社会開発調査部報告書

GOVERNMENT OF MALAYSIA

STUDY
ON
KELANTAN RIVER BASIN-WIDE
FLOOD MITIGATION

FINAL REPORT

PART II

PRE-FEASIBILITY STUDY
ON
COMBINATION PLAN
OF
LEBIR DAM, KEMUBU DAM AND RIVER IMPROVEMENT

(MAIN REPORT)

NOVEMBER, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

A List of Reports

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   (Main Report)

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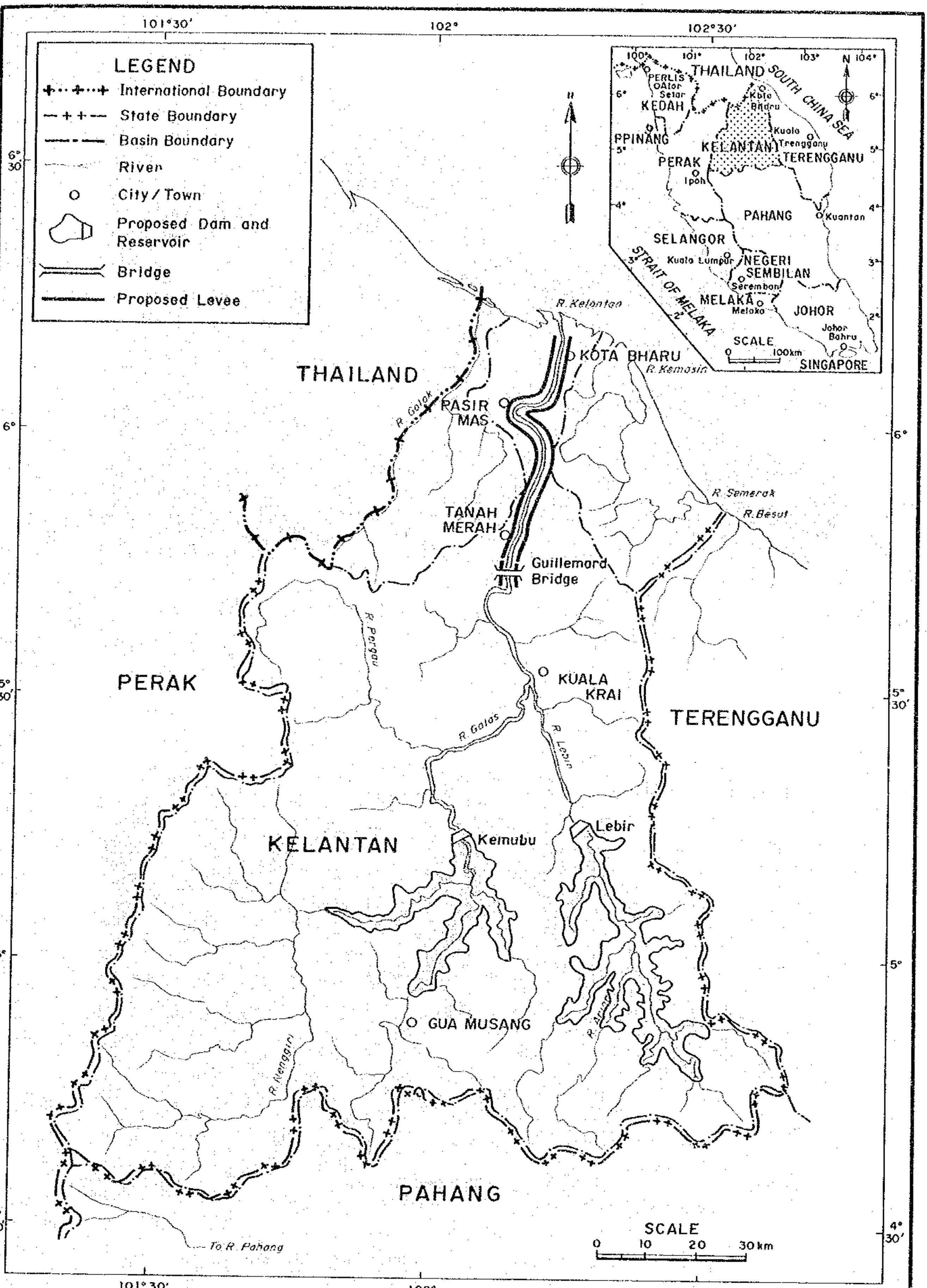

LOCATION OF PROJECT AREA

GOVERNMENT OF MALAYSIA
STUDY
ON
KELANTAN RIVER BASIN - WIDE FLOOD MITIGATION
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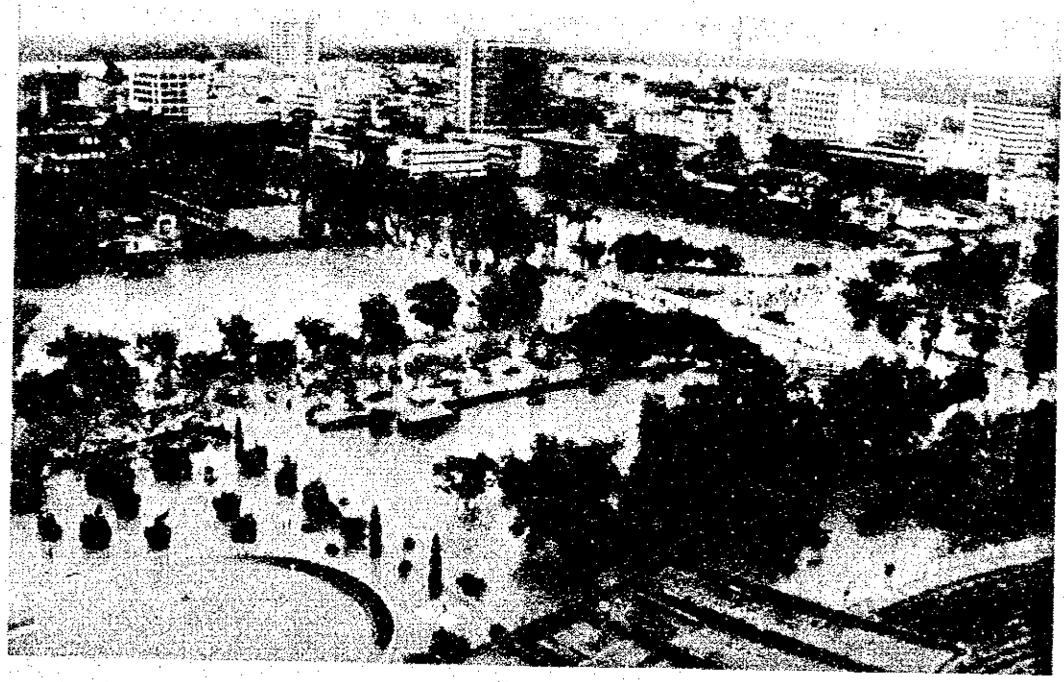

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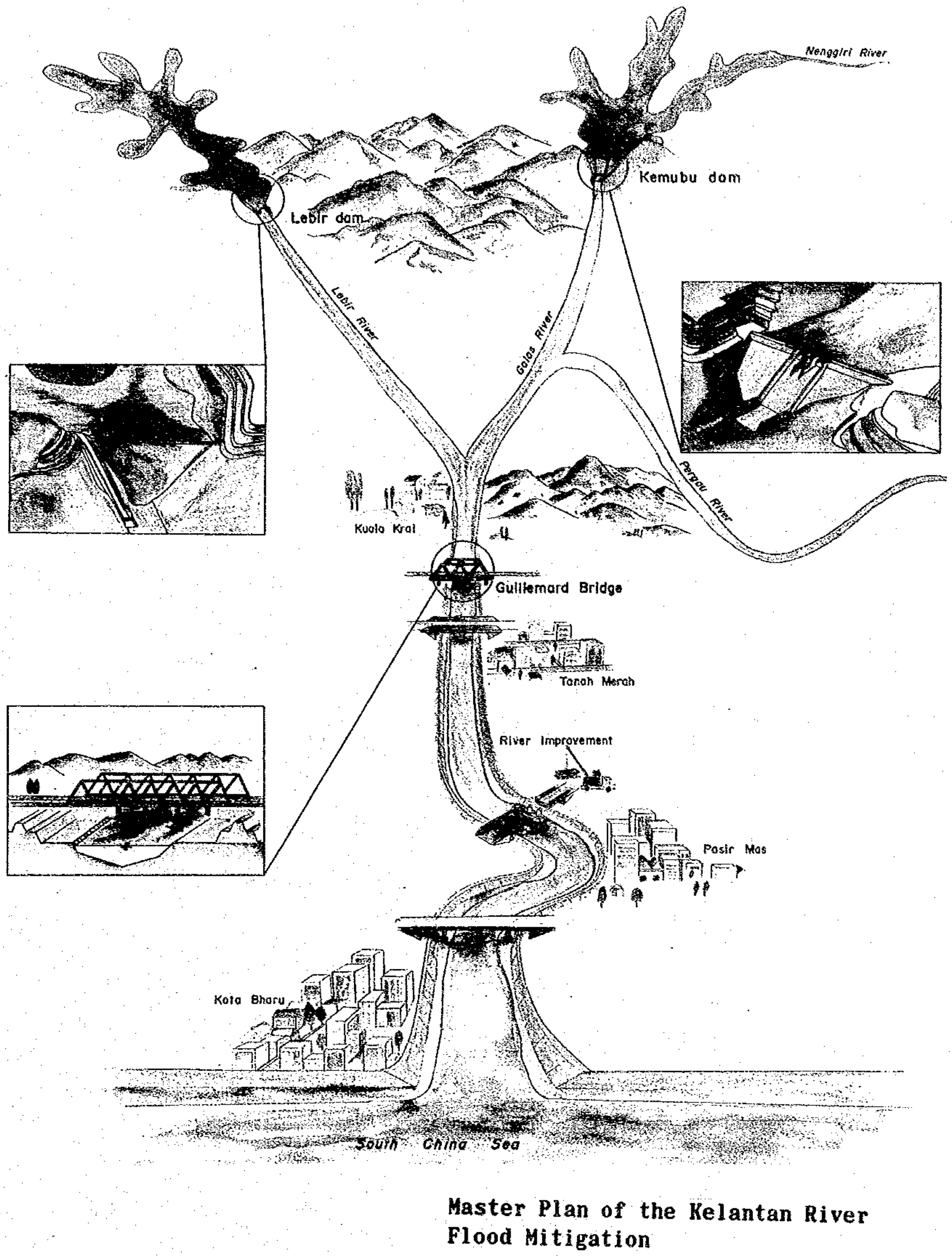

Master Plan of the Kelantan River Flood Mitigation

PRE-FEASIBILITY STUDY

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ABBREVIATIONS

Domestic Organization

DID (JPT)	:	Drainage and Irrigation Department
DOA	:	Department of Agriculture
DOE	:	Division of Environment
DOF	:	Department of Forestry
DOFS	:	Department of Fishery
DOM	:	Department of Mines
DOS	:	Department of Statistics
EPU	:	Economic Planning Unit
FAMA	:	Federal Agricultural Marketing Authority
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
GSD	:	Geological Survey Department
ICU	:	Implementation and Coordination Unit
JOA	:	Orang Asli Department
KADA	:	Kelantan Agricultural Development Authority
KESEDAR	:	South Kelantan Development Authority
MARDI	:	Malaysian Agricultural Research and Development Institute
MHA	:	Ministry of Home Affairs
MIDA	:	Malaysian Industrial Development Authority
MLRD	:	Ministry of Land and Regional Development
MMS	:	Malaysian Meteorological Service
MNRD	:	Ministry of National & Rural Development
MOA	:	Ministry of Agriculture
MOE	:	Ministry of Education
MOF	:	Ministry of Finance

MOH : Ministry of Health

MOPI : Ministry of Primary Industries

MPE : Ministry of Public Enterprises

MPKB : Majilis Perbandaran Kota Bharu

MRRDB : Malaysian Rubber Research and Development Board

NDPC : National Development Planning Committee

NEB (LLN) : National Electricity Board

PORIM : Palm Oil Research Institute of Malaysia

PWD (JKR) : Public Works Department

RDA : Regional Development Authority

RISDA : Rubber Industry Small-holders Development Authority

RRIM : Rubber Research Institute of Malaysia

SEDC : State Economic Development Corporation

S(E)PU : State (Economic) Planning Unit

UDA : Urban Development Authority

International and Foreign Organizations

ADB : Asian Development Bank

IBRD : International Bank for Reconstruction and Development

JICA : Japan International Cooperation Agency

MOC : Ministry of Construction, Japan

WMO : World Meteorological Organization

Others

BOD : Biochemical Oxygen Demand

CIF : Cost, Insurance and Freight

COD : Chemical Oxygen Demand

DFWL : Reservoir Design Flood Water Level

El. : Elevation above Mean Sea Level

Eq.	:	Equation
Fig.	:	Figure
FSL	:	Reservoir Full Supply Level
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
Kg.	:	Kampung
NHWL	:	Reservoir Normal High Water Level
O&M	:	Operation and Maintenance
PMF	:	Probable Maximum Flood
PMP	:	Probable Maximum Precipitation
Ref.	:	Reference
SWL	:	Reservoir Surcharge Water Level

ABBREVIATIONS OF MEASUREMENT

Length

mm = millimetre
cm = centimetre
m = metre
km = kilometre
ft = foot
yd = yard

Area

cm^2 = square centimetre
m^2 = square metre
ha = hectare
km^2 = square kilometre
sq.km = square kilometre
$mile^2$ = square mile

Volume

cm^3 = cubic centimetre
l = lit = litre
kl = kilolitre
m^3 = cubic metre
gal. = gallon
MCM = million cubic metre

Weight

mg = milligram
g = gram
kg = kilogram
ton = metric ton
lb = pound

Time

s = sec = second
min = minute
h = hr = hour

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt
GW = Gigawatt
kWh = kilowatt hour
GWh = Gigawatt hour

Other Measures

% = percent
^{o} = degree
' = minute
" = second
^oC = degree in centigrade
10^3 = thousand
10^6 = million
10^9 = billion (milliard)

Derived Measures

m/s = metre per second
m^3/s = cubic metre per second
cms = cubic metre per second
cusec = cubic feet per second
mg/l = milligram per litre
Mld = million litre per day
kWh = kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
kWh/y = kilowatt hour per year
kVA = kilovolt ampere

Money

M$ = Malaysian ringgit
US$ = US dollar

LIST OF ANNEX

I. INTRODUCTION

1.1 Background

The Kelantan River lying in the north-eastern part of Peninsular Malaysia originates from the mountain ridge which is the border with the State of Perak (refer to Location Map). A total catchment area is 13,100 km^2. Meandering the hilly areas in the upper and middle reaches northwardly and collecting major tributaries of the Pergau and Lebir rivers, the Kelantan River comes in the plain where the majority of Kelantan people reside practising agriculture.

Although the Kelantan River brings enormous benefits to the people as a water source of water supply, irrigation, power generation and so on, the people lived in the downstream reaches on the other hand suffer from habitual flooding.

Especially, rainstorms occurred in January, 1967 caused an overflow of the Kelantan and its adjacent rivers including tributaries, resulting in inundation of the entire coastal area of the Kelantan State. According to the Flood Report of 1967, the inundation area spreads over 3,000 km^2 which is equivalent to 20 percent of the Kelantan State area. Inhabitants of 540,000, 85 percent of state population of 637,000, including the evacuated persons of 125,000 suffered from flooding, and damages were estimated to be a historical maximum.

Annually repeating floods of the Kelantan River bring not only extensive economic losses and human sufferings, but also the threat of floods contributes to such negative psychological attitudes that farmers tend to be reluctant to adopt modern agricultural technology, and industrialists would refrain from investing in flood prone areas.

In this circumstance, the Government of Malaysia requested to the Government of Japan technical assistance to formulate a basin-wide flood mitigation plan of the Kelantan River. In response to the request of Government of Malaysia, the Government of Japan sent a mission to Malaysia on November, 1987, and it was agreed by both governments that the study to formulate a basin-wide flood mitigation of the Kelantan River would be carried out under the Japanese technical assistance.

The study to formulate a basin-wide flood mitigation plan was commenced in April, 1988 under the cooperative work of Drainage and Irrigation Department (DID) and Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programmes of the Government of Japan.

1.2 Outline of the Project

A combination plan of the Lebir and Kemubu dam schemes with river improvement was selected to be suitable for the basin-wide flood mitigation plan of the Kelantan River and mentioned in Part I. The pre-feasibility study for those three schemes is successively discussed in this Part II.

The Lebir dam scheme is located in the Lebir River, at about 138 km upstream from the river mouth or about 36 km upstream from the Galas confluence. The main project features are summarized as follows:

Dam crest elevation	:	84.9 (91.1) m
SWL	:	78.0 (84.9) m
NHWL	:	70.0 (80.0) m
Flood control volume	:	860 million m^3
Type of dam	:	rockfill
Embankment volume	:	4.9 million m^3
Construction cost	:	M$500 million.

The Lebir dam scheme is planned to develop in two stages. In the first stage, the dam with a smaller scale is built so as to keep the almost same flood mitigation effect as that for the second stage. The reservoir space below NHW is used for augmenting irrigation water.

The normal high water level (NHWL) is raised by 10 m from El. 70.0 m to El. 80.0 m in the second stage for ensuring the reservoir capacity for hydropower generation. The figures in parentheses show the features in the second stage.

The Kemubu dam scheme is situated in the Galas River at about 167 km upstream from the river mouth. The main project features are summarized as follows:

Dam crest elevation	:	73.4 m
SWL	:	63.1 m
NHWL	:	55.0 m
Flood control volume	:	307 million m^3
Type of dam	:	concrete gravity
Concrete volume	:	150,000 m^3
Construction cost	:	M$226 million

The Kemubu dam scheme is built exclusively for flood mitigation of the Kelantan River Basin.

The river improvement is carried out for the 100 km long river stretches between Kuala Krai and the estuary. The main features of river improvement are as follows:

Total levee length	:	164 km
- Urban area	:	29 km
- Rural area	:	135 km
Embankment volume	:	13.2 million m^3
Average levee height	:	4.0 m
Construction cost	:	M$576 million
- Urban area	:	M$165 million
- Rural area	:	M$411 million

1.3 Contents of Report

The report in this study consists of five parts. Part I consisting of main and supporting reports deals with the formulation of a basin-wide flood mitigation plan in the Kelantan River basin.

Part II consisting of main and supporting reports discusses the pre-feasibility study of Lebir and Kemubu dam schemes as well as river improvement. The specification on the study of river mouth treatment, which will be carried out in future, is also attached in Part II. Part III deals with the survey for 1988 flood.

Part IV contains the survey result of geological investigation carried out at the Kemubu and Dabong damsites. Meanwhile, the result of longitudinal and cross-sectional survey carried out between Kuala Krai and the estuary is complied in the Data Book (Part V). The Executive Summary briefs the major outcomes in this study.

II. PROJECT AREA

2.1 Natural Condition

2.1.1 Topography and river features

The Kelantan River basin with a catchment area of 13,100 km^2 locates in the northeastern part of Peninsular Malaysia, occupying more than 85% of the Kelantan State (refer to Location Map). The basin is bounded by the State of Perak and Thailand on the west, by the State of Pahang on the south and by the State of Terengganu on the east. The northern part of the basin faces the South China Sea.

The Kelantan River is divided into the Galas and Lebir rivers just at the upstream reach of Kuala Krai, about 100 km upstream from the river mouth. The Galas River is further divided into the Nenggiri and Pergau rivers. The Nenggiri River originates from the central mountain range in the southwestern part of the State of Kelantan, and flows down northeastward collecting many tributaries and changing its name to the Galas River.

The Galas River joins the Pergau River near Dabong, flows down eastward and joins with the Lebir River which originates from the Taban mountain range. After joining the Lebir River with the Galas River, the river changes its name to Kelantan and flows down northward passing along such major towns as Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu, finally debauching to the South China Sea near Kota Bharu. A total river length is about 360 km.

2.1.2 Meteorology and hydrology

(1) Meteorology

The climate in the State of Kelantan is characterized by the seasonal monsoon. The north-east monsoon, which prevails mainly from October to December, brings heavy rainfall in the coastal plain. Around 50% of annual rainfall, which is about 2,700 mm, occurs in the coastal plain on an average during these three months. This downpour in this period causes habitual flooding in the downstream areas of the Kelantan River, resulting in suffering from flood damages.

In the upstream river basin, however, there is no distinctive rainy season because of the rain shadow effect under the lee of coastal plain and the south-west monsoon which is generally less vigorous than the north-east monsoon, prevailing from May to September.

The mean annual temperature at Kota Bharu (5 m a.m.s.l) is 26.7^{o}C on January to 27.9^{o}C on May. The variation of temperature depends upon a diurnal change ranging from 23^{o}C at 6 o'clock in the morning to 30^{o}C at 2 o'clock in the afternoon.

According to the data at Tanah Rata meteorological gauging station (1,470 m a.m.s.l) which locates in the State of Pahang about 20 km south from the state boundary of Kelantan and Pahang, the mean annual temperature is 18.1°C on an average and there is also a slight seasonal change ranging from 17.4°C on January to 18.8°C on May.

As well as the pattern of monthly average temperature, there is no significant change of relative humidity throughout the year. The annual mean relative humidity at Kota Bharu is 81% ranging from 79% on March to 86% on November, whilst 87% varying from 83% on February to 90% on November at the Tanah Rata station.

Daily sunshine hours have been recorded at the Kota Bharu and Tanah Rata stations. The annual mean daily sunshine hours are about five hours at Tanah Rata and about seven hours at Kota Bharu.

Average surface wind velocity is relatively low ranging from 0.24 m/sec at Kg. Lalok and 1.1 m/sec at Tanah Rata. The fastest instantaneous wind velocity of 45.9 miles/hour (20.5 m/sec) was recorded during the flood in 1967 at Kota Bharu on January 5, 1967.

According to the data collected in and around the State of Kelantan, the annual pan evaporation amount is 961 mm at Tanah Rata and 1,749 mm at Kota Bharu.

(2) Hydrology

The Kelantan River is generally characterized as the river with ample flow replenished by abundant rainfall of the basin. The mean flow of the Kelantan River is 540.6 m^3/sec at Guillemard Bridge, a stream gauge located just upstream of Tanah Merah, over the period of 1961 to 1984, which is equivalent to the annual runoff of 1,411.3 mm for the catchment area of 12,080 km^2.

The seasonal variation of flow shows the lowest level in April with an average of 282.2 m^3/sec, whilst the north-east monsoon occurred between November and December brings the highest rate of runoff with an average of 1,121.8 m^3/sec. The period of July and August has slightly high flow of 315.0 m^3/sec.

The Kelantan River is also characterized by the vast coastal plain and the relatively small flow capacity of river channel. The flow capacity of 5,500 m^3/sec corresponds to the arithmetic average of annual maximum peak discharges at Guillemard Bridge.

The sediment deposit volume in the reservoir of storage dams were estimated based on the other schemes in and around the Kelantan River basin. The average annual sediment deposit volume of 410 m^3/km^2/year was applied to determine Minimum Operating Level (MOL) for the reservoir of storage dams.

Tidal data at Geting locating at the river mouth of the

Golok River is the nearest tidal level gauging station from the river mouth of the Kelantan River. The datum level was set at El. 0.259 m and its HWL was estimated at El. 0.691 m at the river mouth of the Kelantan River.

2.1.3 Geology

(1) General

A geological map of the Kelantan River basin is given in Fig.2.1. High mountains running from east to west in the southern part of the basin consist mainly of granites which are intruded at the Palaeozoic-Tertiary age. The granites, being massive and sound, form the steep mountain slopes.

The hilly areas extended in the middle reaches are predominated by the Palaeozoic-Mesozoic rocks comprising sandstones, shales, limestones, tuffs and volcanics, which are very often metamorphosed regionally into phyllites and slates and further into crystalline schists. Thermal metamorphism due to the granite intrusion is often observed in the formation of hornfels. Particularly, phyllites, slates and schists are deeply weathered because of abundance of cracks and foliations.

Weathering resistant limestones from the high pinnacles with some caves in these-bodies. Granitic masses sporadically intruded in the hilly areas are generally small in size.

Geological structure runs in the north-south or northwest-southeast. The axes of folding and major faults also orient these directions, but they are sometimes intersected by other groups of faults trending northeast to southwest.

The flat areas stretching about 40 km long from the river mouth consist of unconsolidated deposits comprising mainly sand, silt and clayey soil and form the alluvial plain. Dunes formed by the westward littoral current are developed with the 10 km wide band alone the coastline, especially at the estuary of the Kelantan River.

(2) Kemubu damsite

The proposed Kemubu damsite is located at about 18 km upstream from the railway bridge in Kemubu village. At the damsite, the Galas River, passing through a narrow gorge, changes its direction from west to northwest.

The river bed at the damsite is about 40 m wide and around El. 37 m high. The slope on the left bank rises at a gradient of about 45^{o} to 50^{o} up to 15 m in height from the river brink and ends up about 40^{o} above it.

On the other hand, the slope on the right bank rises at a gradient of about 20^{o} up to 10 m in height from the river brink and changes gradient to 40^{o} above it.

The bedrock, massive and comparatively sound, consists mainly of schist which is foliated due to metamorphism. The rock is exposed along the river brink and slopes of both banks, up to 15 - 20 m above the river bed.

Schistosity, parallel to the bedding plane, strikes and dips N60° - 80°W/70° - 80°W. The existence of small scale faults is presumed by the aerophotograph interpretation. However, no fault is expected to deteriorate geological conditions of the damsite judged by the field survey.

(3) Lebir damsite

The proposed Lebir damsite is located at about 3 km upstream from existing Tualang Bridge. The Lebir River forms an incised meander around the damsite, turning its direction from north to south and then returning to north.

The river bed at the damsite is about 150 m wide and El. 26 m high. There exist rapids in the reaches where the dam site.

River terraces are developed on both banks, the top of which is El. 45 m. The terrace on the left bank is narrow, behind which decomposed rocks rise at the gradient of about 16 to 18°. On the right bank, the river terrace is approximately 50 m wide, and the slope above it rises at the gradient of 20°.

Bedrocks underlying the damsite consist mainly of green tuffs, purple tuffs, green tuffaceous sandstones and shales with thin layers of tuffaceous conglomerates. These bedrocks, which are slightly metamorphosed and non-foliated, are hard and massive. Bedding is monoclinic with fairly consistent strike and dip of N40°E/34°SE on an average.

(4) Downstream reaches

Low hilly areas, from Kuala Krai to Kg. Godang, consist mainly of the Permian sedimentary rocks covered with river terrace deposits.

Terrace deposits on both banks of the river are composed mainly of sand and silt, and occasionally gravel and clay. The thickness is estimated to be less than 5 m. The deeply weathered Permian sedimentary rocks sporadically expose on the brinks of the river.

The alluvial plain consists of fluvial and marine deposits. The fluvial deposits are composed mainly of sand, silt, clay, gravel and their alternation. On the other hand, marine deposits consist of medium-coarse sand and organic clayey soil behind rised beaches and dunes.

Both banks of the Kelantan River are mainly covered with soft and loose silt and clay layers as well as their alternation in 5 m to 10 m thickness. Medium-coarse sands with gravels transported by floods remain on the river bed, river bar and some parts of the riverside.

Marine deposits comprising medium-coarse sand and organic clayey soil are distributed at and around the river mouth. Organic clayey soil such as peat is expected to form a soft foundation.

2.2 Socio-economy

2.2.1 General

Malaysia with a land area of 329,745 km^2 is composed of Peninsular Malaysia and the two Regions of Sabah and Sarawak. The State of Kelantan, lying at an eastern part is one of eleven States in Peninsular Malaysia. The State has a land area of 14,943 km^2, accounting for 4.5% of the land area of Malaysia.

The State of Kelantan is composed of ten Districts as shown in Fig. 2.2; Bachok, Kota Bharu, Machang, Pasir Mas, Pasir Puteh and Tumpat in North Kelantan and Tanah Merah, Jeli, Gua Musang and Kuala Krai in South Kelantan. Each District comprises several Daerahs.

Kota Bharu is the capital of Kelantan as well as the development centre of North Kelantan. Gua Musang is on the other hand the development centre of South Kelantan. Six Daerahs including Bandar Kota Bharu in Kota Bharu District are under the jurisdiction of MPKB (Majlis Perbandaran Kota Bharu) or Kota Bharu Municipal Council.

The State has an estimated population of 1,091,756 as of 1988, out of which 78.8% live in the northern sub-region occupying 16.4% of the total land area in the State. On the other hand, the southern sub-region with 83.6% of the State area is the abode of 21.2% of the State people. The population of the State corresponds to 6.4% of the national population.

The State economy is dominated by agriculture with 70% of population, 50% of work force and 30% of GDP. The area of 65% in North Kelantan is used as agricultural land, while 86% of South Kelantan is covered with forests.

The GDP of the State is estimated at M$2,684.4 million in 1988 at market prices, accounting for 3.4% of the national GDP. Per capita GDP works out at M$2,459, which is only a half compared with the national average.

The Kelantan River annually brings extensive economic losses and human sufferings by flooding. Furthermore, the threat of floods contributes to such negative psychological attitudes that farmers tend to be reluctant to adopt modern agricultural technology, and industrialists refrain from investing in flood prone areas.

The mitigation of the flooding of the Kelantan River is a prerequisite to develop the State into a modern economy.

2.2.2 Population

The population of Kelantan is estimated at 1,091,756 in 1988 as shown in Table 2.1. District-wise, Kota Bharu District has the biggest population of 357,995, accounting for 32.8% or almost one third of the State population. The population under the jurisdiction of Kota Bharu town council, MPKB, is estimated at 224,719 in 1988, constituting 20.6% or one fifth of the population of Kelantan. Gua Musang District has the smallest population of 28,198, corresponding to 2.8% of the total population in Kelantan.

The population of Kelantan grew during the last inter-censal period of 1970 to 1980 at the average annual rate of 2.6% (refer to Table 2.1). It is estimated that population is growing at the average annual rate of 2.5% since 1980.

Applying the average annual growth rate for population of 2.5%, the State population is forecasted to grow from 893.8 thousand in 1980 to 1,147.0 thousand in 1990, 1,468.3 thousand in 2000 and 1,879.5 thousand in 2010.

Population growths in all Districts in South Kelantan are greater than the State average. The average annual growth rate in the whole of South Kelantan works out at 3.8% from 1980 to 1988. In contrast, population of all Districts in North Kelantan except Kota Bharu District is growing at a lesser rate than the State average. The population in the whole of North Kelantan is growing at the average annual rate of 2.2% since 1980. The population of Kota Bharu District has grown from 1980 to 1988 at an average annual rate of 2.8%, while a slightly higher rate of 2.9% for the area under MPKB.

The population of North Kelantan will increase from 859.4 thousand in 1988 to 1,354.4 thousand in 2010, whilst 232.4 thousand in 1988 to 525.0 thousand in 2010 for South Kelantan. The population of Kota Bharu District is estimated to reach 658.2 thousand in 2010 from 358.0 thousand in 1988. During the same period the population of area under MPKB which forms the core of the District population will grow from 224.7 thousand to 429.6 thousand.

2.2.3 Economic profiles

(1) Agriculture

Supporting 70% of population, employing 50% of workforce, producing 30% of GDP and using 20% of land area, the agricultural sector plays a major role for the socio-economy of the State.

There are four main crops, i.e. paddy, tobacco, rubber and oil palm. Paddy is the most important crop in the State with the annual planted area of around 70,000 ha and the annual production of about 200,000 tons. The State's share to national paddy production is as much as 13.5%. Paddy is not only consumed within the State, but also exported to other States.

Tobacco is grown under the Federal guidance to lift the economic status of the farmers concerned. Green tobacco leaves of 7 to 9 million tons are annually produced with the planted area of around 10,000 ha. Kelantan's share to the national tobacco production is 80% or so.

Rubber is one of traditional crops in the State. Now replanting of the crop is in progress, and 60% out of 130,000 ha has been replaced with young plants. The State shares about 3% to the total production of rubber with the annual average production of 45,000 tons.

Oil palm is grown like rubber mainly for export. In 1988, Kelantan is estimated to produce 84,000 tons of palm oil over the planted area of 60,000 ha, which will correspond to 1.7% of the total production in Malaysia.

Livestocks, a non-crop product belonging to the primary industry, are important as a supplementary income source to the farmers in Kelantan. In 1988, the State is estimated to have cattle and buffalo population of around 130,000, which will correspond to 15% of the said population over the whole Malaysia. Up to 1988, grazing reserves of 4,178 ha have been developed.

(2) Industry, commerce and service

In 1988, the manufacturing industry in Kelantan is expected to produce the added value of M$121 million and to employ workforce of 23,954. GDP and employment of the manufacturing industry are estimated to be 4.5% and 7.3% for the State total respectively.

Most of the manufacturing industries in the State fall under the category of the so-called agro-industry or the like, i.e. wood, rubber, food and tobacco industries. Undergoing only a primary processing, the resultant products are not high in terms of the added value.

In 1988, commerce and service industries in Kelantan are expected to produce the added value of M$825 million with the total employment of 50,537. The industries comprise wholesale, retail, transport, restaurant, storage, banks, insurance and real estate. GDP and employment are estimated to be 30.7% and 15.4% for the State total respectively.

2.2.4 Gross domestic product

The Gross Domestic Product (GDP) of Kelantan for 1988 is estimated at M$2,684.4 million at market prices, while GDP of Malaysia is estimated at M$78,458 million at market prices for the same year. Therefore, the State GDP as percentage of the national GDP is 3.4%. This ratio is much smaller than the populational ratio of 6.4% as well as the areas "developing" State in Malaysia.

Sector-wise, the agricultural, forestry and fishery sectors will produce an amount of M$772.3 million in 1988, accounting for 28.8% of the State GDP. This sector is the single biggest contributor to the economy of the State. The government services sector is placed second, producing M$677.9 million and sharing 25.2% of the State GDP.

The overall industrial structure of Kelantan is estimated at 28.8% for the primary industry, 11.0% for the secondary industry and 60.2% for the tertiary industry in 1988, while 21% for the primary industry, 37% for the secondary industry and 42% for the tertiary industry in the nation in the same year. One striking feature of the State economy is that the secondary sector is in the low level compared with the primary sector.

The primary industry's contribution to the State employment is 48.3%, while the same sector's contribution to the State economy is 28.8%. It means that the labour productivity of the primary industry in the State is in a great degree lower than the State average. Also, the secondary industry's share in the State employment is 15.5%, while the same sector's share in the State GDP is 11.0%. It implies that labour productivity of the secondary industry in the State is markedly lower than the State average.

According to the SEPU forecast in "5th Malaysia Plan for Kelantan", the state economy will grow from M$1,668.6 million to M$3,060.0 million during the period of 1980 to 1990 at an average annual rate of 6.25%. The JICA Study Team assumed that the slightly low growth rate of 6.0% would be appropriate from 1990 onward. Applying this assumption, economy of Kelantan is forecasted to grow from M$2,684.4 in 1988 to M$9,816.8 million in 2010.

Living standard of Kelantan in terms of per capita GDP for 1988 is calculated at M$2,459 and 1988 prices. The amount is almost equal to US$1,000 at the exchange rate of M$2.50 to US$1.00. It is equal to or higher than per capita GDP's in most of other ASEAN countries. However, it may be about one half of the national average. It is expected to grow from M$2,459 in 1988 to M$5,223 in 2010 (1.8 times) at an average annual rate of 3.4%.

2.2.5 Transportation

Infrastructural deficiency in both quantity and quality has been habitually cited as one of major factors retarding the economic growth of the State, confining it to the traditional agriculture-based self-sufficient economy. The Government has persistently placed the highest priority infrastructural development against such background.

Road length in 1987 is 2,004 km, out of which 1,225 km is State roads and 749 km is Federal roads. Noteworthy events for the last few years are the development of the Kuala Krai-Gua

Musang-Kuala Lipis Highway, Jeli-Dabong-Gua Musang road and East-West Highway. The Kuala Krai Highway links the northern sub-region with the southern sub-region as well as with other States.

The Jeli-Dabong-Gua Musang road connects the Sg. Pergau-Sg. Galas Valley with the new growth centre of Gua Musang, and the East-West Highway links not only Kelantan but also the East Coast with the northern West Coast of Peninsular Malaysia.

Railway runs in parallel with the Kelantan River starting from Tumpat down to Gua Musang and beyond. The total length within the State is 207 km. Besides, the highway and railway networks, there is an air system, which connects Kota Bharu with major cities in Malaysia with several daily flights.

2.3 Land Use

2.3.1 Present land use

Present land use is depicted in Fig. 2.3. As of 1988, 74.4% of the State, 1,504,009 ha, is covered with forest, and another 21.3% is planted with agricultural crops; that is, 95.7% of the State area is occupied by forest and agricultural lands.

Out of 320,583 ha of agricultural land areas in 1988, 129,413 ha or 40.4% is the rubber plantation area, followed by 71,248 ha or 22.2% of paddy fields and 61,261 ha or 19.1% of oil palm plantations. The combined acreage of these three major crops works out at 261,922 ha, accounting for 81.7% of the total State agricultural land area.

Since 1981 the outward expansion of rubber land has stopped. And now an emphasis is upon the intensive utilization of the existing rubber areas by replanting. Distributed all over Kelantan, rubber areas are especially concentrated in the three southern Districts of Kuala Krai, Tanah Merah and Gua Musang.

During 22 years from 1966 to 1988, oil palm plantations have multiplied 123 times from 497 ha to 61,261 ha. This trend will be kept up into future. District-wise, 74.6% of the total oil palm areas in the State are shared by Gua Musang District.

Paddy fields are distributed all over Kelantan, but three Districts of Pasir Mas, Kota Bharu and Pasir Puteh distinguish themselves with more than 10,000 ha of paddy areas. North Kelantan shares 89.5% of total paddy areas in the State.

Tobacco is normally grown in paddy areas. The acreage of tobacco for 1988 in 8,219 ha. District-wise, Bachok, Pasir Puteh and Pasir Mas have the acreage of more than 1,000 ha. North Kelantan dominates in tobacco planting areas with the share of 95.8%.

The Government is making a great effort to develop grazing reserves considering the important place of Kelantan in livestock farming. As of 1988, 4,178 ha has been developed, of which 2,385 ha or 57.1% belongs to Pasir Mas District. North Kelantan shares 89.9% of pasture reserves.

Forest is decreasing along with grasslands and swamps at an average annual rate of 0.4% since 1966. The trend will be maintained or intensified in future as the economic development of Kelantan progresses.

Urban and associated areas composed of urban, estate buildings, mining and power line and other associated areas are estimated at 5,365 ha as of 1988, accounting for 0.4% of the total State land area. Kota Bharu with 2,381 ha occupies 44.4% of the total State urban and associated area.

2.3.2 Future land use

(1) Urban development

Urban areas will continue to expand in future due to the migration of rural population seeking better employment opportunities as well as to the natural increase of urban population.

The area managed by MPKB was declared in 1978 to be urbanized as the development centre of the State. The development plan of MPKB toward year 2000 as given in Fig. 2.4 consists of three development centres with corridors, Bandar Kota Bharu, Kubang Kerian and Pengkalan Chepa. Bandar Kota Bharu will have a function as a pivot of these three development centres as well as the centre of commerce and trading.

The development of Kubang Keria includes the residential and industrial areas as well as Istana Negeri (State Palace)and the campus and hospital of Science University of Malaysia. The development centre of Pengkalan Chepa area will be an airport with the industrial estate, army camp and residential area.

(2) Rural development

The persistent policy of the Government is to narrow down the gap in the standard of living and basic amenities existing between Kelantan and other States.

Agriculture and forestry sectors form the nuclei to achieve socio-economic parity for the Kelantan people. The centerpiece for the development of North Kelantan is more intensive use of agricultural land along with diversification of crops. The development strategy for South Kelantan centres on more extensive use of land for agricultural as well as more systematic approaches for the preservation and utilization of forest.

According to the government policy, rice production will be concentrated on the granary areas; that is, paddy lands in Kelantan will be developed only in the KADA project area as one of eight granary areas in Malaysia. KADA's policy target during the 5th Malaysia Plan period is to increase paddy yields by 0.1

ton per ha per year. Furthermore, the development of KADA granary area is still in progress with the target level of 500 ha a year.

Development of oil palm plantations in South Kelantan will be further stepped up, and oil palm accordingly will jump up from 61,261 ha in 1988 to 140,013 ha in 2010 along such rivers as the Galas and Lebir rivers, which would be almost maximum. Thus, the share of oil palm acreage in the total State areas will rise from 4.1% to 8.0%.

2.4 Existing River and Related Structures along the River

The structures such as bridges, pumping stations, jetties for small fishing ships and so on are located along the Kelantan River and its tributaries as shown in Fig. 2.5.

There are three roadway bridges crossing over the Kelantan and Lebir rivers, connecting with the national road networks. They are Sultan Yahya Putra Bridge crossing at Kota Bharu, Tanah Merah Bridge upstream of the Tanah Merah and a bridge spanning over the Lebir River at about 30 km upstream from the Galas confluence. The superstructures of these bridges are of concrete type and their substructures are constructed by concrete piles or concrete pier structures. A roadway bridge is under construction at Pasir Mas. Furthermore, JKR has a plan to build a roadway bridge at Dabong spanning over the Galas River.

There are four railway bridges crossing over the Kelantan River and its tributaries. They are Guillemard Bridge crossing over the Kelantan River at 15 km upstream of Tanah Merah: Others are on the Galas, Lebir and Nenggiri rivers. The superstructures of these railway bridges are steel truss type and their substructures are concrete pier structures. The scouring at the bottom of the substructures and at both banks in the up and downstream sides of the bridges is not found at present. The features of these bridges are given in Table 2.2.

To supply river water for irrigation use, four pumping stations connected with the main irrigation canals are provided in the downstream reaches of the Kelantan River (refer to Fig. 2.5). They are Kemubu and Lemal pumping stations in the right bank upstream from the Pasir Mas, and Salor and Pasir Mas pumping stations in the left bank up and downstream of the Pasir Mas. There exists a pumping station for water supply of Tanah Merah. The features of these pumping stations are listed in Table 2.3.

There are several wooden-made jetties on the downstream reaches near the estuary. Those are used for unloading the marine products carried by small ships. A jetty is under construction by the Fishery Development Board at Kg. Che Latiff near the estuary (refer to Fig. 2.2). The dredging works with a scale of 5 m deep and 90 m wide is included as part of the project to ensure the access of fishing ships from the sea to the jetty. Dredging of the clogged river mouth will have not only the ensurance of navigation canal, but also advantageous effect for flushing flood discharge.

2.5 Flood Problem and Damage

2.5.1 Rainfall characteristics and past large scale floods

(1) Rainfall characteristics

An isohyetal map of average annual rainfall is prepared using data from 21 rain gauges in the basin as given in Fig. 2.6, showing that annual basin rainfall is 2,700 mm on an average.

The isohyetal map so prepared suggests that annual rainfall in the Pergau River basin is the greatest in the basin with the annual rainfall of 3,200 mm in the Jeli area. On the other hand, an isohyetal line of 2,600 mm a year passes in the Lebir River basin, causing a depression of annual rainfall with the value of 2,200 mm a year in the Galas and Nenggiri river basins. This may be resulted from the lee of the north-east monsoon which brings considerable rainfall in the coastal area (2,800 mm a year).

Table 2.4 and Fig. 2.7 give the distribution of monthly rainfall in the Kelantan River basin, showing that around 50% of annual rainfall on an average occurs from October to December in the coastal plain, while there is no distinctive rainy season and the monthly rainfall depth is evenly distributed in the upstream river basin. The downpour in the period from October to December may endorse the habitual flooding in the downstream area of the Kelantan River.

(2) Past large scale floods

Floods with a magnitude of more than 5,500 m^3/sec occur almost once in two years in the downstream stretches. Among them, the floods occurred in 1967 and 1983 have relatively sufficient data, including hourly rainfall records and data for inundation phenomena.

On 2nd January 1967, heavy rainfall occurred and lasted up to 7th January in the entire Kelantan River basin. The recorded maximum daily rainfall was 585 mm at JPT store, Kota Bharu and 420 mm at Machang P.S. Flood peak discharges at the major gauged were 3,400 m^3/sec at Chegar Atas, 8,700 m^3/sec at Dabong, 4,200 m^3/sec at Tualang and 16,000 m^3/sec at Guillemard Bridge. On 4th January, flood water overtopped the bank of the Kelantan River and the entire coastal plain was inundated. Most of the Kota Bharu town was under water at night time on 4th January.

On 1st December 1983, rain started and lasted up to 15th December in the entire basin area. The maximum rainfall occurred during 3rd to 5th December. The recorded maximum daily rainfall was 290 mm at Machang and 270 mm at Kuala Krai. Flood water overtopped the river bank, and the Kota Bharu town inundated on 5th December. Flood peak discharges were about 1,900 m^3/sec at Chegar Atas, 6,000 m^3/sec at Dabong 4,000 m^3/sec at Tualang and 12,000 m^3/sec at Guillemard Bridge

The floods with double peaks hit the downstream area on November and December of 1988, causing considerable damage. A detail survey for these floods is discussed in the separate Volume (Part III).

2.5.2 Flood flow analysis

The daily rainfall data in the upstream basin for the period of flooding at Guillemard Bridge are not available before 1970, while the records of annual maximum flood peak discharge at Guillemard Bridge are available for the period from 1941 to 1986. The number of samples of annual maximum peak discharge is about two times more than that of basin mean rainfall data.

Furthermore, the second, third and fifth largest floods were recorded in a series of annual maximum peak discharges, while the basin mean rainfall is unable to estimate for those floods because of no rainfall data in the upstream basin.

In the Study, probable rainfall depth of 5-day basin mean was estimated to enlarge the recorded hourly hyetographs.

The recorded hyetographs during the flood in December 1983, December 1984 and November 1986 were enlarged up to the 5-day rainfall depth with the selected return period from which the simulated peak discharge corresponding to the probable peak discharge is derived at Guillemard Bridge.

The probable rainfall depth and probable flood peak discharges at storage damsites, Kuala Krai and Guillemard Bridge are enumerated in Table 2.5.

According to the probable distribution of annual peak discharge at Guillemard Bridge, the peak discharge of 15,589 m^3/sec in 1967 corresponds to the probability of once in about 50-year. The simulated 50-year probable flood hydrograph is verified with the flood hydrograph recorded at Guillemard Bridge in 1967 and shown in Fig. 2.8.

2.5.3 Flood damage

A large magnitude flood in 1967 caused heavy flood damages in the downstream plain areas of the Kelantan River basin. The flood damages exert not only to the destruction of houses, losses of properties and damages to the social infrastructures but also to the loss of lives especially in the riparian areas.

Such major towns along the Kelantan River as Kuala Krai, Tanah Merah and Pasir Mas were inundated at the beginning of January 1967. In the river stretches along Kota Bharu, flood water overtopped the Kelantan River bank on 4th January and inundated gradually the town area. The maximum inundation depth reached about 4 m in the lowest area on 6 to 7th January. The inundation lasted for about 4 to 5 days in the most of the town area and 3 to 4 weeks in the lowest area.

The inundation area at the flood time in 1967 was about 297,900 ha. The flood report, January 1967 states that about 537,000 persons were affected by the flood, about 125,000 persons evacuated from the lowland area and death toll went up to 38 persons in total. It is reported that flood damages in 1967 were about M$30 million in total in the State of Kelantan. Among them, the damage for agricultural crop is estimated at around M$14 million. Among about 17,400 ha of irrigation schemes, 2,800 ha of the acreage corresponding to about 16% of the scheme areas were damaged.

Since December 1966, the Golok River and its tributaries were already in a spate condition and river water partly overtopped the river bank. On 5th January 1967, flood water of the Golok River overtopped the river bank in its entire stretch and inundation depth reached 1.5 m at the Rantau Panjang town and 4.3 m at Kuala Jambu. Overtopped flood water flowed down to the South China Sea at the coast between Tumpat and the river mouth of the Golok River inundating the plain area in the right bank of the Golok River.

The flood occurred in December 1983 also caused damages in the downstream area of the basin. On 4th December, most of the towns along the Kelantan River stretches inundated due to overtopping of flood water. The maximum inundation depth reached about 1 m in Kuala Krai and Tanah Merah, 0.9 m in Pasir mas and 2.6 m in Kota Bharu. The inundation lasted for about one week in the most of the area in Kota Bharu. The inundation area in the basin amounted to about 60,700 ha and about 27,000 persons in the riparian area along the Kelantan River were affected by the flood. The estimated flood damage in the basin is around M$11.4 million comprising M$3.5 million for agricultural crops, M$0.5 million for livestocks and poultry, M$1.0 million for houses, properties and business and M$6.4 million for public services and facilities.

III. BASIC CONCEPT FOR THE DESIGN OF FLOOD MITIGATION PLAN

3.1 General

The flood mitigation plan of the Kelantan River basin was at first formulated by seeking the high economic efficiency as discussed in Annex VIII of Part I; that is, the development of water resources and hydropower generation is added as one of major objectives besides flood mitigation.

As a result, the Dabong dam and river improvement was selected as the most promising plan for the dual objectives of water resources development and flood mitigation. However, this plan requires a large scale relocation of houses, plantations and public facilities, causing considerable social impacts.

The formulation of flood mitigation plan was studied stressing on the minimization of social impacts as mentioned in Annex IX of Part I, so that a combination plan of Lebir and Kemubu dams and river improvement was selected for the flood mitigation of the Kelantan River basin. This Chapter deals with the basic concept for the design of this combination plan.

3.2 Protection Areas and Level from Floods

3.2.1 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.

3.2.2 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 as given in Fig. 3.1 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. 3.2 prepared on basis of the assumptions and conditions mentioned above as well as the inundation map of 1967-flood (refer to Fig. 3.1) 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.

In order to carry out the study on the flood analysis and the selection of flood protection priority areas, the Kelantan River stretches along the flood prone areas are divided as follows:

KL 1 : About 2.5 km long river stretch from the river mouth

KL 2 : 2.5 km from the river mouth to 5 km downstream of Kota Bharu

KL 3 : 5 km downstream of Kota Bharu to 4.4 km upstream of Kota Bharu

KL 4 : 4.4 km upstream of Kota Bharu to 3.2 km downstream of Pasir Mas

KL 5 : 3.2 km downstream of Pasir Mas to 3.2 km upstream of Pasir Mas

KL 6 : 3.2 km upstream of Pasir Mas to 18 km downstream of Guillemard Bridge

KL 7 : 18 km downstream of Guillemard Bridge to 5.7 km downstream of guillemard Bridge

KL 8 : 5.7 km downstream of Guillemard Bridge to 3.8 km upstream of Guillemard Bridge

KL 9 : 3.8 km upstream of Guillemard Bridge to 13.9 km upstream of Guillemard Bridge

KL 10 : 13.9 km upstream of Guillemard Bridge to 9.5 km downstream of Kuala Krai

KL 11 : 9.5 km downstream of Kuala Krai to 1.9 km downstream of Kuala Krai

KL 12 : 1.9 km downstream of Kuala Krai to the confluence of the Galas and Lebir rivers.

The river stretches thus divided are shown in Fig. 3.3. The urban areas of Kota Bharu, Pasir Mas, Tanah Merah belong to the river stretches of KL 3, KL 5, KL 8 and KL 12, respectively.

3.2.3 Flood protection level

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.

Considering the above facts as well as the development of the flood-prone area extended in the downstream reaches and habitual flooding, the flood mitigation Master Plan of the Kelantan River is targeted for a 50-year flood.

3.3 Basic Concept for the Design of Flood Mitigation Plan

The basic concept in designing 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 reason mentioned in the preceding Section 3.2.3.

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 Lebir and Kemubu dams built in the upstream reaches as much as possible for making the burden to the levee lighter.

c. The Lebir and Kemubu dams will be built with a single purpose of flood mitigation to reduce the social impacts. However, there is some space used for water resources development below the space for flood mitigation in the

Lebir scheme. This space is thus used for the augmentation of irrigation water.

d. Design flood peak discharge at Guillemard Bridge is aimed at controlling to below 11,000 m^3/sec by the Lebir and Kemubu dams 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. 3.4).

- 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. 3.5), 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. 3.6).

- The relocation of existing and under-construction bridges should be avoided as far as possible (refer to Fig. 3.6).

- 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.

IV. ENGINEERING STUDIES FOR DAMS AND RELATED STRUCTURES

4.1 General

A combination plan of the Lebir and Kemubu dams and river improvement was selected as the one for the flood mitigation of the Kelantan River basin. This Chapter deals with the Engineering issues of Lebir and Kemubu dam schemes in the pre-feasibility study level.

The Lebir 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. 4.1. The feasibility study of the scheme has been completed by JICA for the purpose of hydropower generation.

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 scheme area. These land development schemes are promoted mainly by KESEDAR and FELDA for oil palm and rubber plantations along the national highway and extending deep into the upper Lebir basin.

Reservoir area and storage capacity are shown in Fig. 4.2, which are derived from the feasibility study of the Lebir dam. The dam type will be rockfill as proposed in its feasibility study.

The Kemubu damsite is located on the Galas River, about 18 km upstream of the Kemubu railway bridge as shown in Fig. 4.3.

The reservoir area and storage capacity are shown in Fig. 4.4. Dam type at this site will be concrete gravity.

4.2 Principle of Flood Mitigation Dam Plan

4.2.1 Proposed flood discharge distribution

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 4.1, the simulation was carried out in the condition that not only both Lebir and Kemubu schemes are completed, but also either of them are built. In this simulation, it is assumed that inundation occurred at the reaches between Kuala Krai and Guillemard Bridge (refer to Fig. VII.2.6 of Annex VII in Part II) 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 (refer to Fig. 4.5), while 15,800 m^3/sec only with the Kemubu scheme (refer to Fig. 4.6) and 10,650 m^3/sec with both Lebir and Kemubu schemes (refer to Fig. 4.7).

The hydrographs of each case are compared at Guillemard Bridge as given in Fig. 4.8. The simulation result under the natural condition, i.e. without structural measures is referred to Fig. 4.9.

4.2.2 Water demand and supply balance

The Kelantan River brings enormous benefits to people in Kelantan as a water source of domestic and industrial water supply, irrigated agriculture development, power generation and so on. Even with ample flow, the Kelantan River decreases its flow in dry seasons, causing salt water intrusion in the downstream reaches. This salt water intrusion affects the irrigation water abstracted in the downstream reaches and groundwater used as potable water in the Kota Bharu area. Thus, river maintenance flow against salt water intrusion is also counted as one of water demands in the Kelantan River basin.

Water demand required for the Kelantan River as discussed in Annex VI of Part I is estimated to increase from the present use of 105.5 m^3/sec as of 1985 to 161.1 m^3/sec in 2010 as summarized in Table 4.2. The water demand in 2010 is further classified into 6.5 m^3/sec for the domestic and industrial water use, 84.6 m^3/sec for the irrigation water use and 70.0 m^3/sec for the river maintenance flow. Irrigation water requires peak demand in April, while other water demands require a constant flow through a year.

The supply capacity of the Kelantan River was estimated by simulating flow data of 24 years from 1962 to 1984 under the natural condition (without dam), so that discharge at Guillemard Bridge becomes 173.8 m^3/sec once in 2 years, whilst 115.4 m^3/sec once in 5 years and 92.3 m^3/sec once in 10 years. The comparison between demand and supply tells that all the demands consisting of domestic and industrial demand, river maintenance flow and irrigation demand can only be satisfied once in 2 years in 2010 or that water deficit of 68.8 m^3/sec, which is equivalent to 81.3% of irrigation demand of 84.6 m^3/sec, will occur once in 10 years.

A storage-draft curve for the Lebir, which has a reservoir space for water resources development, was developed as given in Fig. 4.10. With NHWL of 70.0 m, firm discharge of 65 m^3/sec can be secured. Under the constant release of 65 m^3/sec from the Lebir reservoir, discharge at Guillemard Bridge becomes 193.8 m^3/sec once in 2 years, whilst 151.4 m^3/sec once in 5 years and 133.8 m^3/sec once in 10 years. The construction of the Lebir dam therefore considerably improves the water supply condition, i.e. water deficit once in 5 years is 9.7 m^3/sec (11.5% of irrigation demand), while 27.3 m^3/sec once in 10 years.

In case that NHWL of the Lebir dam is raised by El. 80.0 m for hydropower generation, firm discharge will increase to 75 m^3/sec (refer to Annex VI of Part I), water deficit once in 5 years will be offset. Furthermore, water deficit of 16.5 m^3/sec (19.5% of irrigation demand) will only occur once in 10 years.

4.2.3 Social impacts due to dam construction

The flood mitigation plan of the Kelantan River basin by combing the Lebir and Kemubu dams and river improvement was formulated by minimizing social impacts caused by the creation of Lebir and Kemubu reservoirs. But, the construction of Lebir and Kemubu dams still causes the submergence of considerable areas. following are the summary of social impacts caused by the creation of Lebir and Kemubu reservoirs:

Items	Scheme	
	Lebir	Kemubu
Dam crest elevation, m	84.9	73.4
DFWL, m	81.4	71.4
SWL, m		
- 50-year flood, m	78.0	63.1
- 25-year flood, m	77.2	62.3
NHWL, m	70.0	55.0
Submerged houses, nos	156	1,000
Submerged plantation, ha		
- SWL (25-year flood)	8,300	430
- SWL (50-year flood)	8,700	450
- Dam crest elevation	12,450	970
Submerged forest, ha		
- SWL (25-year flood)	5,000	750
- SWL (50-year flood)	5,300	790
- Dam crest elevation	7,000	1,910

As the land acquisition problem, agricultural activities for the area higher than SWL (the 50-year flood) are allowed, whilst construction of structures such as houses, roads, bridges and so on is restricted up to the dam crest elevation. The relationship between elevation and acreage of plantation including the number of submerged houses is shown in Figs. 4.11 and 4.12 for the Lebir and Kemubu schemes, respectively.

Fig. 4.13 gives the difference between the areas delineated along the dam crest elevation and SWL for the 50-year flood in the Lebir scheme (refer to Fig. 4.14 for the 25-year flood), showing the considerable plantation areas to be saved. On the other hand, the difference of areas corresponding to the dam crest elevation and SWL for the 50-year flood in the Kemubu scheme is shown in Fig. 4.15, while Fig. 4.16 for the 25-year flood.

Relocation is considered as one of appropriate measures to compensate the plantation to be submerged. A survey was carried out to search for the potential areas to relocate the plantation to be submerged, but there scarcely exist appropriate areas for relocation around the Lebir and Kemubu areas. Thus, in the coming feasibility study and detailed design stages, an endeavour should be placed on searching the potential areas to relocate the plantation of 9,150 ha.

4.3 Design of Dam and Related Structures

4.3.1 Design of Kemubu dam scheme

(1) Main dam and spillway

Geological and material investigations consisting of the following items have been carried out at Kemubu damsite for the period from September 1988 to April 1989:

Item	Quantity
1. Field geological mapping	7.5 km^2
2. Core boring	2 holes 40 m each
3. Borehole permeability test	14 nos.
4. Test pitting in the river bed	2 pits
5. Dam construction material test	4 samples

The riverbed at the damsite is about 40 m wide and around El. 37 m high. The slope on the left bank rises at a gradient of about 45^o to 50^o up to 15 m in height from the river brink and ends up about 40^o above it. The slope on the right bank rises at a gradient of about 20^o up to 10 m in height from the river brink and changed gradient to 40^o above it.

The bedrock of the proposed damsite consists of calcareous quarts-mica schist which clearly exposes along the both banks of the damsite. Weathered and decomposed zones (CL) are found at about 5 to 10 m on the left bank and 10 to 15 m on the right bank. Main group of joints run in parallel with the schistocity plane at an interval of 0.5 to 1 m. No major fault is found at the damsite but several minor faults paralle to the schistocity locally appear in the bedrock. The result for core boring shows as follows:

Rock classification		Shear strength	
Rock class	Characteristic	Cohesion (kgf/cm)	Internal friction angle (degree)
CL	Weathered zone or 'cracky' zone	less than 5	30 to 35
CM	Slightly weathered, sound, massive	10 to 15	40 to 45
CH	Sound, massive	20	45 to 50

The bedrocks belonging to CM or CH and are evaluated to be sufficient for construction of 50 m high class concrete gravity dam. No serious deformation is found since foundation is massive and sound.

The proposed quarry site of limestone, which is located at about 5 km south-east of the Kemubu damsite, will be used for concrete aggregate. Sufficient amount necessary for the construction of concrete gravity type dam is available in this quarry site. While, the result of test pitting for the river deposit shows that the sand and sand/gravel in about 2 km downstream and 1 km upstream of the Kemubu damsite can be used for concrete aggregate. However its quantity is limited and besides washing is needed to remove organic matter and wood fragment. Considering the above situation, it is planned to use the limestone of the proposed quarry site for coarse and fine concrete aggregates.

Design of dam and spillway

In order to determine the dimension of the concrete gravity dam, safety factor for sliding was examined by means of the following Henny's formula and following conditions:

Internal friction angle of bedrock; 40° - 45°
Shearing strength of bedrock ; 100 t/m^2
Unit weight of concrete ; 2.3 t/m^3
Coefficient of uplift ; 0.4
Coefficient of silt pressure ; 0.6
Seismic coefficient ; 0.1
Assumed shape of dam body
  Upstream ; vertical
  Downstream; 1:0.80

The safety factor under the four cases of reservoir water level is as follows;

Case	R.W.L(m)	S.F.
I	71.400	4.09
II	63.100	4.96
III	55.000	5.93
IV	-	57.92

Since allowable safety factor is set at 4, the obtained safety factor for all of the case satisfies the requirement.

It is planned to excavate the damsite down to 5 to 10 m at the left bank and 10 to 15 m at the right bank to remove the anticipated weathered and decomposed zones.

The result of the Lugeon test clarifies that the sound rock which lies below 15 m in depth shows impermeability. However, there may be some possibility to encounter the places with high permeability. To improve the layer with probably high permeability, curtain grouting as an interval of 2 m corresponding to the dam height is provided.

In the Master Plan Study, probable maximum floods for Nenggiri, Kemubu, Lower Pergau, Dabong and Lebir were calculated. The hydrological data in the upstream basin, however, are insufficient and not reliable. Then, the largest Creager's coefficient of 55 at Lebir damsite of the above was applied to the other damsites. Finally, the probable maximum flood having peak discharge of 15,000 m^3/sec was adopted at Kemubu damsite.

Normal high water level (NHWL) of the reservoir is set at El. 55 m considering the sediment deposit for a period of 100 years (410 m^3/km^2/year x 5630 km^2 x 100 year ÷ 231 x $10^6 m^3$). Width of spillway is decided at 100 m considering the topographic condition. The design flood water level (DFWL) of reservoir is set at El. 71.4 m considering the retardation effect of peak discharge through the flood routing for probable maximum flood.

The spillway having five spans with 20 m wide and crest elevation of El. 55.0 m is set at the middle part of the concrete dam body considering the extent of excavation volume for construction of the stilling basin. Since there is no reliable flood forecasting system in the reservoir area and it is contemplated to take place miss operation of gates if the spillway gate is provided, non-gated spillway is planned (refer to Figs. 4.17 and 4.18). The elevation of non-overflow portion of dam is determined at El. 73.400 which is estimated by adding 2.0 m to the design flood water level of El. 71.400 considering the wave height due to strong wind of max. 20.0 m/sec and allowance of 0.5 m.

(2) Related structures

Diversion tunnel and cofferdam

The probable flood having a probability ranging from once in 7 months to 2 years is generally applied to the design discharge for diversion facilities of the concrete gravity type dam taking the construction period into considerations.

Since the Kemubu dam is designed as concrete gravity type, the 2-year probable flood which is the largest in the above was adopted for design flood for diversion facilities.

Hydrological analysis shows that the peak discharge of 2-year probable flood is estimated at 1,600 m^3/sec at damsite. Based on the relation among the design flood, dimension of diversion tunnel and dimension of cofferdam, it was determined to provide two lanes of diversion tunnel with a diameter of 9 m and 283 m in length and cofferdam with crest elevation of El. 55.0 m at the upstream of the damsite.

Two lane diversion tunnels with inlet elevation of El. 39 m and outlet elevation of El. 34 m are provided in the right river bank connecting with the river meandering portion. Since the diversion tunnel is aligned through a massive schist zone, only consolidation grouting is planned to be provided.

General plan, profile and typical section of the divedrsion tunnel and cofferdam are shown in Figs. 4.17 and 4.18.

Design of stilling basin

Stilling basin is generally classified into three types considering the existing river condition and dam types as follows:

1) Hydraulic jump type with open chute
2) Ski jump type with open chute
3) Free falling type.

Considering the existing river condition due to curved river course and downstream water level, hydraulic jump type with open chute is selected as referred in Figs. 4.17 and 4.18. Since the stilling basin is formed with a curved portion, it is recommended to perform the hydraulic model test at the detailed design stage to confirm the dimension of its structure.

Access roads to damsite and quarry site

About 5 m wide non-paved road for transportation of timber log connecting Bertam with Gua Musang is located along the left bank of the proposed Kemubu reservoir. This existing road is planned to use as the access road after expanding 5.0 m to 8.0m, and about 5 km long additional road is planned to be provided from this road to the damsite. Since the proposed quarry site is situated just beside the existing road, it is planned to improve the existing road between the quarry site and junction point of the additional road and the existing road. Location of the additional road and the existing road to be improved is shown in Fig. 4.19.

Relocation of railway