3.2.4 Total water demand

Water demand required for the Kelantan River is estimated to increase from the present use of 105.5 cumecs as of 1985 to 161.1 cumecs in 2010 as shown in Table 3.10. The water demand in 2010 is further classified into 6.5 cumecs for the domestic and industrial water use, 84.6 cumecs for the irrigation water use and 70.0 cumecs for the river maintenance flow. Irrigation water demand implies the annual peak demand requires in April, while other water demands require a constant flow through a year.

3.3 Water Demand and Supply Balance

The water balance study aims at clarifying available dam development schemes to cope with the incremental water demand by the target year of 2010. Methodology of the study is by comparing between;

- The probable minimum discharges of the Kelantan River which are calculated subject to "without dam" and "with dam" conditions, and

- The future water demand for the source of the Kelantan River which was estimated in the preceding Sub-section 3.2.4, Total water demand.

In connection with the condition of "with dam", alternative dam development schemes were selected from the potential dam reservoirs which can provide multipurpose functions including flood mitigation and hydropower generation, as well as water supply. Thereby, the dam sites of Lebir, Dabong and Nenggiri was considered for the water balance evaluation.

The probable minimum discharges were estimated at the point of Guillemard Bridge located just upstream of all existing and proposed major water intakes. The basic data for estimation are annual and semi-annual minimum discharges expressed in 5-day average values for 24-year period from 1961 to 1984. The semi-annual minimum discharges are herein regarded as the minimums for every off-season of paddy cropping (from March to August) and main-season (from September to February), and used specially for the balance study of irrigation water demand which has seasonal variations.

The annual minimum discharges are distributed from 69.7 cumecs (gauged in 1969) to 344.9 cumecs and averaged at 177 cumecs. The occurrences of annual minimum discharges are mostly during the off-season of paddy cropping calendar, specially in April.

The probable minimum discharges for annual and semi-annual basis are estimated to be 114.7 and 114.5 cumecs for 5-year drought respectively, whilst 92.1 and 90.8 cumecs for 10-year drought, 76.9 and 74.8 cumecs for 20-year drought and 63.7 and

60.8 cumecs for 50-year drought by Gumbel Extremal Method.

The dam development scheme is assumed to ensure firm discharge which is constantly supplied as the minimum outflow discharge from the dam reservoir and used not only for the downstream water supply but also for the stable hydropower generation. Assuming alternative firm discharges, a continuity equation was set up at Guillemard Bridge.

Probable minimum discharges for annual basis at Guillemard Bridge were estimated to be 140 cumecs for 5-year drought, 125 cumecs for 10-year drought, 112 cumecs for 20-year drought and 102 cumecs for 50-year drought by the Gumbel Extremal Method, when the Lebir dam scheme is developed with the firm discharge of 55 cumees. It is herein noted that the alternative firm discharges were assumed at 55 to 80 cumecs for Lebir dam, 160 to 240 cumecs for Dabong dam and 75 to 90 cumecs for Nenggiri dam, which are effective ranges for the hydropower generation as discussed in the subsequent Section 3.4, Hydropower Potential (refer to Table 3.13).

As estimated in the preceding Section 3.2, Future Water Demands, the domestic and industrial water demand will be about 6.5 cumecs in 2010, and by adding the river maintenance flow of 70.0 cumecs, the requirement of 76.5 cumecs is assumed at the water demand constantly required throughout a year. Furthermore, the monthly variable water requirement springs out from the irrigation water demand which has the annual maximum of 84.6 cumecs on every April after 2010. Thus, the total water demand runs up to 161.1 cumecs as the annual maximum in 2010.

In order to estimate the water deficit for the above water demand, it is assumed that the water supply would be made according to the following priority of demand item:

Priority 1: Domestic and industrial water demand as well as river maintenance flow projected by 2010,

Priority 2: Irrigation water demand projected by 1990 for which all necessary irrigation facilities are under either planning or construction,

Priority 3: Irrigation water demand projected from 1991 to 2010 which has an indefinite plan for necessary irrigation facilities.

The water deficit for domestic/industrial demand and river maintenance flow in 2010 will occur once in about 20 years in case of "without dam", whilst the deficit will be almost completely offset by any alternative dam development scheme.

As for the deficit of irrigation water demand in 2010, the condition of "without dam" will bear about 12 cumecs in average annual deficit and a 2.2-year return period of deficit. On the other hand, the annual average deficit will be reduced to less than 5 cumecs, and the return period of deficit will be extended to more than 3 years by any alternative dam development scheme.

Assuming that the allowable occurrence in irrigation water deficit should be once in more than five years, the following are selected as the available range of alternative firm discharges for each dam development scheme; 75 to 80 cumecs for Lebir dam, 160 to 240 cumecs for Dabong dam and 75 to 90 cumecs for Nenggiri dam.

3.4 Hydropower Potential

3.4.1 Electric power and energy demands

The State of Kelantan currently receives the electric power supply from the National Grid Network circulating Peninsular Malaysia with the high voltage of 275 KV as shown in Fig. 3.2.

The National Electricity Board (NEB) will have the installed capacity of 4,899 MW for the Network by 1991 as shown in Table 3.11. Thermal power plant is to take charge of about 74% of the total installed capacity and plays a vital role in the base load supply. Hydropower plant sharing remaining 36% of the total installed capacity is a reservoir type (7 stations) and is used primarily for the peak load supply.

The National Grid Network supplied the peak power of 2,268 MW to the system in 1986. In comparing the peak power supply with the installed capacity, the system keeps enough reserve capacity. However, according to the forecast of NEB, the future power demand will increase with an annual growth rate of 6 to 7%, so that the system peak demand will reach about 85% of the installed capacity in 1995 and will exceed the installed capacity before 2000 as shown in Table 3.12.

It is necessary to add new power plant in late 1990's to cope with such incremental power demand. In this connection, several hydropower projects in the Kelantan River basin such as the Nenggiri, Pergau, and Lebir dam projects will be promising for development. The feasibility studies for the Nenggiri, Pergau and Lebir dam projects were successively completed in 1986, 1987 and 1989 respectively.

3.4.2 Dam schemes for hydropower generation

The primary aim in this Study is placed on a comprehensive flood mitigation plan which contains the development of storage reservoirs in the upper reaches of the Kelantan River. The creation of storage reservoirs also makes possible the development of hydropower potential.

Due to the aforesaid primary aim of the Study, the hydropower potentials are herein examined for the possible multi-purpose dam schemes which can contain the flood mitigation effects for the downstream development areas. The following three dams are selected as the promising schemes to evaluate hydropower potential; the Lebir, Dabong and Nenggiri dam schemes, all of which are expected to contain a certain flood mitigation effect. The screening process of those schemes is discussed in the Annex VI of the Supporting Report on Master Plan Study in detail.

Annual generated energy was computed as the function of Normal High Water Level and firm discharge as given in Fig. 3.3. It can be read that respective Normal High Water Level has the optimum firm discharges; that is, maximum generated energy is obtained on the curves drawn for each Normal High Water Level. Consequently, the hydropower potentials for each dam scheme are estimated as shown in Table 3.13 and summarized as below:

Dam	Normal High Water Level (El.m)	Required Storage Volume (MCM)	Dependable Capacity (MW)	Annual Generated Energy (GWh)
Lebir	65 - 90	460 - 1650	60 - 150	240 - 430
Dabong	54 - 67	410 - 1520	140 - 270	630 - 940
Nenggiri	135 - 160	250 - 550	170 - 280	580 - 790

3.5 Multi-purpose Dam Schemes

3.5.1 Yielding benefits

(1) Hydropower benefit

The hydropower benefit is estimated as the cost of a thermal power plant which substitutively can have the equivalent dependable capacity and energy generation to those of the hydropower plant. In order to select the best alternative thermal power plant, several configurations of thermal power plant were conceived subject to various combinations of plants such as steam oil, steam coal, combined cycle and gas turbine as shown in Table 3.14.

In case of a combination of two conceivable plants, the plant factor of 0.1 was assumed for peak load generation which can be done by the gas turbine, while the plant factor of 0.7 was assumed for base load generation which can be done by steam oil, steam coal and combined cycle.

Unit costs of the alternative thermal power plant were estimated in terms of the fixed and variable costs as shown in Table 3.15. The fixed and variable costs are derived from:

- The installation cost, the fixed and variable O/M cost and the fuel cost as assumed in Table 3.15, and

- The life time, construction time period, disbursement of construction cost and the system generation loss as assumed in Table 3.16.

On the basis of the aforesaid assumptions, the hydropower benefit was estimated for each development case as the function of Normal High Water Level as shown in Table 3.17. In the estimate, a mix of combined cycle and gas turbine plants was selected as the best alternative thermal plant to give the lowest cost and therefore be most conservative in terms of the benefit attributable to the hydropower projects.

(2) Irrigation benefit

The dam development scheme will reduce the annual average deficit of water supply in the projected irrigation scheme and therefore yield the irrigation benefit. In this study, the benefit calculation was made within the scope of irrigation schemes projected by 1990 such as KADA and Kemasin schemes where all necessary irrigation facilities are being allocated.

The irrigation benefit was calculated as the differences between the net production values with and without dam development schemes. For calculation of the economic benefit, the following assumptions were made:

(1) The average yield of paddy crop was estimated at 3.6 ton/ha which was derived from the following actual results of crop yield in the State of Kelantan in 1986; 49,407 ha of area harvested and 175,720 tons of production (refer to "Kelantan Development Statistics, 1987). The economic farm gate price of paddy was also estimated at M$457/ton as 1988 price level (refer to Table 3.18). Multiplying the average crop yield by the economic farm gate price, the gross production value of paddy amounts to M$1,645.2/ha. The paddy production cost was further estimated at M$1,314.4/ha as shown in Table 3.19. The unit of net production value is expressed as the balance between the gross production value and the production cost, and therefore estimated at M$330.8/ha.

(2) The available irrigation area for a unit of water supply was assumed at 491 ha/cumecs which comes out from the total irrigation area in 1990 (35,697 ha) divided by the peak water supply projected in 1990 (72.7 cumecs). The assumption derives that the annual average irrigation area would increase in proportion to the reduction of annual average deficit of irrigation water supply at the rate of 491 ha/cumecs.

The reduction of annual average deficit in irrigation water supply is attributed to alternative dam development schemes and can be estimated as a balance of the annual average deficits without and with dam development scheme. On the basis of the reduction of annual average deficit together with the aforesaid assumptions, the irrigation benefit was estimated for each alternative dam development case as shown in Table 3.20.

3.5.2 Construction costs

Construction costs for the Lebir, Dabong and Nenggiri dam schemes were estimated at the preliminary level for searching their optimal development scale as a multi-purpose dam scheme. As discussed in the preceding Section 3.4.2, the Kemubu dam scheme will be developed as a single purpose project of flood mitigation, so that the construction cost estimate for this scheme will be discussed in the subsequent Chapter V, Formulation of Flood Mitigation Plans.

A rockfill type is selected as a dam type of the Lebir and Nenggiri dam schemes for searching the optimal development scale based on the recommendations of feasibility study carried out for those schemes. On the other hand, a concrete gravity type is applied for the Dabong dam scheme taking into account the topographic and geological conditions at the site.

Construction costs are estimated on a unit price basis. Construction costs of such similar projects as Kenir and Kenering in Malaysia and Chiew Larn in South Thailand are mainly referred to the estimate of unit prices. Furthermore, such costs are compared with the unit prices applied in the Nenggiri project for obtaining a practical and uniform basis.

Cost estimates are made in Malaysian Ringgit(M$) at the price level of mid-1988. An exchange rate of US$1.00 = M$2.55 is used for the estimate of foreign portion.

Compensation for the area submerged in the reservoir is estimated based on the relocation of houses, social infrastructures, plantations and so forth. Thus, costs related to compensation are counted as the economic costs for searching the optimal development scale of the Lebir, Nenggiri and Dabong dam schemes.

Construction costs so estimated for several development scales of the Lebir, Nenggiri and Dabong dam schemes are summarized in Table 3.21.

3.5.3 Economic evaluation

The economic evaluation was made by comparison between the project costs and their corresponding yielding benefits in each alternative dam development scheme. The project costs are divided into investment cost and operation/maintenance costs. In order to estimate the cash flow of the project costs, it is assumed that the construction period spreads over seven years with the disbursement of 0.05, 0.10, 0.25, 0.25, 0.20, 0.10 and 0.05 (refer to Table 3.16) and the project life is 50 years from the completion of construction. Furthermore, the annual operation/maintenance cost was estimated at (1) M$ 13 per kW of unit installation capacity for hydropower generation and (2) M$ 0.06 million per cumecs·year of unit pumping capacity for irrigation supply. The pumping capacity used for cost estimation was assumed as a value for the additional irrigation supply which is made possible by the dam water resources development.

The yielding benefits were derived from the hydropower generation and irrigation benefits as discussed in the preceding Sub-section 3.5.1, Yielding benefit. The annual average benefits are assumed to spring out immediately after completion of construction. Based on the cash flow of the project costs and the yielding benefits, the conventional economic indicators were computed as shown in Table 3.22 in terms of the expected economic internal rate of return (EIRR), the benefit-cost ratio (B/C) and the net benefit (B-C).

As shown in Table 3.22, it became apparent for all potential dam reservoirs that the economic internal rate of return increases with the height of normal high water level; that is, the higher the dam, the greater the hydropower generation and irrigation benefits gain. The greatest economic internal rate of return is extracted corresponding to the allowable highest Normal High Water level of each potential dam site; 6.0% for Lebir dam, 15.1% for Dabong dam and 17.4% for Nenggiri dam.

3.6 Engineering Studies for Dam and Related Structures

The Lebir, Nenggiri and Dabong dam schemes are developed as a multi-purpose project, whilst a single purpose project of flood mitigation for the Kemubu and Lower Pergau dam schemes. Engineering issues for those schemes are discussed hereinafter.

(1) Lebir dam scheme

The Lebir dam scheme was identified by ENEX as the Jeram Panjang and by JICA for the nation-wide study. The feasibility study of the scheme with the objective of hydropower generation has been completed by JICA.

The damsite is located on the Lebir River at about 40 km upstream from the confluence with the Galas River or about 3.5 km upstream of the highway bridge spanning over the Lebir River. The valley at the proposed damsite is wide although the site is relatively attractive compared with other damsites on the Lebir River. Furthermore, one or two saddle dams are required on the right rim of the main dam as shown in Fig. 3.4.

Land Development of the Lebir scheme area is in progress owing to the opening of the National Highway from Kota Bharu to Kuala Lumpur via Gua Musang in the early 1980's. The completion of the highway planned between Chiku and Kuala Brang in Terengganu through the Lebir area will give a spur for further development of the Lebir scheme area. These land development schemes promoted mainly by KESEDAR and FELDA for oil palm and rubber plantation along the national highway and extending deep into the upper Lebir basin are the considerable constraints against the Lebir dam project. The reservoir area to be created by the Lebir dam and land development schemes by KESEDAR and FELDA are shown in Fig. 3.5. Since the creation of Lebir reservoir will submerge the highway route proposed between Chiku and Kuala Brang in Terengganu, the re-planned highway route is proposed as given in Fig. 3.6.

Reservoir area and storage capacity are shown in Fig. 3.7, which are derived from the Interim Report of the feasibility study for the Lebir dam. The dam type will be rockfill as proposed in its feasibility study. A basic development plan for the Lebir dam scheme is given in Fig. 3.8.

(2) Dabong dam scheme

The Dabong dam scheme was identified by ENEX and by JICA. the damsite is located on the Gals River at about 33 km upstream from the confluence with the Lebir River or about 5 km downstream of the junction of the Pergau River as shown in Fig. 3.9.

The site is just at the centre of the Kelantan River basin draining a catchment area of 7,480 sq km, or 60% of the whole basin catchment. Thus, the Dabong dam will be most effective for flood mitigation in the downstream reaches of the Kelantan River basin as well as power generation.

Land is well developed along the Pergau River, which is to be submerged by the Dabong dam. This is a big constraint against the Dabong dam project. Besides, the railway along the Galas River shall be realigned with the development of the Dabong dam. Plan and profile of the existing railway together with the conceivable damsites are shown in Fig. 3.10, whilst the Dabong reservoir in Fig. 3.11. The villages to be affected with the reservoir development is summarized in Table 3.23.

Reservoir storage capacity of the Dabong dam is shown in Fig. 3.12. The proposed site is ideal for dam construction forming a gorge, and a concrete gravity type dam will be suited as proposed by ENEX. A basic development plan for the Dabong dam scheme is given in Fig. 3.13.

(3) Nenggiri dam scheme

The Nenggiri dam scheme was also identified by ENEX and JICA, and its feasibility study was performed by ELC in 1986. Its main purpose is power generation. Since the site is located in the low precipitation zone of the far western of the Kelantan River basin as shown in Fig. 3.14, its effect of flood mitigation for the lower reaches is small.

The site is located on the Nenggiri River at about 18 river miles (30 km) upstream from the confluence with the Galas River, or 22 km north of Gua Musang. For the Nenggiri dam project, the social constraints are scarce compared with the Lebir and Dabong dam projects. The reservoir area of the Nenggiri dam is shown in Fig. 3.15. Reservoir storage capacity is shown in Fig. 3.16, which is derived from the feasibility study report by ELC. The dam type will be rockfill as proposed in its feasibility study. A basic development plan for the Nenggiri dam scheme is given in Fig. 3.17.

(4) Kemubu dam scheme

One of alternatives for the Dabong dam, which would be less effective for flood mitigation, but could considerably reduce the social constraints, is the Kemubu dam as identified by ENEX.

The site is located on the Galas River, about 18 km upstream of the Kemubu railway bridge as shown in Fig. 3.18. This site could be an alternative for the Dabong dam, since the Pergau valley does not suffer from submergence and the realigment of the railway as such in the case of the Dabong dam is not required, although the formation level of the railway between the pass (between Kemubu and Bertam) and Gua Musang shall be raised up.

The reservoir area and storage capacity are shown in Fig. 3.19. Dam type at this site will be concrete gravity. A basic development plan for the Kemubu dam scheme is given in Fig. 3.20.

(5) Lower Pergau dam scheme

The site identified by ENEX is on the Pergau River at about 10 km upstream from the confluence with the Galas River as shown in Fig. 3.21, however, it is not suited for dam construction from view points of both dam engineering and social aspects. The land in the Pergau valley is well developed for rubber plantation and paddy field, and hence, it could be a less advantageous alternative for the Dabong dam.

As for the dam engineering, the possible dam type at this site is earth dam with a height of 20 m at most from the topographical and geological conditions. Reservoir storage capacity of the Lower Pergau is shown in Fig. 3.22.

IV. BASIC CONCEPT FOR THE FORMULATION OF FLOOD MITIGATION PLANS

4.1 General

Inundations take place over the vast plain in the downstream reaches of the Kelantan River basin. It is deemed impractical from the viewpoints of economic effectiveness and budgetary fund to realize perfect flood mitigation works for the entire stretches of the large river system. Therefore, it should be contemplated to mitigate flood damages to a practical extent by adopting structural and non-structural measures.

The structural measures will be adopted in due consideration of their economic effectiveness, safety of livelihood of the riparian people and social urgent requirement. In application of the structural measures, a high target level of protection as much as possible would be desirable to adopt for the safety of facilities, long term stability and livelihood of the riparian people concerned. However, a large amount of construction costs and a long construction period will be needed for realizing the high target level plan. In order to realize the flood mitigation plan as early as possible and to meet with the social urgent requirement, stage-wise flood mitigation plans have to be contemplated.

The non-structural measures will be contemplated to supplement the structural measures and/or to the flood-prone areas where the structural measures are not adopted.

A pre-feasibility study to be carried out in the following stage will be made for the structural measures.

4.2 Protection Areas from Floods

According to the report on 1967-flood, which corresponds to 50-year probable flood, inundation took place even in the upstream areas of Kuala Krai (Ulu Kelantan), however, damages in these areas were as small as one percent of total damages. Due to this, the protection area from floods in this study is determined for the Kelantan River basin extended in the downstream reaches of Kuala Krai.

It can be read from the map for 1967-flood (refer to Fig. 2.9) that flood water overflowed from the Kelantan River came up to the right bank of the Golok River. A boundary to divide the flood-prone areas between the Kelantan and Golok rivers is however drawn using a railway running between Tanah Merah and Pasir Mas and a highway between Repek and Tumpat.

A low mountain running towards the north from Machang to Bukit Mak Lipah and a low ridge running towards the northeast from Gunong Timor to the coast through Jelawat show a divide between the Kelantan and Semerak river basins except for a paddy area between Melor and Gunong Timor. A highway running between Melor and Jelawat through the paddy area is used as the boundary to divide the flood-prone areas between the Kelantan and Semerak rivers based on the results of the interview at sites.

Overflow from the Kelantan River in 1967-flood swept over the entire Kemasin River basin. Thus, the entire Kemasin River basin is counted as the flood-prone area of the Kelantan River.

Fig. 4.1 prepared on basis of the assumptions and conditions mentioned above as well as the inundation map of 1967-flood (refer to Fig. 2.9) delineates the maximum extent of inundation area for the 50-year probable flood caused by flooding of the Kelantan River; that is, this maximum extent of inundation area is defined as the protection area from floods in this study.

4.3 Flood Mitigation Level

It is contemplated to work out flood mitigation plans in the Kelantan River basin by stage-wise development, considering flood mitigation levels such as provisional stage and long term stage as a final target.

In application of structural measures, a high target level of protection as much as possible would be desirable to adopt for the safety of facilities for their long term stability and livelihood of the riparian people. However, a long term plan with the high target level needs a considerable amount of construction costs and a long term construction period. On the other hand, the flood mitigation master plan has tentatively been decided to formulate for condition in the year 2000. Considering these situations and socio-economic conditions in the basin area, a 20-year probable flood is applied as the design flood toward year 2000 to protect the rural riparian areas in the river stretches between Kuala Krai and the river mouth, and a 50-year probable flood is adopted to protect urbanized riparian areas such as Kota Bharu, Pasir Mas, Tanah Merah and Kuala Krai.

National Water Resources Study, Malaysia set a criterion to select the flood protection level as follows:

(1) The riparian area with the annual flood damage less than M$20,000/$km^2$ and population density of about 500 person/km^2 is relieved from the flood with a 20-year return period.

(2) The riparian area with the annual flood damage more than M$20,000/$km^2$ and population density more than 1,000 person/km^2 is relieved from the flood with a 50-year return period.

The result of socio-economic studies in the Kelantan River basin indicates that the urban areas of Kota Bharu, Pasir Mas, Tanah Merah and Kuala Krai have the population density of more than 1,000 person/km^2. Thus, these urban river stretches, i.e. KL3, KL5, LK8, KL9 (Temangan Lama and Bharu) and KL12 as referred in Fig. 4.2, are endorsed to protect from a 50-year probable flood as priority protection areas.

On the other hand, remaining rural river stretches from Kuala Krai to the estuary are protected from a 20-year probable flood according to the above criteria. However, it is desired to make one flood protection level in a river; that is, all the river stretches from Kuala Krai to the estuary are protected from a 50-year probable flood. Thus, the rural river stretches are initially protected from a 20-year probable flood, and their protection level will be brought up to a 50-year probable flood as an ultimate goal. If the flood mitigation works to cope with a 50-year probable flood is completed, flood peak discharge with the same scale as that in 1967 can safely flow down without inundating all the riparian areas downstream from Kuala Krai.

4.4 Flood Mitigation by Structural Measures

4.4.1 Conceivable flood mitigation measures and their combinations

The following structural measures are contemplated for flood mitigation planning of the Kelantan River basin in view of river profile, inundation condition and basin topography:

- Widening of river channel,
- Dredging of riverbed,
- Levee construction,
- Treatment of the river mouth, and
- Flood mitigation dams.

Present flow capacity of the river channel along the flood-prone areas is more or less 5,000 m^3/sec which corresponds to the frequency of more than once in two years. Even if the river improvement works by means of widening of the existing river channel, dredging of the river bed and levee construction are executed, increase in the flow capacity will be around 3,000 m^3/sec. Since it is practically impossible to provide higher levee and larger widening of the river channel to discharge the design flood corresponding to a 50-year probable flood as an ultimate goal, combination plans of the flood mitigation dam and river improvement will have to be contemplated.

Once an optimum combination plan of the dam and river improvement scheme is determined to protect in the river stretches between Kuala Krai and the river mouth from a 50-year probable flood, a plan to protect rural river stretches from a 20-year probable flood will be worked out as a provisional stage.

For each combination scheme, probable peak discharges for the design flood will be determined at the selected points. Based on these probable flood discharges, dam and river improvement plans will be worked out, and construction cost for the schemes will be estimated.

Since the dam scheme is worked out as multipurpose use including hydroelectric power generation, water supply for irrigation, municipal and industrial use and river maintenance, the suitable combination plans will be selected based on the concept that the combination to give the net benefit maximum is optimal. The net benefit is defined as the difference between the benefits resulting from flood mitigation and water resources development and all the costs necessary for the development of the schemes.

4.4.2 Flood mitigation by dam

The southern part of the Kelantan River basin is occupied by mountainous zones, and therefore several flood mitigation dam plans have been contemplated. Among them, following dams are contemplated to be promising in taking into account water resources development and flood mitigation in the downstream reaches of the basin (refer to Appendix 2 of Annex VI on Master Plan Study):

(i) Dabong dam is located in the Galas River, about 132 km upstream from the river mouth or about 30 km upstream from the Lebir confluence. A catchment area is around 7,480 km^2.

(ii) Kemubu dam as a mutually exclusive alternative of the Dabong dam is situated in the Galas River at about 167 km upstream from the river mouth. A catchment area is about 5,630 km^2.

(iii) Nenggiri dam is located in the Nenggiri River at about 210 km upstream from the river mouth. A catchment area is about 3,690 km^2.

(iv) Lower Pergau dam as a mutually exclusive alternative of the Dabong dam is located in the Pergau River at about 10 km upstream from the Galas confluence. A catchment area is about 1,280 km^2.

(v) Lebir dam is situated in the Lebir River, at about 138 km upstream from the river mouth or about 36 km upstream from the Galas confluence. A catchment area is about 2,480 km^2.

For the flood mitigation in the downstream reaches of the basin, combinations of a dam or two dams selected from above five dams plus river improvement will be contemplated. Fig. 4.3 shows the location of those five dams.

The study on the flood mitigation by dam will be made under the following criteria:

(1) An optimum reservoir capacity is first of all searched for water resources development, i.e. hydropower generation, water supply for irrigation, M & I use and so on. Flood spaces for flood mitigation and safety of dam itself are

allocated above the capacity for water resources development.

In case that the crest of dam determined from the above procedure is higher than the topographical maximum elevation to build a dam, flood spaces for flood mitigation and safety of dam itself are at first allocated below the topographical maximum elevation, and then the remaining reservoir capacity is used for water resources development. In case that no space is allocated for water resources development, the scheme is developed as a single purpose project of flood mitigation. It is noted for the determination of topographical maximum elevation that the geological condition at the site is also taken into account.

(2) The spillway comprises two sections; that is, an overflow weir to safely release PMF for dam itself and an ordinary overflow weir for flood mitigation. There are two ways to provide the ordinary overflow weir; that is, one is to provide the ordinary overflow weir under Normal High Water Level (NHWL) and to regulate water levels in dry and wet seasons by gates. Meanwhile, the other is to provide the ordinary overflow weir above NHWL without gates.

A reservoir simulation study in case of having the ordinary overflow weir under NHWL shows that water level lowered by the crest of ordinary overflow weir in wet seasons has high possibilities not to recover to NHWL in dry seasons, resulting in considerable losses of power generation (refer to Section 4.6 of Annex VI). Thus, the ordinary overflow weir is provided above NHWL. Furthermore, the suitable dimensions of it are searched by changing the peak-cut ratio (A routed peak outflow for the design flood/peak inflow of design flood).

(3) The dimension of the overflow weir for dam safety is determined under the condition that PMF is safely released by both ordinary overflow weir and overflow weir for dam safety. The crest of dam is decided by adding the freeboard to the flood water level for PMF.

(4) Probable flood discharges at the selected points for the respective outflows routed with the ordinary overflow weir are determined by flood routing study. Based on these probable floods, the river improvement scheme is worked out, and its construction cost is estimated. The optimum dimension of the ordinary overflow weir is determined in the comparison of benefits and costs including water resources development.

4.4.3 Flood mitigation by river improvement

Based on the probable flood peak discharges for the respective outflow from the ordinary overflow weir as stated in the foregoing, the river improvement scheme to protect the river stretches between Kuala Krai and the river mouth from a 50-year probable flood will be worked out under the following criteria:

(1) The flood water level to discharge the specified flood discharge should be lowered as much as possible.

(2) The widening of the river channel is only limited to remarkably narrow places.

(3) Since it is considered undesirable from the viewpoint of the stability of river bed to alter drastically the existing river bed slope, the dredging to arrange the river cross section should be contemplated.

(4) The levee with low height as much as possible should be contemplated to avoid the risk of water leakage through the levee structure for the flood with a long duration and to drain easily the interior water.

Once an optimum combination plan of the dam and river improvement schemes is determined to protect the riparian areas between Kuala Krai and the river mouth from a 50-year probable flood, a stage development plan protecting from a 20-year probable flood will be worked out for the rural riparian area.

4.5 Flood Mitigation by Non-structural Measures

Considering the economic effectiveness, safety of inhabitants, social urgency and so on, non-structural measures should also be contemplated as a measure for the mitigation of flood damages in the flood-prone area extended in the downstream reaches of the Kelantan River. The following are contemplated as the non-structural measures:

- Flood forecasting and warning system
- Flood zoning
- Legislation
- Others.

The flood forecasting and warning system has been introduced to the Kelantan River basin for making ease the evacuation from the threatened area, and the current problem for it was discussed in the preceding Section 2.8.

Flood zoning is to restrict the occupancy of high flood risk zone for mitigating the damages during floods. Legislation includes the restriction of development for the flood-prone area, where structural measures cannot be economically justified, or will not be implemented over the foreseeable future.

Flood proofing, land use change and resettlement of population are counted as others of non-structural measures. Flood proofing is the actions taken by individuals or small groups within the flood plain to reduce flood damage to their property.

Land use change is the measure to reduce the potential damage to crops by applying less damage-susceptible crops. Resettlement of population will be applied to the areas where the potential damage to property as well as loss of life in the flood-prone area cannot be reduced by structural measures.

V. FORMULATION OF FLOOD MITIGATION PLANS

5.1 General

A 50-year probable flood is selected as the design flood of an ultimate goal to protect the entire riparian area in the river stretches between Kuala Krai and the river mouth, and then 20-year and 50-year probable floods are selected as the design flood to protect rural and urban riparian areas in the provisional stage, respectively.

The formulation of flood mitigation plans is carried out by two steps. Several promising combination plans are at first worked out for protecting the entire riparian area in the river stretches between Kuala Krai and the river mouth from a 50-year flood. A stage development plan for protecting the rural riparian areas from a 20-year flood is studied as a second step for the promising combination plans selected in the first step.

5.2 Combination Plans for Flood Mitigation

Five dam schemes (refer to Fig. 4.3) as discussed in the preceding Section 4.4.2 are proposed not only for the flood mitigation in the downstream reaches of the Kelantan River, but also for hydropower generation, domestic and industrial water use, irrigation supply and so on.

To make combination plans for flood mitigation, flood mitigation effect by each dam was evaluated by incorporating it on the simulation model to predict flood peak discharges and hydrographs at the designated points. A 50-year probable flood is selected for the simulation, because the downstream reaches of the Kelantan River is protected from the 50-year probable flood as a final target.

The hydrological simulation model reveals that flood peak discharge with a recurrence interval of 50-year is some 16,400 m^3/sec under the natural condition, i.e. without structural measures, at Guillemard Bridge as shown in Table 5.1. In case that flood discharge inundated at the reaches between Kuala Krai and Guillemard Bridges (refer to Fig. 2.7) is confined in the river channel only by river improvement (R/I), 50-year flood peak discharge increase by 17,400 m^3/sec.

In comparison with the present flow capacity of the Kelantan River (more or less 5,000 m^3/sec) and the flood peak discharge of 17,400 m^3/sec, the flood mitigation only by river improvement will not necessarily be a promising alternative for a 50-year probable flood. However, the alternative by river improvement only is kept as one of alternatives in selecting the most suitable combination plan for the flood mitigation of the Kelantan River.

The Nenggiri dam plus river improvement shows little flood peak reduction even by changing the peak-cut ratio (=peak discharge from the spillway for flood mitigation/peak inflow) probably due to the fact that the catchment draining an area of 3,690 km^2 is located at the uppermost reaches with relatively little rainfall. Therefore, it is less advantageous to include the function of flood mitigation in the development objectives of the Nenggiri dam scheme. This fact is endorsed in comparison between Case 19 (Lebir + R/I) and 23 (Lebir + Nenggiri + R/I) of Table 5.1 that flood peak discharge of 850 m^3/sec is only reduced by the addition of the Nenggiri dam scheme.

The Kemubu dam scheme is a mutually exclusive alternative with the Dabong dam scheme and will be developed as a single purpose project of flood mitigation. Flood peak discharge at Guillemard Bridge is about 13,900 m^3/sec in the highest peak-cut ratio (40%) of the Kemubu dam scheme plus river improvement (refer to Table 5.1). Since the reduction of flood peak discharge by the Kemubu dam scheme is not so great due to a small reservoir scale, an addition of the Lebir dam scheme is also conceived for reducing the burden of flood mitigation to the river improvement as depicted in Case 27 to 30 of Table 5.1.

The Lower Pergau dam plus river improvement shows less flood peak reduction probably due to the small catchment area and low reservoir efficiency. The topographical maximum elevation of building a dam is assumed to be El.72.0 m for assessing the flood mitigation effect of the Lower Pergau scheme. Since the topographical maximum elevation at the site for building a dam is informed to be much lower than El. 72.0 m, the topographical survey to confirm the topography at the site was commenced, and then revealed that the topographical maximum elevation was El. 50.0 m at the site. Therefore, the Lower Pergau dam scheme is excluded from the alternatives to mitigate floods in the downstream reaches of the Kelantan River.

The Lebir dam scheme plus river improvement shows considerable flood mitigation effect with flood peak discharge of about 12,500 m^3/sec at Guillemard Bridge (refer to Table 5.1). Thus, this Lebir dam scheme plus river improvement will be one of promising combination plans to protect the entire riparian area in the river stretches downstream from Kuala Krai.

Flood peak discharge in the plan of the Dabong dam scheme plus river improvement greatly decreases by about 10,600 to 10,800 m^3/sec (refer to Table 5.1). Thus, this plan is also one of promising combination plans to protect the downstream reaches of the Kelantan River from a 50-year flood.

Considering the flood mitigation effect of dams to the downstream reaches and flow capacity of the Kelantan River, following combination plans are contemplated with stage development (refer to Figs. 5.1 to 5.8):

Case	Combination of Structures	Stages	
		Provisional Stage	Final Stage
1	R/I only	R/I	R/I
2	Nenggiri + R/I	Nenggiri + R/I	R/I
3	Kemubu + R/I	Kemubu + R/I	R/I
4	Dabong + R/I	Dabong + R/I	R/I
5	Lebir + R/I	Lebir + R/I	R/I
6	Lebir + Nenggiri + R/I	Lebir + Nenggiri + R/I	R/I
7	Lebir + Kemubu + R/I	Lebir + Kemubu + R/I	R/I
8	Lebir + Dabong + R/I	Lebir + Dabong + R/I	R/I

Note: R/I means river improvement.

Combination plan 1, river improvement only, requires the river improvement works for the flood peak discharge of 14,400 m^3/sec in the rural riparian areas and 17,400 m^3/sec in the urban riparian areas as the provisional stage (refer to Table 5.1). River improvement works for the incremental discharge of 3,000 m^3/sec will be carried out in the rural riparian areas as the final stage.

Combination plans 2 to 5, which are the combination of a dam plus river improvement, need the construction of dam as well as river improvement to meet the protection requirement of urban and rural riparian areas set forth in the provisional stage. The protection level for the rural riparian areas will be raised from 20 to 50-year probable flood by river improvement as the final stage.

Simultaneous construction of two dams as well as river improvement is necessary for the provisional stage in Combination plans 6 to 8. Out of them, the river improvement of Combination plan 8 is only limited to the urban riparian areas in the provisional stage. The final stage to raise the protection level from 20 to 50-year probable flood in the rural riparian areas requires the river improvement for the incremental discharge of some 1,200 m^3/sec. It is noted in Table 5.1 that an overflow weir for flood mitigation is not provided to the spillway for the case with the lowest peak-cut ratio of each dam scheme; that is, the flood mitigation to the downstream reaches is only expected with the overflow weir for PMF.

5.3 Structural Plan for Dam and River Improvement

5.3.1 Structural plan for dam

An optimization study for water resources development stressing on hydropower development was carried out for the Nenggiri dam scheme, and then reckoned that the higher NHWL, (normal high water level), the greater the net benefit gains as discussed in the preceding Chapter 3. Thus, the crest of dam constructed as a rockfill type was at first fixed at El. 169.0 m of topographical maximum elevation, and then the crest of spillway for PMF (probable maximum flood) was determined by coinciding with Surcharge Water Level (SWL), a water level routed a 50-year probable flood with the spillway for flood mitigation, for the respective peak-cut ratio. NHWL for water resources development was finally determined at El. 150.7, 152.9, 155.0 and 157.0 m by coinciding with the crest elevation of spillway for flood mitigation, which corresponds to the respective peak-cut ratio as shown in Table 5.2. The spillway for the flood mitigation is a non-gated type. The width of 75 m adopted in the Feasibility Study of Nenggiri Dam Project is selected as the one of spillway for PMF.

The Kemubu dam scheme is developed as a single purpose of flood mitigation. The crest of dam was set at El. 82.0 m by coinciding with the topographical maximum elevation, and then applying the same procedure used for the Nenggiri dam scheme, the crest of spillway for the flood mitigation was determined at El. 53.0, 58.4, 63.0 and 65.7 m for the peak-cut ratios of 40, 30, 20 and 15%, respectively. The Kemubu dam will be built with a concrete gravity type considering topographic and geological favours at the site.

The Dabong dam scheme will be constructed with a concrete gravity type by availing the topographic and geological favours at the site. An optimization study for water resources development of the Dabong dam scheme revealed that the higher NHWL, the greater the net benefit gains as did for the Nenggiri dam scheme. Thus, the crest of dam was at first fixed at El. 80.0 m of topographical maximum elevation, and then NHWL was determined at El.62.4, 64.1, 65.6 and 66.7 m for the peak-cut ratios of 80, 70, 60 and 59% respectively by the routing calculation for PMF and a 50-year probable flood.

The optimization study for water resources development of the Lebir dam scheme reckoned that the net benefit increases by lowering NHWL. However, the highest benefit-cost ratio and EIRR (economic internal rate of return) were gained by setting NHWL at El.80.0 m. In this situation, the crest of dam was at first set at El.91.1 m of topographical maximum elevation, and then NHWL was computed at El.76.3, 77.9, 79.3 and 80.0 m for the peak-cut ratios of 70, 60, 50 and 37% respectively by the routing calculation for PMF and a 50-year probable flood. By seeking the benefit-cost ratio and EIRR as high as possible, NHWL was determined at El.76.3, 77.9, 79.3 and 80.0 m for the peak-cut ratios of 70, 60, 50 and 37%, respectively.

The Lebir dam will be constructed with a rockfill type, and then the spillway for PMF has the width of 150 m, which is selected in the Feasibility Study of Lebir Project.

The construction costs of the Lebir, Dabong and Nenggiri dam schemes developed for hydropower generation and irrigated agriculture are estiamted as discussed in the preceding Section 3.5, Multi-purpose Dam Schemes. The construction costs of those dam schemes including the Kemubu dam scheme are re-estimated for NHWL corresponding to the respective peak cut-ratios as shown in

Table 5.3.

5.3.2 Structural plan for river improvement

(1) Conditions for the structural plan of river improvement

For the flood mitigation in the downstream reaches of the Kelantan River basin, the several combinations of storage dams with river improvement works were contemplated as discussed in the preceding Section 5.2, Combination Plans for Flood Mitigation. Peak discharges for designing the alternative plan of river improvement works range from 5,000 m^3/sec up to 17,500 m^3/sec. The following conditions are adopted for the structural plan of river improvement:

(i) Predominant flow of the mesh-like channels near the estuary

The river mouth of the Kelantan forms mesh-like river channels, and a large scale sand dune is being developed at the debouchment of the river. 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 level. 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. 5.9, and roughness coefficient of the river channel is 0.025.

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. 5.9 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.

(ii) Levee

The levee is basically constructed with an earth embankment type by the following reasons:

- It is easy to obtain a large amount of construction materials near the project site, resulting in the reduction of construction cost,
- It is rather easy to make the levee higher and wider in case that stage-wise development is considered, and
- Maintenance is easier than that for river channel.

The levee is constructed by securing the clearlance of 50 m wide from the bank of low-water channel at least.

Fig. 5.10 shows the typical cross section of levee. The side slope of earth embankment is set at 1:3.0 taking into account the stability and the long duration of flood. To protect the toe of the levee from seepage water, toe drain is provided. While, the width of crest and height of freeboard are designed on the basis of the following design criteria:

Peak Discharge (cms)	Width of Crest (m)	Freeboard (m)
below 10,000	6.0	1.5
above 10,000	7.0	2.0

A special levee constructed with concrete is also taken into consideration at the places where land acquisition is not easy due to the urbanization developed by the river side such as Kota Bharu as shown in Fig. 5.11.

(iii) River structures

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

(2) Comparative study of river improvement plan

The possible measures of river improvement for the downstream reaches of the Kelantan River are enumerated below:

(i) To confine flooding within the specified width by constructing the levee,

(ii) To increase the flow capacity of river channel by widening the river channel,

(iii) To increase the flow capacity of river channel by dredging the riverbed, and

(iv) To increase the flow capacity of river channel by steepening water gradient by introducing short-cutting at the meandering portion.

The combination of the above measures was contemplated on the basis of the cross sections and longitudinal profile of the Kelantan River surveyed in this Study. As a result, the following four alternatives are taken up to determine the suitable river improvement plan;

(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 by dredging works.

(iii) **Alternative-C**

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

(iv) **Alternative-D**

In addition to the most suitable plan selected among foregoing three alternatives, short-cutting is performed at a large meandering portion at Pasir Mas.

The comparative study on these alternatives is carried out under the conditions that the flood peak discharge is 12,000m^3/sec.

Fig. 5.12 shows the results of the comparative study. Based on this figure, the variation of flood water level, earthwork volume and required cost are enumerated as follows:

Item	Alt-A	Alt-B	Alt-C
1. Flood water level			
. Water level in Alt-A is almost same as that of Alt-B, but is several ten centimetres lower at narrow places due to dredging.			
. Water level in Alt-C is several ten centimetres to 1.5 metres lower than that of Alt-A and B.			
2. Work Quantity (mill. m^3)			
Dredging Work	-	2	58
Embankment for Levee	17	14	9
3. Cost of Earthwork (mill.M$)	138	118	400

The above results show that the flood water level for Alternative-C is lowered remarkably because of a huge amount of dredging work and widening of low water channel throughout all the 70 km long river stretches. Especially excavation volume near the river mouth occupies about 44% of the total volume. Consequently the required cost is about 4 times of Alternatives-A and B. Furthermore, Alternative-C is supposed to bring about the problem of difficulty of maintaining the design cross section of river channel and the intrusion of salt water during dry seasons.

The required cost for Alternative-B is almost same as that for Alternative-A. But the flood water level for Alternative-B is lower than that of Alternative-A. Thus, Alternative-B was selected as the suitable scheme in this study.

Besides, the combination of Alternatives B and D is studied to examine the effect of short-cutting (refer to Fig. 5.13). In the flood water level for the discharge of 12,000 m3/sec, the volume of earthwork and its cost are also enumerated as follows:

Item	Alt-B	Alt-D
1. Flood water level		
Water level of Alt-D in the stretches of 40 km upstream from the short-cut portion is 3 m lower than that of Alt-B at most.		
2. Work Quantity (mill. m^3)		
Dredging Work	2	52
Embankment for Levee	14	8
3. Cost of Earthwork (mill.M$)	118	352

The above results show that Alternative-D, short-cutting of meandering portion at Pasir Mas, is not only a high cost measure, but also brings about the problems of spoiling excavated materials and of the reconstruction of existing irrigation distribution network. Besides, the river sand eroded in the short-cut channel is apt to deposit in the Kota Bharu river stretch. Considering these situations, Alternative-B is finally adopted as the optimum plan of river improvement measure.

5.3.3 Treatment of river mouth

A large scale sand dune is 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 that the low discharge continues in dry seasons. This phenomenon causes the inconvenience to navigational activities.

In order to examine flooding effect by the sand blockage at the river mouth, the relation between the flood water level and with-and-without sand blockage was studied by non-uniform flow calculation. Fig. 5.14 shows the result of this study using the flood peak discharge of 11,100 m^3/sec. This figure shows that flood water level does not effectively go down only with the removal of sand dune at the river mouth. It would be required to dredge river bed upto several kilometres upstream from the estuary, when effective lowering of flood water level is expected. And, the dredging volume would be some million m^3 with a huge amount of annual maintenance cost. Accordingly, the river improvement plan in this study is carried out under the condition that the river mouth is remained as it is.

The river mouth of the Kelantan River always varies its location and causes the difficulty to navigational activity. 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 following data:

- Tidal level and its wave height
- Topographic map of the river mouth and coast with a large scale
- Volume and direction of littoral drift sand
- Direction and velocity of surface wind velocity
- Grain size distribution of riverbed material
- Wind-blown sand.

Additionally, a hydraulic model test for the treatment of river mouth is one of useful methods to clarify the effect of the treatment works.

5.3.4 Urban drainage in Kota Bharu

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 draind 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 occurrance 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 II.5.5 in ANNEX II, HYDROLOGY, 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 flooded 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 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.

5.3.5 Stage-wise development plan

In case that river improvement is carried out with stage development as discussed in the preceding Section 5.2, the construction of levee will be executed in the following steps:

1) Provisional stage

- Continuous levees will be constructed on both banks to protect the rural riparian areas from a 20-year probable flood, i.e. river stretches of KL2, KL4, KL7, KL10 and KL11 (refer to Fig. 4.2).

- A continuous levee will be constructed along the river to protect the urban riparian areas of Kota Bharu (KL3), Pasir Mas (KL5), Tanah Merah (KL8), Temangan Lama and Bharu (KL9) and Kuala Krai (KL12) from a 50-year probable flood.

2) Final stage

The levee in the rural riparian area will be made higher and wider to raise the protection level from a 20-year probable flood to a 50-year probable flood.

5.3.6 Relationship between peak discharge and construction cost of river improvement

The construction cost of river improvement was estimated assuming the five peak discharges at Guillemard Bridge; that is, 6,000, 9,000, 12,000, 15,000 and 18,000 m^3/sec.

The construction cost for the above river improvement as given in Fig. 5.15 was estimated referring to the unit price in the similar projects in the basin.

5.4 Implementation Programme for Flood Mitigation Plans

5.4.1 Construction time schedule

The construction time shcedule for the conceivable eight flood mitigation plans was prepared under the following conditions and considering Malaysia Five-Year Development Plan:

(1) Construction period and disbursement:
- Seven years for the Dabong, Lebir and Nenggiri schemes with the disbursement of 0.05, 0.10, 0.25, 0.25, 0.20, 0.10 and 0.05,

- Three years for the Kemubu shceme with the disbursement of 0.20, 0.50 and 0.30.

(2) The construction period for river improvement is estimated based on the embankment capacity of 2.0 million m^3 a year for levee, and the construction costs are uniformly disbursed.

(3) The construction of river improvement for the final stage is commenced immediately after the completion of the provisional stage.

(4) Consideration be given to disburse the annual construction fund evenly throughout the construction period.

(5) Prior to the implementation works, a series of pre-requisite works such as feasibility study, loan arrangement and detailed design are performed.

Fig. 5.16 shows the construction time shcedule for eight conceivable flood mitigation plans prepared based on the foregoing conditions.

5.4.2 Annual disbursement schedule

Based on the foregoing construction time schedule, the annual disbursement schedule for eight conceivalbe flood mitigation plans and construction cost estimated in Table 5.3, the annual disbursement schedule was prepared as shown in Table 5.4.

5.5 Selection of Suitable Combination Plans

5.5.1 General

The benefits accrued from hydropower generation and irrigted agricultural development are discussed in Chapte 6, Economic Evaluation of Annex VI, whilst the benefits for flood mitigation are estimated in Annex V.

The construction costs for the development of dams and river improvement are estimated as discussed in the preceding Section 5.3. The economic viability of each combination plan is assessed by preparing the streams of those benefits and costs. The basic assumptions and conditions applied for the economic evaluation are given as follows:

(1) A project life is 50 years from the in-service date.

(2) Construction period and disbursement:
- Seven years for the Dabong, Lebir and Nenggiri schemes with the disbursement of 0.05, 0.10, 0.25, 0.25, 0.20, 0.10 and 0.05.
- Three years for the Kemubu shceme with the disbursement of 0.20, 0.50 and 0.30.

(3) The construction period for river improvement is

estimated based on the embankment capacity of 2.0 million m^3 a year for levee, and the construction costs are uniformly disbursed.

(4) The construction of river improvement for the final stage is commenced immediately after the completion of the provisional stage.

(5) Economic cost is 85% of construction cost.

(6) The O&M costs of dams and river improvement are taken to be 0.5% of their direct construction costs. In case that hydropower generation is included as an objective of dam development, the O&M costs are assumed to be M$13 per KW.

(7) It is assumed that the river improvement works proceed from downstream to upstream stretches and benefit for flood mitigation by the river improvement in a certain river stretch accrues immediately after the completion of the river improvement work in this stretch.

5.5.2 Selection of suitable combination plan including water resources development

Based on the foregoing conditions and assumptions, economic evaluation by means of economic internal rate of return (EIRR) was made for the conceivable combination plans. The result is given in Table 5.5, in which benefits for power generation, irrigation and flood mitigtion are counted.

The Dabong dam scheme shows the highest economic efficiency in terms of EIRR. Thus, the Dabong dam scheme is selected as the most promising plan for the water resources development of the Kelantan River basin and the flood mitigation in the downstream reaches of the Kelantan River.

It is noted there are negative socio-economic impacts for dam schemes as enumerated in Table IV 3.1 of ANNEX IV SOCIO ECONOMY. In this table, large constraints for dam construction are raised for Dabong. They are resettlement of about 7,400 houses with inhabitants of about 37,200, relocation of about 55 km long railway and 57 km long national highway and submergence of 11,000 ha wide rubber and oil palm plantation.

VI. FLOOD MITIGATION PLAN TO MINIMIZE SOCIAL IMPACTS

6.1 General

As discussed in the preceding Chapter 5, the Dabong dam plus river improvement was selected as the most promising plan for the dual objectives of water resources development stressing on hydropower generation and the flood mitigation in the downstream reaches of the Kelantan River.

However, this multipurpose dam scheme requires a large scale relocation for houses, plantations and public facilities, causing considerable social impacts. Consequently, it was strongly requested by the State Government through the discussion of the Interim Report to study a number of new combinations of dams and river improvement with emphasis on the minimization of social impacts.

In accordance with this request, the flood mitigation study was carried out incorporating newly obtained topographic data at the proposed Dabong, Kemubu and Lower Pergau damsites and referring to the situation of flood occurred in November 1988. The formulation of flood mitigation plan stressing on the minimization of social impacts is discussed hereinafter.

6.2 Formulation of Flood Mitigation Plans

6.2.1 Basic concept

The basic concept in formulating the flood mitigation plan of the Kelantan River basin stressing on the minimization of social impacts is summarized as follows:

a. Flood mitigation Master Plan of the Kelantan River is targeted for a 50-year flood, considering the development of the flood-prone area extended in the downstream reaches and habitual flooding.

b. A levee with 7 m high will be required to safely release flood water of 17,400 m^3/sec at Guillemard Bridge, when without dam. Levee is desired to be as low as possible, taking into account the damage caused by the break of high levee. Thus, flood water of the Kelantan River is to control with the dams built in the upstream reaches as much as possible for making the burden to the levee lighter.

c. The dams will be built with a single purpose of flood mitigation to reduce the social impacts by lowering their height. Unless the inclusion of hydropower generation causes the change of reservoir capacity and flood mitigation effect, the dam scheme is considered as the one with dual purposes of flood mitigation and hydropower generation.

d. Flood peak discharge at Guillemard Bridge is aimed at controlling to below 11,000 m^3/sec by the dams to be built in the upstream reaches based on the following reasons:

- Flood water level should be kept within 3 m higher than the ground level (A levee height will be within 5 m at a maximum point as referred to Fig. 6.1).
- Since the present flow capacity ranges from 4,500 m^3/sec at Kota Bharu in the downstream reaches to 11,000 m^3/sec in the upstream reaches of Guillemard Bridge (refer to Fig. 6.2), the design flood peak discharge of 11,000 m^3/sec is not considered to be heavy burden for levee construction, and levee with height lower than 5 m can be constructed even for the highest case (refer to Fig. 6.3).
- The relocation of existing and under-construction bridges should be avoided (refer to Fig. 6.3).
- The treatment of tributaries against backwater from the Kelantan River should be in the reasonable extent.
- Treatment of interior water should be in the reasonable range.
- Influence to the existing irrigation facilities should be minimized (for example, reconstruction of water intake facilities caused by the river bed deepening with a large scale).
- As intangible factors, the separation of local communities by levee should be avoided, and the change of micro-climate at local places should be minimized.

6.2.2 Selection of damsites for flood mitigation

In order to study the flood mitigation plan by flood mitigation dam, potential dam sites were selected from the basin area concentrating in the river stretch between Kuala Krai and about 150 km upstream from the confluence with Galas and Lebir rivers, since further upstream stretches form a steep river bed slope and reservoir storage sufficient for flood mitigation cannot be ensured.

The site selection was made based on the topographic map with a scale of 1 to 63,360, and 15 potential damsites were identified in this study as shown in Fig. 6.4 (refer to Appendix-2 of Annex VI); six sites in the Galas River, one site in the Pergau River, four sites in the Nenggiri River and four sites in the Lebir River. The longitudinal profile for these 15 potential damsites is illustrated in Fig. 6.5.

The screening to select the damsites suitable for the flood mitigation of the Kelantan River was carried out for the identified 15 damsites. As a result, Dabong, Kemubu, Nenggiri and Lebir are eventually selected as promising schemes in terms of flood peak reduction. Further discussions on screening process are referred to Annex VI of Part I.

6.2.3 Comparison of social impacts among four dam schemes

Village, commercial and industrial establishment, public institution, infrastructures, irrigation and agricultural lands and so on have been developed along the upstream stretches of the selected damsites. The construction of dam requires the relocation of these existing facilities, and the extent of the facilities to be relocated will increase in proportion to the scale of the reservoir area.

In order to clarify the extent of the social impacts due to the submergence of reservoir, the relationship between dam height and facilities to be relocated was investigated based on the newly obtained topographic map with a scale of 1 to 10,000 for the conceivable Dabong and Kemubu reservoir areas and available data for the Nenggiri and Lebir reservoir areas.

Figs. 6.6, 6.7, 6.8 and 6.9 show the relationship between the dam height and facilities to be relocated for four schemes. Fig. 6.6 shows that the majority of the villages, public institutions and infrastructures submerges even if the dam with about 23 m in height is constructed at the Dabong site. It also shows that if relocation of the existing railway has to be avoided, the dam height is obliged to be limited to less than 20 m, resulting in no substantial flood mitigation effect.

Fig. 6.10 depicts the relative social impact among the Kemubu, Nenggiri and Lebir dam schemes, presenting a large number of households to be submerged in the Kemubu scheme compared with the Lebir and Nenggiri schemes, whilst the Lebir scheme is the greatest in the plantation area.

6.2.4 Combination plans of flood mitigation dams and river improvement

In order to study the flood mitigation plan by means of flood mitigation dam, four dam schemes, i.e. Nenggiri, Kemubu, Dabong and Lebir, were selected. For these flood mitigation dams, three heights were examined in evaluating the flood mitigation effect; the minimum, medium and maximum scales.

The minimum scale is planned to lower the dam height as much as possible to minimize the social impacts. The dam height is decided by coinciding the crest of spillway with the sediment deposit level in the reservoir. The spillway has the scale capable of releasing P.M.F.

The maximum scale is the same as the one selected in the optimization study for flood mitigation and water utilization in preceding Chapter 5. The medium scale has the intermediate scale between the minimum and maximum.

Table 6.1 shows the relationship among the scale of dam and spillway, flood space in the reservoir, and flood peak discharge of inflow and outflow, whilst the relationship between the scale of dam and spillway and flood peak discharge at Guillemard Bridge is given in Table 6.2.

Besides the independent plan of each dam scheme, the study was carried out for the plans combined with the selected four schemes. The combination alternatives selected by considering the mutual exclusiveness of schemes are as follows:

(i) Dabong + Lebir
(ii) Dabong + Lebir + Nenggiri
(iii) Kemubu + Lebir
(iv) Lebir + Nenggiri.

For these four combination plans, three kinds of the dam scale; that is, the minimum, medium and maximum are contemplated. The consideration of three dam scales for the above combination plans and the independent plan of each dam scheme results in 48 alternatives; 12 alternatives prepared from the independent plan of each dam scheme, whilst 9 alternatives each for the combination plans of (i), (ii), (iii) and (iv).

In combination plan of (ii), only the minimum scale is considered for the Dabong dam scheme, because DFWL on the medium and maximum scales of the Dabong dam scheme is higher than the riverbed elevation of the Nenggiri dam scheme (refer to Table 6.1); that is, the Dabong and Nenggiri dam schemes are only compatible in case of the minimum scale of the Dabong dam scheme.

In relation with the Kemubu and Nenggiri dam schemes, DFWL of the Kemubu dam scheme is higher than the riverbed elevation of the Nenggiri dam scheme even in the minimum scale, resulting in the mutual exclusiveness between the Kemubu and Nenggiri dam schemes in terms of flood mitigation. However, the relation between the tailwater level of El. 65.5 m (refer to Annex VI of Part I) for the Nenggiri dam scheme and NHWL of the Kemubu dam scheme, El. 65.7 m in the maximum scale, suggests that even if the Kemubu dam scheme is built, the Nenggiri dam scheme can be developed as the scheme with the objective of hydropower generation. It is noted that the proper treatment will be required for the toe end of the downstream slope of the Nenggiri dam, since the reservoir water level of the Kemubu dam scheme has high chances to become higher than the toe end of the downstream slope of Nenggiri dam.

Table 6.3 shows the 48 combination plans so prepared as well as the reduction of flood peak discharge at Guillemard Bridge, while Table 6.4 gives the construction cost required for the flood mitigation schemes combined the river improvement with the dam plan as well as the extent of social impacts caused by the creation of reservoirs for respective dam schemes. The economic viability for the flood mitigation plans was also examined in terms of EIRR.

6.2.5 Selection of suitable flood mitigation plan

A total of 48 combination plans as given in Tables 6.3 and 6.4 was prepared by varying dam height of the Dabong, Kemubu, Nenggiri and Lebir dam schemes as discussed in the preceding Section 6.2.4. Among 48 combination plans, only 15 combinations could meet the basic concept that flood peak discharge at Guillemard Bridge is aimed at controlling to below 11,000 m^3/sec by the dams to be built in the upstream reaches as summarized in Table 6.5.

Those 15 combination plans were grouped into two based on social impact, i.e. the number of households to be submerged in the reservoir as follows:

(a) Households to be submerged are 1,000 to 1,500

(b) Households to be submerged are 5,000 to 7,500.

The combination plans with the submerged households of more than 5,000 were discarded due to great social impact caused by the relocation of houses; that is, all the combinations including Dabong are eliminated.

Only three combinations, Ks+Ll+R/I, Km+Ll+R/I and Kl+Ll+R/I, are grouped in (a), i.e. relatively small number of households to be submerged in the reservoir (1,000 to 1,500). The difference on the flood mitigation effect of Kemubu dam is little in Ks to Kl (refer to Table 6.2). Thus, Kemubu with a small scale is selected to minimize the social impact. The general features of Ks are summarized as follows (refer to Fig. 6.11 on social impacts):

Dam crest elevation	73.4 m
DFWL	71.4 m
SWL	
- 50-year flood	63.1 m
- 25-year flood	62.3 m
NHWL	55.0 m
Submerged houses, nos	1,000
Submerged plantation, ha	
- SWL (25-year flood)	430
- SWL (50-year flood)	450
- Dam crest elevation	970
Submerged forest, ha	
- SWL (25-year flood)	750
- SWL (50-year flood)	790
- Dam crest elevation	1,910

On the other hand, Lebir is selected to be optimal with a large scale. Considering the submergence of a large area by building Lebir with a large scale, a study to search the possibility to lower the dam was tried by keeping the almost same flood mitigation effect with large scale dam (Ll) as well as the possibility of water resources development. An ordinary overflow weir for flood mitigation was provided in the spillway to lower the dam by keeping the almost same flood mitigation effect with

Ll. As a result, Ll′ is proposed. Comparison of Ll and Ll′ on the social impacts to be expected is tabulated below (refer to Fig. 6.12):

Items	Ll, m	Ll′, m
Dam crest elevation	91.1	84.9
DFWL	87.6	81.4
SWL		
- 50-year flood	84.9	78.0
- 25-year flood	84.4	77.2
NHWL	80.0	70.0
Submerged houses, nos	165	156
Submerged plantation, ha		
- SWL (25-year flood)	12,200	8,300
- SWL (50-year flood)	12,450	8,700
- Dam Crest Elevation	17,130	12,450
Submerged forest, ha		
- SWL (25-year flood)	6,800	5,000
- SWL (50-year flood)	7,000	5,300
- Dam Crest Elevation	8,600	7,000
Peak Discharge at Guillemard Bridge, cms		
- 50-year flood	10,720	10,650

The above table shows that if the Lebir large scale dam is initially developed as the scheme for single purpose plus some possibility for water resource development, the area of plantation to be submerged is reduced to 12,450 ha compared with 17,130 ha for hydroelectirc power scheme. In addition, 12,450 ha can be further reduced to about 8,700 ha if only land submerged by 50-year probable flood is considered.

A detailed comparison between Ll and Ll′ on social impacts is given in Fig. 6.13. Since Ll′ makes possible to reduce social impacts by keeping the same flood mitigation effect with Ll, Ll′ is recommended as the plan of Lebir scheme. Thus, the combination plan of Ks + Ll′ + R/I is proposed as an optimal plan of flood mitigation in the Kelantan River basin.

Reservoir water level comes up to El. 78.0 m with the frequency of once in 50 years in Ll′. Since this implies that water level goes above El. 78.0 m with quite rare chances, agricultural activities in the reservoir above El. 78.0 m can be allowed, while construction of structures such as houses, roads, bridges and so on is restricted up to the dam crest elevation (refer to Fig. 6.14). Fig. 6.15 depicts the acreage of plantation areas at dam crest elevation and that at surface water level for 50-year probable flood for Ll′, while Fig. 6.16 is for a 25-year probable flood.

The schemes to proceed in the pre-feasibility study stage are Lebir and Kemubu dam schemes and river improvement between Kuala Krai and the estuary. It is noted that the Lebir dam will be designed with the possibility to make dam higher for hydropower generation use in future as given in Fig. 6.17.

Finally, a conceptual feature of the master plan for the Kelantan River flood mitigation is sketched as given in Fig. 6.18.

6.3 Implementation Schedule

6.3.1 General

The flood mitigation of the Kelantan River basin was decided to carry out by the combination plan of the Lebir and Kemubu dams and river improvement. Considering the scale of project in terms of construction cost, period and so forth, a study was carried out to prepare a realistic time schedule for the implementation of this project.

The main things to be taken in consideration are to increase the substantial flood mitigation effect as early and much as possible considering the even distribution of financial burden.

6.3.2 Implementation period

It is not considered 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" 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, totalling M$22,895 million. On the other hand, the construction cost required for this project is M$1,302 million.

Although the construction cost of the project shares 5.7% of allocation to the energy and public utilities sector, it would be possible to implement the project by giving the high priority as the national project. As a conclusion, it would be adequate to implement the project for 20 years from sixth to ninth Malaysia Plan for avoiding excessive investment for the project, even if a greater allocation in the development budget would be necessary to the project.

6.3.3 Implementation order

The Lebir and Kemubu dam schemes and river improvement will be implemented step by step for the investment period of 20 years. The implementation order of those schemes in the investment period will be studied by classifying into dam schemes and river improvement.

(1) Implementation order of dam schemes

A simulation study of flood for the selected combination plan was carried out to predict probable peak discharges and hydrographs at the designated point, Guillemard Bridge, by applying a hydrological simulation model called storage function method.

As the results are summarized as given in Table 6.6, the simulation was carried out in the condition that not only both Lebir and Kemubu schemes are completed, but also either of them is built. In this simulation, it is assumed that inundation occurred at the reaches between Kuala Krai and Guillemard Bridge is confined in the river channel by river improvement (R/I).

The building of Lebir dam decreases the peak discharge of 50-year probable flood from 17,400 m^3/sec under R/I only to 12,900 m^3/sec, while 15,800 m^3/sec only with the Kemubu scheme and 10,650m^3/sec with both Lebir and Kemubu schemes.

The above fact implies that the flood mitigation effect of the Lebir dam scheme is greater than that of the Kemubu dam scheme. It is therefore desired to implement both projects in the order of Lebir and Kemubu to gain the greater flood mitigation effect as early as possible. It takes six years for the construction of Lebir which is built as the rockfill type, while four years for Kemubu, which is built as the concrete gravity type.

(2) Implementation order of river improvement

The height of levee, which is the main work of river improvement, is 4.3 m on an average including the freeboard of 2.0 m against the design flood discharge of 10,650 m^3/sec.

Urban areas developed along the Kelantan River sporadically exist in the rural areas which are extensively used for agricultural development. Considering the high investment effect of the urban areas, the implementation programme of river improvement was prepared by dividing the riparian areas into the urban and rural areas.

The river course of the Kelantan River is re-divided as shown in Fig. 6.19, considering the independence of river improvement works, work quantity and the difference of investment effect in the urban and rural areas. The independence of river improvement works means that the river improvement works of a certain river stretch located in the low elevation can bear the substantial flood mitigation effect by connecting the levee to the high place located at the uppermost end of that reach. In other words, the independence of river improvement works on a certain river stretch cannot be ensured without a high place free from flooding at the uppermost end of that stretch.

The urban area of Kota Bharu is in DR2, while DL2 for Pasir

Mas, DL5 for Tanah Merah and DR6 for Kuala Krai. The information of population, population density, potential damage and so on for each division is summarized in Table 6.7. It can be said that the flood damage potential in the downstream river stretches and urban river stretches is higher than that of the upstream river stretch.

On the other hand, the flow capacity of the Kelantan River for each river division increases towards upstream reaches as given in Fig. 6.20. Taking into account the potential damage against flood and flow capacity, the river improvement works will be carried out from the downstream reaches towards the upstream reaches. It is noted that actual river improvement works in each river division is carried out from the uppermost and to the lowermost end.

(3) Overall implementation programme for the project

An implementation programme for the flood mitigation plan of the Kelantan River basin was prepared as shown in Fig. 6.21 based on the discussions of implementation order of dam schemes and river improvement mentioned in the preceding Sub-sections.

River improvement works of urban and rural areas are respectively commenced at the beginning of 1993 following the pre-requisite work such as feasibility study, financing, detailed design and tendering. The river improvement works of the urban areas will be completed by year 2000 or by the end of seventh Malaysia Plan to gain the benefit from flood mitigation as early as possible, while the river improvement works of the rural areas will be finished by year 2010.

The construction of the Lebir dam scheme will be started at the beginning of year 1993 following the pre-requisite work, and will be completed by the end of year 1998. Out of pre-requisite work, the feasibility study has been finished with the objective of hydropower generation, so that the feasibility study started in year 1990 will only be limited to the review work of it. On the other hand, the Kemubu dam will be built by the end of year 2010 for avoiding the intensive investment in sixth and seventh Malaysia Plans.

The disbursement schedule based on the implementation programme given in Fig. 6.21 is prepared as presented in Table 6.8. The relatively heavy financial burden is charged in sixth and seventh Malaysia Plans compared with the eighth and ninth Malaysia Plans.

The implementation of schemes based on Fig. 6.21 will gradually increase the protection level for floods. As an example, the river improvement works for the river division of DR2 (Kota Bharu area), which will be completed at the end of 1996, will make free from some 8-year flood as shown in Fig. 6.22. Furthermore, the protection level will increase by 20-year by the completion of the Lebir dam scheme at the end of year 1998. The final introduction of the Kemubu dam scheme in year

2010 will increase the protection level upto a 50-year flood, which is the flood mitigation target of the Kelantan River basin.

For other river divisions, construction of the Lebir dam in 1998 raises the substantial flood mitigation effect in a considerable level (refer to Fig. 6.22). This implies that the earlier implementation of the Lebir dam scheme is recommendable for the basin-wide mitigation of the Kelantan River.

VII. RECOMMENDATION FOR NON-STRUCTURAL MEASURES

7.1 General

As discussed in the preceding Chapters, all the river stretches extended in the downstream reaches of the Kelantan River, flood-prone area, are planned to be protected from a 50-year flood with the structural measures by combining flood mitigation dams and river improvement.

Non-structural measures such as flood zoning, restriction of development, land use change and resettlement of population are normally applied to the flood-prone areas where the structural measures cannot be economically viable or will not be implemented over the foreseeable future. Since the flood-prone areas in the downstream reaches of the Kelantan River will be protected with such structural measures as dams and river improvement in the foreseeable future, the application of non-structural measures such as flood zoning, restriction of development, land use change and resettlement of population is not conceived to be necessary for the flood-prone area in the downstream reaches of the Kelantan River.

Flood proofing of houses by means of elevated floor is commonly applied with individual basis in the flood-prone area of the Kelantan River. Considering the frequency of floods and time requirement for the dam construction and river improvement works, the construction of new houses with elevated floor is encouraged as one of measures for the flood mitigation in the Kelantan River basin. The guidance to construct new houses to the high elevation or newly protected areas is another measure for the flood mitigation in the Kelantan River basin.

There is no comprehensive flood mitigation plan by structural measures; that is, flood threat still remains even after the introduction of structural measures for flood mitigation. A flood forecasting and warning system will be introduced for mitigating the remaining flood threat as the reinforcement of the structural measures. Furthermore, flood mitigation by flood proofing requires the prediction of a coming flood for the advance preparation. In this sense, the introduction of flood forecasting and warning system is desired.

In fact, a flood forecasting and warning system was introduced for the entire Kelantan River basin in 1971, and was renewed in 1986 as discussed in the preceding Section 2.6, Existing Flood Forecasting and Warning System. Therefore, the improvement of existing flood forecasting and warning system is recommended as the non-structural measure for the flood mitigation in the Kelantan River basin.

7.2 Recommendation for Non-Structural Measures

A forecasting and warning system introduced in the Kelantan River basin consists of a real time water level and rainfall telemetric system. The Tank Model and the stage correlation techniques have been applied with much success over the years in forecasting the flood water levels which are then used in the release of flood warning to public. As explained in the preceding Section 2.5, the fact that inhabitants in the flood-prone areas evacuated to safe places when the warning of emergency level was issued shows that the flood forecasting and warning system in the Kelantan River basin functions well. Therefore, the current issue is to improve further reliability of flood prediction.

At present, the prediction of flood runoff relies on six telemetered rain gauges scattered over the 12,000 km^2 catchment area. Although the flood forecasting model used had predicted the flood discharges/levels quite well at Guillemard Bridge, the reliability of the model prediction can be further enhanced by having a higher density and well distributed telemetric outstations. Over the catchment area upon close inspection on the present telemetric network, it is recommended to install a new telemetered rainfall station in the Nenggiri River basin. In case that a dam or dams are built in the upper basin, the existing flood forecasting model shall be modified, and additional combined telemetric rainfall and water level stations shall be installed at the dams to facilitate in the flood prediction.

At present the flood forecasting and warning operation by the State DID in Kota Bharu is manned by State hydrological staff and backed-up by the Flood Forecasting Centre in DID Kuala Lumpur. In order to ease the data processing and decentralising the flood operation to the State DID, it is recommended to install micro-computer based link-up system to the existing telemetric terminal station at Kota Bharu. If the dams are built, new flood forecasting model would be required. Hence, training in the model development and its forecasting operation are required for the new system.

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 Annual Max. Peak Discharge at Guillemard Bridge

No.	Year	Peak Discharge (cms)	No.	Year	Peak Discharge (cms)
1	1941	2,030	24	1964	1,610
2	1942	11,480	25	1965	6,170
3	1943	4,630	26	1966	16,000
4	1944	5,230	27	1967	8,280
5	1945	12,850	28	1968	1,700
6	1946	3,970	29	1969	6,650
7	1947	13,580	30	1970	8,800
8	1948	3,420	31	1971	5,550
9	1949	7,050	32	1972	10,260
10	1950	8,090	33	1973	11,130
11	1951	2,600	34	1974	4,490
12	1952	1,970	35	1975	5,247
13	1953	4,060	36	1976	2,610
14	1954	4,550	37	1977	2,525
15	1955	2,310	38	1978	3,291
16	1956	2,580	39	1979	10,400
17	1957	6,050	40	1980	1,711
18	1958	1,500	41	1981	2,028
19	1959	3,440	42	1982	7,172
20	1960	3,610	43	1983	12,007
21	1961	2,700	44	1984	7,744
22	1962	3,410	45	1985	1,722
23	1963	2,790	46	1986	6,901

Note : Data from 1941 to 1974 --- "The Kelantan River Basin Study (ENEX)", 1977

Data from 1975 to 1986 ---- Observed data by D.I.D.

Table 2.3 Existing Bridges over the Kelantan River and Its Tributaries

No.	Name	Road/ Railway	River	Distance from the estuary	Dimensions, m			Administration office	Year of construction	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 2.4 Existing Pumping Stations in the Kelantan River

No.	Name	Location from Pasir Mas	Left/right bank	Features: No. of pumps	Features: Capacity, cms	Features: Intake design level, m	Administration office	Year of construction	Remarks
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 3.1 Present Irrigable Area and Maximum Irrigation Water Demand for the Kelantan River

Irrigation Scheme	Irrigation Area (ha)	Annual Peak Demand (cms)	Monthly Demand during Off Season				
			Mar. (cms)	Apr. (cms)	May (cms)	Jun. (cms)	Jul. (cms)
Kemubu	19,200	43.3	38.1	43.3	26.4	23.0	23.3
Salor	890	2.2	1.8	2.2	1.2	1.2	1.1
Lemal	9,805	22.1	19.5	22.1	13.5	13.5	11.9
Pasir Mas	1,905	4.3	3.8	4.3	2.6	2.6	2.3
	31,800	71.9	63.2	71.9	43.7	40.3	38.6

Source: "KADA II Improvement Project, 1982"

Table 3.2 **Maximum Capacity of Pumping Stations for Irrigation on the Kelantan River**

Pumping Station	Year of Completion	Controlled by	Original Design Capacity (cms)	Present Available Capacity (cms)	Projected Capacity (cms)
(1) Kemubu (Old)	1971	KADA	28.3	10.8	10.8
(2) Salor	1948	KADA	2.0	1.7	2.0
(3) Lemal	1963	KADA	18.3	18.3	24.0
(4) Pasir Mas	1956	KADA	4.3	3.4	6.0
(5) Kemubu (New) 1/	1990	DID/KADA	37.2	-	37.2
(6) Others				-	4.0-5.0

Source: Interview from "Mechanical Division of KADA" and "Kemasin-Semerak Project Office, DID".

Note: 1/ The pumping station is being implemented by DID and will be maintained by KADA after its completion.

Present total available capacity : 35 cms
Total capacity projected in 1990 : 80 cms
Total capacity projected for the period 2000 to 2005 : 85 cms

Table 3.3 Record of Past Irrigated Area

Year	Off-season		Main-season	
	Area Irrigated ('000 ha)	Percentage to Whole Irrigable Area (%)	Area Irrigated ('000 ha)	Percentage to Whole Irrigable Area (%)
1975	22.3	70	28.0	88
1976	21.7	68	22.4	70
1977	25.4	80	26.0	82
1978	25.7	81	23.0	72
1979	21.3	67	21.0	66
1980	21.4	67	22.3	70
1981	19.1	60	16.2	51
1982	18.1	57	21.6	68
1983	18.8	59	41.3	13
1984	24.2	76	19.7	62

Source: KADA Statistical Digest

Table 3.4 Maximum Supply Capacity for Domestic and Industrial Water

Water Source	District for Water Supply	Name of Supply System	Maximum Capacity (Mld)	Year of Commission
Kelantan River	(1) Pasir Mas	Kg.Kelar	22.70	1983
	(2) Tanah Merah and Machang	Tanah Merah	20.43	1984
	Total		43.13	
Ground Water	(1) Kota Bharu	Kg.Puteh	25.06	1935
		K.Krian	12.00	1935
		P.Geng	1.00	1976
		Tg.Mas	9.08	1978
		P.Chepa	3.27	1950
	(2) Tumpat	Wakaf Baru	18.16	1984
	(3) Bachok	Kg.Chap	2.27	1978
		Kg.Jelawat	0.82	1978
	(4) Pasir Mas	R.Panjang	0.74	1978
	Total		72.40	
Others	(1) Pasir Puteh	Wakaf Bunut	18.16	1983
	(2) Tanah Merah	Air Lanas	0.50	1980
	Total		18.66	
	Grand Total		134.19	

Source: "Water Supply in Northern Kelantan, 1986"

Table 3.5 Present Use of Domestic Water

Item	Unit	Actual Results 1980	Actual Results 1985
(1) Average Supplied Water			
from Kelantan River	Mld	0	24
from Ground water,etc.	Mld	39	52
Total		39	76
(2) Average Consumed Water	Mld	20	Data Not Available
(3) Served Population	'000 people	147	230
(4) Coverage of Public Water Supply	%	19.5	25.6
(5) Supply Loss ((1) - (2)/(1))	%	48.7	Data Not Available
(6) Per Capita Consumption ((2)/(3))	l/day.person	137	Data Not Available

Source: "Water Supply in Northern Kelantan, 1986" and "Kelantan Development Statistics, 1987".

Note: The present use of domestic water is estimated for the lower reaches of Kelantan River covering the districts of Kota Bharu, Tumpat, Pasir Mas, Tanah Merah, Machang, Bachok and Pasir Puteh.

Table 3.6 Industrial Water Demand in Kelantan State as of 1985

Type of Industry	Value of 1/ Industrial Output (Mil.M$)	Unit Water Use 2/ per Industrial Output (l/day/M$)	Potential Water Demand (Mld)
Rubber Manufacture	69.2	0.085	5.88
Food/Tobacco	33.2	0.080	2.66
Chemicals	11.5	0.150	1.73
Wood Product	105.5	0.015	1.58
Textiles	31.3	0.075	2.35
Non-Metal	10.2	0.070	0.71
Basic Metal	0.8	0.050	0.04
Machinery	30.0	0.020	0.60
Publishing	4.3	0.010	0.04
Miscellaneous	4.2	0.050	0.21
Total	300.2		15.80

Note: 1/ Estimated based on the publishment of Department of Statistics, Malaysia.

2/ Estimated from the results of sumpling survey carried out by JICA Study Team for "National Water Resources Study, Malaysia 1982".

Table 3.7 Maximum Supply Capacity for Major Industrial Estates in Kelantan State

Name of Estate	District	Water Source	Max.Capacity (Mld)
Pengkalan Chepa I	Kota Bharu	Ground Water	4.5
Pengkalan Chepa II	Kota Bharu	Ground Water	2.4
Tanah Merah	Tanah Merah	Kelantan River	20.9
Jeli	Kuala Krai	Kelantan River	2.0
Kemubu	Kuala Krai	Kelantan River	0.1
Gua Musang	Gua Musang	Kelantan River	0.1
Total			30.0

Source: "Kelantan Development Statistics, 1987"

Table 3.8 Future Irrigable Area and Irrigation Water Demand for the Kelantan River

Year	Cumulate Irrigable Area (ha)	Cumulate Annual Peak Demand (cms)	Irrigation Scheme to be Developed		Off Season Demand					Main Season Demand				
			Name of Irrigation Scheme	Irrigable Area (ha)	Mar. (cms)	Apr. (cms)	May (cms)	Jun. (cms)	Jul. (cms)	Sep. (cms)	Oct. (cms)	Nov. (cms)	Dec. (cms)	Jan. (cms)
1990	35,697	72.7	Kemubu	19,200	38.1	43.3	26.4	23.0	23.3	8.3	14.3	3.1	13.2	21.5
			Salor	890	1.8	2.2	1.2	1.2	1.1	0.4	0.7	0.1	0.6	1.0
			Lemal	9,805	19.5	22.1	13.5	13.5	11.9	4.2	7.3	1.6	6.7	11.0
			Pasir Mas	1,905	3.8	4.3	2.6	2.6	2.3	0.8	1.4	0.3	1.3	2.1
			Bendang Jah	120	0.3	0.3	0.2	0.2	0.2	0.1	1.0	0.0	0.9	0.2
			Kemasin	3,775	0.7	0.5	5.4	4.2	2.7	-	-	-	-	-
			Total	35,697	64.2	72.7	49.3	44.7	41.5	13.8	24.7	5.1	22.7	35.8
1995	46,382	81.4	Semerak	7,745	1.6	1.7	10.4	10.4	5.1	-	-	-	-	-
			Ulu Lemal	2,130	4.5	5.1	3.1	2.7	2.8	1.0	1.7	0.4	1.6	2.5
			Bagan II	810	1.7	1.9	2.4	2.1	1.0	0.4	0.6	0.1	0.6	1.0
			Total	10,685	7.8	8.7	15.9	15.2	8.9	1.4	2.3	0.5	2.2	3.5
2000 to 2010	50,002	84.6	Others	3,620	1.6	3.2	1.7	1.7	1.5	0.5	0.9	0.1	1.7	1.6

Source: (1) "KADA II Improvement Project, 1982"
(2) "Kemasin-Semerak Integrated Rural Development Project, 1979"
(3) "Water Supply Study in Northern Kelantan, 1986"
(4) Interview from Kemasin-Semerak Project Office.

Table 3.9 Future Domestic and Industrial Water Demand (1/2)

Item	Unit	Actual	Projected 1990	1995	2000	2005	2010
I. Domestic water		(As of 1980)					
(1) Population 1/	'000 people	850	1075	1205	1348	1505	1680
(2) Coverage of Water Supply	%	19.5	80	90	100	100	100
(3) Per Capita Demand Excluding Supply Loss	l/day	137	200	210	220	230	240
(4) Supply Loss	%	48.7		30.0	30.0	30.0	30.0
(5) Per Capita Demand Including Supply Loss	l/day	265	286	300	314	329	343
(6) Water Demand							
- Gross (1)x(2)x(5)	Mld	44	246	325	423	495	576
- from Kelantan River 2/	Mld	-	155	234	332	404	485
II. Industrial Water		(As of 1985)					
(1) Annual Growth rate 1/ of GDP	%	6.25 (1986-1990)	(..................6.0..................) (1991-2010)				
(2) Percentage of Industrial 1/ Product to GDP	%	12.9	13.9	14.1	14.4	14.7	14.7
(3) Growth Rate of Industrial Product		1.0	1.5	2.0	2.7	3.7	5.0
(4) Water Demand							
- Gross (Demand in 1980)x(4)	Mld	16	24	32	43	59	80
- from Kelantan River	Mld	16	24	32	43	59	80

- to be continued

Table 3.9 Future Domestic and Industrial Water Demand (2/2)

Item	Unit	Actual	Projected				
			1990	1995	2000	2005	2010
III. Domestic and Industrial Water Demand							
- Gross	Mld		270	357	466	554	656
- from Kelantan River	Mld		159	266	375	463	565

Notes: 1/ Estimated on the basis of "Population and Housing Census, 1980 and the projections given in "Kelantan Regional and Township Development Project, 1987".

2/ Water demand from Kelantan River is estimated by subtracting the maximum supply capacity of ground water as of 1985 from the gross water demand.

Table 3.10 Gross Water Demand for the Kelantan River

Item		Demand (cms)
1.	Present Max. Supply Capacity (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 3.11 Installed Capacity of National Grid Network Projected in 1991

Type of Station	Installed Capacity (MW)
1. Hydro Power Station	
(1) Sultan Yussuf (Jor)	100
(2) Sultan Idris (Woh)	150
(3) Chenderoh	40
(4) Bersia	72
(5) Kenering	120
(6) Temengor	348
(7) Kenyir	400
(8) Sungai Pia	64
Sub-total	1294
2. Thermal Power Station	
(1) Gas Turbine	1427
(2) Steam Oil	405
(3) Steam Coal	600
(4) Combined Cycle	1173
Sub-total	3605
Grand Total	4899

Table 3.12 Demand Forecast for National Grid Network

Year	Annual Generation (TWH)	System Peak Load (MW)
1986	13.236	2268
1990	17.520	2984
1995	24.495	4142
2000	33.449	5615
2005	44.952	7546

Notes: 1/ Demand in 1986 is actual value.

2/ Demand from 1995 to 2005 is forecasted by NEB.

Table 3.13 Alternative Plan for Hydro-power Generation (1/2)

Dam	Description	Unit	Alternative							
Lebir	NHWL	EL.m	65	70	75	80	85	90		
	LWL	EL.m	56	59	61	70	75	81		
	Live Storage Volume	MCM	460	678	1192	1192	1645	1645		
	TWL	EL.m	27	27	27	27	27	27		
	Firm Discharge	cms	55	65	75	75	80	80		
	Max. Discharge	cms	220	260	300	300	320	320		
	Install Capacity	MW	67	87	112	126	147	162		
	Dependable Capacity	MW	59	73	88	110	130	149		
	Firm Energy	GWH/yr.	145	188	242	272	318	349		
	Secondary Energy	GWH/yr.	93	91	80	87	76	81		
	Total Energy	GWH/yr.	238	279	322	359	394	430		
Dabong	NHWL	EL.m	54	56	58	60	62	64	66	67
	LWL	EL.m	48	48	47	52	52	55	58	58
	Live Storage Volume	MCM	407	640	910	916	1213	1213	1213	1524
	TWL	EL.m	26	26	26	26	26	26	26	26
	Firm Discharge	cms	160	180	200	200	220	220	220	240
	Max. Discharge	cms	640	720	800	800	880	880	880	960
	Install Capacity	MW	144	171	200	215	246	261	275	303
	Dependable Capacity	MW	137	158	172	193	218	235	250	269
	Firm Energy	GWH/yr.	310	370	432	464	531	564	595	654
	Secondary Energy	GWH/yr.	317	309	295	312	293	307	322	289
	Total Energy	GWH/yr.	627	679	727	776	824	871	917	942

Note: NHWL; Normal High Water Level
LWL; Low water Level
TWL; Tailrace Water Level

- to be continued

Table 3.13 Alternative Plan for Hydro-power Generation (2/2)

Dam	Description	Unit	Alternative					
Nenggiri	NHWL	EL.m	135	140	145	150	155	160
	LWL	EL.m	130	136	140	146	150	155
	Live Storage Volume	MCM	253	253	344	344	442	546
	TWL	EL.m	65.5	65.5	65.5	65.5	65.5	65.5
	Firm Discharge	cms	75	75	80	80	85	90
	Max. Discharge	cms	300	300	320	320	340	360
	Install Capacity	MW	175	188	213	227	255	284
	Dependable Capacity	MW	168	182	206	221	249	277
	Firm Energy	GWH/yr.	378	405	461	490	550	613
	Secondary Energy	GWH/yr.	205	218	204	215	196	176
	Total Energy	GWH/yr.	583	623	665	705	746	789

Note: NHWL; Normal High Water Level
LWL; Low water Level
TWL; Tailrace Water Level

Table 3.14 Configuration of Alternative Thermal Power Station

Alternative No.	Composition of Thermal Plant	Plant Factor	Unit Fix. Cost (M$/KW.YR)	Unit Var. Cost (M$/KWH.YR)
(1)	Gas Turbine (GT) + Combined Cycle (CC)	0.1 (GT) 0.7 (CC)	70.782 109.211	0.054 0.041
(2)	Gas Turbine (GT) + Steam Coal (SC)	0.1 (GT) 0.7 (SC)	70.782 215.114	0.054 0.026
(3)	Gas Turbine (GT) + Steam Oil (SO)	0.1 (GT) 0.7 (SO)	70.782 148.245	0.054 0.062
(4)	Gas Turbine (GT)	0.25	70.782	0.054
(5)	Combined Cycle (CC)	0.25	109.211	0.041

Table 3.15 Unit Cost of Thermal Power Plant

Plant Type	Item	Unit	Value
Steam Oil	1. Installation Cost	M$/KW	2116
	2. Fix. O/M Cost	M$/KW	7.3
	3. Var. O/M Cost	M$/KWH	0.002
	4. Fuel Cost		
	(1) Buying Price	M$/t	437
	(2) Calorific Value	Kcal/l	9700
	(3) Equivalent Price	M$/Mcal	0.045
	(4) Heat Rate	Kcal/KWH	2400
	(5) Standard Cost	M$/KWH	0.108
Steam Coal	1. Installation Cost	M$/KW	1800
	2. Fix. O/M Cost	M$/KW	23.0
	3. Var. O/M Cost	M$/KWH	0.001
	4. Fuel Cost		
	(1) Buying Price	M$/t	114
	(2) Calorific Value	Kcal/l	6500
	(3) Equivalent Price	M$/Mcal	0.018
	(4) Heat Rate	Kcal/KWH	2500
	(5) Standard Cost	M$/KWH	0.045
Combined Cycle	1. Installation Cost	M$/KW	1541
	2. Fix. O/M Cost	M$/KW	13.8
	3. Var. O/M Cost	M$/KWH	0.002
	4. Fuel Cost		
	(1) Buying Price	M$/MBTU	7.8
	(2) Equivalent Price	MS/Mcal	0.031
	(3) Heat Rate	Kcal/KWH	2300
	(4) Standard Cost	M$/KWH	0.071
Gas Turbine	1. Installation Cost	M$/KW	1000
	2. Fix. O/M Cost	M$/KW	0.96
	3. Var. O/M Cost	M$/KWH	0.003
	4. Fuel Cost		
	(1) Buying Price	M$/MBTU	7.8
	(2) Equivalent Price	M$/Mcal	0.031
	(3) Heat Rate	Kcal/KWH	3000
	(4) Standard Cost	M$/KWH	0.093

Table 3.16 Comparative Characteristics of Power Plant

Item	Thermal Power				Hydro Power
	Steam Oil	Steam Coal	Combined Cycle	Gas Turbine	
Life Time (yr.)	25	25	20	15	50
Construction Time (yr.)	5	5	3	2	7
Transmission Loss (%)	3.0	3.0	1.0	1.0	5.0
Forced Outage (%)	15.0	15.0	10.0	20.0	0.5
Auxiliary Power Use (%)	5.0	7.0	2.0	2.0	0.5
Overhaul (%)	15.0	15.0	10.0	10.0	1.0
Annual Investment Rate during Construction Period (%)					
Year 1	-	-	-	-	5
2	-	-	-	-	10
3	5	5	-	-	25
4	25	25	-	-	25
5	40	40	10	-	20
6	20	20	70	40	10
7	10	10	20	60	5

Table 3.17 Economic Benefit of Hydropower Generation

Dam	Normal High Water Level (EL.m)	Dependable Capacity (MW)	Average Annual Energy (GWH)	Benefit Derived from Corresponding Cost of Thermal Plant	
				Alter. 1/ No.	Annual 2/ Benefit (Mil.M$/yr)
Lebir	90	149	430	1	35.16
	85	130	394	1	31.53
	80	110	359	1	27.85
	75	88	322	1	23.87
	70	73	279	1	20.34
	65	59	238	1	17.01
Dabong	67	269	942	1	71.03
	66	250	917	1	67.90
	64	235	871	1	64.24
	62	218	824	1	60.32
	60	193	776	1	55.53
	58	172	727	1	51.10
	56	158	679	1	47.45
	54	137	627	1	42.89
Nenggiri	160	277	789	1	64.88
	155	249	746	1	60.00
	150	221	705	1	55.21
	145	206	665	1	51.82
	140	182	623	1	47.40
	135	168	583	1	44.12

Notes: 1/ Alternative No.1: Gas Turbine + Combined Cycle,
Alternative No.2: Gas Turbine + Steam Coal,
Alternative No.3: Gas Turbine + Steam Oil,
Alternative No.4: Gas Turbine,
Alternative No.5: Combined Cycle.

2/ Assuming discount rate of 10%.

Table 3.18 Economic Farm Gate Price of Paddy

(Unit : M$/ton)

	Item	Price in 1988
1.	Export Price of Thai 5% Brokens, FOB Bangkok	650
2.	Grade Adjustment (less 10%)	-65
3.	Ocean Freight & Insurance	75
4.	CIF at Port Klang	660
5.	Port Handling	22
6.	Transportation from Klang to Kota Bharu	92
7.	Wholesale Price, Kota Bharu	774
8.	Transportation, KADA Area to Kota Bharu	-4
9.	Ex-mill Price, KADA Area	770
10.	Paddy Equivalent, KADA Area	501
11.	Milling Cost	-44
12.	Farm-gate Price	457

Source : The Lebir Dam Project, JICA and Half-Yearly Revision of Commodity Price Forecasts, Feb. 1988, World Bank.

Table 3.19 Production Cost of Paddy

Description	Unit	Production Type A	Production Type B	Production Type C
1. Mechanical working Item		Land Prep.	Land Prep./ Harvesting	Land Prep./ Harvesting
2. Planting method		Trans-planting	Trans-planting	Direct Seeding
3. Harvesting time	day	150	130-140	130-140
4. Area in percentage to entire paddy cropping area	%	85	10	5
5. Production cost				
5-1 Land preparation	M$/ha	228.00	225.00	330.00
5-2 Field levelling	M$/ha	-	-	20.00
5-3 Planting	M$/ha	292.50	300.00	70.00
5-4 Manuring	M$/ha	222.80	222.80	204.70
5-5 Pest/Disease control	M$/ha	122.25	122.25	312.00
5-6 Harvesting	M$/ha	425.00	333.00	370.00
5-7 Land tax	M$/ha	6.80	6.80	6.80
5-8 Irrigation fee	M$/ha	25.00	25.00	25.00
5-9 Total	M$/ha	1,322.35	1,234.85	1,338.50

Average Production Cost = M$ 1,314.4/ha
((4) x (5))

Source : Farm Budgets 1987, Kelantan SEPU, Malaysia