The existing railway connecting Gua Musang with Dabong is located inside of the proposed reservoir area. Besides, this existing railway is situated approximately at El 70 m. Since the design flood water level of the Kemubu dam is set at 71.4 m, it is necessary to relocate a part of the existing railway to the place higher than El 71.4 m. Study on the relocation route was made based on 1/10,000, 1/25,000 and 1/63,360 maps. Features of the new route to be relocated are as follows:

- Location of relocation ; Between Bertam and Gua Musang
- Distance of relocation ; 26 km
- Lowest and highest El of railway after relocated; El 76.4 m and El 100 m
- Average longitudinal railway slope ; 4.2 o/oo
- Number of bridge to be heightened ; 4 Nos
- Number of bridge to be newly constructed ; 4 Nos (about 150 m/unit).

All of the new relocated route is aligned along the mountain side but tunnel is not planned.

The proposed relocated route of the railway is shown in Fig. 4.20.

4.3.2 Design of Lebir dam scheme

The Lebir dam scheme is planned with two construction stages, namely;

First stage : For the purpose of flood mitigation as well as the possibility of water resources development

Second stage: For the multipurpose development including hydropower generation with the same dimension as designed in the Feasibility Study on hydropower scheme by JICA.

Main dam and related structures on the first stage are designed for the purpose of flood mitigation keeping the almost same flood mitigation effect as that for the second stage as well as the possibility of water resources development. The dam crest on the first stage is designed at El.84.9 m and NHWL is set at EL.70.0 m. Main dam and spillway are designed with the possibility to make dam higher for hydropower generation use in future stage. It is recommended to provide an intake structure in the first stage to cope with the hydropower generation in future stage.

(1) Main dam and saddle dams

<u>Geological features of main damsite</u>

Geological and material investigations for proposed damsite have been carried out twice in 1979 and 1987. These data have been used for the Feasibility Study of Lebir dam for the purpose of hydroelectric power generation by JICA in 1989.

Main items for the geological investigation and construction materials are enumerated as follows;

Item	Quantity
(a) Damsite	
- field geological mapping	25 km^2
- core boring in 1979	10 holes (240m in total)
- core boring in 1987	7 holes (390m in total)
- lugeon test in 1987	7 holes (54 nos.)
- seismic prospecting	3 lines (1,700m in total)
(b) Construction materials	
- core boring (quarry site)	4 holes (160m in total)
- core boring (borrow area)	2 holes (40m in total)
- seismic prospecting	3 lines (2,200m in total)
- rock test for each boring	hole material
- soil test for each boring	hole material

The river width at the proposed damsite is about 150 m. River terraces are developed on both banks. The terrace on the left bank is narrow, behind which decomposed rocks rise at the gradient of about 16° to 18°. On the right bank, the river terrace is about 50 m wide and the slope above it rises at the gradient of 20°. It is contemplated to employ a fill type dam or concrete gravity dam from the topographic viewpoint. The result of preliminary study on the cost comparison of two types shows that the fill type dam is superior to the concrete gravity dam.

Bedrocks underlying the damsite consist mainly of green tuffs, purple tuffs, green tuffaceous sandstones and shales with layers of tuffaceous conglomerates. These bedrocks, which are slightly metamorphosed and non-foliated, are hard and massive. Irregular joints having main strike and dip of NW-SE/40°-10°NE or SW occur in the bedrocks of damsite. It is, however, found by field survey of core drilling and seismic explanation that the possibility of the existence of large-scale faults is extremely little at the main damsite.

In the feasibility study report which has been submitted by JICA dated March 1989, classification of bed rocks and its depth in the main dam site are described through the core boring, seismic test and Lugeon test as follows:

Place	Riverbed				Left abutment				Right abutment			
<u>Rock class</u>	<u>D</u>	<u>CL</u>	<u>CM</u>	<u>CH</u>	<u>D</u>	<u>CL</u>	<u>CM</u>	<u>CH</u>	<u>D</u>	<u>CL</u>	<u>CM</u>	<u>CH</u>
<u>Depth (m)</u>	-	0-3	3-7	7-	0-5	5-7	7-10	10-	0-7	7-21	21-56	-

The feasibility report also states the excavation depth to be required as the foundation of main dam as follows:

Place	Foundation for core and filter portion, and depth	Foundation for rock and depth
Riverbed	CH (d = 7.0 m approx)	-
Left bank	CM (d = 7.0 - 10.0 m)	D (d = 2.5 m approx)
Right bank	CM (d = 7.0 - 21.0 m)	D (d = 3.5 m approx)

According to the Japan Society of Engineering Geology, strength and internal friction angle of following rocks by means of visual observation are presumed as follows:

Classification of Rock	C (t/m^2)	ϕ (^{o})
D	0 - 50	30 - 40
CL	10 - 100	35 - 40
CM	50 - 150	40 - 45
CH	100 - 200	40 - 50.

Judging from these figures, it is considered that the foundation rock of the damsite has sufficient strength to sustain a 65 m high dam.

Geological features of saddle damsite

In order to construct an about 70 m high dam, it is obliged to construct two saddle dams at about 2 km northeast of the proposed Lebir damsite. Geological investigations for saddle damsites have been also carried out twice in 1979 and 1987. Main items for the above investigations are enumerated below:

Item	Quantity
Core boring in 1979	4 holes (90 m in total)
Core boring in 1987	6 holes (215 m in total)
Seismic prospecting	1 line (560 m)

The bedrocks underlying saddle dam I consist mainly of tuffaceous conglomerates and tuffaceous sandstones. Heavily and deeply weathered zones are developed on both banks. Decomposed rocks with high permeability of more than 30 Lugeon are 5 to 10 m thick in the bottom, 25 to 30 m in the left bank and 5 to 20 m in the right bank. To reach the fresh rocks, it will be necessary to excavate 15 m in the bottom, more than 30 m in the left bank and 10 to 30 m in the right bank. The zones showing high permeability correspond to the weathered zones exceeding 30 Lugeon.

The bedrocks underlying saddle dam II are comprised mainly of tuffs, tuffaceous sandstones and intruded meta-dacites. Tuffs and tuffaceous sandstones alternate closely. Hard meta-dacites probably with some dozen metres in width are distributed on the right bank of the damsite. Weathering will be as shallow as about 7 m at most. The left bank of this damsite which corresponds to the right bank of the saddle dam I is weathered by around 25 m in depth.

It is judged from the foundation condition that rockfill dam can be constructed by removing the weathered zone.

Construction materials

Geological data for the construction materials are as follows:

Item	Quantity
Core boring in 1987 for quarry site	4 holes (160 m in total)
Core boring in 1987 for borrow area	2 holes (40 m in total)
Seismic prospecting 1987 for quarry site	3 lanes (2,215 m in total)

The reviews of these data and reconnaissance for the construction material were carried out. Results are given as follows;

Rock materials and concrete aggregates:

River deposits suitable for concrete aggregates and rock materials are insufficient in volume.

A proposed quarry site is located at 1.5 km north of the proposed main damsite. It consists of tuffs, tuffaceous breccias and rounded conglomerates. However, its surface layer with 10 to 15 m in depth is weathered and not suitable for rock materials and concrete aggregate. The available amount beneath the weathered zone is enough for dam construction, and suitability of quality as rock materials and concrete aggregates has been confirmed by the laboratory test.

Core materials:

The borrow site for core materials is situated in the granite area near the boundary with the Mesozoic sedimentary rocks, 4 km east-northeast from the proposed main damsite. The granite mass is heavily weathered by 15 to 20 m in depth. This weathered granite is adequate for core materials in quality since the material tests show that the materials contain the natural water content of 15 to 20% and are well graded. A sufficient amount of the core material is supposed to obtain from the proposed borrow area.

Filter materials:

There are no descriptions for filter material in the feasibility study report. The result of field survey in this time clarified that the suitable filter materials have not been found around the proposed damsite, and then it is proposed to obtain them by crushing the rock material at the proposed quarry site.

Design of dam

An inclined core type rockfill dam and centre core type rockfill dam are conceivable as the dam type. Among them the centre core type rockfill dam was adopted in this study considering the workability of execution. The crest width of the dam is decided at 10 m considering the transportation during and after the construction of dam. Crest elevation of the dam is set at El. 91.1 m considering 3.5 m of freeboard to the design flood water level. The stability analysis of the dam was made assuming the final stage although the crest elevation of the first stage is El. 84.900 m.

The stability analysis by means of surface sliding method was carried out under the following conditions for construction materials and design conditions:

Material	Dry unit weight (ton/m^3)	Sat. unit weight (ton/m^3)	Int. fric. angle (deg.)	Cohesion (kg/cm^2)
1 Rockfill	1.85	2.10	41.00	0.00
2 Filter	1.85	2.10	35.00	0.00
3 Core	1.60	1.80	30.00	0.00
4 Riverbed	1.85	2.10	36.00	0.00

No.	Condition	Water level (El;m)	Seismic coefficient
1.	Reservoir empty	-	0.05
2.	Design flood water level	87.6	0
3.	Surcharge water level	84.9	0.05
4.	Normal high water level	80.0	0.10
5.	Medium water level	75.0	0.10

The embankment slopes on both upstream and downstream are assumed as follows:

Dam	Upstream slope	Downstream slope
Main dam	1 : 1.85	1 : 1.75
Saddle dam	1 : 1.85	1 : 1.75

The result of stability analysis on the above condition is summarized as follows:

Main dam;

		Safety factor				
		Normal Condition		Seismic condition		Seismic coeffi-
Case	R.W.L.(m)	Upstream	Downstream	Upstream	Downstream	cient
I	DFWL 87.600	2.345	1.544	1.851	1.451	0
II	SWL 84.900	2.211	1.567	1.776	1.473	0.05
III	NHWL 80.000	2.077	1.596	1.447	1.417	0.10
IV	MWL 75.000	2.041	1.608	1.461	1.464	0.10
V	-	2.246	1.558	1.933	1.464	0.05

Saddle dams;

		Safety factor				
		Normal Condition		Seismic condition		Seismic coeffi-
Case	R.W.L.(m)	Upstream	Downstream	Upstream	Downstream	cient
I	DFWL 87.600	2.002	1.592	1.576	1.372	0
II	SWL 84.900	1.941	1.644	1.543	1.421	0.05
III	NHWL 80.000	1.842	1.707	1.232	1.299	0.10
IV	MWL 75.000	1.773	1.707	1.219	1.341	0.10
V	-	2.004	1.707	1.781	1.511	0.05

The safety factors calculated on the above satisfy the required safety factor, i.e. 1.5 on the normal condition and 1.2 on the seismic condition. It is noted that stability analysis is carried out under the completion of second stage and that stability analysis of saddle dams is carried out for Saddle Dam I with a bigger scale than Saddle Dam II.

Intensive weathering develops on both banks of the Lebir damsite. The decomposed zones are 5 to 7 m thick on both slopes, and show high permeability of more than 20 Lugeon. To reach the fresh rocks, it is planned to excavate by 5 m at the river bed, 10 m at the left bank and about 20 m at the right bank. Curtain grouting with an interval of 2 m is planned to be provided to cope with probable permeability in the tuffaceous conglomerates and tuffaceous sandstone.

General plan, profile and typical cross sections of main dam and saddle dams are shown on Figs. 4.21 to 4.25.

(2) **Related structures**

Diversion tunnel and cofferdam

The probable flood having a probability ranging from once in 10 years to 20 years is generally applied to the design discharge for diversion facilities of rockfill type dam.

Since the Lebir dam is planned as rockfill type, it is necessary to avoid an overtopping from cofferdam during the construction of main dam. The 20-year probable flood peak discharge of 6,000 m^3/sec, which is the largest among the above, is then adopted for the design discharge for diversion facilities.

Based on the relationship between dimension of the diversion tunnel and dimension of the cofferdam, it was determined to provide two lane diversion tunnels with a diameter of 13 m and about 600 m in length and a cofferdam with crest elevation of El 59 m in the upstream side of the damsite. Two lane diversion tunnels with inlet elevation of El. 29 m and outlet elevation of El. 26 m are provided through tuff zone (CH class rock) in the right bank connecting with river meandering portion. Since the tunnel route closes remarkably to thin-ridge near the damsite, a curtain grouting is planned to be provided.

General plan, profile and typical section of the diversion tunnel and cofferdam are given in Figs. 4.21 and 4.26.

Spillway and stilling basin

In the Master Plan Study, the probable maximum flood was estimated for every proposed damsite. The value is, however, less reliable because of insufficient rainfall data in the upstream basin. Then, the largest Creager's coefficient of 55 at Lebir damsite was applied. In addition, the following 3 values were compared each other in accordance with the dam construction code in Japan:

(i) Recorded maximum peak discharge,
(ii) 200-year probable flood at damsite, and
(iii) Peak discharge referring to the largest Creager's coefficient in and around the basin.

Of the above values, the peak discharge of 200-year probable flood approximately corresponds to that of Creager's coefficient of 55. However, the flood volume of the latter is larger than that of the former. Then, the probable maximum flood having Creager's coefficient of 55 was adopted for the spillway design flood. Besides, the safety factor of 1.2 was multiplied by the peak discharge for the rockfill type dam according to the dam construction code in Japan. Consequently, the flood peak discharge of 12,400 m^3/sec was adopted to the spillway design flood.

In order to ensure the function of spillway against flood on first and second stages, non-gated spillway of 150 m in total width is contemplated. Of 150 m in total width of spillway crest, the crest of 70 m wide is lowered down to El. 70.0 m (NHWL) keeping the almost same flood mitigation effect on the second stage against 50-year probable flood. The surcharge water level of El. 78.0 m, which is the highest reservoir water level during flood routing for 50-year probable flood, was set at the crest elevation of the remaining width of spillway crest. The design flood water level of El. 81.4 m was determined by the flood routing for spillway design flood considering the flood retardation effect by the reservoir in accordance with the concept for large reservoir in the World Large Dam Committee.

It is planned to provide the spillway structure on the tuff zone (CM class rock) in the ridge of the right river bank utilizing the river meandering and considering safety against seepage of dam. A chuteway type spillway was adopted from the topographic viewpoint.

The design flood for the stilling basin was determined by the peak outflow from reservoir during flood routing for spillway design flood. The adopted outflow is 6,500 m^3/sec. It is planned to provide a hydraulic jump type with open chute considering the existing river condition and location of the spillway as shown in Fig. 4.27. It is herein recommended that definite dimension of the stilling basin is determined by means of model test in the detailed design stage.

<u>River outlet</u>

A facility should be installed for releasing maintenance water to the downstream reach. A river outlet facility having two jet flow gates with a diameter of 1.7 m each is provided in the diversion tunnel to release 70 m^3/sec of reservoir water (refer to Fig. 4.26).

<u>Power intake</u>

The dam will be heightened in the second stage for hydropower generation. Power facilities such as intake, waterway and powerhouse will be the works in the second stage. However, the intake structure as given in Fig. 4.28 is desired to be constructed in the first stage, since a dry space must be prepared for the construction of intake by drawing down the reservoir water level lower than El. 47 m, when the intake is constructed in the second stage.

<u>Access roads to main damsite, saddle damsite, quarry site and borrow pit site</u>

The existing Gua Musang-Kuala Krai national highway is located in the left bank along the proposed Lebir reservoir. It is planned to provide about 2.5 km long additional road connecting this highway near Kg. Tembeling with the damsite.

While, existing road with about 5 m in width is situated in the right bank along the proposed reservoir area. Since the proposed saddle dams are located on this route, the access road to the saddle dams is planned by providing about 2 km long road connecting the main damsite with the existing road.

Since the proposed quarry site is located besides the existing road, about 2 km long additional road is planned to connect the quarry site to the existing road.

Since the proposed borrow pit site is located at about 3 km northeast of the existing road, about 4 km long additional road connecting the borrow pit site with the existing road is planned.

Location of these access roads is given in Fig. 4.29.

Alternative route of the proposed highway plan

A highway plan linking Gua Musang to Kuala Brang in Tereggánu has been proposed by the Government. This highway route crosses the proposed Lebir reservoir area. To cope with this problem, two alternative routes were contemplated as shown in Fig. 4.30. Alternative-1 is proposed to connect point A with point B by the shortest way and crossing the most narrowest place of the reservoir by bridges. Three bridges with span of 500 m are proposed. Total length connecting points A and B is about 15 km. Alternative-II is proposed by detouring the reservoir area without large scale bridges. Total length for Alternative-II is about 30 km. Among these Alternatives, Alternative-I is recommendable from the economic viewpoint.

V. ENGINEERING STUDIES FOR RIVER IMPROVEMENT AND RELATED STRUCTURES

5.1 General

Regulation by the Lebir and Kemubu dams decreases peak discharge of a 50-year flood to 10,650 m^3/sec at Guillemard Bridge, which is the design discharge of river improvement for the distance of 100 km between Kuala Krai and the estuary.

This Chapter deals with the engineering issues of river improvement in the pre-feasibility level by availing the longitudinal and cross-sectional topographic survey additionally carried out for the urban areas in 1989 and the field investigation data of 1988 flood. This Chapter refers not only to the river improvement for the main channel of the Kelantan River, but also to the treatment of river mouth, tributaries and interior water drainage in the urban areas.

5.2 Principle of River Improvement Plan

The principle of river improvement plan in this pre-feasibility study follows the one mentioned in the master plan study.

5.2.1 Principle of river mouth treatment

Large scale sand dunes are being developed at the river mouth of the Kelantan River because of a strong westward littoral current and relatively low velocity of discharge from the main river. The river mouth is apt to be closed by sand dunes in case where low discharge continues in dry seasons. This phenomenon causes the inconvenience to navigational activities.

The 1988 flood flushed out the sand dune developed at the river mouth. It is considered that the sand dunes formed by the interaction of westward littoral current and relatively low velocity of discharge of the Kelantan River were iteratively flushed out by big floods in the past.

It is quite hard at this moment to fix the configuration of the estuary due to the interaction of westward littoral current and river discharge. In addition, it is difficult to keep the design flood water level lowered by a large scale dredging of river bed as annual maintenance work, in which a huge amount of dredging is required. Thus, the river improvement plan is carried out under the condition that the river mouth is remained as it is.

The river mouth in the Kelantan River always varies its location and causes the difficulties to navigational activities. In order to stabilize and maintain the river mouth and its direction and its upstream river channel, some measures including the provision of a jetty will be contemplated. However, the study on this river mouth treatment plan needs the solution for several technical problems such as the direction and length of the river mouth to be protected, the relation between erosion and scoring near the protected river mouth and littoral current and the relation among the river channel variation near river mouth, river discharge in the rainy and dry seasons and littoral current. To meet with these requirements, sufficient investigation is needed during a long term to obtain the necessary data. A technical specification for the investigation is attached in Appendix-1 of Annex VII (Part II).

5.2.2 Principle of river improvement plan

The design flood discharge for the sturctural plan of river improvement is 10,650 m^3/sec. The design conditions for the structural plan of river improvement are the same as the conditions applied in the master plan as discussed below.

(1) Levee

The levee is basically constructed with an earth embankment type. In the river stretch where the land acquisition is not easy due to urbanization such as Kota Bharu, the levee will be provided by shifting the levee structures to the river side.

(2) River structures

The construction of levee along the main river inevitably causes a problem of tributary treatment and interior drainage, so that interior water and water from tributaries must be drained by such structures as box culverts with sluice gate. Some meandering portions of channel downstream from Pasir Mas are observed to be eroded. Revetment works will thus be needed for protecting them.

(3) River flow near the estuary

The river mouth of the Kelantan forms the mesh-like river channels and a large scale sand dune is being developed at the debouchment of the river. The river flow in the rainy season discharges mostly to the northern direction and partly to the western direction through the mesh-like river channels. The river mouth is apt to be closed in the dry season due to relatively low velocity of discharge from the main river.

It is planned in this study to protect the river stretch upstream of the mesh-like river channel by provision of levee. The flood water level in the upstream stretch varies due to the flow condition of the mesh-like river channel. In order to study the treatment of the mesh-like river channels, the relationship between the most predominant flow condition in the mesh-like river channels at flood time and flood water level in the upstream river channel was studied based on the data for tidal water level at Geting which is located at the river mouth of Golok, flood water level at Kota Bharu and flood discharge at Guillemard Bridge. The study was carried out by means of non-uniform flow calculation using the record of flood discharges occurred in November 1988.

It was clarified in this calibration study that the flood flows discharge dominantly through the Kelantan main stream and Suri channel near the coastal area as shown in Fig. 5.1.

It is considered to be suitable to straighten the river channel as far as possible from the viewpoint of stability and maintenance of river channel. Present dominant flow condition as shown in Fig. 5.1 fits with the above requirement. Thus the river improvement plan was worked out under the condition that the mesh-like river channels to the direction of Tumpat are closed.

(4) Method of river improvement

Several alternatives for river improvement plan have been studied to select the most suitable measure for river improvement in the master plan study. They are;

(i) Alternative-A

A large scale levee is constructed along the main river without any improvement of river channel.

(ii) Alternative-B

A medium-sized levee is constructed along the main river. Additionally, the low-flow channel and remarkably narrowed river channel portion are reformed.

(iii) Alternative-C

Low-flow channel is widened with the average width of present river channel and reformed by dredging works. Additionally, the small levee is constructed at the river banks with the low elevation.

Among those three alternatives, construction cost for Alternative-C is about three times of that for Alternative-A and B. the construction cost of Alternative-A and B is the almost same but the flood water level for Alternative-B is lower than that of Alternative-A. Thus, Alternative-B has been selected as the suitable river improvement measure in this study.

In addition, short-cutting was contemplated to perform for Alternative-B at a large meandering portion at Pasir Mas. However, this plan shows little attractiveness due to high cost, problems of spoiling excavated materials and of the reconstruction of existing irrigation distribution network. Further discussions are referred to Annex VIII of Part I.

5.2.3 Principle of tributary treatment

There exist eight major tributaries of S. Durain, S. Nal, S. Tak, S. Sokor, S. Sal, S. Bagan, S. Kemubu and S. Keday in the Kelantan River downstream of Kuala Krai. Compared with the main channel of the Kelantan River, the scale of them is small.

In the past floods, flood water level in the main channel of the Kelantan River was higher than that of tributaries, so that flood water in the main channel flowed into the tributaries and caused the inundation in the tributaries.

To cope with such a situation, two measures are considered; one is to extend the levee along the main channel upto the influential area of backwater in the tributaries. The other is to provide water gates to prevent the reverse flow from the main channel to the tributaries. Levee extension rather than provision of water gates would be desirable in the Kelantan River taking into account the problem of operation and maintenance. For the minor tributaries besides the major tributaries mentioned above, box culverts with sluice gates will be equipped not to cause the reverse flow.

5.2.4 Treatment for the drainage of interior water in the urban area

Present drainage system in the town of Kota Bharu divides into three catchment areas; that is, south-west part of the town of Kota Bharu with a catchment area of 23.4 km^2, south-east part of the town of Kota Bharu with a catchment area of 12.5 km^2 and northern coastal plain of 74.9 km^2. The central part of Kota Bharu is located in the northern coastal plain area. Majority of sewage and runoff caused by localized storm is drained to the South China Sea through the Pengkalong Chepa River flowing from the downstream area of Kota Bharu to northeastern direction and Lubok Mulong River flowing from the upstream area of Kota Bharu to northern direction.

In order to clarify the relation between the inundation caused by overflow of flood from the Kelantan River and that due to intensively localized storm, the relation between the occurrence of relatively heavy rainfall in Kota Bharu and concurrent flood peak discharge at Guillemard Bridge was studied based on the rainfall record at Kota Bharu during the 1956-1986 period and water level record at Guillemard Bridge during the 1965-1986 period.

The 5-day rainfall more than 1,000 mm and concurrent flood peak discharge are estimated in Table 5.1 and they are summarized as follows:

Date	5-day rainfall (mm)	Flood peak (m^3/s)
1967, Jan.	1385	16,000
1981, Nov.	1123	2,028
1986, Dec.	1463	6,901

The flow capacity of river channel at Kota Bharu stretch has been estimated at around 5,000 m^3/sec. The Flood Report prepared by DID states that the town of Kota Bharu was not inundated during the intensively localized storm in 1981. The 5-day rainfall in November 1981 corresponds to about 15-year probability. This fact implies that the present drainage system has capacity to discharge the runoff with about 15-year return period, which is caused by intensively localized storm, and inundation in the town of Kota Bharu may scarcely occur unless the overtopping of flood from the Kelantan River takes place.

In order to further study the urban drainage in Kota Bharu, investigation and study on the existing drainage network and hydraulic conditions at the occurrence of intensively localized rainfall will be needed. These investigation and study should, however, be carried out after confirming sufficiently the inundation condition after the implementation of the proposed flood mitigation project.

In other towns such as Pasir Mas, Tanah Merah and Kuala Krai along the Kelantan River, inundation is reported to be caused not by intensively localized storm, but by overtopping of flood from the Kelantan River. Thus, special treatment for the drainage of interior water may not be necessary for these town areas.

5.3 Structural Plan of River Improvement

5.3.1 Design for the structural plan of river improvement

The results of the design for the structural plan are summarized as given in Figs. 5.2, 5.3 and 5.4 based on the following studies:

(1) Design conditions

- Flooding in the downstream reaches of the Kelantan River is mainly caused by overtopping from the main river and reverse flow from the main river to tributaries. This kind of phenomena will occur for the design discharge of 10,650 m^3/sec even after the completion of Lebir and Kemubu dams, resulting in the necessity of river improvement works.

- Mean HWL 0.691 m observed at Tumpat is used as the design water level of non-uniform flow calculation due to no available water level data at the river mouth of the Kelantan River (refer to Annex II of Part I).

(2) Design of longitudinal profile

- The design slope of river bed is decided to be 1 to 12,000 for the stretches between the estuary and Pasir Mas and 1 to 6,000 for further upstream stretches by keeping the present river bed slope as much as possible.

- The design high water level is determined by non-uniform flow calculation for the design discharge of 10,650 m^3/sec.

- The crest of levee is determined with the freeboard of 2 m above the design high water level.

(3) Design of cross section

- The ratio of design discharge of 10,650 m^3/sec to mean annual discharge of 600 m^3/sec is as great as 18:1. In order to obtain the stable river channel, a compound cross sectional channel is applied.

- A distance of more than 50 m is secured between the low-water channel and levee for the safety of levee itself.

- The width of low-water channel is kept as it is, however, the narrow places with considerably low flow capacity are widened; 400 m wide upto 55 km upstream from the estuary and 300 m wide for the further upstream reaches.

(4) Alignment of levee

- Alignment of levee is made smooth taking into account the land use, topography, houses and structures.

- The existing levee is used for connecting new levee.

The main work volume and cost of the proposed river improvement are as follows:

(1) Kelantan River

- Levee length	:	131 km
- Embankment volume for levee	:	$11x10^6m^3$
- Channel excavation	:	$2x10^6m^3$
- Reconstruction of bridges	:	one (Sultan Yahya Petra)
- Sluice	:	33 nos
- Revetment (low water channel)	:	10.8 km
- Revetment (high water channel)	:	12.5 km

(2) Tributaries

- Levee length	:	33 km
- Embankment volume for levee	:	$2x10^6m^3$
- Sluices	:	21 nos
- Bridges	:	5 nos

(3) House evacuation and land acquisition

Land to be acquired and houses to be evacuated are estimated to be 1,600 ha and 770, respectively. It is noted that the houses to be evacuated are counted based on 1 to 25,000 scale maps.

(4) Project cost

Construction cost required for the river improvement is estimated at M$580 million. Further details of construction cost are referred to Annex VIII of Part II.

Following are noted for the design of river improvement:

(1) Houses and trees located in the high water channel between levees should be evacuated to warrant smooth flow on floods.

(2) Embankment materials of levee are basically obtained from high water channel located at its spot and from the materials excavated for the drain located behind it. However, since suitable materials for levee embankment are not found at the reaches downstream of Kota Bharu, embankment materials are hauled from borrow areas or high water channel upstream of Kota Bharu.

(3) Flooding of Kota Bharu is caused by overtopping from the Kelantan River as well as the Sg. Keladi, a tributary in the Kota Bharu town area. Provision of a sluice at the confluence of both rivers is necessary for the flood protection of the Kota Bharu town area besides the construction of levee along the Kelantan River. The gate is open in a normal condition for cleaning of Sg. Keladi, and is closed during flood time for preventing from the overtopping from the Kelantan River.

(4) The Sultan Yahya Petra bridge should be reconstructed, since the design high water level is higher than the girder of the bridge.

(5) The crest of wall at Pasir Mas is as high as the design high water level. Thus, heightening of 2 m is required for freeboard. However, since it is not easy to heighten the wall due to the structure of wall, earth levee was considered in this study. In coming feasibility and detailed design stages, a further study is desired to be carried out.

(6) Three pumping stations for irrigation near Pasir Mas should be relocated, because the existing pumping stations will be left in the high water channel after the completion of new levee.

(7) A main cause of flooding in Tanah Merah and Kuala Krai is the reverse flow from the main river to the tributaries (Sg. Kusial for Tanah Merah and Sg. Durian for Kuala Krai). Thus the treatment of tributaries is important.

(8) The planning of river improvement in this study is based on the topographic maps with a scale of 1 to 25,000. In coming feasibility and detailed design stages, more large scale maps such as 1 to 2,500 are desired to be prepared for the detailed design.

The plan of river improvement, longitudinal profile and cross sections in more details are summarized in Appendix-2 of Annex VII (Part II).

5.3.2 Preliminary design of related structures

(1) Levee

The levee is basically constructed with an earth embankment type having the side slope of 1:3.0 taking into account the stability of levee structure against a long duration of flood. To protect the toe of the levee from seepage water, toe drain is provided, but not for the levee lower than 2.5 m in height. While the width of crest is set at 7 m.

Tarmac road with 3 m wide will be provided on the crest of levee for flood fighting and the operation space of machines to be used for maintenance. The slope of earth levee is sodded to prevent from erosion caused by heavy rainfall and river flow. The typical cross section of earth levee is shown in Fig. 5.5.

(2) Revetment

To protect the bank from erosion, revetment made of wet masonry will be provided on the levee slope of the river side and side-slope of low-water channel at the concave side of the sharpest bends as shown in Fig. 5.6.

(3) Box culverts with sluice gates

Box culverts with sluice gates are constructed with reinforced concrete. The typical structure of these is given in Fig. 5.7.

VI. ENVIRONMENTAL IMPACT STUDY

6.1 General

The land in the study area, i.e. the Kelantan River basin is topographically classified into two; hilly and flat land in the northern part and mountainous land in the southern part. The northern part is well developed as agricultural lands. The southern part is reserved as forest lands. Various kinds of wildlives and aborigines in Malaysia called Orang Asli inhabit and migrate in the forest land. In fact, the southmost area is enacted as Taman Negara (National Park) for protecting wildlives. On the other hand, logging activities in this forest land progress in a considerably high pace as a major source of foreign exchange earning.

Flood mitigation in the downstream reaches of the Kelantan River is contemplated by regulating flood flow by the reservoirs created by the Lebir and Kemubu dams in the upstream reaches (refer to Fig. 6.1) and river improvement in the downstream river stretches. The proposed two dam schemes are located in the southern hilly and mountainous areas covered with forests, and will have a considerably large reservoir area, resulting in property losses due to submergence and environmental changes. Considering these points, the objectives of the environmental impact survey are focussed on the following:

- to analyse the present environmental status of the Kelantan River basin, and

- to point out environmental problems in relation to basin-wide flood mitigation plan, especially the creation of reservoirs by dam schemes.

The following two environmental impact assessment reports are available in this study area;

(1) Nenggiri Dam Project Feasibility Study
Environmental Impact Assessment (September 1986)

(2) Environmental Impact Statement for the Lebir Dam Project in Malaysia (February 1988).

The environmental impact survey in this study is in principle based on the review of the above two reports.

The items discussed in this environmental impact study are as follows:

- River Environment (water quality, and fish and fisheries)
- Flora
- Fauna
- Ethnicity
- Public Health.

6.2 Present Environmental Status of the Project Area

6.2.1 River environment

(1) Water quality of the Kelantan River system

Organic pollution in the Kelantan River is caused by domestic and industrial sewage in the urban areas and effluent from rubber factories, palm oil mills and animal husbandries in the rural areas. Fig. 6.2 shows the organic pollution sources in the Kelantan River, which are mainly located downstream of Kuala Krai. A part of waste water from Kota Bharu, which is the largest pollution source in the basin, drains to the Kelantan River some 10 km upstream from the estuary, resulting in no direct relation with this environmental impact study.

Chemical quality of surface water in the Kelantan River was recently surveyed by DID and environmental impact survey of the Nenggiri and Lebir dam projects at the monitoring stations as shown in Fig. 6.3. The Kelantan River system is in general neutral with pH values ranging from 6.3 to 7.6. A little lower value representing slightly acidic water is observed at the Lebir River.

Suspended solid (SS) in water samples shows high concentration with the range of 5.0 to 244.0 mg/l in surface water. This high concentration of suspended solids is considered to be associated with heavy rainfall prior to sampling. At the monitoring stations located upstream, SS level is relatively low. However, river water presents a reddish brown colour which indicates characteristics of laterite.

Dissolved oxygen measured in the Kelantan River indicates an amount of more than 6.0 mg/l, the level of which accounts for high saturation. BOD concentration in the Kelantan River is low. This means that there are no high pollution sources along the Kelantan River.

The level of phosphorus indicates the values of 0.08 to 0.60 mg/l in the Kelantan River. This high level of phosphorus is likely to be associated with heavy rainfall prior to sampling; that is, heavy rainfall flushes out sediments deposited in the riverbed. On the contrary, the level of phosphorus in the upper reaches of the Kelantan River indicates the low values of N.D - 0.23 mg/l at the Lebir River and 0.01 - 0.07 mg/l at the Nenggiri River.

Although the Kelantan River is a tidal river, the average of the chloride level is 2.8 mg/l at Guillemard Bridge. Therefore, theree is no influence of tide in the middle stream of the Kelantan River. Further discussions on salt water intrusion are discussed in the Master Plan Study (Annex VI of Part I). The level of all metal ions is low in all the water samples obtained from the Kelantan River system.

(2) Fish and fisheries

The Kelantan River system is well known as an abundant area of freshwater fishes. Besides, there are some rare and endangered fish species in the Kelantan River system.

The existing fisheries in the Kelantan River system consist mainly of artisanal fisheries in a small scale. The majority of participants within riverine fisheries is part-time fishermen who catch fish mainly for their own consumption. There is only a small group of fishermen who actively participate in the fisheries in full time.

The most common species of production are Lompan Jawa, Lee Koh, Tongsang Makan Rumput, Tongsang Kepala Besar, constituting about 60% of the total freshwater fish production.

6.2.2 Flora

The natural vegetation in the Kelantan River basin mostly consists of tropical rain forest which has the most complex and abundant species. This forest mainly consists of lowland Dipterocarps. According to the foregoing two EIS reports, there exist no precious or rare species in the Kelantan River basin.

In respect of the nature conservation, forest reserve areas are designated in the south-east and south-west of the State of Kelantan as shown in Fig. 6.4. A part of Lebir reservoir is in the forest reserve area.

6.2.3 Fauna

It is stated in the previous EIS reports that the mammalian fauna more than 25 species is recorded in the State of Kelantan. Among those mammals, eight species are endangered. They are Stump-tailed macaque, Indian elephant, Red dog, Leopard panther, Malaysian tiger, Banteng, Malaysian tapir and Sumatran Rhinoceros.

In the project area, 65 species of birds have been observed. Among these species, pheasants, hornbills and carnivorous birds are considered to be endangered.

The pheasants are ground living birds that are found in primary and secondary forests. The outstanding one is Great Argus Pheasant which is normally found in primary forests.

The hornbills are the primary indicators of tropical Dipterocarp forests. According to the previous studies, six species are observed. They are Black hornbill, Rhinoceros hornbill, Helmeted hornbill, Wrinkled hornbill, Bushycrested hornbill and Wreathed hornbill.

Carnivorous birds are famous for their wide territory during their food phase of livelihood, and six species are observed. They are Black eagle, Crested serpent eagle, Short-toed eagle, Blythis hawk eagle, Black kite and Black-shouldered kite.

6.2.4 Ethnicity

There are 18 settlements of Orang Asli, which is an indigenous group of Malaysians, in the survey area as shown in Fig. 6.5. The biggest settlement is Kuala Betis which is located along the Nenggiri River. Almost all the settlements of Orang Asli are observed in the upper reaches of the Kelantan River system.

The majority of Orang Asli living in the State of Kelantan is Senoi and Negritos. They may be further classified into dialect groups. The difference between dialect groups is not significant since they understand each other and mix freely.

Orang Asli has been treated as nomadic hunting and gathering people who mainly subsist on wild tubers, fruits, and small game which they hunt with blow pipes and poisoned darts. They are therefore dependent on the forest for their livelihood. All the forest products captured are shared by all. They have no concept to keep private property besides only a few basic essential household items.

6.2.5 Public health

Malaria, acute respiratory infections and diarrhoea diseases have high infection percentage. However, the most prevalent disease is malaria in the State of Kelantan. It is reported that schistosomiasis is not in fashion in Peninsular Malaysia.

Malaria in the State of Kelantan tends to increase little by little until 1986, while the number of occurrence decreased in 1987. Furthermore, malaria cases in the State of Kelantan share high percentage in Paninsular Malaysia in spite of all efforts of the Department of Health at Kelantan.

6.3 Environmental Impact by the Lebir and Kemubu Dam Schemes

Flood mitigation in the downstream reaches of the Kelantan River is contemplated by regulating flood flow by Lebir and Kemubu dams in the upstream reaches and river improvement in the downstream river stretch.

The creation of the reservoir by dam will bring about the transportation of the existing natural riverine ecosystem to man-made lacustrine ecosystem, although this change may be brought with some time lag.

As for river environment, the level of total phosphorus is not so high at the upper reaches of the Kelantan River system that the eutrophication will not occur by nutrients from rivers which flow in a reservoir. However, the value of parameters showing water pollution such as BOD and COD will increase. To cope with such pollution of the water quality, burning of trees in the reservoir area would be one of appropriate measures.

With the change in the river environment that river changes to reservoir, the fish fauna is anticipated to change to lacustrine fauna. But, it is considered that many existing fish species would be able to adapt to the new environment.

The existing EIS reports state on flora that there exist no precious or rare species and forest groups in the proposed reservoir areas, so that it is not expected at this moment that dam construction will give environmental impacts on precious or rare species.

The creation of the reservoir area due to the dam construction may result in the impact to animals inhabitated there. However, since broad rain forest is spreading in the upstream reaches of the Kelantan River basin, it is considered that the creation of reservoir scarcely exerts to living of the wildlives.

There are many settlements of Orang Asli in the upper basin of the Nenggiri River, many of which are not located in the proposed Lebir and Kemubu reservoir areas. However, it is necessary for Orang Asli to look for the appropriate resettlement place so that they can keep their way of life, when their settlement is submerged under both reservoir.

6.4 Environmental Impact by River Improvement

River improvement by levee construction will be carried out between Kuala Krai and the estuary as part of the overall flood mitigation works of the Kelantan River. Since a 5 m high class levee will at most be constructed along the river, it is not considered that river improvement would cause the notable environmental impact.

However, there may be a discussion that the value of SS (suspended solid) will increase during the construction of levee. The SS level under the natural condition is so high that slight increase of turbidity will hardly cause the environmental impact. It is finally noted that it would be convenient for riparian people to provide gentle slopes or stairs on the levee.

VII. CONSTRUCTION PLAN AND COST ESTIMATE

7.1 General

This chapter deals with a construction plan and cost estimate for the flood mitigation in the downstream area from Kuala Krai to protect the envisaged area against 50-year probable flood by means of construction of the Lebir dam, Kemubu dam and river improvement works.

The construction plan was worked out in consideration of the topographic and meteo-hydrological conditions in the project area, result of geological investigation and other factors affecting the implementation of the project.

7.2 Construction Plan

7.2.1 Work items and quantities

In order to implement the project work within the limited construction period, it is herein proposed to execute the project works by an international contract system. In consideration of the scale of the works and anticipated amount of construction cost, it is determined to execute the construction work by dividing into 4 packages, namely, construction of the Lebir dam project (Package 1), execution of river improvement for urban areas such as Kota Bharu, Pasir Mas, and Tanah Merah (Package 2), construction of the Kemubu dam project (Package 3) and execution of river improvement works for the rural areas (Package 4).

Construction works will be administrated by DID in association with an international engineering consulting firm.

The construction works for the divided 4 packages are summarized in Table 7.1.

7.2.2 Conditions and assumptions for construction planning

(1) Labour force

Skilled and semi skilled labour will be recruited in such major towns as Kota Bharu, Pasir Mas, Tanah Merah and Kuala Krai. Common labour with a sufficient number can be recruited in the Kota Bharu and Pasir Mas.

(2) Construction materials

The required materials such as cement, steel materials, wooden materials, fuel and lubricant and reinforced concrete pile are available locally at the major towns.

(3) Construction equipment and plant

The required equipment to be used for a long period is considered to be purchased by the contractors. In case that the equipment will be required for construction works for a short period, it may be arranged by the contractors on a rental basis.

(4) Workable day and working hour

Since construction will predominantly be controlled by rainfall and flooding, the workable day was estimated based on the past rainfall records and regulations applied in Malaysia. The criteria is established as follows;

a) No works are carried out on the national holidays.

b) The works to be suspended due to rainfall are estimated from the following criteria:

Amount of rainfall (mm)	Suspended day	
	For embankment	For excavation and concrete works
0 - 5	0	0
5 - 30	1	0.5
30 - 50	2	1
50 - 100	3	1.5
over 100	4	2

The workable days throughout the year are estimated at 175 days for embankment work and 276 days for excavation and concrete works on the basis of the above criteria. The execution works are planned under the condition that the works are generally on a single 8 hour-shift basis except for the dredging work.

7.2.3 Works for Lebir dam project (Package 1)

(1) Site preparations

Main offices, quarters, labour camps, warehouses and fuel storage tank will be provided at Tualong near the existing road at about 3.5 km apart from the damsite. While repair and work shops will be provided at the damsite.

Concrete plant capacity is estimated at 1.5 m^3 with two units based on the concrete volume required at peak time.

The capacity of aggregate plant which consists of grizzly, primary crusher (jaw crusher), secondary crusher (cone crusher), tertiary crusher (impact crusher), washing plant, rod mill and spiral classifier will be estimated at 150 ton/hr. The capacity of filter production plant is estimated at 76 ton/hr.

Aggregate and filter plant will be located adjacent to the quarry site to avoid double handling.

The proposed quarry site is located at 1.5 km in the north-east of the main dam. It consists of tuffs, tuffaceous breccias and rounded conglomarate.

The quarry will be developed on a bench-cut system of 7.5 m bench height.

(2) Diversion tunnels

Two lane diversion tunnels with 13 m in diameter and 570 m in length will be constructed in the order of upper half, lower half, side wall and concrete lining. Simultaneous construction of two diversion tunnels was planned to complete them within 22 months. When the main dam embankment is completed, two diversion tunnels will be permanently closed by concrete plugs.

(3) Cofferdams

Immediately after the completion of the diversion tunnels, river water will be diverted through the completed tunnels, and embankment of upstream and downstream cofferdams for the main dam and also cofferdam for the saddle dam will be commenced. The upstream cofferdam is designed as the centre core type and consists of a part of the main dam. The embankment volume of the cofferdam is as follows:

	At main damsite	At saddle damsite
Foundation excavation;	25,000 m^3	18,000 m^3
Embankment;		
Core material	117,000 m^3	13,000 m^3
Filter material	29,000 m^3	4,000 m^3
Rock material	541,000 m^3	56,000 m^3

It is scheduled to complete the cofferdam for the main damsite within 7 months. It is planned that the impervious core material is transported from the borrow area at about 4 km apart from the damsite, and all of the filter material and a half of the rock material are transported from the quarry site at 1.5 km apart from the damsite. The remaining required volume of the rock material will be obtained from the excavated rock of the dam foundation. The cofferdam for the saddle damsite will be constructed using the excavated material from the saddle damsites.

(4) Main dam

The excavation of the main dam including dam foundation and gallery trench at higher elevation will be executed prior to the completion of the cofferdam. The estimated excavation volume is 502,000 m^3. After the river water is diverted through the completed diversion tunnel, excavation of the dam foundation for the remaining river bottom site will be executed.

The consolidation grouting will be performed from the excavated core trench. Total grouting length is estimated at about 9000 m. The grouting work is scheduled to be carried out during one year.

The curtain groutings will be executed from the gallery below the core zone, in parallel with the embankment of the dam. Total length of the grouting is estimated at 34,000 m.

The main dam volume is estimates as follows:

Core	437,000 m^3
Filter	92,000 m^3
Rock	2,171,000 m^3
Total	2,700,000 m^3

The impervious core and filter embankment will be carried out only in dry season starting from January to September, in principle, while the rock embankment will be done throughout the year.

The core material will be obtained from the borrow area at 4 km away from the dam site and will be spread on the embankment area in 300 mm thick layers. Compaction will be achieved by six passes of tamping roller.

Filter materials will be loaded out by 20 ton dump truck at filter plant and will be placed by dumping into a spreader box and then spread in layers of 600 mm thick. Water will be added to aid compaction which will be accomplished by four passes of vibrating roller.

Rockfill for the shells of the dam will be obtained from the quarry without further processing. The material will be loaded by 5.0 m^3 wheel loader and transported to the embankment by 32-ton dump trucks and it will be dumped and spread by bulldozers in up to 1500 mm thick layers and compacted by six passes of 15 on vibrating roller. The whole of dam embankment work will be completed within 3 years.

(5) Spillway

Excavation for the spillway will be carried out in parallel with the dam foundation excavation. Work quantity is estimated as follows;

Common	; 158,000 m^3
Weathered rock	; 845,000 m^3
Rock	; 757,000 m^3

The excavated materials will be transported to the spoil bank. The excavated rock will be used for dam embankment. Rock materials will be loosened by blasting using 15 m^2/min crawler drill, then ripped by 32-ton bulldozer and loaded by 5 m^3 wheel load into 30 ton dump truck to stockpile for re-use in embankment. Final controlled excavation of the spillway will be carried out using 32-ton bulldozer to rip areas where blasting could not be carried out or will be unnecessary, and by small hand held drills where blasting is necessary.

Concrete works for 103,000 m^3 in volume will be carried out in the order of overflow weir, stilling basin and chuteway. Mass concrete for overvlow weir concrete will be placed by using combination of 40-ton truck crane and concrete bucket, while their wall structures will be constructed using a concrete pump.

Concrete for the stilling basin will be placed in the same manner as for the above. Concrete for the chuteway will be placed using concrete pump. Concerte will be delivered by agitator trucks.

(6) Saddle dams

It is scheduled to commence the construction works for the saddle dams after the completion of the main dam in order to minimize the number of the construction equipment.

The work quantity of the saddle dams is as follows:

Excavation	
Common	121,000 m^3
Weathered rock	634,000 m^3
Rock	46,000 m^3
Total	801,000 m^3
Embankment	
Core	305,000 m^3
Filter	66,500 m^3
Rock	1,143,000 m^3
Total	1,514,000 m^3

The construction of the saddle dams is planned to be executed in the same manner as that for the main dam.

(7) Outlet facility

When the main embankment has reached an adequate height, the inlet to the tunnel No. 1 which is close to the main dam will be closed by the intake gate. Immediately after the closure of the tunnel No. 1 a concrete plug will be placed. Two lane steel pipe units of 1.7 m in diameter will be embedded in the concrete plug as the river outlet use. The intake shaft with crest elevation of El. 50 m will be constructed for the outlet use of reservoir water.

When this work is completed the gate at the inlet tunnel No. 1 will be removed and transferred to that for the No. 2 for plugging of the tunnel No. 2.

After the concrete plugging works for No. 1 tunnel is completed, an access tunnel with 2 m in diameter in upper half and 1.5 m in height in lower half and 280 m in total length will be excavated from toe of the main dam in the downstream site. The gated chamber with valves is constructed at immediately downstream of the concrete plug.

7.2.4 River improvement works for urban area (Package 2)

(1) General

To protect urgently such major towns as Kota Bharu, Pasir Mas and Tanah Merah, river improvement works comprising construction of levee, revetment and drainage gate and reconstruction of bridge is planned to be executed in the following river stretches;

Kota Bharu stretch ; 9.5 km
Pasir Mas stretch ; 5 km
Tanah Merah stretch ; 10.6 km

The construction work will be executed in parallel with the work for Package 1.

(2) River improvement works

Project features:

The following works are planned for the river improvement works;

- Levee
  - 9.5 km in right bank of Kota Bharu stretch
  - 5 km in left bank of Pasir Mas stretch
  - 10.6 km in left bank of Tanah Merah stretch
  - 4.0 km for tributaries
- Revetment
  - Revetment for low water channel ; 4.3 km
  - Revetment for high water channel; 4.3 km
- Sod facing; 829,000 m^2
- Drainage facility; 8 places
- Construction of Sultan Yahya Petra bridge

Location of these works is given in Fig.5.2.

Levee construction:

The earth type levee with crest width of 7 m and side slope of 1:3 for both sides and toe drain and drain ditch at toe portion of inner side will be executed using the earth material at river bank near the embankment site. However for levee embankment in Kota Bharu stretch, earth material will be transported from high water channel portion in the upstream of

Kota Bharu.

The embankment volume and work quantity of toe drain made from cobble stone are as follows;

- Embankment volume; 2,600,000 m^3
- Toe drain ; 29,000 m

Loading of the embankment material will be made using back-hoe, and hauling and unloading will be carried out by dump truck. The compaction work will be made with a layer of 30 cm and by six passes of combination of sheep foot roller and 13 ton class bulldozer.

The levee embankment work will be also executed in the tributary up to the stretch where design high water level reaches.

The stone necessary for construction of toe drain will be obtained from the mountaneous area at about 20 km east from the project site.

Revetment work:

The revetment work for low water channel comprising foot protection by gabion and sheet pile and wet masonry will be executed in the dry season by means of coffering.

The revetment by wet masonry without coffering will be provided on the river side slope of the newly constructed levee.

The work quantity of revetment work is as follows:

Wet masonry ; 106,900 m^2
Sheet pile (0.4 m x 7 m); 10750 Nos

Drainage facility:

In order to drain the interior water to the Kelantan River and also to prevent the river water from flowing into the inner area, drainage facility comprising sluice gate will be provided at the debouch of 8 tributaries flowing into the Kelantan River in the urban area.

Construction of new Sultan Yahya Petra bridge:

Since the lowest beam of the existing Sultan Yahya Petra bridge with 850 m in total span and 12 m in width is lower than the design flood water level, it is planned to construct new Sultan Yahya Petra bridge at immediately upstream of the existing bridge, because this bridge was constructed about 30 year ago and consequently it seems that the strength of the bridge substructure after its heightening cannot satisfy the present load conditions.

The new bridge with same dimension as the existing one will be constructed at the elevation of about 2 m higher than that of the existing bridge.

7.2.5 Work for Kemubu dam project (Package 3)

(1) Site preparations

A 8 m wide and 5 km long access road to the dam site will be needed to construct to branching from the existing logging track. The existing logging track in a distance of 2 km between quarry site and branching point to the damsite will be upgraded for hauling rock and filter materials from quarry site.

A main office, quarters, labour camps, warehouses and a mosque will be provided on the logging track while repair shop, motor pool will be provided at the dam site.

Concrete plant which consists of batching plant and aggregate plant, will manufacture the concrete from central batching plant located near the left abutment of the dam.

The batching capacity will be designed to produce 72 m^3/hr at a peak output. The plant will be equipped with 2 units of 1.5 m^3 mix drum. The concrete will be transported by bunker line and by 9 ton cable crane to the pour site.

Aggregate plant will be located adjacent to the batching plant and designed to produce 150 ton/hr at a peak output. The aggregate plant will consist of the following components:

Plant	Aggretage size
Primary crusher (jaw crusher)	150 - 80 mm
Secondary crusher (cone crusher)	80 - 40 mm
Tertiary crusher (impact crusher)	40 - 20 mm
	20 - 5 mm
Quarternary crusher (rod mill)	5 - 0 mm

The quarry will be located at 5 km southwest from the dam site. A large pinnacles of limestones will be developed on a bench system of 3 m bench height for production of concrete aggregate and rock materials for both upstream and downstream cofferdams.

A 9.5 ton cable crane will be installed for use in placing concrete in the dam except for stilling basin. Considering the topography and geology at the damsite, the cable way of which one side will be fixed on the left bank and the other side on the right bank will be movable will be installed. The cable span between the two anchors will be 320 m at El. 100m. The two anchors will be a concrete gravity type. The cycle time of 3 m^3 class bucket to be attached to the cable crane will be about 3 minutes.

Bunker line will be provided on the left abutment connecting with the batching plant.

(2) Diversion tunnel

Two lane diversion tunnels with 9 m in diameter and 280 m in length are planned to be constructed in the right bank in the order of upper half, lower half and side wall and concrete lining. It is scheduled to commence the excavation work of two tunnels simultaneously to complete the tunnel works within 13 months. After the dam and spillway concrete works are completed, the diversion tunnel will be closed by concrete plug.

(3) Cofferdams

Immediately after the completion of the diversion tunnel, river water will be diverted through the completed tunnel and embankment work of the cofferdams with centre core type at the upstream and downstream sites of the damsite will be commenced. The work quantity of the cofferdams is as follows;

Foundation excavation;	21,000 m^3
Embankment;	
Core material	32,000 m^3
Filter material	8,000 m^3
Rock material	148,000 m^3

It is planned that impervious core material is transported from the borrow area at about 2 km apart from the damsite and all of the filter material and a half of the rock material are transported from the quarry site at about 5 km apart from the damsite. The remaining required volume of the rock material will be obtained from the excavated rock of the dam foundation.

It is scheduled to complete the cofferdam within 4 months.

(4) Main dam

The excavation of the damsite at higher elevation will be executed prior to the completion of the cofferdam. After the river water is diverted through the completed diversion tunnel, excavation of the dam foundation for the remaining river bottom site will be executed. The required excavation volume is estimated at 336,000 m^3 comprising 30,000 m^3 for river portion and 306,000 m^3 for the remaining portion.

Immediately after the excavation work, curtain grouting and consolidation grouting will be executed. The required work quantity is as follows;

Curtain grouting ;	8,000 m
Consolidation grouting ;	4,000 m

Concrete will be batched and mixed at the central concrete plant of two 1.5 m^3 tilting type mixers and transported by 4.5 m^3 agitator trucks to the point of placement at the damsite. A mobile crane unit and bottom-discharge buckets will be utilized for concrete placement. Concrete temperature in the dam body will be controlled by artificial cooling operation during concrete works. Concrete lift layer will be 1.5 m.

The main dam volume is estimated at 152,000 m^3 and dam construction is scheduled to be completed within 37 months.

(5) Spillway

Excavation of the stilling basin will be carried out in parallel with the excavation of the dam foundation. The excavation volume of the stilling basin is estimated at 80,000 m^3.

The concrete work for the spillway and stilling basin will be executed by combination of truck crane and concrete pump.

7.2.6 River improvement works for the rural area (Package 4)

(1) General

In parallel with the river improvement works for the urban area, river improvement in the rural areas will be executed. The required work quantity of the river improvement is as follows;

- Levee
  - 4.1 km in the right bank downstream of Kota Bharu
  - 10 km in the left bank downstream of Kota Bharu
  - 53.1 km in the right bank upstream of Kota Bharu
  - 38.7 km in the left bank upstream of Pasir Mas
  - 29 km in right bank upstream of Pasir Mas for tributaries
- River dredging; 2,100,000 m^3
- Revetment;
  - Revetment for low water channel ; 6.5 km
  - Revetment for high water channel; 8.2 km
- Sod facing; 4,220,000 m^2
- Drainage facilities; 46 places
- Removal of existing pumping facility ; 3 places

Location of these works is given in Fig.5.2.

(2) River improvement works

Levee construction:

The levee with same dimension as that stated in the urban area will be constructed. The work quantity of the levee construction is as follows:

- Embankment volume; 10,600,000 m^3
- Toe drain ; 89,500 m

The levee embankment works will be executed in the same manner as stated in the river improvement work in the urban areas. The required construction equipment is referred to Section 7.2.3.

River dredging:

There are several large scale sand dunes in the river channel in the downstream of Kota Bharu. It is planned to remove these sand dunes by means of dredging work. The dredging volume is estimated at 2,100,000 m^3. The dredging work will be executed using one unit of 600 HP suction type dredger.

Revetment work:

The work quantity of the revetment works is estimated as follows:

Wet masonry ; 161,000 m^2
Sheet pile (0.4 m x 7 m); 1575 Nos

The revetment works will be executed in the same manner as stated in the river improvement work in the urban area.

Drainage facility:

In order to drain interior water of urban area to the Kelantan River, the drainage facility with sluice gate will be provided at the debouch of 46 tributaries flowing into the Kelantan River in the rural area. The construction of the gated weir will be executed in the dry season by means of coffering.

Removal of existing pumping station:

Due to the provision of the levee, the existing pumping stations at Lemar, Salor and Pasir Mas are obliged to be shifted to the new place. It is scheduled to construct the pumping station with same function as the existing one prior to the levee construction.

7.2.7 Construction time schedule

The implementation period of 4 packages was studied considering site condition, extent of the works, identification of land acquisition, and financial balance to meet the Malaysian five year plan. The determined construction time schedule is given in Figs.7.1, 7.2 and 7.3 and summarized as follows:

Package no.	Starting time	Scheduled completion time	Duration of construction period (year)
1	January 1993	December 1998	6
2	January 1993	December 2000	8
3	January 2007	December 2010	4
4	January 1993	December 2010	18

7.3 Construction Cost to Be Required

7.3.1 Conditions for cost estimate

The construction cost of the project works is estimated by the following conditions;

(1) Price level : August, 1988

(2) Exchange rate : US$1.00 = M$2.70 = ¥150.00

(3) The construction cost consists of 3 main items, namely, direct cost, indirect cost and contingency. The direct cost is estimated based on the required work items and quantities derived from the pre-feasibility study. The indirect cost includes the cost of land acquisition and house evacuation, government administration cost and engineering services cost for detailed design and supervision. The physical contingency is counted into direct and indirect costs accordingly.

(4) The direct cost for civil works is estimated by multiplying the unit cost and corresponding work quantity. The preparatory works and minor work items are estimated by lump sum basis with a certain percentage of main works. The unit cost for each work item consists of the cost of construction materials, labour and equipment. The contractor's indirect cost is incorporated in the unit cost of each work item.

(5) Labourer's daily charge is estimated including the living allowance, leaves, bonus, medical care and others.

(6) Prices of construction material available in local market were surveyed at the project area. They are principally counted into the local currency component but their certain proportions are considered into foreign currency component according to their usage of imported raw material and production facilities. Table 7.2 shows the unit price of construction materials divided into the foreign and local currencies.

(7) Equipment cost consists of depreciation and interest, maintenance and repair cost, and management cost.

The currency component of the equipment cost is assumed to be 80% of the total cost for foreign currency and 20% for local currency, taking into account the following currency components;

<u>Foreign currency component</u>

- CIF purchase cost
- Spare parts cost

<u>Local currency component</u>

- Labour cost of repairing
- Landing and delivery cost
- Cost of equipment made in local market

Hourly cost per each equipment is tabulated in Table 7.3 by dividing into the foreign and local currency components.

(8) A 20% of direct cost for dam works is assumed as the contractor's indirect cost (contractor's overhead and profit), and added to the direct cost in the unit cost of each work item. A 15% of direct cost for river improvement works is assumed as the contractor's indirect cost.

(9) Cost estimate for mechanical works is based on market research and past tendered record of similar works.

(10) Land acquisition and house evacuation costs are estimated on the basis of the prevailing cost for land, buildings and other private properties in the State of Kelantan. All of these costs are estimated as the local currency component.

(11) Engineering services and administration costs are estimated at 15% of total direct cost for construction supervision with 80% and 20% for foreign and local components respectively.

(12) Physical contingency is provided to cope with the unpredictable physical conditions and 10% of total cost except for land acquisition is assumed.

7.3.2 Financial cost and annual disbursement schedule

The construction cost divided into foreign and local currency portions was estimated by multiplying the work quantities by the respective unit costs. The bill of quantities with unit cost are tabulated in Annex VIII based on the foregoing conditions. The construction cost estimated for each package is summarized in Table 7.4. Furthermore, the construction cost required for the Kelantan River basin-wide flood mitigation project is summarized as follows:

Unit:thousand M$

Cost items	F.C	L.C	Total
- Direct cost (Construction cost including preparatory works)	289,186	389,574	678,760
- Indirect cost (Land acquisition, administration and engineering service cost)	96,426	408,078	504,504
- Contingency (Phisical contingency)	38,561	79,765	118,326
Total	424,173	877,417	1,301,590

Note; (1) FC; Foreign currency. LC ; Local currency

(2) The cost for intake for power generation in Lebir dam is not included in this cost estimate (estimated direct cost for intake structure is M$22,523,000).

Based on the construction time schedule as shown in Figs. 7.1, 7.2 and 7.3, the annual disbursement schedule is prepared as given in Table 7.5.

VIII. ECONOMIC EVALUATION

8.1 General

The flood mitigation in the Kelantan River basin is carried out by the combination of the Lebir and Kemubu dams and river improvement. The Kemubu reservoir is exclusively developed for flood mitigation. Some reservoir space is secured for the augmentation of irrigation water below the space for flood mitigation in the Lebir reservoir.

Direct benefits of the Kelantan basin-wide flood mitigation project will accrue from the reduction of flood damage in the project area and from the enhancement of agricultural products by augmenting supply of irrigation water. The benefits from the latter are marginal compared with those from the former.

The economic viability of the project is evaluated under the condition that all the project components, i.e. Lebir and Kemubu dams and river improvement are completed according to the proposed implementation programme.

The Lebir dam will be raised for power generation in the second stage. The economic viability of the project is furthermore assessed with the benefit from power generation by heightening the Lebir dam besides the benefits from flood mitigation and irrigation augmentation. The heightening of Lebir dam is assumed to follow the construction of Kemubu dam.

As discussed in Section 6.2.4 of Part I (Main Report), the Kemubu and Nenggiri dam schemes are compatible to one another, when the Nenggiri dam scheme is developed for power generation. The viability to add the Nenggiri dam scheme to the Kelantan River basin is assessed by coinciding the commencement of construction to the second stage of the Lebir dam scheme.

As discussed in the preceding Section 4.2.3, Social impacts due to dam construction, considerable areas of plantation will be submerged under the Lebir and Kemubu reservoirs. The compensation for the area submerged in the reservoir is intended to be carried out by relocation. A sensitivity test was examined under the assumption that there exist no areas to relocate the plantation and that annual net profit from the plantation to be submerged is counted as negative benefits.

A height of 2 m is adopted as freeboard of levee by referring to the Code applied in Japan. As discussed in Section 5.4 of Annex VII (Part II), the reduction of construction cost was estimated for the case with 1 m freeboard. The improvement of project viability was also assessed for the case with 1 m freeboard as another sensitivity test.

8.2 Economic Cost

Construction costs including relocation costs of plantation are estimated as discussed in the preceding Chapter 7. Economic costs for the project are assumed at 85% of the construction cost, considering the shadow price of unskilled labour, transfer of payment in the local cost portion and so forth.

The O & M costs of Lebir and Kemubu dams and river improvement are taken to be 0.5% of their direct construction cost.

The disbursement of economic costs is accorded to the annual disbursement schedule as follows:

Lebir scheme	:	0.10, 0.15, 0.20, 0.25, 0.20 and 0.10 for 6 years
Kemubu scheme	:	0.10, 0.30, 0.40 and 0.20 for 4 years
River improvement	:	Even distribution for the construction period of 18 years.

The economic cost of the Nenggiri project is referred to Section 3.5 of Part I (Main Report).

8.3 Project Benefit

The flood damage in the basin, which is counted as the benefit of the project, is discussed in Annex V, flood Damage Study, of Part II. A summary of flood damage in each river stretch, KL 1 to KL 12 is given in Table 8.1. The damage in the level of year 2010 is presented in Table 8.2.

Firm release of 65 m^3/sec from the Lebir reservoir makes possible the net incremental benefit of M$0.62 million a year in the irrigation project, which is also counted as a project benefit. Further discussion is given in Annex VI of Part I.

Hydropower benefits of the Lebir and Nenggiri projects are estimated from the costs of alternative thermal plants, most likely least cost of which is inferred by combining the gas turbine with a plant factor of 0.1 and the combined cycle with a plant factor of 0.7. Further discussions are referred to Section 3.5 of Part I (Main Report).

A sensitivity test is carried out by assuming that potential areas for relocation of plantation are not available. Annual net profit from plantation, which is assessed to be M$1,037/ha for rubber and M$1,628/ha for oil palm (further details are referred to Appendix-3 of Annex VII in Part II), is counted as negative benefits of the project. In this case, all the costs for relocation are excluded from the project cost. Further discussions to estimate the net profit from plantation are referred to Annex V of Part II.

8.4 Economic Evaluation

The basic assumptions and conditions applied for the economic evaluation are given as follows:

(1) The evaluation period is 50 years from the in-service date of the Lebir dam scheme.

(2) Flood mitigation benefits accrue immediately after the completion of river improvement works for respective river stretches.

(3) Irrigation benefits are gained after the completion of the Lebir dam scheme.

(4) Economic evaluation is carried out in terms of Economic Internal Rate of Return (EIRR).

Based on the conditions and assumptions mentioned above, the economic viability of the project was assessed to be 2.2% in terms of EIRR. Power generation by raising the dam height of the Lebir project in the second stage improved the project viability to 4.4%. Furthermore, an addition of the Nenggiri hydropower project to the basin gained a higher value of 5.7% in the entire project viability.

A sensitivity test under no available relocation area of plantation was reckoned to be 0.8%. Another sensitivity test to give 1 m freeboard for levee gained the marginal improvement on economic viability, 2.5% from 2.2% of the original case with 2 m freeboard.

IX. SOCIO-ECONOMIC IMPACT DUE TO IMPLEMENTATION OF THE PROJECT

9.1 Impacts on Development Budget

It is not assumed that there will be a drastically high growth of development budget from now on, and that the annual development budget may grow at least at the same rate as the target economic growth rate of 5% in the Fifth Malaysia Plan.

Also, it is assumed that the future share of the State of Kelantan in the national development budget will be 6.5% based on the Fifth Plan. In like manner the future share of the "energy and public utilities" sector consisting of "electricity", "water supply" and "drainage and flood mitigation" in the national development budget will be 12.0%.

Upon the above assumptions the allocations to the "energy and public utilities" sector in the Sixth (1991-1995) to Ninth Malaysia Plan (2006-2010) work out at M$3,826 to 7,954 million, and the allocations to the State of Kelantan in the same periods work out at M$2,072 to 4,309 million is shown in Table 9.1. On the other hand, the estimated project cost in the Sixth to Ninth Malaysia Plan period ranges from M$409 to 381 million, totalling M$1,302 million.

The shares of the project cost in the allocations to the "energy and public utilities" sector in the above periods are 10.1% in Sixth Malaysia Plan to 4.8% in Ninth Malaysia Plan.

9.2 Negative Socio-economic Impacts

(1) Non-agriculture

The formation of Lebir dam reservoir is estimated to inundate 19 villages, affecting 785 people or 156 households. Likewise, Kemubu dam reservoir will inundate 17 villages, affecting 5,030 people or 1,000 households (Refer to Tables 9.2 and 9.3.). The number of people to be affected by Lebir reservoir corresponds to 2.8% of the population of Gua Musang District. The number of people to be affected by Kemubu reservoir corresponds to 4.0% of the combined population of Kuala Krai and Jeli District. (Refer to Table 9.4.)

The combined number of people and houses to be affected comes to 5,815 and 1,156, respectively. This number of people accounts for 2.5% of the population of South Kelantan. (Refer to Table 9.5.)

The railway track of some 26 km will have to be shifted to a higher elevation before the formation of Kemubu dam reservoir. It means that 7.7% of the railway track within the State will be involved. Public road length to be submerged will sum up to 14 km, which constitutes 0.7% of the total public road length within the State. Feeder road to be submerged will add up to 91 km. Thus, the combined road length involved will reach 105 km (Refer to Tables 9.5 and 9.6.). Mention must be made of the Chiku-Aring Timur-K/Brang road now at a planning stage. This proposed road to the east of Gua Musang with the length of 45 km within the State will be affected by the construction of Lebir dam unless the course is changed.

(2) Agricultural

The formation of Lebir dam reservoir is estimated to inundate 5,650 ha of oil palm area, 3,050 ha of rubber area and 5,300 ha of forest area. It means 12.4% of oil palm area, 27.8% of rubber area and 0.7% of forest area in Gua Musang District will be lost. Likewise, Kemubu dam reservoir will inundate nil of oil palm area, 450 ha of rubber area and 790 ha of forest area. It means 0% of oil palm area, 1.0% of rubber area and 0.3% of forest area in the two Districts of Kuala Krai and Jeli will be lost (Refer to Tables 9.4 and 9.6.).

The total area of oil palm, rubber and forest to be inundated comes to 5,650 ha, 3,500 ha and 6,090 ha, respectively. In other words, 9.5% of oil palm area, 4.2% of rubber area and 0.6% of forest area in South Kelantan will disappear. Combined area of oil palm and rubber to be lost accounts for 6.4% of the corresponding area in South Kelantan. Further, combined area of oil palm, rubber and forest to be lost accounts for 1.2% of the corresponding area in South Kelantan. (Refer to Tables 9.5 and 9.6.)

The permanent submergence of 5,650 ha of oil palm area and 3,500 ha of rubber area will invite combined annual income loss of M$13 million, which corresponds to 1.7% of the primary sector GDP in the state for 1988.

9.3 Positive Socio-economic Impacts

Direct benefits of project implementation including reduction of flood damages to properties and production of agricultural water have been incorporated in project evaluation. There are other benefits such as indirect and intangible benefits.

The greatest indirect benefits will be the emergence and subsequent pervasion of positive mental climate among farmers, industrialists and businessmen. Especially this climate will be beneficial for a greater productivity and expansion of the primary and secondary sectors. However, all sectors will be eventually benefited, resulting in a higher growth of the State economy.

Also, the related construction works will create employment opportunities for labourers. After completion of the works, permanent jobs will be created for operation and maintenance of equipment and facilities.

The project will facilitate and accelerate urbanization of the basin, which in turn will transform land use pattern, raising the value of land.

Through a heightened pace of intensive and extensive use of agricultural land, productivity and production of agricultural crops will go up, which will lead to an increased export of related agricultural products, thereby contributing towards an increase of foreign exchange earnings.

Flood mitigation will provide an amenity to the inhabitants by removing or alleviating psychological burdens. Furthermore, scenic beauty of the basin brings positive effects on tourism.

TABLES

Table 2.1 Population of Kelantan, 1970 to 1980

Item	1970	Annual Growth	1980	Annual Growth	1988/1
State of Kelantan	690,800 (100.0%)	2.6%	893,800 (100.0%)	2.5%	1,091,756 (100.0%)
Bachok	62,593 (9.1%)	2.1%	76,991 (8.6%)	2.0%	90,549 (8.3%)
Kota Bharu	209,210 (30.3%)	3.2%	286,742 (32.1%)	2.8%	357,995 (32.8%)
Machang	51,977 (7.5%)	1.5%	60,436 (6.8%)	1.5%	67,930 (6.2%)
Pasir Mas	101,354 (14.7%)	2.0%	123,026 (13.8%)	1.9%	142,867 (13.1%)
Pasir Puteh	71,608 (10.4%)	1.6%	84,317 (9.4%)	1.6%	95,536 (8.8%)
Tanah Merah	49,318 (7.1%)	2.7%	64,568 (7.2%)	2.7%	79,942 (7.3%)
Jeli	14,477 (2.1%)	5.3%	24,321 (2.7%)	5.4%	37,120 (3.4%)
Tumpat	73,533 (10.6%)	2.0%	89,516 (10.0%)	2.0%	104,492 (9.6%)
Gua Masang	12,578 (1.8%)	4.4%	19,349 (2.2%)	4.8%	28,198 (2.6%)
Kuala Krai	44,152 (6.4%)	3.9%	64,534 (7.2%)	3.8%	87,127 (8.0%)
MPKB	127,290 (18.4%)	3.5%	179,307 (20.1%)	2.9%	224,719 (20.6%)

Note : 1) /1 = Estimate
2) Figures for 1970 are adjusted figures based on Population Census.
3) Figures in parentheses are shares by District.

Sources : Population Census 1970 & 1980, 5th Malaysia Plan for Kelantan and JICA

Table 2.2 **Existing Bridges over the Kelantan River and Its Tributaries**

No.	Name	Road/ Railway	River	Distance from the estuary	Dimensions, m			Administration office	Year of Const- ruction	Remarks
					Length	Width	Lowest El. of girder			
1	Sultan Yahya Petra	Road	Kelantan	13	840.2	12.2	8.2	JKR	1963	
2	Pasir Mas	Road	Kelantan	28	633.0	12.5	15.3	JKR	1989	Under construction
3	Tanah Merah	Road	Kelantan	63	630.0	9.0	24.9	JKR	1987	
4	Guillemard	Railway	Kelantan	65	619.5	3.0	23.8	Railway Dept.	1924	
5	Manek Urai	Railway	Lebir	121	330.0	3.0	-	Railway Dept.	1928	TBM:El.117.751 m
6	Lalok	Road	Lebir	132	166.0	9.0	52.7	JKR	1982	
7	Kemubu	Railway	Galas	147	240.0	3.0	-	Railway Dept.	1930	TBM:El.142.670 m
8	Bertam	Railway	Nenggiri	174	210.0	3.0	66.7	Railway Dept.	1931	TBM:El.220.072 m

Table 2.3 **Existing Pumping Stations in the Kelantan River**

No.	Name	Location from Pasir Mas	Left/right bank	Features			Administration office	Year of Instal-lation	Remarks
				No. of pumps	Capacity, cms	Intake design level, m			
1	Kemubu	18 km upstream	Right	5	10.8	5.4	KADA	1971	Extension up to 37.2 cms
2	Salor	4 km upstream	Right	2	1.7	2.4	KADA	1948	
3	Lemal	2 km upstream	Left	4	18.3	1.6	KADA	1963	
4	Pasir Mas	3 km upstream	Left	3	4.3	(1.9) 1/	KADA	1956	
5	Tanah Merah		Left	2	0.3		JKR	1984	Water supply
6	Pasir Mas		Left		0.3		JKR	1983	"

Note: 1/ A figure in the parentheses shows the low level.

Table 2.4 Monthly Mean Rainfall Depth in the State of Kelantan

(Unit:mm)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Blau	69	103	169	138	270	151	230	68	204	267	236	157	2,062
Gua Musang	85	107	100	140	238	183	181	209	297	272	233	207	2,252
Aring	93	78	51	114	270	158	205	232	289	328	228	378	2,424
Bertam	59	96	69	136	206	90	197	178	242	266	137	280	1,956
Dabong	93	78	72	171	158	138	200	203	193	247	315	311	2,179
Lubok Bungor	190	132	136	137	231	179	179	200	241	372	435	560	2,992
Lalok	85	94	93	111	216	153	188	200	273	258	274	444	2,389
Kuala Krai	106	166	153	108	160	121	124	168	231	175	188	761	2,461
Jeli	152	133	115	184	252	187	199	229	294	332	433	682	3,192
Kuala Pertang	201	107	93	105	166	138	172	195	274	261	379	548	2,639
Machang	170	60	128	91	190	175	187	216	307	253	451	533	2,761
Lawang	98	157	140	129	246	218	264	255	306	303	271	589	2,976
Pasir Puteh	140	71	91	81	170	134	199	198	289	260	493	539	2,765
Tandak	161	71	74	95	201	193	265	277	352	368	456	583	3,096
To' Uban	146	85	71	73	180	178	216	246	288	297	435	571	2,786
Melor	207	74	92	86	155	186	208	242	292	297	534	654	3,027
Bachok	138	60	106	93	122	126	182	192	211	310	624	609	2,773
Kuala Jambu	82	34	61	51	101	121	178	192	208	248	483	464	2,223
Kota Bharu	79	36	66	55	106	101	177	142	209	257	702	743	2,673
Total	2,354	1,742	1,880	2,098	3,638	2,930	3,751	3,842	5,000	5,371	7,307	9,713	49,626
Average	124	92	99	110	191	154	197	202	263	283	385	511	2,611

Table 2.5 Comparison of Probable Rainfall Depth and Probable Flood Peak Discharges

Return Period (years)	Basin Mean Rainfall (mm)	Hyetograph Type	Hyetograph Depth (mm)	Hyetograph Ratio of Expansion	Probable Flood Peak Discharge (cms) Nenggiri Damsite	Kemubu Damsite	Pergau Damsite	Dabong Damsite	Lebir Damsite	Kuala Krai	Guillemard Bridge
100	699	1983	475.7	1.47	4,204	5,597	3,462	9,451	6,231	18,841	18,331
	580	1984	300.6	1.93	5,527	5,255	2,961	8,559	8,052	19,669	18,373
	695	1986	289.7	2.40	3,432	5,205	3,084	8,626	7,039	18,806	18,382
50	633	1983	475.7	1.33	3,482	4,943	3,145	8,431	5,561	16,831	16,383
	530	1984	300.6	1.76	4,668	4,624	2,698	7,648	7,102	17,490	16,369
	626	1986	289.7	2.16	2,959	4,559	2,837	7,682	6,201	16,696	16,314
30	576	1983	475.7	1.21	2,901	4,352	2,907	7,557	4,997	15,110	14,714
	490	1984	300.6	1.63	3,957	4,134	2,519	6,911	6,342	15,758	14,768
	571	1986	289.7	1.97	2,556	4,078	2,666	6,995	5,539	15,092	14,749
20	533	1983	475.7	1.12	2,486	3,939	2,715	6,918	4,559	13,826	13,468
	450	1984	300.6	1.50	3,248	3,796	2,392	6,402	5,604	14,318	13,437
	524	1986	289.7	1.81	2,212	3,716	2,503	6,444	4,983	13,777	13,466
10	-	1983	475.7	-	-	-	-	-	-	-	-
	395	1984	300.6	1.31	2,327	3,152	2,159	5,497	4,626	12,095	11,422
	452	1986	289.7	1.56	1,584	3,102	2,248	5,542	4,104	11,685	11,429
5	-	1983	475.7	-	-	-	-	-	-	-	-
	316	1984	300.6	1.05	1,204	2,409	1,791	4,383	3,259	9,184	8,665
	351	1986	289.7	1.21	868	2,363	1,871	4,393	2,893	8,878	8,680

Note : The above values are calculated on the basis of the return period at Guillemard Bridge.

Table 4.1 Flood Mitigation Effect at Guillemard Bridge

(Unit : m^3/sec)

Case	Combination	Probability				
		1/5	1/10	1/20	1/30	1/50
1.	Natural condition	8,680	11,430	13,470	14,770	16,370
2.	R/I only 1/	9,190	12,100	14,350	15,760	17,420
3.	Lebir + R/I	6,860	8,840	10,520	11,530	12,910
4.	Kemubu + R/I	8,630	11,440	13,180	14,290	15,800
5.	Lebir + Kemubu + R/I	6,260	8,060	9,270	9,940	10,650

Note : 1/ Flood discharge inundated at the reaches between Kuala Krai and Guillemard Bridge is confined in the river channel by river improvement.

Table 4.2 Gross Water Demand for the Kelantan River

Item	Demand (m^3/sec)
1. Present Demand (in 1985)	
(1) Domestic and Industrial Water	0.5
(2) Irrigation Water	35.0
(3) River Maintenance Flow	70.0
(4) Total	105.5
2. Demand in 1990	
(1) Domestic Water	1.8
(2) Industrial Water	0.3
(3) Irrigation Water	72.7
(4) River Maintenance Flow	70.0
(5) Total	144.8
3. Demand in 2000	
(1) Domestic Water	3.8
(2) Industrial Water	0.5
(3) Irrigation Water	84.6
(4) River Maintenance Water	70.0
(5) Total	158.9
4. Demand in 2010	
(1) Domestic Water	5.6
(2) Industrial Water	0.9
(3) Irrigation Water	84.6
(4) River Maintenance Flow	70.0
(5) Total	161.1

Table 5.1 Annual Maximum Rainfall Depth at Kota Bharu

(Unit:mm)

Year	1-day	2-day	3-day	5-day	7-day
1956	195.6	356.9	407.7	519.2	700.8
1957	109.5	163.8	236.0	365.5	386.8
1958	153.7	263.9	360.7	525.7	607.5
1959	263.4	469.6	675.3	837.1	924.3
1960	195.6	312.4	356.1	443.9	503.3
1961	204.5	255.3	278.2	333.4	466.9
1962	148.6	231.2	325.4	386.7	419.8
1963	115.3	140.2	149.1	224.3	283.8
1964	175.3	238.8	242.6	242.6	242.9
1965	310.4	414.5	550.1	743.4	907.7
1966	167.6	292.6	330.1	371.5	391.6
1967	585.0	984.3	1,238.6	1,384.6	1,397.8
1968	160.5	268.2	283.9	375.3	453.1
1969	326.1	559.0	594.8	607.8	698.2
1970	228.6	268.7	279.9	288.5	309.3
1971	187.7	300.5	313.5	393.7	460.0
1972	132.3	177.5	242.5	296.6	332.4
1973	302.3	431.6	522.3	658.9	715.6
1974	235.5	287.5	332.5	380.5	414.5
1975	194.0	269.5	329.5	386.5	404.0
1976	351.0	470.0	535.0	629.0	687.5
1977	176.5	261.5	290.5	378.5	388.0
1978	-	-	-	-	-
1979	230.0	380.0	446.0	504.5	671.0
1980	-	-	-	-	-
1981	431.4	787.3	1,042.5	1,122.5	1,178.5
1982	162.5	253.5	257.5	265.5	341.5
1983	212.8	393.5	535.2	722.2	732.5
1984	228.0	290.0	402.0	438.5	450.0
1985	-	-	-	-	-
1986	555.0	852.0	1,235.5	1,463.0	1,614.5
Average	240.7	370.5	456.9	546.1	610.1
Maximum	585.0	984.3	1,238.6	1,463.0	1,614.5
Minimum	109.5	140.2	149.1	224.3	242.9

Table 7.1 Major Work Quantity (1/2)

Package No.	Major work items	Unit	Work quantity
1.	Lebir dam project		
	1.1 Access road	Km	7
	1.2 Diversion tunnel, 2 lanes		
	1) Tunnel excavation, l=535 m, 13 m dia.	m3	335,000
	2) Tunnel and portal lining	m3	84,400
	3) Consolidation and curtain grouting	m	14,000
	4) Gate	set	1
	1.3 Cofferdams		
	1) Excavation	m3	63,000
	2) Embankment	m3	687,000
	1.4 Main dam		
	1) Excavation	m3	527,000
	2) Embankment	m3	2,700,000
	3) Consolidation and curtain grouting	m	43,000
	4) Gallery concrete	m3	16,000
	1.5 Spillway		
	1) Excavation	m3	1,760,000
	2) Concrete	m3	103,000
	1.6 Saddle dams		
	1) Excavation for cofferdam	m3	18,000
	2) Embankment for cofferdam	m3	73,000
	3) Excavation for saddle dams	m3	801,000
	4) Embankment for saddle dams	m3	1,514,000
	5) Consolidation and curtain grouting	m	11,000
	1.7 River outlet works		
	1) Concrete	m3	1,440
	2) Metal works		L.S.
	1.8 Intake structure		
	1) Excavation	m3	1,045,500
	2) Concrete	m3	14,000
	3) Consoldation grouting	m	612
	4) Gate	set	2
	1.9 Relocation cost		
	1) Tarmac road	Km	5
	2) Feeder roads	Km	86
	3) Forest	ha	5,300
	4) Houses	no.	165
2.	River improvement in urban area		
	2.1 Main civil works		
	1) Clearing and stripping	m2	197,000
	2) Embankment	m3	2,605,000
	3) Revetment	m2	106,900
	4) Sluice	pc	8
	5) Toe drain	m	29,100
	6) Maintenance road	m	29,100
	7) Sod facing	m2	829,000

Table 7.1 Major Work Quantity (2/2)

Package No.	Major work items	Unit	Work quantity
	2.2 Relocation		
	1) Land acquisition	ha	197
	2) House evacuation	no	170
	3) Bridge	no	2
3.	Kemubu dam project		
	3.1 Access road	Km	7
	3.2 Diversion tunnel, 2 lanes		
	1) Excavation , l=271 m & 294 m, 9 m dia	m3	169,600
	2) Concrete	m3	26,000
	3) Consolidation grouting	m	4,000
	4) Gate	set	1
	3.3 Cofferdams		
	1) Excavation	m3	21,000
	2) Embankment	m3	188,000
	3.4 Main dam		
	1) Excavation	m3	413,500
	2) Concrete	m3	148,800
	3) Consolidation and curtain grouting	m	4,000
	3.5 Relocation cost		
	1) Rough road	Km	9
	2) Railway	Km	26
	3) Plantation	ha	456
	4) Feeder road	Km	5
	5) Forest	ha	790
	6) Houses	no	1,000
4.	River improvement in rural area		
	4.1 Main civil works		
	1) Clearing and stripping	m2	1,378,000
	2) Dredging	m3	2,100,000
	3) Embankment	m3	10,635,000
	4) Revetment	m2	161,100
	5) Sluice	no	46
	6) Toe drain	m	89,500
	7) Maintenance road	m	134,900
	8) Sod facing	m2	4,217,000
	4.2 Compensation		
	1) Land acquisition	ha	1,378
	2) House evacuation	no	600
	3) Pumping station for irrigation	no	3
	4) Bridge	no	4

Table 7.2 Material Cost (1/3)

No.	Particular	Description	Unit	Total amount (MS$)	Assumed material unit cost: Component (%) local	Foreign	Local currency (MS$)	Foreign currency (MS$)
1	Gasoline		litre	0.95	60	40	0.57	0.38
2	Light oil		litre	0.51	60	40	0.31	0.20
3	Electric power charge		kwh	0.24	60	40	0.14	0.10
4	Lubricant		litre	2.40	60	40	1.44	0.96
5	Grease		kg	3.00	60	40	1.80	1.20
6	Portland cement	by rail	ton	192.00	60	40	115.20	76.80
7	Air entraining agent		kg	3.60	40	60	1.44	2.16
8	Water reducing agent		kg	4.10	40	60	1.64	2.46
9	Air bubble agent		kg	2.10	40	60	0.84	1.26
10	Round bar		ton	891.00	60	40	534.60	356.40
11	Deformed bar		ton	921.00	60	40	552.60	368.40
12	Channel steel		ton	1,500.00	60	40	900.00	600.00
13	H-shaped steel		ton	1,500.00	60	40	900.00	600.00
14	Dynamite for open		nmb	10.00	20	80	2.00	8.00
15	Dynamite for tunnel		nmb	10.00	20	80	2.00	8.00
16	An-Fo power		nmb	0.89	20	80	0.18	0.71
17	Detonator		nmb	2.20	20	80	0.44	1.76
18	Timber, plank		cu.m.	300.00	100	0	300.00	0.00
19	Timber, square		cu.m.	280.00	100	0	280.00	0.00
20	Timber, log		cu.m.	230.00	100	0	230.00	0.00
21	Metal form	300 x 1500	nmb	41.65	40	60	16.66	24.99
22	Metal form	200 x 1500	nmb	37.55	40	60	15.02	22.53
23	Metal form	150 x 1500	nmb	33.00	40	60	13.20	19.80
24	Metal form	100 x 1500	nmb	28.05	40	60	11.22	16.83
25	Plywood		nmb	36.00	60	40	21.60	14.40
26	Separator		m	0.76	40	60	0.30	0.46
27	Cone		nmb	0.50	40	60	0.20	0.30
28	Form oil		litre	0.50	60	40	0.30	0.20
29	Cast iron pipe	75 mm	m	11.00	40	60	4.40	6.60
30	Cast iron pipe	100 mm	m	12.50	40	60	5.00	7.50
31	Cast iron pipe	150 mm	m	15.00	40	60	6.00	9.00
32	Gas pipe	20 mm	m	6.00	40	60	2.40	3.60
33	Gas pipe	40 mm	m	9.60	40	60	3.84	5.76
34	Gas pipe	65 mm	m	12.00	40	60	4.80	7.20
35	Galvanized pipe	25 mm	m	7.00	40	60	2.80	4.20
36	Galvanized pipe	100 mm	m	16.48	40	60	6.59	9.89
37	Galvanized pipe	150 mm	m	50.00	40	60	20.00	30.00
38	Galvanized pipe	200 mm	m	67.50	40	60	27.00	40.50
39	P.V.C. pipe	40 mm	m	5.68	20	80	1.14	4.54
40	P.V.C. pipe	50 mm	m	8.18	20	80	1.64	6.54
41	P.V.C. pipe	75 mm	m	15.84	20	80	3.17	12.67
42	Vinyl vent pipe	400 mm	m	319.20	20	80	63.84	255.36
43	Vinyl vent pipe	500 mm	m	385.20	20	80	77.04	308.16
44	Vinyl vent pipe	600 mm	m	464.40	20	80	92.88	371.52
45	Vinyl vent pipe	700 mm	m	538.20	20	80	107.64	430.56
46	Vinyl vent pipe	800 mm	m	646.40	20	80	129.28	517.12
47	Vinyl vent pipe	900 mm	m	725.60	20	80	145.12	580.48

Table 7.2 Material Cost (2/3)

No.	Particular	Description	Unit	Total amount (M$)	Component (%) local	Component (%) Foreign	Assumed material unit cost Local currency (M$)	Assumed material unit cost Foreign currency (M$)
48	Vinyl vent pipe	1000 mm	m	810.00	20	80	162.00	648.00
49	Vinyl vent pipe	1100 mm	m	904.80	20	80	180.96	723.84
50	Rock bolt 25 mm	grout type	m	61.00	20	80	12.20	48.80
51	Rock bolt 22 mm	grout type	m	56.00	20	80	11.20	44.80
52	Rock bolt 22 mm	non-grout	m	50.00	20	80	10.00	40.00
53	Rock bolt 25 mm	non-grout	m	56.00	20	80	11.20	44.80
54	P.V.C. water stop	flat, 200	m	15.00	60	40	9.00	6.00
55	Annealed iron wire		kg	1.00	60	40	0.60	0.40
56	Nail		kg	2.50	60	40	1.50	1.00
57	Wire mesh		sq.m	5.20	60	40	3.12	2.08
58	Fence		m	2.08	60	40	1.25	0.83
59	Welding electrode		kg	4.65	40	60	1.86	2.79
60	Cross bit	36 mm	nmb	96.00	20	80	19.20	76.80
61	Cross bit	55 mm	nmb	200.00	20	80	40.00	160.00
62	Cross bit	65 mm	nmb	232.00	20	80	46.40	185.60
63	Insert bit 22 mm	L=1.4 m	nmb	232.00	20	80	46.40	185.60
64	Insert bit 22 mm	L=1.7 m	nmb	256.00	20	80	51.20	204.80
65	Insert bit 22 mm	L=2.3 m	nmb	292.00	20	80	58.40	233.60
66	Taper rod 22 mm	L=2.0 m	nmb	274.00	20	80	54.80	219.20
67	Rod, core drill 35 D	L=3 m	nmb	247.20	20	80	49.44	197.76
68	Rod, core drill 35 D	sleeve	nmb	221.20	20	80	44.24	176.96
69	Rod, core drill 35 D	shank rod	nmb	663.20	20	80	132.64	530.56
70	Rod, core drill 795D	L=3 m	nmb	247.00	20	80	49.40	197.60
71	Rod, core drill 795D	sleeve	nmb	221.20	20	80	44.24	176.96
72	Rod, core drill 795D	shank rod	nmb	663.20	20	80	132.64	530.56
73	Rod, core drill M110	L=3 m	nmb	269.00	20	80	53.80	215.20
74	Rod, core drill M110	sleeve	nmb	221.20	20	80	44.24	176.96
75	Rod, core drill M110	shank rod	nmb	663.20	20	80	132.64	530.56
76	Boring rod	40.5 mm	nmb	269.00	20	80	53.80	215.20
77	Metal bit	46 mm	nmb	84.86	20	80	16.97	67.89
78	Metal bit	56 mm	nmb	92.54	20	80	18.51	74.03
79	Tube core barrel	46 mm	nmb	347.80	20	80	69.56	278.24
80	Tube core barrel	56 mm	nmb	2,194.00	20	80	438.80	1,755.20
81	Core lifter		nmb	117.82	20	80	23.56	94.26
82	Diamond bit	diamond	carat	270.00	0	100	0.00	270.00
83	Diamond bit	diamond	carat	270.00	0	100	0.00	270.00
84	Concrete aggregate	fine	cu.m.	37.10	100	0	37.10	0.00
85	Concrete aggregate	coarse	cu.m.	42.25	100	0	42.25	0.00
86	Crusher run		cu. m.	42.40	100	0	42.40	0.00
87	Crusher stone		cu. m.	37.10	100	0	37.10	0.00
88	Sand		cu. m.	13.25	100	0	13.25	0.00
89	Gravel		cu. m.	13.25	100	0	13.25	0.00
90	Rubble		cu. m.	37.10	100	0	37.10	0.00
91	Bentonite		ton	2,750.00	60	40	1,650.00	1,100.00
92	Turf		sq.m.	1.00	60	40	0.60	0.40
93	Fertilizer		kg	49.16	60	40	29.50	19.66

Table 7.2 Material Cost (3/3)

No.	Particular	Description	Unit	Total amount (M$)	Assumed material unit cost: Component (%) local	Foreign	Local currency (M$)	Foreign currency (M$)
94	Rust preventing paint		kg	6.72	60	40	4.03	2.69
95	Paint		kg	15.30	60	40	9.18	6.12
96	Packer		nmb	1,786.00	60	40	1,071.60	714.40
97	Elastic packing		nmb	81.18	60	40	48.71	32.47
98	Outer tube		nmb	232.00	60	40	139.20	92.80
99	Injection tube		nmb	192.40	60	40	115.44	76.96
100	Packer holder		nmb	1,391.60	60	40	834.96	556.64
101	Injection branch		nmb	1,159.60	60	40	695.76	463.84
102	Injection hose		m	32.46	60	40	19.48	12.98
103	Return hose		m	32.46	60	40	19.48	12.98
104	Ready mixed concrete		cu.m.	100.00	60	40	60.00	40.00
105	Bamboo	L=5 m	nbm	6.00	100	0	6.00	0.00
106	Bamboo net		sq.m	13	100	0	13.00	0.00
107	Oxygen		kg	6.19	60	40	3.71	2.48
108	Acetylene		m3	16.45	60	40	9.87	6.58
109	Asphalt		ton	85	60	40	51.00	34.00
110	Steel sheet pile		ton	1,500.00	60	40	900.00	600.00
111	Rail, 32 kg/m		m	48.00	60	40	28.80	19.20

Table 7.3 Hourly Equipment Cost (1/4)

No.	Description		H/T	H/T	HP	CIF Kuala Lumpur	Delivery cost at site	Life	Time	Dep	Rep	Admin	Rate	Total cost	Hourly equipment Foreign	Hourly equipment Local	P.O.L.
						(M$)	(M$)	year	hour				*10-6	(M$)	(M$)	(M$)	(M$)
(1)	(2)		(3)	(4)	(5)	(6)	(7)		(8)	(9)	(10)	(11)	(12)	(13)	(14)x0.80	(15)x0.20	(16)
1	Bulldozer with ripper	32-ton	66.00	34	320	500,000	505,280	12	1,050	90%	80%	5%	183	92.47	73.98	18.49	44.2
2	Bulldozer with ripper	21-ton	46.00	23	211	400,000	403,680	12	900	90%	55%	5%	190	76.70	61.36	15.34	29.1
3	Bulldozer with ripper	15-ton	37.00	16	150	340,000	342,960	12	900	90%	55%	5%	190	65.16	52.13	13.03	20.7
4	Bulldozer	11-ton	30.50	12	108	300,000	302,440	12	900	90%	50%	5%	185	55.95	44.76	11.19	13.2
5	Bulldozer for swamp	18-ton	46.00	19	170	360,000	363,680	12	900	90%	60%	5%	194	70.55	56.44	14.11	20.7
6	Bulldozer for swamp	13-ton	37.00	13	118	320,000	322,960	12	900	90%	55%	5%	190	61.36	49.09	12.27	14.4
7	Tractor shovel	3.1-m3	55.00	30	250	430,000	434,400	12	1,000	90%	55%	5%	171	74.28	59.42	14.86	29.8
8	Tractor shovel	2.3-m3	42.00	21	200	380,000	383,360	12	1,000	90%	55%	5%	171	65.55	52.44	13.11	23.8
9	Tractor shovel	1.2-m3	23.00	11	93	290,000	291,840	12	850	90%	45%	5%	191	55.74	44.59	11.15	11.1
10	Tractor shovel side dump	1.8-m3	46.00	20	152	340,000	343,680	10	850	90%	40%	5%	212	72.86	58.29	14.57	18.1
11	Tractor shovel side dump	1.5-m3	40.00	15	112	305,000	308,200	10	850	90%	40%	5%	212	65.34	52.27	13.07	13.3
12	Backhoe	1.0-m3	93.00	29	193	480,000	487,440	10	1,200	90%	40%	5%	150	73.12	58.50	14.62	24.9
13	Backhoe	0.6-m3	70.00	27	105	300,000	305,600	10	1,200	90%	40%	5%	150	45.84	36.67	9.17	13.5
14	Backhoe	0.3-m3	28.00	11	79	270,000	272,240	10	1,100	90%	35%	5%	159	43.29	34.63	8.66	10.5
15	Wheel loader	5-m3	113.00	35	380	505,000	514,040	12	1,100	90%	60%	5%	159	81.73	65.38	16.35	39.5
16	Wheel loader	3.5-m3	67.00	20	240	420,000	425,360	12	1,100	90%	60%	5%	159	67.63	54.10	13.53	25.0
17	Wheel loader	2.3-m3	49.00	14	159	350,000	353,920	12	1,000	90%	55%	5%	171	60.52	48.42	12.10	16.5
18	Wheel loader	1.2-m3	23.00	7	75	260,000	261,840	12	850	90%	45%	5%	191	50.01	40.01	10.00	7.8
19	Dump truck	32-ton	115.00	+26	427	586,000	595,200	10	1,600	90%	65%	5%	128	76.19	60.95	15.24	24.3
20	Dump truck	20-ton	84.00	19	290	408,000	414,720	10	1,400	90%	60%	5%	143	59.30	47.44	11.86	16.5
21	Dump truck	15-ton	65.00	15	210	219,300	224,500	10	1,400	90%	60%	5%	143	32.10	25.68	6.42	12.0
22	Dump truck	11-ton	56.00	9	285	142,200	146,680	8	1,550	90%	45%	5%	141	20.68	16.54	4.14	11.1
23	Dump truck	8-ton	49.00	7	240	100,800	104,720	8	1,400	90%	45%	5%	156	16.34	13.07	3.27	9.4
24	Dump truck	6-ton	41.00	6	170	73,150	76,430	8	1,200	90%	45%	5%	182	13.91	11.13	2.78	6.6
25	Ordinary truck	6-ton	41.00	4	175	66,120	69,400	8	1,250	90%	40%	5%	170	11.80	9.44	2.36	6.3
26	Truck-bed crane	4-ton	50.00	5	162	83,220	87,220	8	1,200	90%	30%	5%	167	14.57	11.66	2.91	5.8
27	Truck crane	40-ton	140.00	37	308	480,000	491,200	14	1,000	90%	20%	5%	129	63.36	50.69	12.67	10.5
28	Truck crane	30-ton	123.00	31	285	460,000	469,840	14	1,000	90%	20%	5%	129	60.61	48.49	12.12	9.7
29	Truck crane	20-ton	96.00	22	230	410,000	417,680	14	1,000	90%	20%	5%	129	53.88	43.10	10.78	7.8
30	Truck crane	10-ton	85.00	16	230	300,000	305,800	14	900	90%	20%	5%	143	43.87	35.10	8.77	7.8
31	Crawler crane	40-ton	140.00	41	106	576,300	587,500	12	1,000	90%	40%	5%	158	92.83	74.26	18.57	3.2
32	Crawler crane	30-ton	123.00	39	106	500,000	311,000	12	1,000	90%	40%	5%	158	49.14	39.31	9.83	3.2
33	Crawler drill	17-m3/hr	12.00	5		143,280	144,240	8	800	90%	30%	5%	250	36.06	28.85	7.21	
34	Crawler drill	17-m3/hr	8.00	5		135,000	135,640	8	800	90%	30%	5%	250	33.91	27.13	6.78	
35	Crawler drill	7-m3/hr	6.00	3		94,680	95,160	8	800	90%	30%	5%	250	23.79	19.03	4.76	
36	Leg hammer	30-kg	0.05	30		4,620	4,624	4	120	90%	20%	5%	2,708	12.52	10.02	2.50 D	
37	Pick hammer	7.5-kg	0.05	8		640	644	4	120	90%	20%	5%	2,708	1.74	1.39	0.35 D	
38	Hydraulic heavy breaker	200-kg	1.50	0		46,550	46,670	6	120	90%	20%	5%	1,944	90.73	72.58	18.15 D	
39	Tire roller	6-8ton	20.00	4	27	108,000	109,600	14	750	90%	35%	5%	186	20.39	16.31	4.08	2.0
40	Tire roller	8-20ton	32.00	9	89	133,200	135,760	14	750	90%	35%	5%	186	25.25	20.20	5.05	6.4
41	Tamping roller	30.8-ton	129.00	31	320	490,000	500,320	10	1,600	90%	60%	5%	125	62.54	50.03	12.51	38.1
42	Vibrating roller	15-ton	35.00	16	162	350,000	352,800	12	600	90%	35%	5%	257	90.67	72.54	18.13	17.7
43	Vibrating roller	8-ton	26.00	10	120	210,800	212,880	12	600	90%	35%	5%	257	54.71	43.77	10.94	13.1

Table 7.3 Hourly Equipment Cost (2/4)

No.	Description		M/T	W/T	HP	CIF Kuala Lumpur	Delivery cost at site	Life	Time	Dep	Rep	Admin	Rate	Total cost	Hourly equipment Foreign	Hourly equipment Local	P.O.L.
						(M$)	(M$)	year	hour				*10-6	(M$)	(M$)	(M$)	(M$)
(1)	(2)		(3)	(4)	(5)	(6)	(7)		(8)	(9)	(10)	(11)	(12)	(13)	(14)x0.80	(15)x0.20	(16)
44	Vibrating roller	4-ton	8.00	4	27	89,300	89,940	12	600	90%	30%	5%	250	22.49	17.99	4.50	3.0
45	Vibrating roller	0.5-0.6 t	2.00	1	10	23,370	23,530	10	600	90%	35%	5%	292	6.87	5.50	1.37	1.1
46	Vibrating compactor	90-kg	0.50	0	4	4,400	4,440	6	115	90%	30%	5%	2,174	9.65	7.72	1.93	0 6.8
47	Macadam roller	10-12ton	30.00	10	73	270,000	272,400	14	750	90%	35%	5%	186	50.67	40.54	10.13	5.5
48	Motor grader	3.7-m	63.00	8	140	330,000	335,040	12	850	90%	35%	5%	181	60.64	48.51	12.13	9.9
49	Portable air compressor	17-m3/min	22.00	3	157	111,960	113,720	12	110	90%	35%	5%	1,402	159.44	127.55	31.89	D 174.6
50	Portable air compressor	13.5m3/min	19.00	3	145	106,920	108,440	12	110	90%	35%	5%	1,402	152.03	121.62	30.41	D 161.2
51	Portable air compressor	10.5m3/min	15.00	2	106	94,140	95,340	12	110	90%	35%	5%	1,402	133.67	106.94	26.73	D 117.9
52	Portable air compressor	7-m3/min	12.00	14	79	49,400	50,360	12	110	90%	35%	5%	1,402	70.60	56.48	14.12	D 87.8
53	Concrete plant, tilting type	0.7-m3*2	180.00	45	50kw	520,000	534,400	12	9,000	90%	50%	5%	222	118.64	94.91	23.73	
54	Concrete plant, tilting type	1.0-m3*2	200.00	52	73kw	580,000	596,000	12	9,000	90%	50%	5%	222	132.31	105.85	26.46	
55	Concrete plant, tilting type	1.5-m3*2	210.00	60	145kw	760,000	776,800	14	10,000	90%	50%	5%	210	163.13	130.50	32.63	
56	Tower crane, radious 60m	9.5-ton	3,000.00	310	180kw	1,290,000	1,530,000	14	13,200	90%	20%	5%	136	208.08	166.46	41.62	
57	Jib crane (movable)	9-ton	1,000.00	155	160kw	1,200,000	1,280,000	14	13,200	90%	20%	5%	136	174.08	139.26	34.82	
58	Concrete pump car	55-60m3/hr	48.00	10	175	360,000	363,840	8	1,100	90%	55%	5%	210	76.41	61.13	15.28	9.8
59	Concrete mixer	0.2-m3	3.00	0	3.7kw	8,360	8,600	10	750	90%	40%	5%	240	2.06	1.65	0.41	
60	Concrete vibrator	0.79-kw	0.20	0	0.79kw	2,940	2,956	6	120	90%	20%	5%	1,944	5.75	4.60	1.15	
61	Crushing plant	150-t/hr	1,000.00	250	450kw	1,600,000	1,680,000	18	1,000	90%	50%	5%	128	215.04	172.03	43.01	
62	Filter plant	150-t/hr	130.00	32	95kw	320,000	330,400	16	9,000	90%	75%	5%	17	5.62	4.50	1.12	
63	Asphalt plant	60-80t/hr	80.00	105	259kw	1,030,000	1,036,400	12	850	90%	45%	5%	191	197.95	158.36	39.59	
64	Asphalt finisher	2.4-5m	40.00	10	43	346,800	350,000	14	550	90%	35%	5%	253	88.55	70.84	17.71	4.6
65	Asphalt distributor	4000l	10.00	3	154	340,000	340,800	12	530	90%	25%	5%	275	93.72	74.98	18.74	9.2
66	Asphalt kettle	4000l	0.50	2		129,600	129,640	12	530	90%	25%	5%	275	35.65	28.52	7.13	
67	Boring machine	5.5-kw	1.50	1	5.5kw	39,060	39,180	12	120	90%	35%	5%	1,285	50.35	40.28	10.07	
68	Boring machine	11-kw	2.50	1	11kw	69,660	69,860	12	120	90%	35%	5%	1,285	89.77	71.82	17.95	
69	Grout pump	3.7-kw	0.60	0	3.7	14,360	14,408	12	85	90%	40%	5%	1,863	26.84	21.47	5.37	
70	Grout pump	7.5-kw	1.10	0	7.5	20,900	20,988	12	85	90%	40%	5%	1,863	39.10	31.28	7.82	
71	Grout mixer vertical	200 l*2	1.80	0	2.2kw	10,560	10,704	12	85	90%	40%	5%	1,863	19.94	15.95	3.99	
72	Grout mixer horizontal	300 l*2	2.30	0	3.7kw	12,600	12,784	12	85	90%	40%	5%	1,863	23.82	19.06	4.76	
73	Agitator truck	4.5-m3	66.00	10	280	155,160	160,440	10	950	90%	30%	5%	179	28.72	22.98	5.74	10.9
74	Agitator truck	3-m3	59.00	7	220	112,860	117,580	10	950	90%	30%	5%	179	21.05	16.84	4.21	8.6
75	Concrete spray gun	4-6m3/hr	1.50	2	30	212,500	212,620	10	900	90%	45%	5%	206	43.80	35.04	8.76	3.6
76	Grout data processor		0.10	0	0	25,740	25,748	14	600	90%	15%	5%	208	5.36	4.29	1.07	
77	Water tanker	8-kl	50.00	8	270	120,060	124,060	10	1,000	90%	35%	5%	175	21.71	17.37	4.34	7.8
78	Water tanker	6-kl	44.00	5	180	95,760	99,280	10	1,000	90%	35%	5%	175	17.37	13.90	3.47	5.2
79	Fuel tanker	6-kl	44.00	5	180	95,760	99,280	10	1,000	90%	35%	5%	175	17.37	13.90	3.47	5.2
80	Cement silo	300-ton	66.00	22	0.75kw	128,340	133,620	16	2,000	90%	15%	5%	58	7.75	6.20	1.55	
81	Cement silo	400-ton	90.00	30	0.75kw	172,080	179,280	16	2,000	90%	15%	5%	58	10.40	8.32	2.08	
82	Water pump	50-mm	0.05	0	1.5kw	1,960	1,964	10	120	90%	95%	5%	1,958	3.85	3.08	0.77	
83	Water pump	100-mm	0.05	0	7.5kw	5,580	5,584	10	120	90%	95%	5%	1,958	10.93	8.74	2.19	
84	Water pump	150-mm	0.25	0	11kw	8,160	8,180	10	120	90%	95%	5%	1,958	16.02	12.82	3.20	
85	Water pump	200-mm	0.50	0	19kw	13,900	13,940	10	120	90%	95%	5%	1,958	27.29	21.83	5.46	
86	Diesel generator	75-KVA	5.00	2	93	55,620	56,020	12	130	90%	20%	5%	1,090	61.06	48.85	12.21	10.9
87	Diesel generator	100-KVA	5.00	2	121	56,700	57,100	12	130	90%	20%	5%	1,090	62.24	49.79	12.45	14.2
88	Diesel generator	150-KVA	8.00	3	185	90,000	90,640	14	130	90%	25%	5%	1,016	92.09	73.67	18.42	21.6

Table 7.3 Hourly Equipment Cost (3/4)

No.	Description		M/T	W/T	HP	CIF Kuala Lumpur	Delivery cost at site	Life	Time	Dep	Rep	Admin	Rate	Total cost	Hourly equipment Foreign	Hourly equipment Local	P.O.L.
						(M$)	(M$)	year	hour				*10-6	(M$)	(M$)	(M$)	(M$)
(1)	(2)		(3)	(4)	(5)	(6)	(7)		(8)	(9)	(10)	(11)	(12)	(13)	(14)x0.80	(15)x0.20	(16)
89	Dredger	1350-ton	200.00	150	1,350	3,172,671	3,188,671	14	3,060	90%	50%	5%	49	156.24	124.99	31.25	300.0
90	Dredger	650-ton	100.00		650	1,137,500	1,145,500	14	2,520	90%	50%	5%	60	68.73	54.98	13.75	140.0
91	Anchor boat	40-ton	40.00		500	304,405	307,605	28	1,980	90%	120%	5%	63	19.38	15.50	3.88	80.0
92	Anchor boat	20-ton	20.00		250	177,659	179,259	28	1,980	90%	120%	5%	63	11.29	9.03	2.26	40.0
93	Dragline	0.6-m3	37.00	27	105	382,500	385,460	14	850	90%	45%	5%	172	66.30	53.04	13.26	13.5
94	Cramshell	0.6-m3	37.00	20	105	300,900	303,860	10	1,000	90%	30%	5%	170	51.66	41.33	10.33	13.5
95	Diesel pile hammer	3.5-ton	25.00	8	0	177,480	179,480	8	800	90%	45%	5%	273	49.00	39.20	9.80	
96	Vibrating pile	30-kw	4.00	3	0	86,760	87,080	8	800	90%	45%	5%	273	23.77	19.02	4.75	
97	Motor grader	2.5-m	55.00	7	76	280,000	284,400	12	850	90%	35%	5%	181	51.48	41.18	10.30	5.4
98	Diesel generator	20-KVA	2.00	1	28	33,060	33,220	12	130	90%	20%	5%	1,090	36.21	28.97	7.24	3.3
99	Hydraulic jack	200-ton	2.00	0	0	10,880	11,040	10	140	90%	45%	5%	1,321	14.58	11.66	2.92	
100	Gantry crane	10-ton	10.00	1	12kw	266,900	267,700	16	120	90%	20%	5%	990	265.02	212.02	53.00	
101	Micro-bus		20.00	3	110	300,000	301,600	10	900	90%	45%	5%	206	62.13	49.70	12.43	4.8
102	ARC welder	300-A	0.20	0	0	3,060	3,076	14	160	90%	35%	5%	871	2.68	2.14	0.54	
103	Drill jumbo rail	50-m2	82.00	7	30kw*2	705,500	712,060	10	600	90%	25%	5%	275	195.82	156.66	39.16	
104	Crawler jumbo	2-8	20.00	17	30kw*2	1,094,400	1,096,000	10	600	90%	25%	5%	275	301.40	241.12	60.28	
105	Crawler jumbo	3-8	30.00	29	30kw*3	1,648,000	1,650,400	10	600	90%	25%	5%	275	453.86	363.09	90.77	
106	Drifter	*30-kg	0.02	0	0	4,660	4,682	4	120	90%	10%	5%	2,500	11.70	9.36	2.34	
107	Drifter	80-kg	0.02	0	0	21,280	21,282	4	120	90%	10%	5%	2,500	53.20	42.56	10.64	
108	Guide cell	2.5m/30kg	0.20	0	0	9,500	9,516	4	120	90%	15%	5%	2,604	24.78	19.82	4.96	
109	Guide cell	2.5m/80kg	0.20	0	0	13,300	13,316	4	120	90%	15%	5%	2,604	34.67	27.74	6.93	
110	Concrete pump stationary	60-65m3/hr	15.00	4	66	260,000	261,200	8	750	90%	30%	5%	267	69.74	55.79	13.95	
111	Air compressor stationary	27-m3/hr	25.00	4	150	340,000	342,000	12	2,500	90%	30%	5%	60	20.52	16.42	4.10	
112	Air compressor stationary	30-m3/hr	30.00	6	150	268,600	271,000	12	2,500	90%	30%	5%	60	16.26	13.01	3.25	
113	Air compressor stationary	70-m3/hr	40.00	10	150*2	560,000	563,200	12	2,500	90%	30%	5%	60	33.79	27.03	6.76	
114	Vent fan tunnel	150-m3/hr	1.40	1	5.5kw*	560,000	560,112	12	170	90%	20%	5%	833	466.57	373.26	93.31	
115	Vent fan tunnel	400-m3/hr	1.60	1	15kw*2	56,430	56,558	12	170	90%	20%	5%	833	47.11	37.69	9.42	
116	Vent fan tunnel	500-m3/hr	2.10	1	30kw*2	67,070	67,238	12	170	90%	20%	5%	833	56.01	44.81	11.20	
117	Turn table	8-ton	24.00	9	2	100,800	102,720	10	210	90%	35%	5%	833	85.57	68.46	17.11	
118	Turn table	121-ton	29.00	10	2	111,600	113,920	10	210	90%	35%	5%	833	94.90	75.92	18.98	
119	Raise climber	10-HP	20.00	5	10	413,100	414,700	10	400	90%	30%	5%	425	176.25	141.00	35.25	
120	Muck car	4.5-m3	12.00	3		21,850	22,810	10	140	90%	30%	5%	1,214	27.69	22.15	5.54	
121	Belt conveyor	750*20	14.00		7.5kw	72,010	73,130	6	140	90%	15%	5%	1,607	117.52	94.02	23.50	
122	Cement screw		8.00	1	7.5kw	18,360	19,000	8	12,000	90%	10%	5%	15	0.29	0.23	0.06	
123	Bucket elevator		45.00	8	22kw	64,220	67,820	8	12,000	90%	10%	5%	15	1.02	0.82	0.20	
124	Rod mill		25.00	71	260kw	1,137,600	1,139,600	9	20,000	90%	40%	5%	10	11.40	9.12	2.28	
125	Vibro-dozer	0.3-m3	10.00	8	57	221,000	221,800	9	6,750	90%	90%	5%	37	8.21	6.57	1.64	7.4
126	Concrete bucket	1.5-m3	2.00	1		20,710	20,870	10	70	90%	40%	5%	2,571	53.66	42.93	10.73	
127	Chain sew	50-cm	0.50	0	55cc	3,380	3,420	8	90	90%	70%	5%	2,778	9.50	7.60	1.90	
128	Soil compactor	20-ton	60.00	21	210	471,240	476,040	10	1,600	90%	60%	5%	125	59.51	47.61	11.90	25.0
129	Concrete bucket	0.75*1	10.00	3	7.5kw	56,810	57,610	10	750	90%	40%	5%	240	13.83	11.06	2.77	
130	Concrete mixer	0.1-m3	1.00	0		1,120	1,200	5	750	90%	40%	5%	413	0.50	0.40	0.10	
131	Floater	4.5*0.9m	5.00			8,480	8,880	6	180	90%	10%	5%	1,204	10.69	8.55	2.14	
132	Discharge pipe	6.0*0.41m	2.00			1,680	1,840	6	180	90%	10%	5%	1,204	2.22	1.78	0.44	
133	Rubber joint	0.9*0.41m	0.30			3,220	3,244	6	180	90%	10%	5%	1,204	3.91	3.13	0.78	
134	Valve	0.4*0.41m	0.10			7,400	7,408	6	180	90%	10%	5%	1,204	8.92	7.14	1.78	

Table 7.3 Hourly Equipment Cost (4/4)

No.	Description		M/T	W/T	HP	CIF Kuala Lumpur	Delivery cost at site	Life	Time	Dep	Rep	Admin	Rate	Total cost	Hourly equipment Foreign	Hourly equipment Local	P.O.L.
						(M$)	(M$)	year	hour				*10-6	(M$)	(M$)	(M$)	(M$)
(1)	(2)		(3)	(4)	(5)	(6)	(7)		(8)	(9)	(10)	(11)	(12)	(13)	(14)x0.80	(15)x0.20	(16)
135	Bend pipe		0.10			1,080	1,088	6	180	90%	10%	5%	1,204	1.31	1.05	0.26	
136	Branch pipe		0.10			1,400	1,408	6	180	90%	10%	5%	1,204	1.70	1.36	0.34	
137	Drainage pump		10.00		120	310,000	310,800	10	120	90%	75%	5%	1,792	556.95	445.56	111.39	
138	Portable belt conveyor		2.00	0	1.0kw	3,420	3,580	4	120	90%	40%	5%	3,125	11.19	8.95	2.24	
139	Grout pump		2.00*	1	11kw	26,220	26,380	12	85	90%	40%	5%	1,863	49.15	39.32	9.83	
140	Drop hammer with rig	600 g	1.00	5	PS	14,280	14,360	7	1,000	90%	70%	5%	279	4.01	3.21	0.80	6.7
141	Diesel generator		4.62	8	KVA	13,990	14,360	5	2,000	90%	65%	5%	180	2.58	2.06	0.52	2.1
142	Boat		30.00	30	PS	330,000	332,400	28	2,000	90%	120%	5%	63	20.94	16.75	4.19	7.2
143	Vibrating screen		2.00		3.7kw	56,600	56,760	28	2,000	90%	120%	5%	63	3.58	2.86	0.72	7.2
144	Cable crane	9.5 ton	30	193	425kw	3,520,000	3,522,400	14	13,200	90%	20%	5%	136	479.05	383.24	95.81	
145	Spiral classifier	14 ton	75.00		1.5 kw	71,060	77,060	9	1,000	90%	20%	5%	172	13.25	10.60	2.65	
146	Belt conveyor	10	10.00		1kw	4,680	5,480	3	1,000	90%	20%	5%	417	2.29	1.83	0.46	
147	Pontoon		150.00			368,380	380,380	12	2,000	110%	20%	5%	79	30.05	24.04	6.01	