
State Economic Planning Unit	SEPU
State Development Department	SDD
Tourist Development Corporation	TDC
University Sains Malaysia	USM

International and Foreign Organizations

Asian Development Bank	ADB
American Association of State Highway officials	AASHO
Egneinering Expert Association of New Zealand, Inc.	ENEX
Japan International Cooperation Agency	JICA
Japan Society of Civil Engineer	JSCE

Others

Aluminum Cable Steel Reinforced	ACSR
Benefit Cost Ratio	B/C
Biochemical Oxygen Demand	BOD
Bench Mark	BM
Capital Recovery Factor	CRF
Cost, Insurance & Freight	CIF
Compacted & Undrained	$\overline{CU}$
Cohesion	c
Center to center	ctc
Chemical Oxygen Demand	COD
Degree centigrade	°C
Design Silt Level	DSL
Elevation above Mean Sea Level	EL.
Environment Impact Statement	EIS
Economic Internal Rate of Return	EIRR
Flood Water Level (Reservoir design flood level)	FWL
Free on Board	FOB
Financial Internal Rate of Return	FIRR
Fiscal Year	F.Y.
Foreign currency	F/C
Figure	Fig.
Geologic N62°E --- Strik 68°S --- dip	N62°E/68°S
Gravity Acceleration	g
Gross Domestic Product	GDP
Growth Production Value	GPV
High Water Level(Maximim Service Level)	HWL
Internal Friction Angle	ϕ
Irrigation Agriculture Development Program	IADP
Japanese Industrial Standard	JIS
Kelantan River Basin Study	KRBS
Kampung (Village)	Kg.
Low Water Level (Minimum Service Level)	LWL
Local currency	L/C

Main Transformer	M.Tr.
Minutes of Meeting	MOM, M/M
Mean Sea Level	MSL
Note of Discussion	NOD
Not available/Not Applicable	n.a.
Ocean Freight & Insurance	OF & I
Operation and Maintenance	O & M
Permeability Coefficient	k
Per unit	P.u
Probable Maximum Flood	PMF
Power Station	P/S
Production Cost	PC
Roller Compacted Concrete	RCC
Revolution per Minute	rpm
Ratio of Total Storage Volume of Reservoir to Total Annual Discharge of River	C/I
Rock Quality Designation	RQD
Seismic Coefficient	k
Standard Penetration Test	SPT
Standard System Kelantan	SSK
Substation	S/S
Sungai (River)	Sg.
Scope of Work	S/W
Sverdrup-Munk-Bretschneider Method	S.M.B.Method
Tailrace Water Level	TWL
Transmission Line	T/L
Velocity	V
Volume	V

CURRENCY EQUIVALENTS

US$ 1.00 = 2.5 Ringgit (M$)

1. Preface

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1.1. Background of the Study

This Project was commenced in March, 1979 with field investigations by the JICA Study Team. In November, 1980, a draft interim feasibility study report was prepared and explained to the Malaysian authorities concerned, and in March, 1981, an interim feasibility study report was formally submitted to the Malaysian counterpart agency. The report recommends to develop primarily a hydroelectric power scheme to construct a 69.5 m high rockfill dam, a reservoir with a maximum water level of 90 m, and a 151 MW power station at Jeram Panjang Site which was considered the optimum site, with secondary functions of flood regulation and irrigation water supply.

On the above interim feasibility study report, an agreement by the State Government of Kelantan was not obtained as the proposed submerged areas conflict partly with the land scheme for agricultural development. For this reason, there was an approach from the Government of Malaysia to the Government of Japan asking for a change of the proposed scheme, a shift to other projects, etc., and in the long run, it was decided in August, 1982 at the annual consultation meeting on technical cooperation between both governments to put an end to technical assistance for the Study.

Afterwards, floods occurred in the drainage basin of the Kelantan River which is the main stream of the Lebir River in its downstream reach, and with the progress of the regional development, recognition of the importance of the Lebir Dam development was deepened among the Malaysian authorities concerned and there occurred a movement seeking to resume this suspended Study for the Project. At the 1984 annual consultation meeting between both governments, the Government of Malaysia proposed a request orally to the Government of Japan to resume the Study for the Project, which was followed in April, 1985 by an official request and then, at the 1986 annual consultation meeting, the Study was requested again for implementation as the first priority.

In these circumstances, the Government of Japan, after careful consideration, dispatched a preliminary study mission to the site in December, 1986 for conducting field investigations and holding discussions with the Malaysian counterpart agency.

As a consequence, justification for resuming the Study for the Project was confirmed, and on December 17, 1986, the scope of work and the minutes of meeting were agreed upon and signed between JICA and EPU.

1.2. Objective and Scope of the Study

The Study is to work out dam layouts of different scales on the Lebir River (including hydropower generation, flood regulation and irrigation) and, after comparative studies of dams of different scales, formulate a technically, economically and financially optimum development scale, and thereby compile a feasibility study report.

This study is to develop the features of the Project as the dam site being located at Jeram Panjang and the dam being of rockfill type based on the conclusions of the Interim Report on Feasibility Study for the Lebir Hydroelectric Power Development Project dated March 1981.

To accomplish the above objective, investigations and studies with regard to the following items were carried out in three (3) stages:

Stage	Period
(1) Project Reappraisal Stage	1 month
(2) Field Investigation Stage	8 months
(3) Feasibility Design Stage	11 months

(1) Project Reappraisal Stage

(a) review proposals for the Project made in the Interim Feasibility Report;

(b) carry out a reconnaissance of the project area in general and the proposed Jeram Panjang dam site in particular;

(c) collect appropriate supplementary data on development plans and other proposals of the project area;

(d) undertake comparative studies and analysis of alternative proposals for the Project;

(e) evaluate and recommend an optimum layout of the Project for detailed feasibility study; and

(f) prepare a detailed programme of field investigation and feasibility design of the preferred Project.

(2) Field Investigation Stage

(a) Dam Surveys

i. ground surveys of proposed sites for dam structures including installation of survey posts and benchmarks;

ii. seismic refraction surveys of proposed sites for major structures and a quarry and other locations as appropriate;

iii. core drilling and permeability testing at these proposed sites for structures and quarries;

iv. geological investigations by trench excavation and collection of samples for laboratory testing;

v. exploration by test pitting and collection of samples for laboratory testing;

vi. measurements of riverflow and sediment at selected observation stations; and

vii. mechanical testing of fill materials, soil tests, concrete aggregate tests, bedrock mechanical tests and water quality tests.

(b) Flood Mitigation Study

i. collect and review relevant data on other proposed dam projects in the Kelantan River Basin;

ii. collect and review data on the socio-economic development in the downstream of the Lebir River basin and the Kelantan River basin;

iii. obtain information on population distribution in the project area as well as the downstream of Lebir River basin; and

iv. collect other information which may be pertinent to the flood mitigation study.

(c) Environmental Impact Study

Examination of environmental impact on the Lebir River and its vicinity, to include the following;

i. baseline surveys of terrestrial and aquatic ecosystems in the Lebir River, reservoir area and catchment area;

ii. survey of public health aspects with particular reference to water-borne disease schistosomiasis and zoonosis;

iii. surveys of archaelogical and other socio-cultural aspects, including population to be displaced by construction activities and reservoir impoundment; and

iv. assessment of alternatives as well as indication of negative and positive effects of the Project.

(3) Feasibility Design Stage

(a) survey power load and generation expansion programme, and assess the capacity and energy output of the Project taking into account development constraints (such as variations of riverflow in the downstream of the multipurpose dam);

(b) carry out preliminary design of structures and prepare drawings, diagrams and tabulations as appropriate;

(c) design electrical equipment including selection of capacities of turbine-generators and associated equipment;

(d) estimate costs of the Project with costs broken down into foreign and local cost components as well as cash flows;

(e) study an optimum reservoir operation plan for power generation, flood mitigation, and irrigation purposes;

(f) assess flood mitigation effects of the Project on the downstream area of the Lebir Dam as well as the whole Kelantan River basin;

(g) carry out economic and financial analysis including non-power benefits (with sensitivity analysis);

(h) assess an impact of the Project on the environment, particularly with regard to the socio-economic aspects; and

(i) prepare a programme for the implementation of the Project construction in the form of a critical path network or logic bar chart.

1.3. Activities Done

This Draft Final Report compiles the results of additional field investigations done and feasibility design carried out in Japan.

The Stage 1 of the Study includes a reappraisal of the previous Interim Feasibility Study Report of March, 1981 and a preliminary Study. In March, 1987, a JICA Study Team was dispatched to the site for the period of one month to collect information and data. The Study Team members consisted of experts and specialists in dam, geology, hydrology, civil engineering, flood regulation, hydro-electric engineering, agriculture, economics and environment. As the result of this Stage 1 Study, the JICA Study Team submitted Inception and Reappraisal Report in March, 1987.

The Report was discussed in June, 1987 at EPU, joined by team leader of the JICA Study Team.

The Stage 2 of the Study includes field investigations. From May, 1987, one expert each in topographic survey and drilling exploration was dispatched to the site and, on the basis of contracts made with local contractors, topographic survey and geologic drilling exploration were carried out. These works were completed at the end of October, 1987. GSD carried out seismic refraction tests for the period of two months from September, 1987, for which an expert in seismic refraction tests from the JICA Study Team was dispatched to the site as technical adviser for the same period. Seismic refraction survey data were sent to Japan by January, 1988 and the analysis was made by the JICA Study Team in Japan. Laboratory tests of the dam embankment materials were carried out at the in-situ laboratory of the Kenyir Dam of NEB, for which the JICA Study Team dispatched an expert in material testing to the site as technical adviser for the period of two months from September, 1987.

Basic environmental study was carried out by the Malaysian authorities concerned. NEB assigned the natural environmental and socio-economic study to USM, the mineral resources survey to GSD, and the medical environmental study to IMR. The JICA Study Team dispatched an expert to the site for half a month in June, 1987 to participate in discussion with the USM Study Team and a joint field survey. Again in November, 1987, the same expert was dispatched to Malaysia to discuss a draft environmental study report prepared by USM. USM submitted a final basic environmental study report in December, 1987. GSD submitted a preliminary assessment report on mineral resources in November, 1987. As of January, 1989, IMR has not yet submitted a medico-ecological sub-study report to JICA Team.

In the stage of field investigations, the progress reports on activities were presented to NEB on June 1987 (Progress Report No.1), September 1987 (Progress Report No.2) and November 1987 (Progress Report No.3).

The Stage 3 of the Study is a feasibility design stage which includes, in the first place, comparative studies of various development scales of the Project to determine an optimum plan. These works were carried out in Japan in two months from December, 1987 till January, 1988.

The results were reported in the following reports together with the results of field investigations, and these were discussed with NEB and the agency concerned.

- Interim Report of Feasibility Study for The Lebir Dam Project and Appendices (February 1988)

- Environmental Impact Statement for The Lebir Dam Project (February 1988)

The contents of discussions held in Malaysia on the above reports are as shown on Attachments 1-1 and 1-2 of this Report.

- Attachment 1-1 : MOM of Technical Meeting (March 7, 1988)
- Attachment 1-2 : MOM of Steering Committee Meeting (March 8, 1988)

JICA Study Team has received comments on the above Environmental Impact Statement from DOE through NEB with the letter dated September 5, 1988.

Feasibility design work was recommenced in August 1988 with a delay of four months from the original work schedule because the Team had to wait for coordination until the main features of the Kelantan River Basin-Wide Flood Mitigation Study were determined.

Based on the above works done, the draft final report was submitted in January 1989 and discussions were made with the Malaysian agencies concerned in February 1989. The draft final report consisted of the executive summary, the main report and the appendix. The contents of the discussions above mentioned are contained as Attachments 1-3 and 1-4 of this Report.

- Attachment 1-3: NOD for Technical Committee Meeting on Lebir Dam Project

- Attachment 1-4: MOM on Draft Final Report for the Feasibility Study of the Lebir Dam Project

This final report, consisting of the executive summary and the main report Volumes I and II, has been finalized by incorporating various comments made during the discussions. The main report Volume I contains Chapters 1, 2, 3, 6, 7, 8, 9, 10, 12, 13 and 14, and the relevant appendices, while Chapters 4, 5 and 11, and relevant appendices are in Volume II.

1.4. Acknowledgements

The JICA Study Team wishes to express its deep gratitude for the cooperation and assistance extended with regard to the Study by the Federal Government of Malaysia, the State Government of Kelantan and the agencies and authorities concerned.

In particular, the JICA Study Team would like to express its appreciation to Economic Planning Units of the Federal Government and the State Government for their playing a coordinating role in promoting the Study and to NEB for its great contribution to accelerate the Study directly as the counterpart implementing agency of the Project by providing technical staff, facilities, data, materials, etc.

The JICA Study Team also wishes to thank Drainage & Irrigation Departments and Public Works Departments of the Federal and the State Governments, KADA, FELDA, KESEDAR, Forestry Department, Health Department, and Environmental Department for their abundant cooperation in providing the relative data and materials.

Finally, the JICA Study Team wishes to express its deep gratitude to USM, IMR and GSD for their various environmental studies, seismic refraction tests and mineral potential study.

2. Summary and Conclusion

2. Summary and Conclusion

2.1. Conclusion

(1) As one of the methods to stabilize flow discharge in the Kelantan River, which is the largest river in Kelantan State, the Lebir Dam Project was proposed at the Jeram Panjang site in a tributary, the Lebir River.

(2) The main features of dams and reservoir designed are as follows.

Main dam	:	Type	Center earth core impervious wall type rockfill dam
		Crest elevation	EL.92.0 m
		Dam height	73.0 m
		Dam volume	$3.1 \times 10^6 m^3$
Saddle dam I	:	Type	Center earth core impervious wall type rockfill dam
		Crest elevation	EL.92.0 m
		Dam height	67.0 m
		Dam volume	$1.5 \times 10^6 m^3$
Saddle dam II	:	Type	Earthfill dam
		Crest election	EL.92.0 m
		Dam height	48.0 m
		Dam volume	$0.7 \times 10^6 m^3$

Reservoir:

	Water Level (EL., m)	Reserved Capacity ($10^6 m^3$)	Impoundment Area (km^2)
10,000 year return flood (Dam design flood discharge)	88.1	3,955	226
50 year return flood (Planned base flood)	84.9	3,276	195
High water level	80.0	2,392	154
Low water level	60.0	502	46
Emergency low water level	50.0	167	21
Design siltation level	47.0	117	15

(3) Submerged area due to the dam construction are estimated as below.

Classification	WL.80 m	WL.88.1 m
Agricultural plantation	9,627 ha	14,717 ha
Forest	5,773 ha	7,883 ha
Total	15,400 ha	22,600 ha

Agricultural plantations are classified into four, i.e. FELDA, KESEDAR, FELCRA and ADB Project. Since the plantation area is being developed, it is assumed that a total cropped acreage below WL 88.1 m will be 10,000 ha in 1990. Therefore, this assumed area of 10,000 ha was used for estimating a compensation cost for resettlement. Non agricultural plantation refers to the settlements of Lebir riverine and Orang Asri.

A total population (Lebir riverine settlers, settlers in the agricultural plantation and Orang Asri) to be affected by the dam construction amounts to 775 families (4,694 persons).

Roads to be submerged are a length of 52 km in the plantation area and about 30 km of the road for timber transportation.

As for countermeasures against these impacts, the extension of existing Ciku plantation northwards, resettlement to the dotted plots in the southern part of Gua Musang and the development of aquaculture industry are proposed.

Upon implementation of aquaculture projects, it becomes possible to give employment opportunities to some hundreds of families.

(4) Other environmental impacts due to the dam construction, and proposed countermeasures, are as follows:

Impact	Countermeasures
Water level fluctuation discharge	. There should be no adverse impact on due to the generation irrigation water supply in the downstream course of the Kelantan River. No countermeasure required. . For maintenance of flow in the Lebir River, the construction of re-regulating pondage is proposed. . Installation of downstream discharge warning system. . No countermeasures are proposed river bank erosion protection because its scale may be small.
Change in water quality	. Clear-felling of the trees in the impoundment area is proposed to be carried out prior to impounding. . Establishment of land use plan based on the results of water quality monitoring. . Securing of the land around the reservoir as a forest reserve for protection against bank erosion.
Fish species	. Installation of a fish ladder, if necessary. . Development of aquaculture industry.
Fauna	. Relocation of large animals . Preservation of valuable animals
Flora	. Preservation of valuable plant species.
Mineral potential	. Detailed survey prior to the impoundment.

Especially, the urgent priority should be given to the mineral potential for further investigation due to its importance.

(5) Stated below are the multi-purpose benefits arising from the implementation of the Lebir Dam Project.

(a) Power development

It becomes possible to generate a maximum output of 267.6 MW, an annual generation of 373.3 GWh and a peak generation of 16% annual plant factor. If the benefit of the Lebir plant was evaluated on the basis of the combined cycle for an alternative power source, it amounts to M$63.8 x 10^6/year. The following figures were adopted for calculation:

Construction cost of the combined cycle power plant	M$1,150/kW
Fuel cost	M$3.5/MBTU
Discount rate	10%

(b) Flood control

By providing a reserved maximum flood control capacity of 1,563 x $10^6 m^3$ above the high water level for generation (EL.80 m), the peak flood discharge at Guillemard Bridge can be reduced. For examples a 50 year return flood without the dam, can be mitigated to a 14 year return flood, and 14 year return flood without the dam is similarly reduced to a 5 year return flood.

Showing these flood mitigation effects in monetary terms, it is estimated to generate an annual benefit of M$16.1 x 10^6 against the property of 2000 year level on a basis of 1987 price. Calculating based on the result of the Interim Report for Kelantan River Basin-Wide Flood Mitigation Study (January 1989), gives an estimated cnnual benefit of M$27.3 x 10^6 per year.

(c) Agricultural irrigation

By regulating the fluctuation of river flows through the year by the Lebir dam, a firm discharge of 80 m^3/s can be obtained, though a peak discharge of 640 m^3/s is discharged to downstream when the plant is operated.

However, since the peak discharge for generation is modulated to 70 to 80 m^3/s at the irrigation pumping station 90 km downstream of the dam, the pumping stations can use this levelized flow for irrigation purposes. Therefore, by the effective use of this steady flow discharge, it becomes possible to produce crops of greater commercial benefit such as, paddy, groundnuts, maize, sorghum, vegetables and etc. by rotational cropping methods in the existing and new irrigation project areas (65,326 ha). Showing these agricultural benefits in monetary terms, M\$15.0 x 10^6 is enumerated as an annual benefit which will be generated.

(6) The Lebir Dam Project is scheduled to be completed within 90 months after commencement of the detailed design. Main activities and required periods are defined as below.

Work Item	Period
Detail design	21 months
Tender and contract procedures	19 months
Main works	50 months
Total	90 months

(7) The total cost of the Lebir Dam Project is estimated to be M\$640 x 10^6 including contingency, and its breakdown is as stated below.

Cost Items	Costs (10^6M$)
Dam	239
Power	262
Environment	139
Total	640

Costs for environment include M$118 x 10^6 for compensation of resettlements and M$17 x 10^6 for environmental measures.

(8) Economic benefit of the Lebir Dam Project is as enumerated hereunder.

Benefit	EIRR (%)	FIRR (%)
Power only	8.6 (below 6)	20.1
Power + Flood Mitigation	12.8 (10.7)	-
Power + Flood Mitigation + Agricultural Irrigation	13.9 (12.4)	-

Notes: The following calculation basis was adopted for economic evaluation.

(a) Annual mean maximum output	:	240.5 MW
(b) Annual energy generated	:	372.2 GWh (sent out energy)
(c) Construction cost for alternative power source (CCYW)	:	M$1,150/kW
Fuel cost for alternative power source	:	M$7.5/MBTU (International price level) M$3.5/MBTU (NEB's purchase price)
Flood mitigation benefit	:	M$27.3 x 10^6 per year (on a basis of Kelantan River Basin-wide Flood Mitigation Study)
Agricultural benefit	:	M$15.0 x 10^6 per year (by rotational cropping methods in 65,326 ha)

(9) The major impact on the environment due to the implementation of the Lebir Dam Project is an inundation of agricultural plantation area of 14,700 ha at the water level of EL.88.1 m. It is the most important matter to resolve. The other environmental impacts can be mitigated to what is considered should be an acceptable degree by utilizing countermeasures incorporating the results of detail investigation conducted in the next stage.

As a plus benefit, it becomes possible to supply peak load by the construction of the Lebir plant, and to relieve longer areas downstream than that inundated in the upstream, from the effects of flooding, by discharge regulation at the dam. With the steady discharge regulated by dam, additional irrigation water will also be supplied to the farm lands over 12,000 ha in the downstream area and additional benefit will be gained.

As stated above, the Lebir Dam Project will largely contribute to the socio-economic development in Kelantan State and Malaysia.

As a conclusion, it is recommended that the necessary steps be taken at the earliest opportunity to implement the Project.

2.2. Multipurpose Dam Development Scheme

2.2.1. Outline of the Project

(1) Kelantan State, located at the northern end of the east coast of the Malay Peninsula bordering upon Thailand, covers an area of 15,000 km^2. The catchment area of the Kelantan River (13,100 km^2) with its total river course of 360 km represents 87% of the total area of Kelantan State.

The Lebir River, where the proposed dam site is located, is a tributary of the Kelantan River, and joins the Galas River at Kuala Kerai 88 km upstream from the estuary. The Lebir River has a catchment area of 3,400 km^2 and a total river course of approximately 120 km. The proposed dam site (Jeram Panjang) is located 37 km upstream of the confluence with the Galas River. The catchment area at the proposed dam site is 2,474 km^2, and at the site 3 km downstream of the proposed dam, the Tualang water level gauging station is situated having a catchment area of 2,480 km^2. Also, in the downstream course of the Kelantan River, Guillemard Bridge water level gauging station is located having a catchment area of 12,100 km^2. The Guilemard Bridge station has an important role in the monitoring of floods in the Kelantan River, and the continuous recording of floods has been carried out since 1940.

(2) Kelantan State has plentiful rainfall in the context of other States in the Malay Peninsula. Generally, there is a mean annual rainfall of about 3,500 mm on the coastal area and over several kilometers inland from the coast.

However, the mean annual rainfall decreases further inland, reaching about 2,000 mm on the central plain amidst the mountain ranges. This is due to the blocking of the northeast monsoon which occurs from October to January every year. By this rainfall, the water levels of the Kelantan River are raised and cause flood damage to the coastal area downstream of the river.

In January 1967, a disastrous flood with maximum discharge of 16,000 m^3/s at Guillemard Bridge corresponding to a 50 year return period flood occurred, which resulted in an inundated area of 3,000 km^2 covering the coastal area and even up to the vicinity of the hinterland. According to the records available, 536,800 people were affected by the flood, 125,000 people were evacuated, and 38 died. The damages were estimated to be M$30 million at 1967 prices, which corresponds to M$75 million at 1986 prices. Thereafter, floods took place many times, and very considerable damage estimated at M$6 to 17 million at the price level of the respective year, was caused in 1973, 1983 and 1984 due to the floods.

(3) However, the flow discharge of the Kelantan River is reduced considerably during a period from April to June, and sometimes there is a drought condition. The annual mean flow at Guillemard Bridge is 567 m^3/s, however, in April (the dry season), the monthly mean flow is decreased to 305 m^3/s. Further, in a drought year it may be reduced to 90 to 115 m^3/s. As the water requirement for irrigation of dry season paddy is increased in this period (April to June), such a reduction can be expected to have a serious impact on irrigation water supplies.

(4) According to the 1985 population consensus, the population of Kelantan State is 1.03 million. The distribution

of population is 898,000 in the coastal region (Population density of 382 persons/km^2) and 126,000 in the hinterland (Population density of 10 persons/km^2) respectively.

The total area cropped is 320,000 ha corresponding to 21% of the total area of Kelantan State, and 74% of the remaining area is forest. In recent years, cropped acreages (especially paddy) have been decreasing, and a tendency of reduced agricultural production is observed. Crops showing an increasing trend of cropped acreage are oil palm, fruits, vegetables and tobacco, etc. The main reasons for the decrease in the cropped acreage of paddy are considered to be damage from flooding, which has frequently occurred in recent years, and a decline in the paddy growers' enthusiasm, due to their anxiety about flooding.

(5) The most important factors relevant to the promotion of socio-economy development in Kelantan State are, stabilization of flow in the Kelantan River, flood reduction, preservation of the infrastructure of production and society and improvement of productivity by irrigation. The Lebir Dam Project was one of the schemes planned to achieve this objective. The creation of the reservoir will result in the inundation of a large area of land, and resettlement problems for people presently living upstream of the dam. The Project cost will also be large, and planning has been directed towards obtaining maximum benefit from the construction of the dam and reservoir by development as a multi-purpose scheme. The overall benefits include, hydro-power generation, flood control, and improvement to agricultural irrigation reliability. Consideration is also given to the development of an aquaculture industry and recreational potential in the area of the reservoir.

2.2.2. Power Development

(6) Power development is not only a regional matter of Kelantan State, but involves the whole of Peninsular Malaysia. NEB, as the responsible agency for supplying power throughout Peninsular Malaysia, has been steadily developing power systems and extending the transmission line network. As a result, the existing power facilities as of 1987 together with implementation of the development programme up to the year 1991, no emergent problems on power supplies are forecast at present. However, according to the demand forecast by NEB in the integrated system, annual growth rates of power demand for the 20 years 1986 to 2005 are predicted as 6 to 7%.

NEB Installed Capacity (MW) in 1991

	(MW)	
Gas turbine	72	(1.5%)
Hydro Power	1,284	(26.3%)
Oil fired	405	(8.3%)
Gas fired	2,528	(51.7%)
Coal fired	600	(12.3%)
Total	4,889	(100.0%)

Note: Power development programme after 1991 is not available at present.

NEB Demand Forecast (1987)

Year	Sales (GWh)	Peak load (MW)
1986	11,421	2,268
1990	14,962 (6.98)	2,984 (7.10)
1995	20,754 (6.76)	4,142 (6.78)
2000	28,216 (6.34)	5,615 (6.27)
2005	37,920 (6.09)	7,546 (6.09)
2010	50,368 (5.84)	10,024 (5.84)

Figures in bracket means the annual growth rate (%).

(7) The planned installed capacity of power sources of NEB in 1991 is 4,889 MW. Assuming the required system reserve to be about 30%, it is considered necessary to develop some new power sources after the year 1993 when the system peak load demand exceeds 3,661 MW.

The load forecast around 1999 when the Lebir plant is to be commissioned is shown below;

	1998	1999	Increase	Growth Rate
Peak load (MW)	4,975	5,286	311	(6.25%)
Energy sales (GWh)	24,961	26,540	1,579	(6.32%)

The increase in peak load requires the development of power sources with a capacity corresponding to the maximum output of the Lebir Plant every year.

(8) How to deal with the fluctuation of power load is one of the most important problems for power industries. Therefore, reservoir or pumped-storage types of project have been considered for the generation of hydro-power, and gas-turbine and combined cycle plants have been designed for thermal power generation.

In Malaysia, the plant factors at maximum output of the existing hydro-power plants have been designed to be kept at approximately 30%. In this study, consideration is given to cover a peak load at the maximum extent by the Lebir plant, a prospective hydro-power plant in West Malaysia, study ranges of the plant factor were expanded up to around 12.5%.

Taking the topographical and geological features at the Lebir dam site, and the river discharge characteristics into account, comparative development plans were formulated with the reservoir HWL varied in the range EL.60 m to

EL.85 m, and the firm discharge varied from 40 m^3/sec. to 80 m^3/sec. For each development plan, the maximum output, annual energy generation and project cost were estimated. (Refer to Main Report Section 6.2.)

Maximum output	19.9 MW - 300 MW
Annual energy generation	142 GWh - 411 GWh
Project cost	384 x 10^6 Ringgit - 888 x 10^6 Ringgit

A total of 81 cases in various scales was studied, and the economic analysis was made of 35 of these cases. (Refer to Table 6-10)

Among the cases subjected to economic analysis (see Table 6-10), some cases are considered beneficial from the economic point of view. However, the net benefit shown here includes multi-purpose benefits arising from flood mitigation by the reserved capacity for flood control designed above the high water level and agricultural irrigation by the regulation of river flow by the dam.

HWL (m)	Qf (m^3/s)	α	MW	GWh	Net benefit ($x10^6$M$) i=8%	i=10%	i=12%
85	80	5	188	402	△ 1.33	△ 22.93	△ 47.54
85	80	6	225.6	402	0.45	△ 21.39	△ 46.27
85	80	8	300.8	416	2.14	△ 20.77	△ 46.91
80	80	5	170.7	365	0.03	△ 18.89	△ 40.35
80	80	6	204.9	370	1.67	△ 17.45	△ 39.17
80	80	8	273.2	380	1.85	△ 18.67	△ 42.00
80	70	6	179.3	377	0.18	△ 18.98	△ 40.71

Since the total project cost at the Interim Report stage was estimated roughly, many cases show minus benefits, i.e. the benefits can be expected only from 6 cases setting the discount rate at 8%. However, the following trend can be observed, because the relative difference in various cases is read from the results of economic analysis.

(a) Higher dam is more beneficial.

(b) Large peak ratio and output is more effective.

From the above, the schemes of HWL = 80 m, Qf = 80 m^3/s, α = 8 and HWL = 85 m, Qf = 80 m^3/s, α = 8 seem to be advantageous from the economic view point. However, the former scheme is proposed as an optimum plan for the reasons given below, and the latter is omitted from further analysis.

i. In the case of the scheme of HWL = 85 m, the design flood discharge level reaches EL. 93 m. This level exceeds the maximum reservoir level by 3 m considered possible to construct, due to topographical and geological limitations at the proposed dam site.

   However, in the case of HWL = 80 m, the design flood discharge level of EL.87.9 m is feasible.

ii. If the reservoir water level exceeds EL.90 m, the submerged area becomes excessively large. Therefore, a case able to minimize the impact on agricultural plantations while achieving the other project objectives is preferable.

(9) As a result of feasibility level design made for the optimum plan, the following main features of the power development scheme have been determined. (For details see Table 2-1-1.)

High water level (HWL)	: EL.80.00 m
Low water level (LWL)	: EL.60.00 m

Effective depth and storage for power generation	:	20 m, 1,890 x $10^6 m^3$ (211 GWh, amount converted in terms of energy)
Tailrace water level (tailrace channel end)	:	EL.28.00 m
Maximum gross head	:	52.00 m
Maximum effective head	:	49.66 m
Firm/peak water discharge	:	80/640 m^3/s
Internal diameter, length and number of pressure tunnels	:	8.6 m, 202.8 m x 2 lines
Turbines	:	Vertical shaft Kaplan (125 rpm), 2 units x 136,800 kW discharge 320 m^3/s
Generators	:	Three-phase, synchronous enclosed type with a vertical shaft and damper windings, 2 units x 149,000 kVA
Voltage and length of the associated transmission line	:	275 kV and 7 km
Annual possible generation	:	373.3 GWh
Maximum output	:	267.6 Mh
Annual mean maximum output	:	240.5 MW
Annual mean inflow	:	112.6 m^3/s (396 GWh, amount converted in terms of energy)
Specific cost for power facilities (1987 prices)	:	M$262.2 x 10^6
Annual mean benefit* (1987 price)	:	M$63.8 x 10^6*

* When the discount rate was set at 10%, the benefit is calculated based on the sending end level as follows: 238,580 kW x M$209.1/year + 372.2 x 10^6 kWh x M$0.03729/kWh = (49.89 + 13.88) x 10^6 = M$63.77 x 10^6

2.2.3. Flood Control

(10) Floods have frequently occurred in the Kelantan River from November through to February due to heavy rain brought by

north-east monsoons from the South China Sea. Flood damage has extended from the lower reaches of Guillemard Bridge to a large area including Pasir Mas and the State capital Kota Bharu. A heavy flood took place in the area in 1927. (No exact records on this flood has been obtained). Again in January, 1967, a disastrous flood occurred, which resulted in an inundated area of approximately 300,000 ha and estimated damage valued at 30 million Malaysian Dollars (at 1967 prices).

At the gauging station at Guillemard Bridge, forty-five floods have been observed during the period of 47 years from 1940 to 1986, and peak flood discharges were in the range, 1,500 m^3/s to 16,000 m^3/s. During that period, floods exceeding a peak discharge of 6,000 m^3/s took place 18 times. Records of the amount of damage which was caused by 10 floods since 1965 have been obtained.

In this study, analyses were made of flood mitigation effects which can be obtained when the Lebir Dam Project is developed for the purposes of power generation and flood control.

(11) The Lebir dam and reservoir can mitigate the extent of downstream flooding by control of the release of flood discharge from the river catchment upstream of the dam. This is basically achieved by the provision of additional storage within the reservoir above the HWL required for power generation. The sizing of the additional storage capacity is related to the magnitude of flood flows at the site, correlated with resulting river levels downstream where damage is known to have occurred. The flows evaluated are based on records of rainfall and river flow. In addition the physical factor of how much additional storage is feasible at the site, and the economic factor relating to the cost/benefit of the storage provision must

be made in reaching a final conclusion. Records relating to 14 floods which took place between 1967 and 1984, measured at the Tualang water level gauging station 3 km downstream of the proposed dam site have been obtained. According to the past record, the discharge of 4,200 m^3/s in 1967 is the largest, followed in magnitude by 3,900 m^3/s in 1979 and 1983. The 14 flood discharges recorded at the Tualang station can be used to obtain a correlation with discharges at Guillemard Bridge water level gauging station.

(12) There are also rainfall gauging stations within the catchment area of Lebir River from which flow data can be evaluated, i.e. one at the upstream reach Stn. Tele. Kg. Aring (No.5), three at the downstream reaches of the dam Stn. Tele. Kg. Lalok (No.11), Stn. Keretapi Manek Urai (No.12) and Sek. Keb. Laloh Ulu (No.20). Among these stations, No.20 station is the nearest to the proposed dam site, and has most records. There are only two years records available at No.5 station, and for No.12 no data is available after 1964.

(13) To deduce a flood inflow to the reservoir, a run-off model was established based on rainfall data input. For calibration of the run-off model, records of two floods which took place in December 1983 (peak discharge at Tualang station: 3,900 m^3/s) and December 1984 (peak discharge at Tualang station: 3,430 m^3/s) were used. From the record, correlation of water level and time at the Guillemard Bridge and Tualang gauging stations both floods can be compared correctly.

The probable flood discharges computed on the basis of probable rainfall using the run-off model established as stated above, were calculated as shown below.

Return period	At Tualang (m^3/s)	At Guillemard Bridge (m^3/s)	Tualang/ Guillmard
10,000	10,604	31,413	0.338
1,000	8,282	25,078	0.330
200	6,663	20,679	0.322
100	5,951	18,752	0.317
50	5,260	16,851	0.312
20	4,323	14,315	0.302
10	3,595	12,340	0.291
5	2,846	10,294	0.276

(14) The further question for flood control by the dam is how much can the reservoir cut flood discharges and mitigate the floods, i.e. how much can the reservoir reduce the flood discharge at Guillemard Bridge, a base point downstream.

For this, the dam height, spillway capacity and flood control method are the relevant parameters for comparison. However, only the dam height and crest width of spillway sill were used as parameters, because the spillway adopted for this project is ungated. It is a free overflow chute type spillway. The capacity of spillway should meet the requirements to discharge the design flood safely, in addition to the requirement of regulating the high water level caused by the flood.

The width of spillway sill was determined to be 160 m after computation of some alternatives, and this sill width has been adopted for comparison in which various dam heights have been considered. The dam height is determined by providing for flood control capacity above the high water level for power generation.

(15) Flood mitigation effects by the dam can be evaluated by calculating the amount of flood damage both with, and without the dam, based on the calculation results of peak flood discharge reduction at Guillemard Bridge, and a chart presenting the relationship between peak flood discharges at Guillemard Bridge and past records of the amount of flood damage (refer to Fig.7-8). DID has compiled a report on flood damage and discharge since 1965. According to the report, the total damage due to the 10 floods which took place during 22 years up to 1986 was estimated to be M$165 million at 1986 prices and represents an annual average cost of M$7.5 million. (Refer to Main Report Table 7-2)

The amount of damage from floods was estimated in monetary terms for various cases with different HWL of the Lebir dam, with and without other dam developments along the Kelantan River. The expected benefits arising from the flood mitigation are shown as follows;

Case	Capacity of flood regulation	Estimated amount of damages on the annual average (1986 prices)	Expected benefit arising from flood mitigation on the annual average
	x $10^9 m^3$	x 10^6 M$	x 10^6M$
Without dam	0	30.1	0
With only Nenggiri Dam		19.3	10.8
With only Dabong Dam		16.5	13.6
With only Lebir Dam (HWL 70 m)	1,329	23.6	6.5
With only Lebir Dam (HWL 75 m)	1,590	21.0	9.1
With only Lebir Dam (WHL 80 m)	1,846	19.1	11.0
With only Lebir Dam (HWL 82 m)	2,011	18.4	11.7

As shown above, the larger the flood control capacity in the Lebir dam is, the larger is the expected benefit arising from flood mitigation.

Stated below are the results of the economic analysis of various cases in consideration of incremental cost and benefit as the reservoir capacity is increased..

Dam height (HWL, m)	(V) Incremental flood control capacity ($10^6 m^3$)	(C') Additional Construction cost (10^6M$)	(ΔB) Incremental mitigative amount of flood (10^6M$)	ΔB/ΔC
70	-	-	-	-
75	261	13.1	2.6	1.50
80	256	12.8	1.9	1.12
82	165	8.3	0.7	0.64

$C' = V \times 0.05$ M$/m^3

$\Delta C = 0.132 \times C'$ (Assuming a discount rate of 10%)

The construction cost of the Lebir dam including compensation ranges from M$0.10 to 0.14 per m^3 of the effect storage. An additional construction cost to get an incremental effective storage is M$0.05/m^3.

Further flood control benefit can be expected if a higher dam was to be designed. However, it can be seen from the above table that HWL 80 m should be the maximum height for the Lebir dam.

(16) According to the Kelantan River Basin-Wide Flood Mitigation Study commenced in April, 1988 by another JICA Team, the base flood discharge was determined as the 50 year return flood, and the four alternative spillway schemes studied

for the Lebir dam provided for discharge of the design flood together with the 50 year return flood.

The Basin-Wide Study Team's Alternative 1, is a fixed weir type with a crest sill level of EL.80 m and overflow width of 150 m, the same type as is proposed by the Lebir Dam Study Team, but the overflow width is shortened 10 m from 160 m to 150 m.

An overflow sill with two steps is proposed in Alternatives 2 to 4, dividing the spillway functions into two; one for discharging the 50 year return flood and the other for the design flood. By adopting this two-step sill, the cut ratio of peak discharge in the 50 year return flood is increased, and it was considered to improve the mitigative effect on the flood. However, as there are restrictions on the dam height due to the topographical and geological features of the proposed site, the crest elevations of spillway sill were determined as EL.79.3 m, EL.77.9 m and EL.76.3 m for Alternatives 2 to 4 respectively.

The Lebir Dam Study Team computed benefits arising from the flood control in each alternative based on the above design sill level, and its results are as shown below.

Case	HWL	50 year return flood discharge	Discharge in flooding	Peak cut ratio	Annual average damaged estimated	Expected benefit* arising from flood mitigation on the annual average
	(m)	(m^3/s)	(m^3/s)	(%)	(10^6M$)	(10^6M$)
Without dam	-	5,560	5,560	0	26.961	0
1	80.0	5,560	3,190	43	18.806	8.155
2	79.3	5,560	2,920	47	18.368	8.593
3	77.9	5,560	2,260	59	17.418	9.543
4	76.3	5,560	1,660	70	16.758	10.203

* 1986 price levels

In calculating the expected benefit, arising from flood mitigation on the annual average even in the flood over 50 year return, the correlation chart mentioned in the above (15) was adopted.

On the other hand, according to Table V.5.7 (Page V-71) of the Interim Report Part II Supporting Report (January 1989) for the Kelantan River Basin-Wide Flood Mitigation Study, M$42.57 million (1988 prices, 1988 levels) is estimated as the annual average estimated amount of damages due to the flood below 50 year return.

The annual average estimated amount of damages in case with Alternative 1 spillway (HWL 80 m, fixed weir type with the crest width of spillway sill of 150 m) was calculated by the Lebir Dam Study Team, based on the results of Table V.5.7 above mentioned, to be M$26.29 million. (Refer to Main Report Table 7-4)

The difference of M$16.28 million is considered to come from the peak cut effect of flood by the Lebir dam in 1988 prices and 1988 (assets) level. If this amount is converted into 2000 (assets) level and 1988 price, the calculation result shall be as follows.

M$16.28 million x 1.665 = M$27.3 million

The estimated amount of damages calculated by the Basin-Wide Flood Mitigation Study Team is more accurate because they assessed it based on the result of field survey from Kuala Kerai to the downstream course of the Kelantan River. While, the calculation made by the Lebir Dam Study Team is based on the past record of damages and does not accurately assess the growth of properties involved up to the present time.

(17) Though four alternative schemes for the spillway were proposed in the above (16), except in the case of Alternative 1, less power benefits are obtained. In considering this together with the incremental benefit of flood mitigation, the following evaluation can be made.

Case	HWL	Output	Generation	Power* benefit	Flood** mitigation benefit	Total benefit
	(m)	(MW)	(GWh)	(10^6M$)	(10^6M$)	(10^6M$)
1	80.0	267.6	373.3	69.87	16.98	86.85
2	79.3	262.0	366.6	68.46	17.90	86.36
3	77.9	246.2	358.5	64.85	19.87	84.72
4	76.3	227.6	348.1	60.57	21.25	81.82

* The generation level was adopted for rough calculation.
** 2000 year level, 1987 price

The dam height remains the same for all alternatives. The construction cost of spillway is gradually increased in proportion to the lower crest elevation of overflow sill level compared to Alternative 1. Besides, the unit cost of generation facility per kW becomes higher when the output of the plant is decreased, thus no economic merit can be found for Cases 2 to 4. Thus, Alternative 1 is confirmed as an optimum scheme for the spillway.

(18) The following are the features for the control scheme determined as the result of a feasibility grade design on the optimum scheme.

Crest elevation of dam	:	EL.92.0 m
Design flood discharge (10,000 year return)	:	10,600 m^3/s
Design flood water level	:	EL.88.1 m
Base flood discharge (50 year return period)	:	5,250 m^3/s
Surcharge water level (in case 50 year flood)	:	EL.84.9 m
Peak discharge	:	2,950 m^3/s
Maximum flood discharge in the past (1967)	:	4,200 m^3/s
High water level for generation	:	EL.80.0 m
Flood control capacity		
EL.84.9 - EL.80	:	884 x $10^6 m^3$
EL.88.1 - EL.80	:	1,563 x $10^6 m^3$
Type of spillway	:	Free overflow chute type
Overflow sill elevation	:	EL.80.0 m
Overflow sill width	:	150.0 m
Flood mitigation benefit (2000 level, 1987 price)	:	16.98 x 10^6 M$
"	:	27.3 x 10^6 (Basin-Wide Study base)

It should be noted that the 50-year return flood can not be completely controlled by the Lebir dam only, but the river improvement of the downstream river channel should also be carried out for the complete protection. By the Lebir dam a 50-year return flood can be mitigated into a 14-year return flood at Guillemard Bridge. The volume of discharge to be completely controlled by the Lebir dam is 6,000 to 7,000 m^3/s of peak discharge at Guillemard Bridge.

2.2.4. Agricultural Irrigation

(19) The possibility of agricultural benefit to be generated from an increased discharge downstream in the Kelantan River, due to the additional water to be released from the Lebir dam, was studied in relation to the total irrigable area of 78,826 ha, consisting of the seven new irrigation projects proposed in the Kelantan River Basin Study (KRBS, 1977) and existing KADA and Kemasin-Semerak Irrigation Projects.

(20) In consideration of the Fifth Malaysia Plan (1986 - 1990), future rice production efforts in Kelantan State will be concentrated in the granary area of Kemubu and Kemasin-Semerak. The production of paddy in the existing paddy land outside these granary areas will be gradually phased out and replaced by other more remunerative crops. Prospects on demand and supply of rice in Malaysia and Kelantan State are studied in relation to the rice policy mentioned above.

The rice self-sufficiency in Kelantan State for six years from 1980 to 1985 is 84 percent to 100 percent and the position is unstable. This is due to the unsteady level of rice production in the State. The share of rice production quantity in the State to Malaysia as a whole was about 8 percent to 12 percent in 1980 and 1985.

The paddy cropping acreage in the rainy season in Kelantan State decreased from 70,389 ha in 1972/73 to 33,189 ha in 1984/85. The main reason for decrease was flood damage, drought and insects, and other factors mentioned below.

- Decline of farmers' enthusiasm to paddy cropping due to their anxiety about floods.

- Spoiling of transplanting seedlings caused by flooding of nursery beds.

- Delay in transplanting off-season paddy due to drought in March and April, which results in the overlapping of the period of nursery and transplanting of main season paddy, in the flood season.

- The period of panicle growing and flowering overlaps the period of shortage of irrigation water from March to April.

A transition of paddy cropping acreage in the off-season in Kelantan State for 14 years from 1972 through 1985 is found not much decrease or little decrease in comparison with that of the main season paddy. It is mainly due to the stability of paddy cropping acreage in KADA Project Area, which occupies about 86 to 96 percent of the total cropping acreage in Kelantan State. However, the cropping acreage has decreased since 1980. The major cause for decrease is a damage by insects.

It is considered that the paddy production level in Kelantan State, which comes up to the national requirement, is represented as the share of paddy production of Kelantan State to the national production. The prospect of paddy production nationwide and in Kelantan State is studied up to 2010. As a result, the larger the expectation given to paddy production increase in Kelantan State than that of other areas in Malaysia, the more meaningful will become the additional supply of rice produced in the new seven (7) irrigation projects located in the non-granary area.

(21) The existing paddy fields of the seven (7) irrigation projects total 19,776 ha, of which the irrigated paddy accounts for 38 percent, and the rainfed paddy 62 percent. In order to use effectively the additional water to be released from the Lebir Dam, conversion of the rainfed paddy to irrigated paddy fields is planned, hence, diversification or intensification of crops will be promoted.

The cropping plan for the seven (7) projects is studied by two systems of mono-cropping of paddy, and irrigated rotational cropping system. As regards to the latter, the upland crops and partial paddy are cropped in the off or dry season. Paddy is the crop of the main or rainy season. Many kinds of upland crops are planned such as tobacco, groundnuts, maize, sorghum and vegetable in consideration of the cropping plan studied in the ENEX Report.

The DID Kelantan estimates the total demand of water to be taken from the Kelantan River as 190 m^3/s including 90 m^3/s for irrigation water, 20 m^3/s for domestic and industrial water (Water demand from Kemasin-Semerak Project, estimated at 5 m^3/s) and 80 m^3/s for residual flow for saline abatement.

When water requirements for the seven new irrigation projects are fulfilled in the future, the gross requirements for irrigation water will exceed a reserved discharge of 90 m^3/s for irrigation water. In this study, a water balance study was made, based on the additional discharge in the Kelantan River which will be made available after completion of the Lebir Dam.

(22) According to the long term development plan of the nine irrigation projects originated mostly from the KRBS, the water requirements for these projects are estimated to increase by staged development. Hence, the water balance studies were conducted on four cases; Case 1, (KADA + Kemasin - Semerak : 46,800 ha), Case 2, (KADA and other four projects : 55,870 ha), Case 3, (nine projects : 78,826 ha) and Case 4, (eight projects : 65,326 ha). Water flow in the river was studied for three cases: the first case, without the Lebir Dam, the second, with 70 m^3/s water release from it, and the third, with 80 m^3/s water release from it. Combining these cases together, ten (10) cases were formulated for the study.

The basic data used in the study are the discharges for each 10 day period of the month at Guillemard Bridge on the Kelantan River, from 1967 to 1984 and the unit water requirements (Lit/s/ha) by each 10 day of the month from 1967 to 1984.

Irrigation water duty (MCM), discharge of river water (MCM), reserved discharge of the Kelantan River excluding irrigation water requirements, and the remaining discharge of the Kelantan River were calculated on a 10 day basis of the month, from 1967 to 1984.

The reserved discharge consists of domestic/industrial water and residual flow for salinity control. Two cases of the reserved discharge of 85 m^3/s and 100 m^3/s are considered in this analysis. The residual discharge in the river is comprised of river discharge measured on a 10 day basis, less the irrigation water requirement assessed on a similar basis. When the residual discharge falls below the reserved discharge (85 m^3/s or 100 m^3/s) water shortage is considered to have taken place during such period.

The probability criterion of a ten-year return period rainfall which is used in the KADA II Improvement Project Study was adopted in the above case study. As a conclusion, it is expected that the release of water from the Lebir Dam exceeding 70 m^3/s will stabilize the supply of irrigation water to the nine irrigation projects in each of Cases 2, 3 and 4, except for the 100 m^3/s reserved discharge in Case 3.

(23) Parts of paddy fields of 1,540 ha, extending into the area of the irrigation canal systems in the Lemal & Alor Pasir and Pasir Mas Area on the west bank area of KADA II Project, are chronically damaged by drought in dry years due to location at high elevation. When the flow of pumped water is small and water levels in the irrigation canal fall lower than the design levels, water does not reach these paddy fields. These fields will suffer from shortage of irrigation water, even after the Lemal Irrigation Component and pumping facilities in KADA II are completed. Hence, the 1,540 ha mentioned above are regarded as areas which will benefit by discharge from the Lebir dam.

The annual average area damaged by drought in Kelantan State for ten years from 1975 to 1985 is estimated at 1,207 ha, of which 1,172 ha are damaged in the main paddy season and 35 ha in the off season. The damaged area in the Kemubu Area of KADA II Project is estimated at 722 ha on an annual basis. Therefore, resolution of the drought damage problem in this area is considered as benefit brought about by water from the Lebir Dam.

Irrigation water shortage at the Kemasin-Semerak Project will be supplemented from the Kemubu pumping station at the Kelantan River. Referring to the results of the water balance study, the benefit to be expected from this project was not considered to be generated by the discharge from the Lebir Dam.

(24) Incremental agricultural benefits will result mainly from the increase in irrigated paddy area, owing to stable irrigation water supply. This means the conversion of rainfed paddy fields to irrigated paddy. Expansion of acreage cropped with paddy and diversification crops can be expected.

Agricultural benefit is estimated for the five (5) cases. The project area with the four (4) cases Nos. 1 to 4 corresponds to those of each case treated in water balance study. The cropping system of these four (4) cases is the mono-cropping system of paddy. Case 5 is planned as using the irrigated rotational cropping system.

The annual incremental benefit was projected to extend from 1999 and reach the following figures in 2018, i.e. after 20 years.

Annual Incremental Benefit	Case 1	Case 2	Case 3	Case 4	Case 5
		- M$ Million -			
Market price base	1.48	8.95	35.57	22.05	48.74
Economic price base	1.25	7.80	28.68	17.56	45.61

The internal rate of return by cases is estimated as below. Case 5 planned by diversification crop shows the highest IRR.

	IRR	
Case	FIRR	EIRR
2	11.0	11.6
3	12.5	12.5
4	12.8	12.7
5	18.3	19.9

In the drought period the river discharge in the downstream reaches of the Kelantan River will increase in a stable manner by river regulation by the Lebir Dam. As a result, the growth of agricultural products in the downstream region will be increased and the annual net production is forecast to reach at M$22.05 to 48.74 million on a market price basis.

(25) The main features of agricultural irrigation programme for the downstream course of the Kelantan River using the discharge from the Lebir dam are as follows.

Possible irrigable area (including the existing areas and the new projects)	65,326 ha
Water requirements based on the existing programme (excluding the regulation by the Lebir dam)	
- Irrigation water supply	90 m^3/s
- Domestic and industrial water supply	20(5) m^3/s
- Residual flow for saline abatement	80 m^3/s
Total	190 (175) m^3/s
10 year draught discharge at Guillemard Bridge	95 m^3/S
Daily firm rate of discharge of the Lebir dam*	80 m^3/s
Emergency discharge of the Lebir dam**	$335 \times 10^6 m^3$ (50 m^3/s x 77 days)
Specific cost for irrigation facilities (1986 price)	M$160.4 x 10^6
Net agricultural benefit (Case 5) on the annual average (Economic prices - 1999 to 2049)	M$15.0 x 10^6

Figures in brackets are extracted from the Kemasin - Semerak Study.

* At times when the discharge is made at 640 m^3/s over a period of 3 to 4 hours (after reservation of flow in the reservoir is made), the corresponding flow at the pumping station for irrigation 90 km downstream, will still remain in the allowable range of 70 to 80 m^3/s, due to the modulating effect of the river course. (Refer to Section 11.12.1.).

** Emergency discharge of 45 to 80 m^3/s up to 335 x $10^6 m^3$ reserved between LWL 60 m and WL 50 m is possible through the bottom outlet (inlet sill level of EL.50 m).

2.3. Environmental Problems

(1) Impound area in the upstream basin

The area and type of lands inundated by construction of the Lebir dam are shown below.

(Unit: ha)

Sort of land	WL 60 m	WL 70 m	WL 80 m	WL 90 m
Agricultural plantation	2,656	5,472	9,588	16,379
Forest	1,944	3,428	5,812	8,321
Total	4,600	8,900	15,400	24,700

Stated below is the classification by owners of the agricultural plantation area to be submerged.

(Unit: ha)

Owner	Total Area	Inundated at WL 70 m	Inundated at WL 80 m	Inundated at WL 90 m
KESEDAR	27,626	3,839	5,667	8,185
FELDA	23,965	1,240	3,094	6,885
FELCRA	405	30	77	129
ADB Project	-	363	750	1,180
Total	51,996	5,472	9,588	16,379

Note: The above figures include the future development plan.

Assuming approval for the implementation of the Lebir Dam Project was given and development after 1990 within the proposed impoundment area was suspended, the agricultural plantation area to be inundated is estimated as given below. The base elevation considered for resettlement was determined to be EL.88.1 m, which corresponds to the design flood water level of the reservoir.

Owner	Agricultural plantation area to be inundated (below EL.88.1 m) (ha)
KESEDAR	4,935
FELDA	3,904
FELCRA	114
ADB Project	1,047
Total	10,000

Of these areas, rubber plantations cover 3,100 ha and oil palms are 6,900 ha. As an alternative location, the USM Sub-study Report suggests the region to the north of the Ciku Plantation.

Unlogged forest within the impoundment area is estimated to be 3,200 to 4,500 ha, and the inundated acreage of land except for plantations is as follows.

- Lebir riverine settlements 2,000 acres (809 ha)
- Orang Asri 55 acres (22 ha)

(2) The units of settlers to be relocated due to inundation by the Lebir Dam were reported in the USM Sub-study Report as follows.

Group	No. of units	No. of people
. Lebir riverine settlers	100	500 persons
. Settlers in the land development area	675	4,050 persons
. Orang Asli	-	144 persons
Total		4,694 persons

In terms of the candidate site for resettlement of the people living in the inundation area, USM Sub-study Report gives the following suggestions.

(a) Small plots dotted over the southern part of Gua Musang be provided for the Lebir riverine settlers.

(b) Prospects of extension northwards of Ciku Plantation area are sought for the settlers in the land development area.

(c) For Orang Asli, it is suggested to make them settle near the Malay settlement areas.

It is considered that the development of an aquaculture industry will contribute to the creation of new employment opportunities for some hundred households. (Refer to Main Report Section 11.11.)

(3) Fluctuation of water level in the downstream area due to discharge for generation.

Since the Lebir power plant is to be constructed as a peak power station, the plant will only be operated for limited hours each day. Thus, there will be large water level fluctuation during the day in the downstream area due to the generation discharge. One of the objectives of this Study is to clarify whether there will be any adverse effects on the downstream irrigation water requirements caused by the peak discharges upstream, and to propose any required corrective measures.

(a) Impact on the downstream irrigation water requirements

It is understood from the result of study that the effective functioning of the pumping station located about 90 km downstream is not adversely affected by the peak discharge for generation of 640 m^3/s from the Lebir power plant. This is because the sudden increase of flow in the river which occurs immediately downstream of the dam, and its effect on river level, is modulated during its passage downstream to the pumping station over a period of 20 to 40 hours from the commencement of the discharge from Lebir reservoir. During these hours the discharge will be gradually modulated to be within the range 68 to 81 m^3/s. (Refer to Main Report Section 11.12.1.)

(b) Minimum flow in the river course downstream of the Lebir Dam

For about 20 hours each day when the power plant is not operated it is anticipated that the 37 km length of river, from the power station to the confluence with the Galas river, will dry up. The minimum flow in the upper reaches of the river channel downstream of the dam during the dry season between April and September is estimated to be only 1 to 2 m^3/s, and to 4 m^3/s in the lower reaches. Thus, it is anticipated that there will be very little flow in the dry season.

By the construction of a re-regulating pondage dam 5.4 m high, with a reserved capacity of 870,000 m^3 at a site 3.3 km downstream of the power station, an average flow discharge of 12 m^3/s can be released downstream to maintain the river when the plant is not operated. (Refer to Section 11.12.3.)

(c) As the supply of sediment load is cut off by construction of the Lebir dam, a study was made of the possibilities of river bank erosion due to lowering of riverbed downstream of the dam, and erosion due to water level fluctuations by the generation discharge. As a result of study, it is estimated that existing riverbed will be lowered by about 1 to 2 m extending approx. 5 km downstream of the dam, and 0.5 to 1 m extending for a further 5 km downstream.

The rates of fall in peak water level are 30 and 20 cm per 0.5 hour in the vicinity of the power station and at 8.5 km downstream respectively. Under these conditions small scale bank erosion may occur, but the possibility of large scale erosion is less. The tractive force on the river bank by current is relatively small, and it is therefore concluded that river bank erosion will only occur to a very limited extent. The limiting size of particles which can be moved by the flow falls rapidly over a short distance downstream. (18 mm of 0.74 km and 3-4 mm at 2.64 km downstream of the dam site. Refer to Section 11.12.4). This also supports the conclusion of limited erosion.

(d) As a result of generation and spillway discharges, the flow in the downstream course of the river increases rapidly, and there could be danger to local residents who commonly use the river as a necessity of their daily lives. To minimize these risks, a downstream discharge warning system will be installed. (Refer to Section 11.12.5.)

(4) Change in water quality

The area of the reservoir to be created by the dam construction varies with a height of the dam. At a water level of EL.70 m, it extends over 8,900 ha and, if the water level rises to EL. 90 m, it is increased to 24,000 ha. These reservoir areas are respectively equivalent to 3.6% and 9.7% of a total catchment area of 247,400 ha. Of the area to be inundated, farm lands occupy 60%, and the remaining 40% is forest.

The storage capacity of the reservoir will be 1.18 billion m^3 at a water level of EL. 70 m and 4.4 billion m^3 at a water level of EL. 90 m. These storage capacities are respectively equal to 33.2% and 123.9% of the annual average discharge (3.55 billion m^3). An average water depth is estimated to be 13 m at a water level of EL. 70 m and 18 m at EL. 90 m.

The water quality of the Lebir River shows the characteristics of a tropical river with little artificial pollution in its upper reaches, but this increases with the increasing development along the river downstream of its confluence with the Aring River. The factors affecting water quality in the reservoir are not the same, since any change in the inflow quality is dependent on the condition in the submerged area. Once reservoir impounding is commenced, nutrients and organic matter will be released from the ground soil and trees submerged, creating conditions for eutrophication of the reservoir water. Extensive farm lands exist around the reservoir for a total area of about 52,000 ha (including the farm land area to be inundated). Many organic inflows including the fertilizer to be used on these farm lands will accelerate aggravation of the water quality. The following are considered appropriate countermeasures to control adverse effects to the water quality.

(a) As a prior countermeasure to prevent eutrophication in the reservoir area, trees within the inundation area are to be logged and removed. In principle, logged trees are to be removed outside the reservoir area.

(b) Development of farm lands around the reservoir area is to be suspended for the time being, and limnological monitoring of water quality and living things in the reservoir area should be carried out. Based on the results of monitoring, a plan of land use in the catchment area should be made with the aim of minimising the flow and deposition of matter likely to give rise to water quality problems in the future reservoir.

(c) In order to cut down the deposition of sediment in the reservoir, bare places should be afforested, to minimize land erosion.

(5) Fish

The Kelantan River is famous for its abundance of fresh-water fishes. Tor tambroides (Ikan Kelah) and Scleropages formosus (Ikan Kelisa) are especially rich in the river. Many fish species are found in the river, and a composition of species is similar to those found generally in large rivers in Peninsular Malaysia. In the upper reaches of the Lebir River, Tor duronensis (Ikan Kelah Puteh), P. daruphani (Ikan Kerai), P. bulu (Ikan Tenggalan), A Hexagonolepis, etc. have been identified in addition to the above two species.

Small scale fishery in the Lebir River is operated by residents of the region, including settlers from the coast. Most of the fishermen operate on a part time basis to supply their own needs, and there are only a few who work full-time and actively participate in fisheries. High-class fish is sold at markets but is only small in quantity.

A change in the water quality resulting from the creation of a new reservoir will determine fish species which can adapt themselves to the change. It is considered that 60 to 70% of the existing fish species found in the Lebir River will be able to adapt to the change. The fish species that will accommodate to the environment of the new reservoir will depend on the bio-chemical conditions in the reservoir. The reservoir has the possibility of providing a good fishing ground for fresh-water fishes. However, the dam will be a hindrance to the migratory species for example M. rosenbergii (Udang Galah), a kind of shrimp.

The following measures should be taken to promote fresh-water fish resources within the new reservoir.

(a) Limnological monitoring of the water quality and living things in the reservoir should be carried out, and a fishery plan should be established on the basis of an ichthyological study.

(b) An organization to commercialize a fishery plan should be established.

(c) In order to maintain continuity of the eco-system of the river and enable anadromous or migratory fish species such as Udang Galah to live in the river, installation of fish ladder should be considered.

(6) Aquatic weeds

Aquatic weeds, which in tropical regions pose problems in the control of a reservoir frequently become established. At present, no aquatic Macrophytes are observed in the Lebir River which will bring about such problems. However, careful attention should be paid to aquatic weeds, to prevent such problems.

Monitoring should be continuously conducted in the reservoir, and a working team should be formed to remove aquatic weeds as soon as they are found in the reservoir.

(7) Fauna

Much wildlife in Malaysia is protected by the Wildlife Laws of Malaysia. It is confirmed that many species of animals and birds live in the project area.

Among small mammals living in the area, there are Stump-tailed Macaques (Macaca arctoides) which are very rare in Peninsular Malaysia. Of the large mammals, there are those which are at the point of extinction and protected species such as Red Dogs, Panthers, Tigers, Bantengs, Elephants, Tapirs, Primates and Giant Squirrels, etc.

Of the birds living in the area, those of particular interest are Hornbills and Argus pheasants.

These counted as species which are at the point of extinction and to be protected comprise eleven (11) mammals and the following three birds;

(a) Pheasants
(b) Hornbills
(c) Birds of prey

It will be necessary to remove these animals from the area to be submerged to higher places of safety to avoid them being trapped during the inundation. Many alternative methods for removal are possible. However, comprehensive measures to protect their existence are recommended to be taken on the basis of the results of investigations conducted thereafter.

(8) Flora

Botanical investigations carried out by USM confirmed 35 families, 75 generas and 122 species, and 27 families, 65 generas and 95 species respectively at two sites. A total of those at the two sites is 40 families, 102 generas and 185 species. Overlaps of those at the two sites are few. This indicates an abundant variety of tropical fauna. Some valuable medical herbs also grow at these sites. A remarkable one is Rafflesia arnoldii which is a parasitic plant with the largest flower in the world. There are 38 species not confirmed during the last investigation, and a high possibility that there are other undiscovered species in the area.

The bio-masses at the two sites are 439.67 tons/ha and 359.39 tons/ha respectively, i.e. an average of 399.53 tons/ha. This figure is a mean bio-mass in tropical forests. The extent of the effect on flora attributable to the creation of a new reservoir is basically that of the inundation area. However, as there are extensive farm lands in the area to be inundated, the extent of the effect by the dam construction should also be evaluated over the forest portion, excluding farm lands and water surface area. The area of the forest portion is estimated as follows:

(a) In the case of a 70 m high dam
    - 3,821 ha, 1.5% of the catchment area

(b) In the case of a 90 m high dam
    - 9,630 ha, 3.9% of the catchment area

The effects on flora cannot be avoided and are an inevitable consequence of the dam construction.

We recommend further botanical studies to identify species not so far recorded, and to ensure that in the case of rare species the varieties are not totally lost.

(9) Tourism

A report on tourism in Kelantan State compiled by TDC (Tourist Development Corporation) indicates that the number of local tourists who visited Kelantan State in 1986 was 224,816, and foreign tourists 29,240. The average period of stay of these tourists was 1.7 days for foreigners and 1.6 days for local people.

Taman Negara is regarded as a sightseeing location in Pahang beyond Mt. Tahan. According to TDC, a connecting road from Kelantan to Taman Negara is being studied in cooperation with the Wildlife Department. However, this idea is still far from realization.

Although the Lebir Dam Project will have an effect on the nature and settlement in the area, it will also open the possibility of tourism development. The first possibility is to utilize the extensive water surface of the reservoir, and the second is to use the reservoir as a "stepping stone" to Taman Negara. It has the benefit of the Kuala Kerai - Gua Musang Highway which passes close by the western side of the reservoir, from which easy access to the reservoir can be obtained. This suggests a strategy of tourism development based on an approach from the west side.

In planning tourism development, studies should be carried out on environmental conditions, such as the state of fish resources and the state of living things in Taman Negara which are difficult to re-settle artificially. Tourism development should be made carefully, with plans which incorporate controls for protection of the environment.

(10) Mineral resources

Geological, geophysical and geochemical studies have discovered 15 interesting anomalies in the area. Out of 15, two are ranked top priority, three are given Priority 2, two Priority 3, and others lower Priority. One of top priority is promising for U,Mo mining, and another of top priority is promising for Pb, Zn mining.

Once the Project is completed, it will not be possible to carry out mining under the reservoir. Therefore, the importance of these study indications should be investigated further to ensure that any mining operations in the future will not be carried out to the detriment of the completed Lebir Dam works.

(11) Archaeological relics

On the basis of records of development by FELDA and KESEDAR, this area does not appear to have valuable archaeological remains. Orang Asli found in this area are Beteq-Negritos who are wandering hunters. There is no report that they possess many properties or have archaeologic objects of worship. There is no historical record of historical ruins in Kelantan State.

(12) Conclusion

The largest environmental consequence of the Lebir dam construction will be an inundation of 14,700 ha of agricultural plantations in the maximum case. This hectarage occupies almost 30% of a total area of 52,000 ha being developed by KESEDAR and FELDA. The key to settlement of this problem is whether adequate substitute lands can be found and re-settled or not.

The other environmental impacts are considered not so serious as to effect the implementation of the project, since it is possible to minimize their effect (although the further detailed investigation is required).

As an alternative candidate site for the agricultural plantations to be inundated, it is suggested to develop the area to the north of existing plantation in Ciku area.

The development of an aquaculture industry in the large reservoir to be created by the dam construction will contribute largely to the creation of new employment opportunities for the people forced to resettle. Floating net units are recommended to be adopted as one of the methods for fishery.

By the construction of the Lebir dam, flooding will be reduced in the downstream areas of the Kelantan River, and an area larger than that submerged by the impoundment is expected to be relieved from inundation by floods. Flood damage will be mitigated.

Further, the Lebir dam contributes to the stabilization of the flow in the Kelantan River. By this effect, agricultural irrigation to new farm land of 12,000 ha becomes possible downstream, and an opportunity for more profitable agricultural production by rotational cropping becomes possible.

For these reasons, it is considered that the Lebir Dam Project should be promoted for implementation followed by the preparatory works set out in this report.

2.4. Economic Analysis of the Project

(1) The estimated cost with and without contingencies by work item is as summarized below:

		Without Contingency 10^6M$	With Contingency 10^6M$
(a)	Preliminaries	54.1	59.5
(b)	Civil Work	218.7	251.5
(c)	Metal Work	19.6	21.6
(d)	Electro-Mechanical Work	141.8	148.9
(e)	Compensation for Resettlement	80.7	88.7
(f)	Engineering Consultancy Services	50.8	55.9
(g)	NEB Administration	12.7	14.0
	Total	578.4	640.1

The costs for the preliminaries work necessary to implement the main construction work are composed of the costs for site preparations such as the construction of access and bypass roads, construction power transmission and telecommunication facilities for construction purposes, site offices and lodging facilities, and environmental measures including relocation roads to mitigate the impacts to be caused by the project implementation.

The costs for environmental works and compensation for resettlement are M$122.5 million without the contingency and M$134.8 million with the contingency respectively.

Contingencies (a total of M$61.7 million) included in the cost estimates of each work item are appropriated not for price fluctuation, but for possible physical changes in the construction work.

Interest during construction is not included and the price level of 1987 base was adopted with an exchange rate of 1US$ to 2.5M$ for the currency conversion in the cost estimates.

(2) The estimated cost of the Project by currency is as summarized below:

	Without Contingency 10^6M$	With Contingency 10^6M$
Local Currency Cost	290.7	325.2
Foreign Currency Cost	287.7	314.9
Total	578.4	640.1

(3) The disbursement schedule of the project cost (including contingencies) by year is as shown below:

Year	Work Done	Foreign Currency Cost	Local Currency Cost	Total
1990	To work out a plantation relocation program	0	2.05	2.05
1991	To start detailed engineering and design	9.23	12.65	21.88
1992	To carry out bidding and start the preparatory work	2.52	18.92	21.44
1993	To implement the plantation relocation program	2.10	20.83	22.93
1994	To start the main construction work	26.52	49.25	75.77
1995		58.35	55.41	113.76
1996		56.65	65.02	121.67
1997	To start reservoir impounding	104.48	73.35	177.83
1998	To start the plant operation	46.51	19.79	66.30
1999		8.60	7.91	16.51
	Total	314.96	325.18	640.14

(4) The project cost is further classified into each category of dam, power and environment as follow. (refer to Table 13-3-4 in Volume I of the Main Report for further details)

Classification	Without Contingency 10^6M$	With Contingency 10^6M$
Dam	210.4	238.9
Power	241.7	262.2
Environment	126.3	139.0
Total	578.4	640.1

Listed below is a detailed classification of the power related cost.

Cost Item	Without Contingency 10^6M$	With Contingency 10^6M$
Preparatory work	7.4	8.1
Civil work	69.4	79.8
Metal work	14.2	15.6
Electro-mechanical work	141.8	148.9
Engineering and owner's administration	8.9	9.8
Total	241.7	262.2

(5) Economic effects of the project are evaluated as stated below.

Sector	Annual Benefit (B) 10^6M$	Annual Cost (C) 10^6M$	B/C	EIRR %
Power generation	63.77	86.19		
Subtotal	63.77	86.19	0.74	>6
Flood control	16.13	0		
Total	79.90	86.19	0.93	9.0
Agricultural irrigation	14.99	0		
Grand total	94.89	86.19	1.10	11.1

The following bases were adopted for calculation.

(a) Discount rate : 10%

(b) Output value of the Lebir power plant

Average maximum output for 35 years : 240.5 MW

(c) Generation value of the Lebir power plant

Average generation for 35 years : 372.2 GWh (Sent out energy)

Fuel cost for alternative power source : M$3.538/MBTU base

Variable cost : M$37.29/MWh

(d) Flood mitigation benetit : Estimate base by the Study Team

(e) Agricultural benefit : The cropping system of Case 5 is to be irrigated rotational cropping. (paddy, groundnuts, tobacco, maize, sorghum and vegetables, etc.

Irrigable area : 65,326 ha

(f) Project cost : M$640 million (including contingency)

It seems probable that the economic benefits evaluated in the above are less than might be expected, because parameters basic were selected to give the most severe case. Therefore, a sensitivity analysis was carried out to assess the respective benefits with each parameter varied within a realistic range.

The following are its results.

Parameter			EIRR (%)		
Output (MW)	Fuel Cost (M$/MBTcl)	Flood Benefit (10^6M$)	Power	Power + Flood	Power + Flood + Agriculture
267.6	3.538	16.1	6.7	10.0	11.8
"	7.5	"	9.5	12.3	13.6
240.5	3.538	"	6>	9.0	11.1
"	7.5	"	8.6	11.3	12.8
"	3.538	27.3*	6>	10.7	12.4
"	7.5	"	8.6	12.8	13.9

* The amount obtained based on the Interim Report on Kelantan River Basin-Wide Flood Mitigation Study 1989 January.

From the above, the economic internal rates of return (EIRR) of this project are estimated to be 6 to 10% in power only, 9 to 13% in combination of power and flood, and 11 to 14% in combination of power, flood and agriculture.

Therefore, it is judged appropriate to develop the Lebir Dam Project from the point of view of the Malaysian economy.

(6) For the financial analysis of this project, the comparative study was made between the supply costs of energy with the combination of the Lebir Plant and other existing power plants to provide an incremental demand of 68% annual load factor, and the income from power tariff.

As a result, it is considered that the project cost of the Lebir Dam will not hamper the financial capability of NEB, and not lead to a rise of power tariff (the average power tariff at 1985 base: 22.26 cents/kWh), even in the case of 10% cost increase, because there will be a financial internal rate of return (FIRR) of 20%.

2.5. Project Implementation Programme

(1) As discussed in the foregoing Sections, if the problems associated with the submerged agricultural plantations in the upstream area are settled successfully, this Project should be developed since there are no other major detrimental environmental impacts, and the economic status is sound. In line with this policy, the implementation programme for the project is described hereunder.

(2) This feasibility grade design is supported by the results of the following field investigations.

(a) Topographical survey

Reservoir area :	Aerophoto maps of 1979 with a scale of 1/10,000 covering an area of about 346 km^2 (28 sheets)
Main dam, spillway, diversion tunnels, waterways and powerhouse:	Surveyed maps of 1987 with a scale of 1/500 covering an area of 1.9 km^2 (30 sheets)
Saddle dams I and II:	Surveyed maps of 1987 with a scale of 1/500 covering an area of 0.4 km^2 (8 sheets)
Quarry site:	Surveyed maps of 1987 with a scale of 1/500 covering an area of 0.9 km^2 (17 sheets)
River cross section in the downstream river channel below the dam:	Cross section profiles of 1987 with a vertical scale of 1/100 and a horizontal scale of 1/500 covering the river course for about 30 km (30 sections)
Datum point survey for main and Saddle dam sites, and quarry site:	Datum points (8 points) installed in 1987

(b) Boring investigation (1987)

Main dam	:	3 holes, 190 m
Spillway	:	3 holes, 130 m
Powerhouse	:	1 hole, 20 m
Saddle dam I	:	4 holes, 160 m
Saddle dam II	:	2 holes, 55 m
Quarry site	:	4 holes, 160 m
Borrow area (granitic)	:	2 holes, 40 m
Reregulating pondage	:	3 holes, 30 m
Total	:	22 holes, 785 m

(c) Seismic prospecting (1987)

Main dam	:	3 lines, 1,621 m
Saddle dam I	:	1 line, 506 m
Quarry site	:	3 lines, 2,109 m
Total	:	7 lines, 4,236 m

(d) Laboratory test

Rock material tests : Uniaxial test (18 samples)

Stability test (3 samples)

Soil material tests : Granitic material (7 samples)

Conglomeratic material (1 sample)

Tuffaceous sand stone material (5 samples)

Sediment material (3 samples)

Total 16 samples

(3) The field investigations detailed above are considered appropriate for the level of feasibility design, however, further field investigation as given below will be required for the detail design stage.

(a) Topographic survey

Preparation of aerialphotogrametric map (S=1/10,000)	: 410 km^2
Preparation of survey map (S=1/500)	: 1.0 km^2
Route survey of transmission line	: 7 km

(b) Boring investigation : 104 holes, 4,300 m

(c) Geological investigation by adits: 7 adits, 360 m

(d) Laboratory, testing of materials : rock, soil materials, concrete and water

(e) Hydraulic model test : Spillway (1 unit)
Power intake (1 unit)

(4) Field investigation will also be required for the design of preparatory works to be carried out by others. These works are:

(a) Access road : 3 km

(b) Relocation of timber transportation road : 8 km

(c) Power transmission line for construction use: 66 km

(d) Owner's base camp facilities: 2,500 m^2 (Building only)

(e) Telecommunication facility : 1 unit

(5) For the investigation, planning, design and training associated with the environmental measures, the following items will be required to be carried out:

(a) Suspension of the development of agricultural plantations within the proposed reservoir area, and the investigation of the alternative candidate sites for such plantations. Implementation of the relocation programme.

(b) Development of an aquaculture industry and implementation of a pilot project.

(c) Training for environmental measures.

(d) Detail field investigation for fauna and flora.

(e) Clear felling of the forest within the impoundment area.

(f) Investigation and planning of the forest reserve for preservation of the reservoir bank, and implementation of afforstation.

(g) Detailed field investigation of sedimentation.

(h) Monitoring (water quality and public health).

(i) Compensation for inundation. Establishment of inventory and criteria for compensation rates.

(j) Relocation of the roads within the proposed reservoir area.

(k) Construction of a fish ladder.

(l) Construction of re-regulating pondage.

(m) Installation of hydrological telemetering and discharge warning systems.

(6) Detail design is scheduled to be carried out within a 21 months period based on the concepts set out below. The environmental measures should not however be limited to the period of detail design. Some items will be completed during the overall period up to Project completion, and others will continue after this time.

	Work Item	Implemented by	With assistance of
(a)	Field investigation	Local consultant	Foreign consultant
(b)	Detail design for the main works	Foreign consultant	Local consultant
(c)	Preparation of the tender documents for the main works	"	"
(d)	Prequalification of the tenderers for the main works	"	"
(e)	Design and preparation of the tender documents for the preparatory works	Local consultant	-
(f)	Supervision of the preparatory works	Project owner	Local consultant
(g)	Environmental measures	"	Foreign and local consultants

The following summarises the engineering cost required for the detail design (contingency exclusive).

Work Item	Local Currency 10^3M$	Foreign Currency 10^3M$	Total 10^3M$
Field investigation	4,886	-	4,886
Detail design	1,149	5,988	7,137
Total	6,035	5,988	12,023

(7) Tendering for the main works will be by International Competitive Bidding, following the prequalification of tenderers. A programme time of 19 months has been allowed from the time of issue of tender documents to the signing of the Contract.

Tender period	3 months
Tender evaluation and determination of the successful tenderer	9 months
Contract negotiation	7 months
Total	19 months

(8) Preparation of the construction drawings for the main works will be commenced immediately after tender opening, and is planned to be completed within 16 months.

(9) The estimated quantities of the major items of the main work are tabulated as below:

Excavation, common	$5.3 \times 10^6 m^3$
Excavation, rock	$1.5 \times 10^6 m^3$
Embankment, rock	$4.0 \times 10^6 m^3$
Embankment, earth	$1.4 \times 10^6 m^3$
Excavation, tunnel	$240 \times 10^3 m^3$
Explosive material	2,500 tons
Concrete	$300 \times 10^3 m^3$
Cement	130×10^3 tons
Re-bar	12,800 tons
Metal work	3,100 tons

(10) The construction period necessary for completion of the main works is estimated to be 50 months.

The schedule from the commencement of detail design to the completion of construction works is as follows:

(a)	Detail design	21 months
(b)	Tender and contract	19 months
(c)	Construction supervision	50 months
	Total	90 months

Note: 1. Construction supervision includes:

(a) Civil construction up to Completion
(b) Erection and commissioning of plant

It does not include supervision of civil or electro-mechanical work during Maintenance periods (i.e. following Completion and following Taking-Over).

2. Some additional provision will be necessary to cover engineering supervision during the Maintenance period following final civil works completion, and similarly for electro-mechanical works.

The total engineering cost (without contingency) required preparation for construction, erection and commissioning supervision (including the services for construction drawings and during the tender and contract periods) is given below. The construction supervision is planned to be carried out by the foreign consultant in association with the local consultant.

Work Item	Local Currency 10^3M$	Foreign Currency 10^3M$	Total 10^3M$
Construction supervision	6,651	32,182	38,833

(Excluding Contingencies)

3. Geology

3. Geology

(1) Geological features of the project area

The proposed sites for the main dam, saddle dams and the quarry site are all located in a zone in which green rock groups are largely distributed. The green rocks, falling under the pyroclastic rock group, consist mainly of tuffs, and these have a characteristic of marked variations of rock facies in grain size (fine to coarse) and colour (green to purple). These tuffs are believed to have been deposited in shallow water, and often contain non-marine admixtures such as quartzite sands and gravels. These rocks are classified as tuffaceous sandstones or tuffaceous conglomerates in this study. It is also found that the rocks are locally interbedded with thin bands of quartzites and shales. Some of the green rock masses involve those rocks which can be assumed to have originated from lava flows, but they are few in quantity.

(2) Geological structure

Geological structure in the Malay Peninsula is harmonious with that generally recognized in a wider area. The geological strata in the area are generally trending north-northwest to south-southeast, but tectonic disturbances can often be observed locally. It is assumed that some slumps and local folding structures exist.

(3) Structural boundary

The tectonic line called "Lebir Fault" is observed at about 3.5 km east of the main dam site and it stretches south-southeastwards along the geological boundary of the granite group and the sedimentary rock group of Mesozoic and Palaeozoic Ages.

In the project area, confirmation has yet to be made on the existence of fault outcrops belonging to the Lebir Fault, but it is often observed that there exist small-scale folding structures, where rock masses are often found to have been fractured.

During the course of this study, large scale faults and fractured zones have not been encountered.

(4) Earthquakes

Past records of seismic activities indicate that deep-focus earthquakes with magnitudes of 6 or greater have frequently occurred in a belt zone along the western shoreline of Sumatra, but practically no earthquakes of such magnitude have occurred along the Malay Peninsula. This is because the Sunda Islands including Sumatra are located at the northern part of the Benioff Zone composed of the Australian and Asian Plates. While Sumatra and the neighbouring Indonesian islands are located along the Benioff Zone and thereby subjected to frequent deep-focus earthquakes, the Malay Peninsula is located on the stable Sunda Continental Shelf which is seldom subjected to deep seismic activity.

Records of the seismic activities along the Malay Peninsula show that an earthquake with magnitude of 3.8 took place southeast of Kuala Lumpur in 1976, and small earthquakes with magnitudes of 2.5 to 4.6 have occurred 30 times since 1984 in an area near the Kenyir dam reservoir in Terengganu State.

(5) Geological field investigation carried out (1987)

Field reconnaissance	:	Extent 30 km^2 Scale 1 : 10,000
Boring investigation	:	22 holes, 785 m in total
Seismic prospecting	:	7 lines, 4.43 m in total
Test pits	:	3 sites

(6) Comments on civil engineering geology

(a) There are no major faults in the foundation rocks at the main dam site such as might cause serious problems in the design of a 70 m high dam.

In the river bed at the proposed main dam site, riverbed deposits are rather less than at other similar locations. There are rock exposures, and the depth of weathering overlying strong bedrock is not large.

The thicknesses of weathered rock at the abutments are estimated to be about 10 m at the left bank and 20 m at the right bank respectively.

(b) The base rocks underlying the proposed Saddle dam I site consist mainly of unweathered hard rock groups.

Thus there should be no major technical difficulties in constructing a 67 m high dam at the proposed site, but since there is a weathered zone of about 30 m thickness over much of the Site, this will require careful attention in the design of the dam.

(c) Seismic investigation reveled a maximum depth of weathered rock of 10 m along the penstock route and at the site of the powerhouse.

The rock underlying the weathered layer is of adequate strength to support the penstock and powerhouse construction, and no major problems are envisaged in the design of these structures.

(d) The base rocks underlying the proposed sites for the spillway and the diversion tunnels are for the most part classified as fresh hard rocks. Thus, it is considered that there are no particular problems raised for the design works.

(e) The thickness of the weathered rock layer at the quarry site which is considered unsuitable for use as rockfill materials or aggregates for concrete work, is estimated to average 10 to 15 m.

Fresh tuffs underlying the weathered layer have suitable properties for use both as rockfill and as concrete aggregates. These rocks have a close pattern of cracks which may limit the size of rockfill which can be obtained from the quarry.

(f) There are two possible borrow areas proposed for obtaining core materials. These consist mainly of materials resulting from the weathering of granite distributions and tuffaceous conglomerates of the green rock groups. The properties of the materials at both sites are considered suitable for the materials to be used as core material.

4. Hydrology

4. Hydrology

(1) The catchment area of each stream flow gauging station in the Kelantan River system is as shown below:

Station	River	Catchment Area
		km^2
Tualang	Lebir	2,480
Bertam	Nenggiri	3,950
Dabong	Galas	7,480
Guillemard	Kelantan	12,100

Note: Locations of each gauging station except Guillemard correspond reasonably to the proposed dam sites of each scheme planned in the Kelantan River system.

(2) Probable rainfall at Tualang was computed as representative rainfall for the watershed of the Lebir dam. For rainfall at other planned dam sites in the Kelantan River System, 5-day rainfall and daily rainfall in the records of each gauging station were converted into the Thiessen rainfall, and probability calculations were made using the Gumbel-Chow method. The results are shown in the following table.

Probable Thiessen 5-Day Rainfall

(by Gumbel - Chow method)

Basin / Probability in years	Lebir Dam	Nenggiri Dam	Nenggiri Dam to Dabong Dam	Lebir Dam, Dabong Dam to Guillemard
	mm	mm	mm	mm
10,000	1,624	498	786	865
1,000	1,257	400	625	695
200	1,000	333	513	576
100	890	304	464	525
50	778	274	416	473
20	630	235	351	404
10	515	205	301	351
5	396	174	248	296

Probable Thiessen Daily Rainfall

(by Gumbel - Chow method)

Basin / Probability in years	Lebir Dam	Nenggiri Dam	Nenggiri Dam to Dabong Dam	Lebir Dam, Dabong Dam to Guillemard
	mm	mm	mm	mm
10,000	422	277	394	409
1,000	333	222	314	329
200	271	184	258	273
100	245	167	234	250
20	182	128	178	194
10	154	111	153	169
5	125	193	127	143

(3) Peak flood discharge corresponding to each probable flood rainfall was simulated, the results of which are given in the following Table:

Probable Flood Discharges
(using the average rainfall curve)

(m^3/s)

Probability in years	Tualang	Bertam	Dabong	Guillmard
10,000	10,604	6,876	16,081	31,413
1,000	8,282	5,600	12,985	25,078
200	6,663	4,730	10,835	20,679
100	5,951	4,339	9,902	18,752
50	5,260	3,944	8,965	16,851
10	3,595	3,439	7,715	14,315
5	2,846			

(4) The amount of sediment flow and bed load in the Lebir River is not so large in quantity. KRBS Report by ENEX (1977) refers to 110 m^3/km^2/year as a unit sediment discharge.

Sediment deposits in the Ringlet Falls Reservoir located in the Cameron Highlands were measured during a period from 1963 to 1986. From the results, an annual sediment volume of 168 m^3/km^2 was calculated.

Referred to in this study are the results of calculation using Dr. Kira's formula (unit sediment discharge: 410 m^3/km^2/year).

5. Feasibility Design

5. Feasibility Design

(1) Dam

An impervious type of rockfill dam with a central earth core is advantageous from the economic view point compared with other feasible alternatives. This type of dam is estimated to be 15% cheaper in its construction cost than a concrete gravity dam.

The steepest possible slope of the rockfill was adopted, based on the consideration that there is little seismic activity in Peninsular Malaysia.

For Saddle dam II, an earthfill design has been adopted, as there is a large quantity of surplus earth excavation available from other work areas nearby with which to form the embankment and thereby minimize cost.

(2) Spillway

An ungated free overflow chute has been selected as the spillway type from the alternatives studied. Although an alternative scheme with gated spillway was also considered, the study confirmed that the construction cost would be higher and the additional factor of gate operation and maintenance is introduced.

A possible scheme to use the diversion tunnel as part of the spillway was looked at in outline. There appeared to exist a possible saving in construction cost of roughly 10 million Malaysian Dollars. However, these were only preliminary considerations and a further detailed hydraulic and cost study would be necessary before the benefit of such a scheme could be determined.

A bucket type was adopted for the spillway stilling basin due to the least construction quantities.

(3) Diversion Tunnel

After comparison of the relationship between tunnel diameter and height of the upstream cofferdam in various alternatives under conditions of 20, 50 and 100 year return period floods, a scheme having two diversion tunnels each with an internal diameter of 12.0 m was selected as the optimum arrangement.

In adopting this diversion tunnel scheme, it is estimated that the upstream water level will rise to EL.58.3 m under 50 year return flood conditions, and to EL.60.9 m for a 100 year flood.

A 50 year return period flood has been adopted as the criterion to be used in the design and this requires a crest level of the upstream cofferdam of EL.59 m.

(4) Pressure Tunnel

The number of pressure tunnels is governed by the geological condition and the convenience of operation and maintenance. For this project, two alternatives of two and three tunnels were considered. The most economic diameters of each tunnel were determined by analysis to be 8.6 m and 7.8 m respectively.

As the result of comparison of total construction cost including powerhouse and electrical works, it was confirmed that the two tunnels scheme is more advantageous, as its construction is M$14 x 10^6 cheaper than the three tunnels scheme, and the construction period can be shortened by three months. Therefore, the two tunnels scheme is proposed as the optimum.

Reinforced concrete is adopted for the upper portion of the pressure tunnel. For the inclined and lower portions, the embedded type of steel penstock tunnel is adopted.

(5) Powerhouse

Ground level of the powerhouse yard will be at EL.45.0 m. This includes a margin of 1.5 m above EL.43.5 m which corresponds to the downstream water level under the conditions of a 1,000 year return flood. The basis of the protection from a flood is relied on this criterion.

The auxiliary building will be built on the upstream side annexed to the main powerhouse building. This will simplify connection of cabling and make for convenient operation and maintenance of the plant.

The main transformer is planned to be placed on a platform constructed above the downstream side of the tailrace outlet from the powerhouse.

(6) Tailrace

Since it was confirmed by the study that no economic benefit is gained by the extension (2.3 km) of the tailrace channel downstream, the shortest length of tailrace channel has been adopted. The cross-sectional shape of the tailrace was based on the results of economic analysis.

(7) Bottom outlet

One of the diversion tunnels will be used as a bottom outlet to provide discharge downstream during reservoir impounding, when the water level of reservoir is low, and as a supplemental irrigation water supply in times of extreme drought.

Table 1 Main Features of the Lebir Dam (Multi-purpose)

Table 1 Main Features of the Lebir Dam (Multi-purpose)

Location	:	Ulu Kelantan District, Kelantan State
River	:	Lebir River, of the Kelantan River System
Location of the main dam:		37 km upstream of Kuala Kerai where the Lebir River joins the Galas River, i.e. 3 km upstream of Tualang Bridge (Gua Musang-Kuala Kerai Highway).
Riverbed Elevation	:	EL. 24.0 m
Hydrological Data	:	Drainage area 2,474 km^2
		Annual mean flow 112.6 m^3/s (average of 1950 to 1984)
		Minimum flow (April, - dry season) 51.1 m^3/s (average of 1950 to 1984)
		Maximum flood recorded 4,200 m^3/s (1967)
		Design flood discharge of the dam (10,000 year return) 10,600 m^3/s
		50 year return flood 5,260 m^3/s
		Annual precipitation in the catchment area 2,250 mm

Reservoir:

Items	Water Level (EL, m)	Reserved Capacity ($10^6 m^3$)	Submerged Area (km^2)
Design flood water level	88.1	3,955	226
Surcharge water level	84.9	3,276	195
High water level for generation	80.0	2,392	154
Low water level for generation	60.0	502	46
Emergency low water level	50.0	167	21
Design silt level	47.0	117	15

Geology: Dam foundation	- Tuff, tuffaceous sand stone and conglomerate	
Quarry site	- Tuff	
Inundation :	Maximum area submerged (WL 88.1 m)	22,600 ha
	Forest	7,900 ha
	Agricultural plantation	14,700 ha
	People to be relocated	4,694 persons
	Lebir riverine settlers	500 persons (100 households)
	Settlers in the land development area	4,050 persons (675 households)
	Orang Asli	144 persons
Compensation for Resettlement :	Agricultural plantation	10,000 ha
	Lebir riverine settlement	809 ha
	Orang Asli settlement	22 ha
	Population to be relocated	4,694 persons (775 households)
	Relocation road	75 km
Environmental Countermeasures :	Installation of hydrological telemetering and discharge warning system	1 set
	Re-regulating pondage	
	Dam height	5.4 m
	Elevation of overflow sill	EL.25.4 m
	Reserved capacity	870,000 m^3
	Fish ladder (tentative plan)	750 m
	Forest reserve for preservation of the reservoir bank erosion	

Power Scheme :

High water level (HWL)	:	EL.80.00 m
Low water level (LWL)	:	EL.60.00 m
Effective depth and storage for power generation	:	20 m, 1,890 x $10^6 m^3$ (211 GWh, amount converted in terms of energy)
Tailrace water level (tailrace channel end)	:	EL.28.00 m
Maximum gross head	:	52.00 m
Maximum effective head	:	49.66 m
Firm/peak water discharge	:	80/640 m^3/s
Internal diameter, length and number of pressure tunnels	:	8.6 m, 202.8 m x 2 lines
Turbines	:	Vertical shaft Kaplan (125 rpm), 2 units x 136,800 kW, Maximum discharge of 640 m^3/s 320 m^3/s x 2 units
Generators	:	A three-phase, synchronous and enclosed type with a vertical shaft and damper windings, 2 units x 149,000 kVA
Voltage and length of the related transmission line	:	275 kV and 7 km
Annual possible generation	:	373.3 GWh
Maximum output	:	267.6 MW
Annual mean maximum output (Average of 35 years)	:	240.5 MW
Annual mean inflow	:	112.6 m^3/s (396 GWh, amount converted in terms of energy)
Specific cost for power facilities	:	262.2 x 10^6M$
Annual mean benefit (1987 price)	:	M$63.8 x 10^6

Flood Control Scheme :

Crest elevation of dam	:	EL.92.0 m
Design flood discharge (10,000 year return)	:	10,600 m^3/s

Design flood water level	:	EL.88.1 m
Base flood discharge (50 year return)	:	5,250 m^3/s
Surcharge water level (in case of 50 year flood)	:	EL.84.9 m
Peak discharge	:	2,950 m^3/s
Maximum flood discharge in the past (1967)	:	4,200 m^3/s
High water level for generation	:	EL.80.0 m
Flood control capacity		
EL.84.9 - EL.80	:	884 x $10^6 m^3$
EL.88.1 - EL.80	:	1,563 x $10^6 m^3$
Type of spillway	:	Free overflow chute type
Overflow sill elevation	:	EL.80.0 m
Overflow sill width	:	150.0 m
Flood mitigation benefit (2000 level, 1987 price)	:	16.98 x 10^6 M$
	:	27.3 x 10^6 M$ (Basin-Wide Study base)

Agricultural Irrigation Scheme:

Possible irrigable area (including the existing areas and the new projects)	65,326 ha
Water requirements based on the existing programme (excluding the regulation by the Lebir dam)	
Irrigation water suply	90 m^3/s
Domestic and industrial water supply	20(5) m^3/s
Residual flow for saline abatement	80 m^3/s
Total	190 (175) m^3/s

Figures in brackets are extracted from Kemasin-Semarak Study

10 year draught discharge at Guillemard Bridge	95 m^3/s
Daily firm rate of discharge of the Lebir dam*	80 m^3/s
Emergency discharge of the Lebir dam**	335 x $10^6 m^3$ (50 m^3/s x 77 days)
Specific cost for irrigation facilities (1986 price)	M$160.4 x 10^6

Net agricultural benefit (Case 5) on the annual average (Economic price of 1999 to 2049) M$15.0 x 10^6

* At times when the discharge is made at 640 m^3/s over a period of 3 to 4 hours (after reservation of flow in the reservoir is made), the corresponding flow at the pumping station for irrigation 90 km downstream will still remain in the allowable range of 70 to 80 m^3/s, due to the modulating effect of the river course. (Refer to Section 11.12.1.)

** Emergency discharge of 45 to 80 m^3/s up to 335 x $10^6 m^3$ reserved between LWL 60 m and WL 50 m is possible through the bottom outlet (inlet sill level of EL.50 m).

Main Dam :

Type	:	Rockfill with center earth core
Crest elevation	:	EL.92 m
Dam height	:	73 m
Crest length	:	638 m
Slope of the upstream face	:	1 : 1.85 (EL.59 m with a berm width of 12.5 m)
Slope of the downstream face	:	1 : 1.75 (EL.40 m with a berm width 10.0 m)
Bottom length of the dam	:	265 m
Bottom elevation of the dam	:	EL.19.0 m
Foundation rock	:	Green and purple tuff
Dam volume	:	2,900,000 m^3 (including 392,000 m^3 of core)

Saddle Dam I

Type	:	Rockfill with center earth core
Crest elevation	:	EL.92.0 m
Dam height	:	67 m
Crest length	:	448 m

Slope of the upstream face	:	1 : 1.85 (EL.59 m with a berm width of 10 m)
Slope of the downstream face	:	1 : 1.75
Bottom length of the dam	:	218 m
Bottom elevation of the dam	:	EL.25.0 m
Foundation rock	:	Tuffaceous sand stone and conglomerate
Dam volume	:	1,532,000 m^3 (including 261,000 m^3 of core)

Saddle Dam II

Type	:	Earthfill
Crest elevation	:	EL.92.0 m
Dam height	:	37 m
Slope of the upstream face	:	1 : 3.5 (EL.67 m with a berm width of 10 m)
Slope of the downstream face	:	1 : 3.0
Foundation rock	:	Weathered tuff, tuffaceous sand stone and intrusion meta-dacites
Dam volume	:	742,000 m^3 (including 89,000 m^3 of core)

Spillway:

Type	:	Ungated concrete free overflow chute type
Overflow sill elevation	:	EL.80.0 (HWL for generation)
Overflow sill width	:	150 m
Length of chute	:	270 m (Overflow weir to bucket)
Chute width	:	95.0 m
Stilling basin	:	Bucket type (upper level of EL.29 m and lower level of EL.26 m)

Design flood discharge	:	10,600 m^3/s (10,000 year return flood)
Spillway capacity	:	6,400 m^3/s
Concrete volume	:	122,000 m^3

Diversion Tunnel :

Type	:	Tunnel
Planned flood discharge	:	5,260 m^3/s
Section	:	Circular reinforcing concrete Inside dia. 12.0 m x 2 lines
Length	:	585 m (No.1 Tunnel) and 576 m (No.2 Tunnel)
Intake sill elevation	:	EL.29.0 m
Outlet sill elevation	:	EL.26.0 m
Slope	:	0.51% (No.1 Tunnel) and 0.52% (No.2 Tunnel)
Discharge capacity	:	3,250 m^3/s (WL.58.3 m)
Geology	:	Green tuff
Concrete volume	:	80,000 m^3

Bottom Outlet :

Location	:	Inside the diversion tunnel No.1
Type/diameter	:	Jet flow gate type, diameter of 2.0 m
Intake level	:	EL.50.0 m
Discharge capacity	:	Maximum 84.0m^3/s and Minimum 46.0m^3/s at WL 50 m

Power Intake :

Type	:	Side intake (Inclined type)/Gate shaft
Intake volume	:	320 m^3/s per gate

No. of intake	:	2
Intake sill level	:	EL.48.0 m
Size of intake portal	:	Width 15.0 to 13.3 m Height 11.6 m
Gate shaft	:	Upper level EL.92.0 m Inside dia. 12.0 m
Gate	:	Two main gates 8.6 m wide x 8.6 m high Two maintenance gates 8.6 m wide x 8.6 m high
Concrete volume	:	12,000 m^3

Pressure Tunnel :

Type	:	Circular reinforced concrete tunnel (partially embedded steel penstock)
No. of tunnels	:	2
Inside diameter	:	8.6 m to 7.4 m
Length	:	196.8 m (No.1) and 208.8 m (No.2)
Steel weight	:	920 ton
Concrete volume	:	8,000 m^3

Powerhouse :

Type	:	Above ground type
Size	:	29 m wide, 73 m long and 59 m high
Foundation level	:	EL.45.0 m
Turbine center level	:	EL.21.1 m
Tailrace yard water level	:	EL.28.78 m (Maximum discharge of 640 m^3/s)
Lowest foundation level	:	EL.3.0 m
Foundation rock	:	Green tuff

Turbine	:	Vertical shaft Kaplan (125 rpm), 2 units x 136,800 kW Maximum discharge of 640 m^3/s 320 m^3/s x 2 units
Generator	:	A three-phase, synchronous and enclosed type with a vertical shaft and damper windings, 2 units x 149,000 KVA
Main transformer	:	Outdoor type transformer 275 kV, 149,000 kVA x 2 units
Concrete volume	:	74,000 m^3

Tailrace :

Type	:	Open type waterway, rectangular section with a concrete lining
Length	:	Tailrace bay 40 m, tailrace channel 499 m
Width	:	Invert width of 20.0 m and sidewall gradient of 1 : 1
Tailrace end level	:	EL.21.0 m
Waterway slope	:	1/3,000
Water depth	:	7.0 m (Maximum discharge of 640 m^3/s)
Concrete volume	:	12,000 m^3

Switchyard :

Type	:	Outdoor type
Ground level	:	EL.53.0 m
Size of switchyard	:	89 m wide x 124 m long
Voltage	:	275 kV
Bus configuration	:	Double bus
No. of outgoing circuits	:	4 circuits

Associated Transmission Line :

Voltage	:	275 kV
No. of circuits	:	Double circuit
Total length	:	7 km

Project Cost :

	$\times 10^6$ M$
Preparatory work	13.4
Civil work	251.5
Metal work	21.6
Electro-mechanical work	148.9
Environment	134.8
Detailed design	13.2
Construction supervision	42.7
Owner's administration	14.0
Total	640.1 (including contingency)

Local cost	M$ 325.2 million
Foreign cost	M$ 314.9 million

Economic Feasibility :

	EIRR %		FIRR %
Power	8.6	(below 6)	20
Power + Flood Control	12.8	(10.7)	-
Power + Flood Control + Agricultural Irrigation	13.9	(12.4)	-

Dam construction cost per m^3 of the reserved capacity : M$0.10/$m^3$

Figures in brackets of EIRR are the calculation results using the alternative fuel cost of NEB purchase base.