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No. 102

GOVERNMENT OF MALAYSIA

STUDY
ON
KELANTAN RIVER BASIN-WIDE FLOOD MITIGATION

PART I

MASTER PLAN STUDY

(SUPPORTING REPORT)

GOVERNMENT OF MALAYSIA

STUDY
ON
KELANTAN RIVER BASIN-WIDE
FLOOD MITIGATION

FINAL REPORT

PART I

MASTER PLAN STUDY

(SUPPORTING REPORT)

NOVEMBER, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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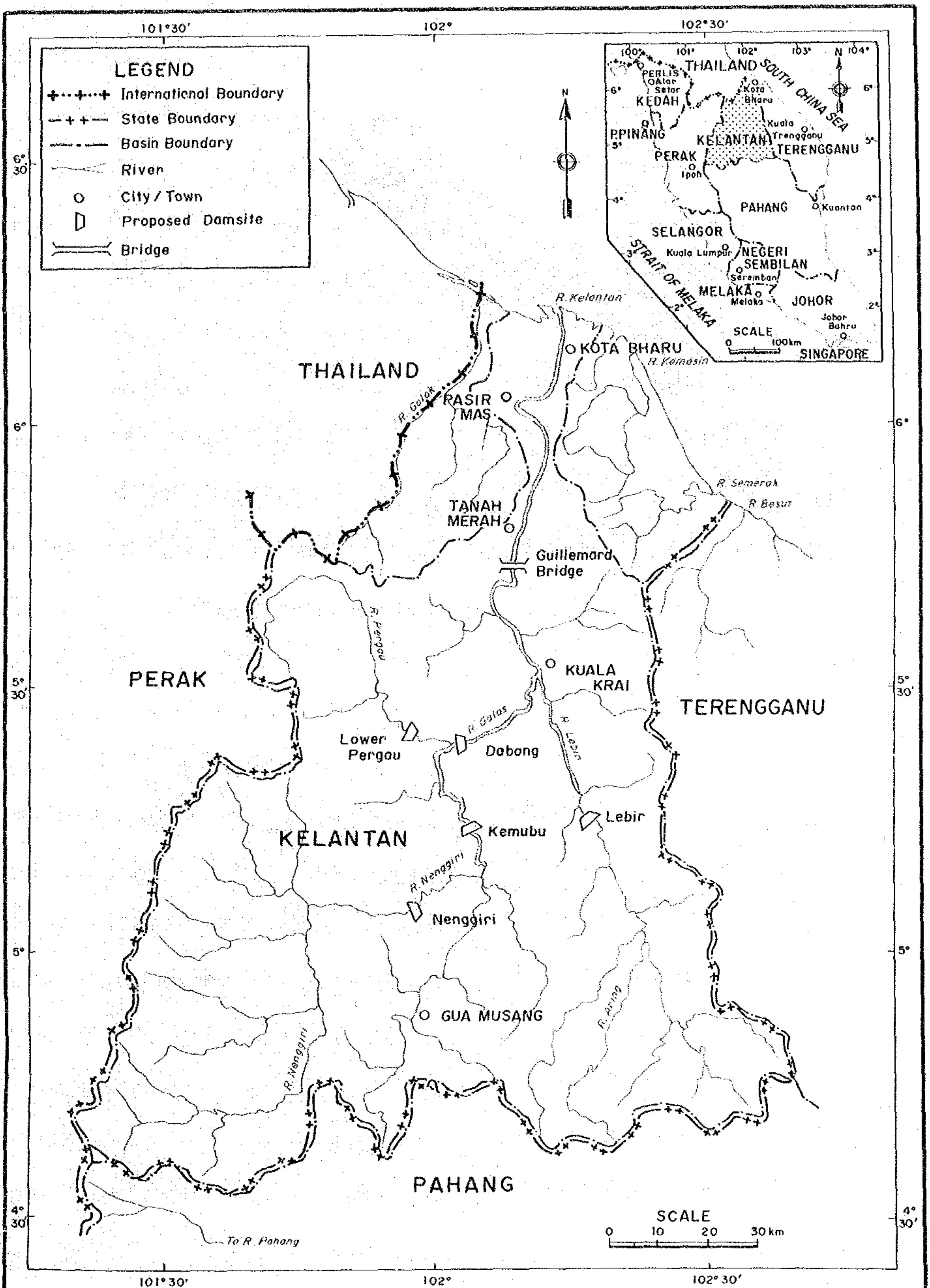

LOCATION OF PROJECT AREA

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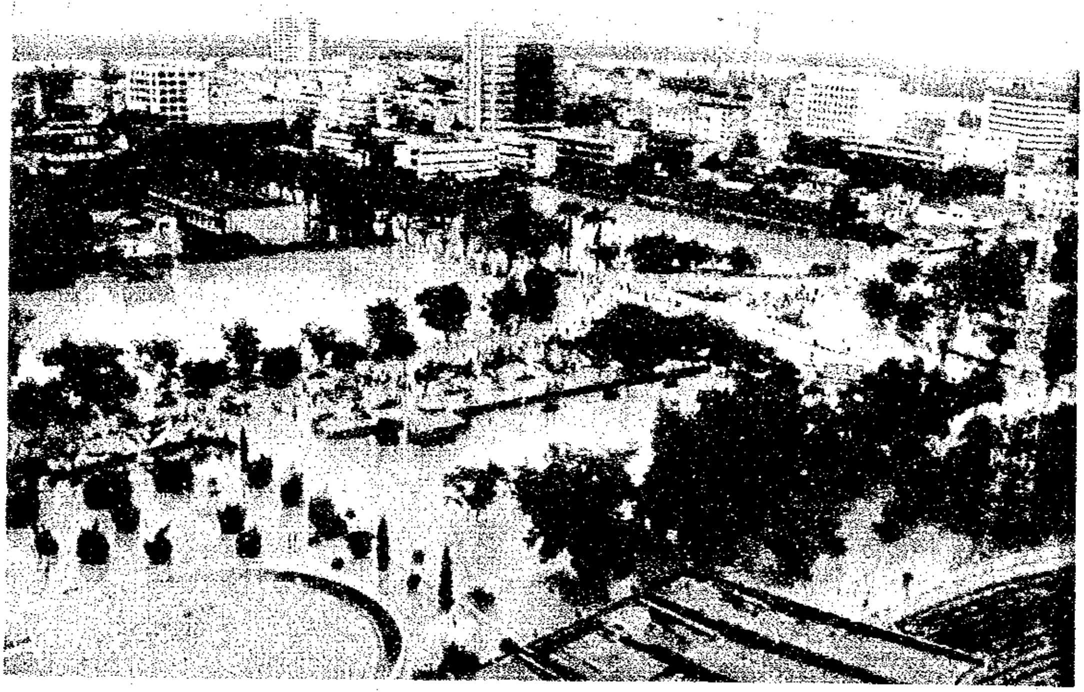

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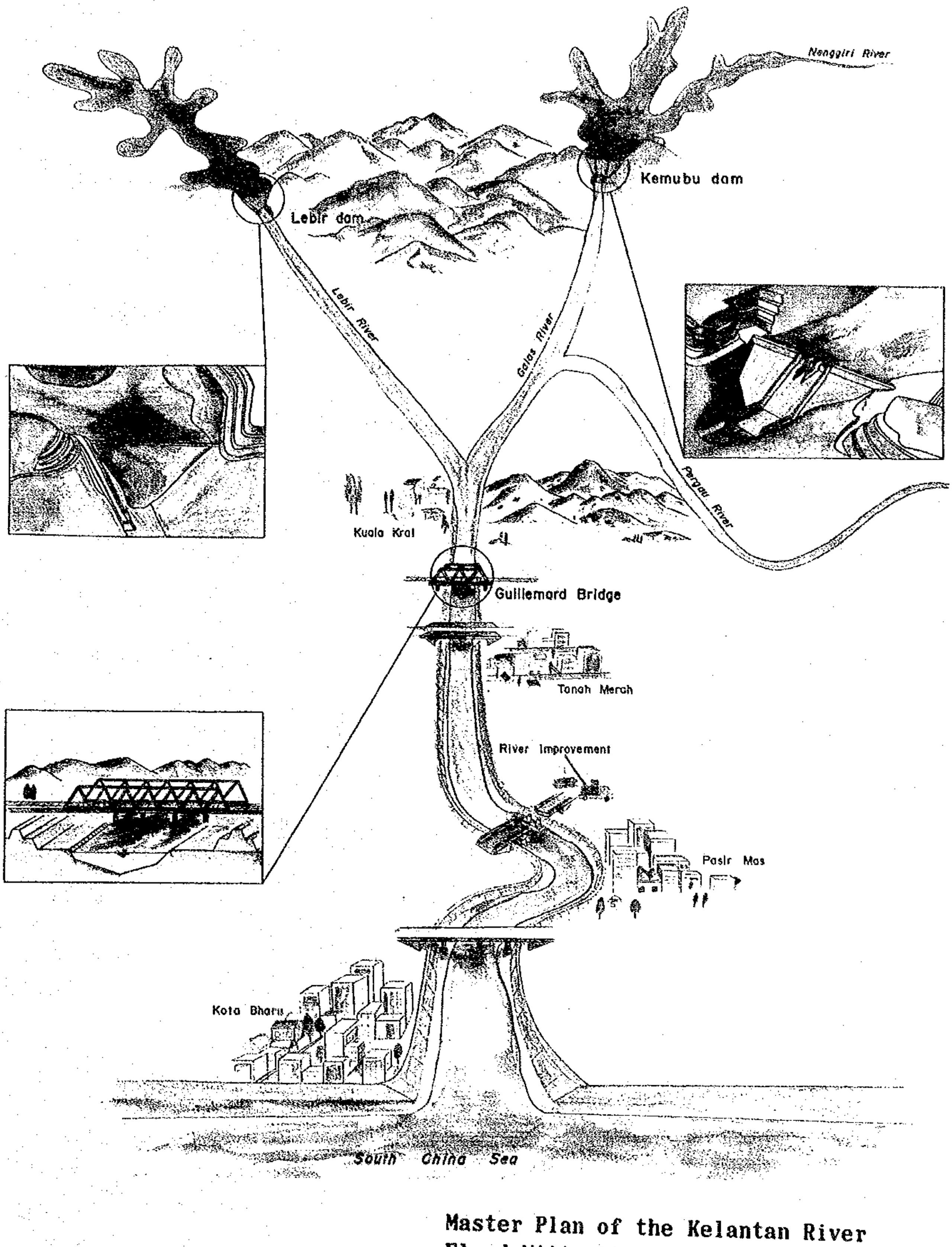

Master Plan of the Kelantan River Flood Mitigation

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
°C = 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

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ANNEX I

TOPOGRAPHIC SURVEY

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I. TOPOGRAPHIC SURVEY

1. INTRODUCTION

The major work of the topographic survey on the Kelantan River Basin-wide Flood Mitigation Study consists of following three items:

(1) Data collection and review,

(2) Updating of national maps, and

(3) Longitudinal and cross-sectional survey of the Kelantan River.

Topographic maps, photomaps, aerial photographs, cross-sections of the Kelantan River, irrigation canal network maps and so forth in the study area were collected from the Survey Department and agencies concerned through DID. Furthermore, a review was carried out to confirm whether or not the collected data are usable for the study.

The national basic maps with a scale of 1 to 25,000 will be in most frequent use for the estimate of flood damages and the study of river improvement. Those maps were however prepared in 1950 and 1960's, and furthermore are contoured with every 50 feet. Since the estimate of flood damages and the study of river improvement require detailed contour maps as well as the grasp of current condition for land use and so on, the updating work of 1 to 25,000 scale national maps as well as the insertion of detailed contours on them were carried out using the photomaps shot in 1974 to 1976, aerial photographs shot in 1980 to 1985 and so on.

Longitudinal and cross-sectional survey was carried out in the Kelantan River for the 100 km long river stretches from the estuary to Kuala Krai. The grasp of current river condition and change of river course is based on this longitudinal and cross-sectional survey.

2. DATA COLLECTION AND REVIEW

2.1 Available Data

Data collected for topography from the Survey Department and agencies concerned through DID are summarized as follows:

(1) National basic and editorial maps

The national basic maps with following scales are available:

Scale	Preparation Year	Contour Interval
1:63,360	1969 to 1975	50 ft
1:50,000	1985 to present	20 m
1:25,000	1955 to 1967	50 ft

Topographic maps with a scale of 1 to 50,000 are currently prepared by the Survey Department, however, four sheets are only available at the coastal area and border with Thailand in the State of Kelantan. The maps with a scale of 1 to 63,360 are available for the whole area of the Kelantan State, while the mountainous region in the southern part of the State is excluded for 1 to 25,000 scale maps.

The editorial maps prepared from the national basic maps such as administrative boundary map, Kota Bharu town map and road map are also collected as supplementary data. Table I.2.1 shows a list of the collected national basic and editorial maps.

(2) Mosaic photomaps and related maps

Mosaic photomaps covering the whole flood prone areas of the Kelantan River basin were prepared as part of the Kelantan River Basin Study carried out by ENEX1/. The maps are prepared with a scale of 1 to 6,336, while the contour interval drawn on the map is 1.0 m.

Cadastral and spot elevation maps were also prepared with a scale of 1 to 6,336 as related maps of the mosaic photomaps for the whole flood prone areas of the Kelantan River basin. Table I.2.2 depicts a list of collected mosaic photomaps.

(3) Aerial photographs

Aerial photographs with a scale of 1 to 40,000 were shot in the period of 1980 to 1985 covering the whole of the Peninsular Malaysia. The stereoscopic aerial photographs of 324 sheets were collected for the proposed damsites and flood prone areas from the Survey Department. In addition, the aerial photographs with a scale of 1 to 20,000, which are the double enlargement of the original aerial photographs, were also gathered for the flood prone areas (89 sheets).

(4) River cross-sectional data

River cross-sectional profiles were prepared at 19 sites for the river stretches between Kota Bharu and Kuala Krai with an interval of 5 km by ENEX as part of Kelantan River Basin Study. Furthermore, five cross-sections are available for the proposed Dabong damsite.

2.2 Review of Available Data

2.2.1 Topographic maps

(1) National basic maps

The collected national basic maps consist of three scales; 1 to 63,360, 1 to 25,000 and 1 to 50,000.

(i) 1 to 63,360 scale national basic maps

The collected national basic maps with a scale of 1 to 63,360 were prepared in 1969 to 1975 based on the aerial photographs shot in 1948 to 1959. The maps consisting of 23 coloured sheets cover the entire area of the Kelantan State located in the north of 4° 22'N. The origin of the maps is 4°N, 120° 15'E with a contour interval of 50 feet.

Since any revision was not made for these national basic maps since new preparation in 1969 to 1975, the infrastructures such as roads, bridges, irrigation canals and so on constructed after the map preparation are not shown in these maps.

(ii) 1 to 25,000 scale national basic maps

The maps with a scale of 1 to 25,000 were prepared in 1955 to 1967 based on the aerial photographs shot in 1948 to 1959. The maps consisting of 49 coloured sheets cover the area of the Kelantan State situated in the north of 5° 06'N; that is, the mountainous region located in the southern part of the State is excluded. The origin of the maps is 4°N, 120°E with a contour interval of 50 feet.

Any revision was not made for these national basic maps also since new preparation in 1955 to 1967, so that the infrastructures such as roads, bridges, irrigation canals and so forth constructed after the map preparation are not shown in these maps.

(iii)1 to 50,000 scale national basic maps

The collected national basic maps with a scale of 1 to 50,000 were prepared with a contour interval of 20 m in 1985 to 1987 based on the aerial photographs shot in 1978 to 1980. Since the maps in this series are under preparation, only four sheets are at present available at the coastal area and border with Thailand as mentioned in the preceding Section 2.1.

The updating of maps was carried out for the 1 to 25,000 scale maps with most frequent uses in this flood mitigation study as discussed in the subsequent Chapter 3. An index of the national maps is depicted in Fig. I.2.1.

(2) Editorial maps

Collected were six sorts of editorial maps, which are edited to meet the respective uses from the national basic maps.

(i) 1 to 500,000 scale administrative boundary map

The administrative boundary map with a scale of 1 to 500,000 published by the Survey Department in 1977 covers the whole states of the Peninsular Malaysia by two sheets, and depicts state and district boundaries, railways, rivers, roads, major cities and towns, representative national trigonometric points, airports and so on.

(ii) 1 to 190,080 scale Kelantan State map

The Kelantan State map with a scale of 1 to 190,080 published by the Survey Department in 1987 shows the land use condition by colour.

(iii)Road map

The road map published by the Survey Department consists of two parts: One shows the road networks of the whole area of Peninsular Malaysia in a 1 to 1,000,000 scale, and the other depicts the road networks of each state capital in a scale of 1 to 25,000 and 1 to 50,000.

(iv) 1 to 7,500 scale Kota Bharu town map

The town map of Kota Bharu (1 to 7,500 scale), a capital city of the Kelantan State, was prepared by the Survey Department based on the aerial photographs shot in 1979, covering a town area of 6 km in the north to south direction and 5 km in the east to west direction.

(v) Irrigation canal network map

The irrigation canal networks in the areas managed by KADA are depicted in a scale of 1 to 12,500 and 1 to 25,000 based on the 1 to 25,000 scale national maps. The preparation year of maps is unknown.

(vi) District map

The maps covering each district area were prepared and updated by each District with a scale of 1 to 25,000 and 1 to 63,000 based on the national basic maps. Compilation date is unknown.

The above editorial maps were referred to the updating work of 1 to 25,000 scale national maps.

2.2.2 Mosaic photomaps and related maps

The mosaic photomaps were prepared in 1974 to 1976 by DID with the cooperation of ENEX.

(1) Mosaic photomaps

The mosaic photomaps drawn with an orthophotoscope are based on the aerial photographs shot at a flight altitude of 5,000 feet. The mosaic photomaps with a scale of 1 to 6,336 cover the flood prone area lain in the north of 5^{o} 42′N with 84 sheets. In other words, the area for the river stretches between Temangan and Kuala Krai is not included. Photomaps with a reduced scale of 1 to 10,000 are also collected in the area where the 1 to 6,336 mosaic photomaps are available.

The photomaps have a 1 m contour interval, the origin of which is 5^{o} 53′38"N, 102^{o} 10′38"E. An index of photomaps is given in Fig.I.2.2. It is noted that 13 sheets located on the right bank of the Kelantan River are not contoured.

(2) Related maps

There are two types of maps prepared on basis of the above photomaps: One is cadastral maps to give the serial number for each land holder, and the other is to show the spot elevation by 3,600 m^2. The division and scale of both maps are same as those of photomaps.

Although there are some uncontoured areas in the photomaps, the assessment of flood damages and the updating work of national maps much rely on these photomaps.

2.2.3 Aerial photographs

The aerial photographs collected in the form of monochromatic contact positive prints (23 cm x 23 cm) were shot in 1978 to 1983 with a scale of 1 to 40,000 from the flight altitude of 12,500 feet. Photographs are well focused with low cloud cover.

These aerial photographs will provide the data for geological investigation and updating work of the national maps. Fig. I.2.3 shows an index of flight courses shot the aerial photographs.

2.2.4 River cross-sectional data

A river cross-sectional and longitudinal survey was carried out as part of Kelantan River Basin Study by ENEX in 1975. Since the levelling route is tied to the national bench marks, height is expressed in elevation above mean sea level, and then the scales and unit applied are V=1:100 and H=1:1,000, and feet respectively. An index map of cross-sectional locations is given in Fig. I.2.4.

3. UPDATING OF MAPS

The estimate of flood damages and the study of river improvement much rely on the topographic maps with a scale of 1 to 25,000. However, those 1 to 25,000 scale maps were prepared with a contour interval of 50 feet in 1955 to 1967.

The estimate of flood damages requires the maps with a small contour interval as well as such structures as roads, bridges, irrigation canals and so on constructed after the map preparation. Furthermore, the expansion of towns and villages and the change of vegetation are a major factor to assess the flood damages.

The mosaic photomaps prepared in a scale of 1 to 6,336 in 1974 to 1976 have contours of every one metre. The contours read by every two metres were drawn on the 1 to 25,000 scale maps by coinciding the coordinates between them. However, the areas covered with 13 uncontoured sheets of mosaic photomaps are not contoured. Furthermore, it is noted that 1 to 6,336 scale mosaic photomaps are not available in the area for the river stretches between Temangan and Kuala Krai, resulting in no insertion of contour lines with an interval of one metre on 1 to 25,000 scale maps.

On the other hand, the updating work for the structures and so on is based on the 1 to 20,000 and 1 to 40,000 aerial photographs and mosaic photomaps as well as the maps to show the irrigation canal network and 1 to 50,000 scale national maps.

The 1 to 25,000 scale topographic maps so prepared with contours of two metre interval and the structures newly constructed after the map preparation were finished by inking work.

4. RIVER PROFILE AND CROSS-SECTIONAL SURVEY

River cross-sections of the Kelantan River were surveyed with an interval of 5 km for the stretches between Kota Bharu and Kuala Krai by ENEX as part of the Kelantan River Basin Study. However, river cross-sectional survey with a short interval is required for the study of river improvement work.

In this situation, river cross-sectional and longitudinal surveys were carried out with an interval of 600 m on an average for the stretches between the estuary and Kota Bharu, while 1 km on an average for the stretches between Kota Bharu and Kuala Krai (refer to Table I.4.1).

There are river channels diverted from the main river channel toward Tumpat near the river mouth. A cross-sectional survey was also carried out for 10 km long diverted river channels with an interval of 1 km on an average. Furthermore, an additional river cross-section and longitudinal profile were prepared in the sea with an echo sounder.

One metre high steel pipes with concrete protection were buried as tentative bench marks (TBM) on both banks of the site where the cross-sectional survey is carried out, and then the height of them is expressed by elevation above mean sea level by tying to the national bench marks.

The sites where ENEX carried out the cross-sectional survey were tried to select as the sites to re-survey in this study in order to confirm the variation of river bed. In addition, datum of four water level gauges at Kota Bharu, Guillemard Bridge, Kuala Krai and KADA pump house was confirmed as part of longitudinal survey. In case that a cross-section is surveyed at the bridge, the deck level and so on are also shown in the cross-sectional map.

The river cross-sectional and longitudinal surveys were carried out by the selected local contractor since the end of May 1988 and their field work was completed in the middle of July, 1988, followed by the office work to prepare the drawings. The outcome of the survey was compiled in V=1:100 and H=1:1,000 and submitted to JICA as one book with the title of Kelantan River Cross-sectional and Longitudinal Survey at the end of July, 1988.

REFERENCE

1. Tonkin & Taylor Consulting Engineers, ENEX of New Zealand, The Kelantan River Basin Study, 1977.

Table I.2.1 Collected Topographic Maps

Area	Scale	Contour Interval	Coordinates		Datum	Publication	Remarks
			Interval	Projection			
Kelantan River basin (North of lat. 4 22'N)	1/63,360	50 feet	1 km	R.S.O.	National	1969-1975	Colour printed
Kelantan River basin (North of lat. 5 6'N)	1/25,000	50 feet	1,000 yards	R.S.O.	National	1955-1967	Colour printed
Coastal area	1/50,000	20 m	1 km	R.S.O.	National	1985-1987	Colour printed
All States of Peninsular Malaysia	1/500,000	None	-	-	-	1977	Administrative map Colour printed
Kelantan State	1/190,080	None	10 km	R.S.O.	National	1973	State map Colour printed
Kota Bharu Town area	1/7,500	5 m	1 km	R.S.O.	National	1985	Town map Colour printed
All States of Peninsular Malaysia	1/1,000,000	None	-	-	-	1977	Road map Colour printed
Administrative area of KADA	1/12,500	None	-	-	-	-	Irrigation canal network Blue print
	1/25,000						
Administrative area of each district	1/25,000	None	-	-	-	-	District planning map Blue print
	1/63,360						

Note: R.S.O.: Rectified Skew Orthomorphic

Table I.2.2 Collected Mosaic Photomaps and References

Area	Scale	Contour Interval	Coordinates		Datum	Publication	Remarks
			Interval	Projection			
Kelantan River basin (North of lat. 5 42'N)	1/6,336	1 m	1 km	-	-	1976	Blue print
Kelantan River basin (North of lat. 5 42'N)	1/10,000	1 m	1 km	-	-	1976	Monochrome printed photo
Kelantan River basin (North of lat. 5 42'N)	1/6,336	None	-	-	National	1976	Spot level diagram Blue print
Kelantan River basin (North of lat. 5 42'N)	1/6,336	None	-	-	-	1976	Cadastral map Blue print

Table I.4.1 River Cross-sections

Name of River	Section	Distance (Km)	Interval (Km)	Scale	
				H	V
S.K. Tongkang	Tumpat - Kg. T. Renjuna	10	1.0	1/1,000	1/100
Kelantan	River mouth - Kota Bharu	10	0.4 - 0.8	1/1,000	1/100
Kelantan	Kota Bharu - Kuala Krai	91	0.8 - 1.0	1/1,000	1/100

Note: H : Horizontal V : Vertical

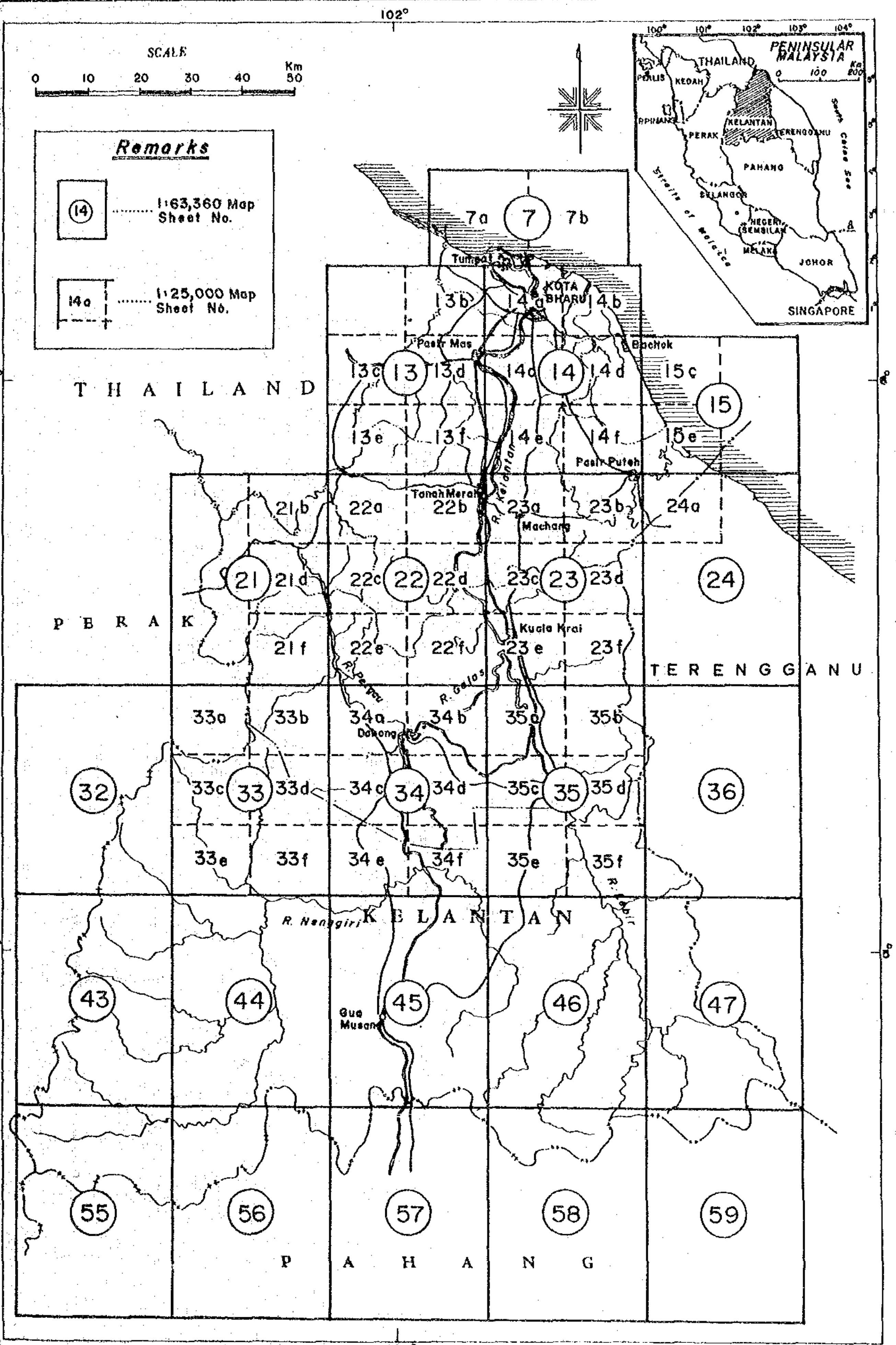

Fig.I.2.1

Index of 1:63,360 and 1:25,000 Scale Maps in the Kelantan River Basin

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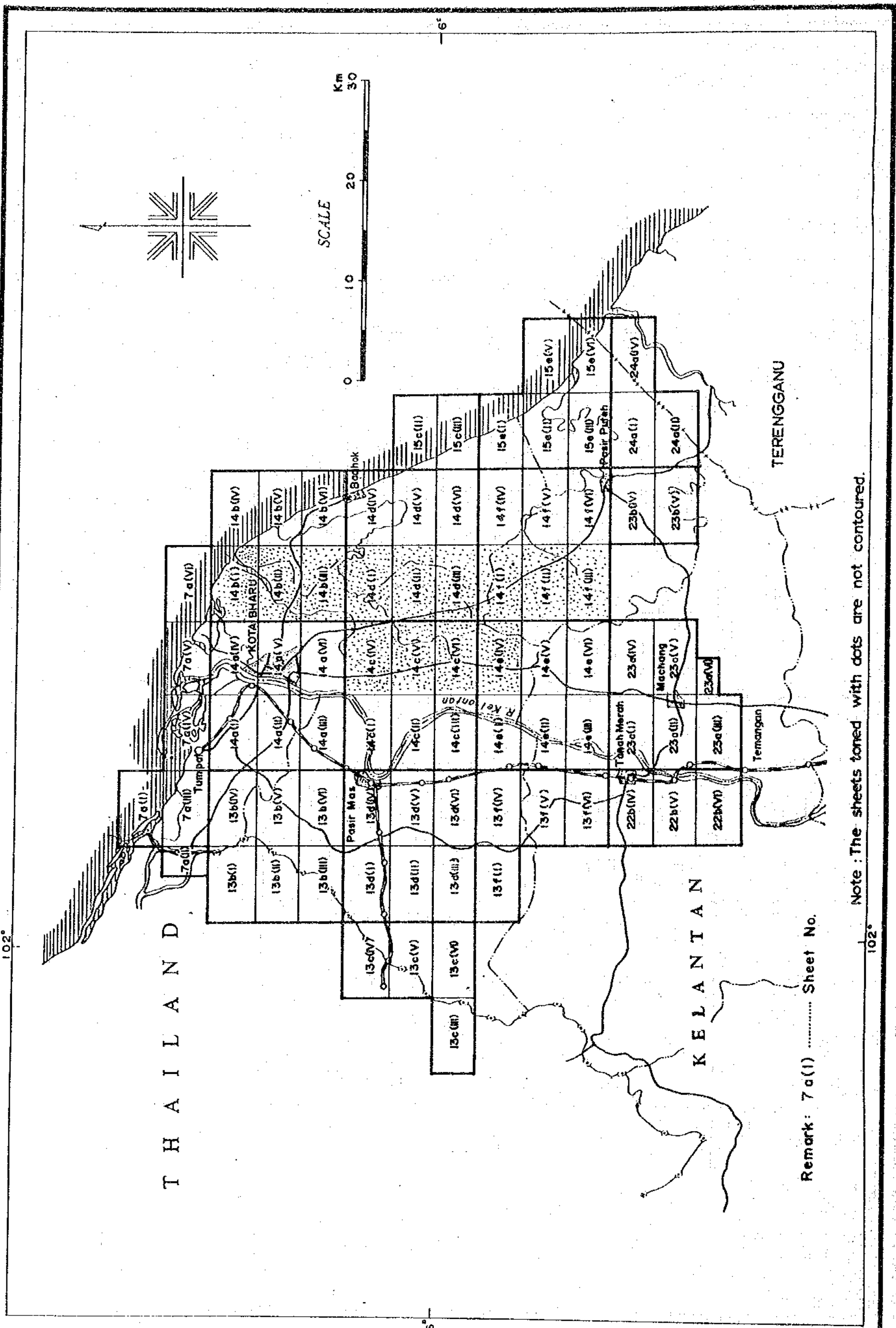

Fig.I.2.2

Index of Mosaic Photo-maps

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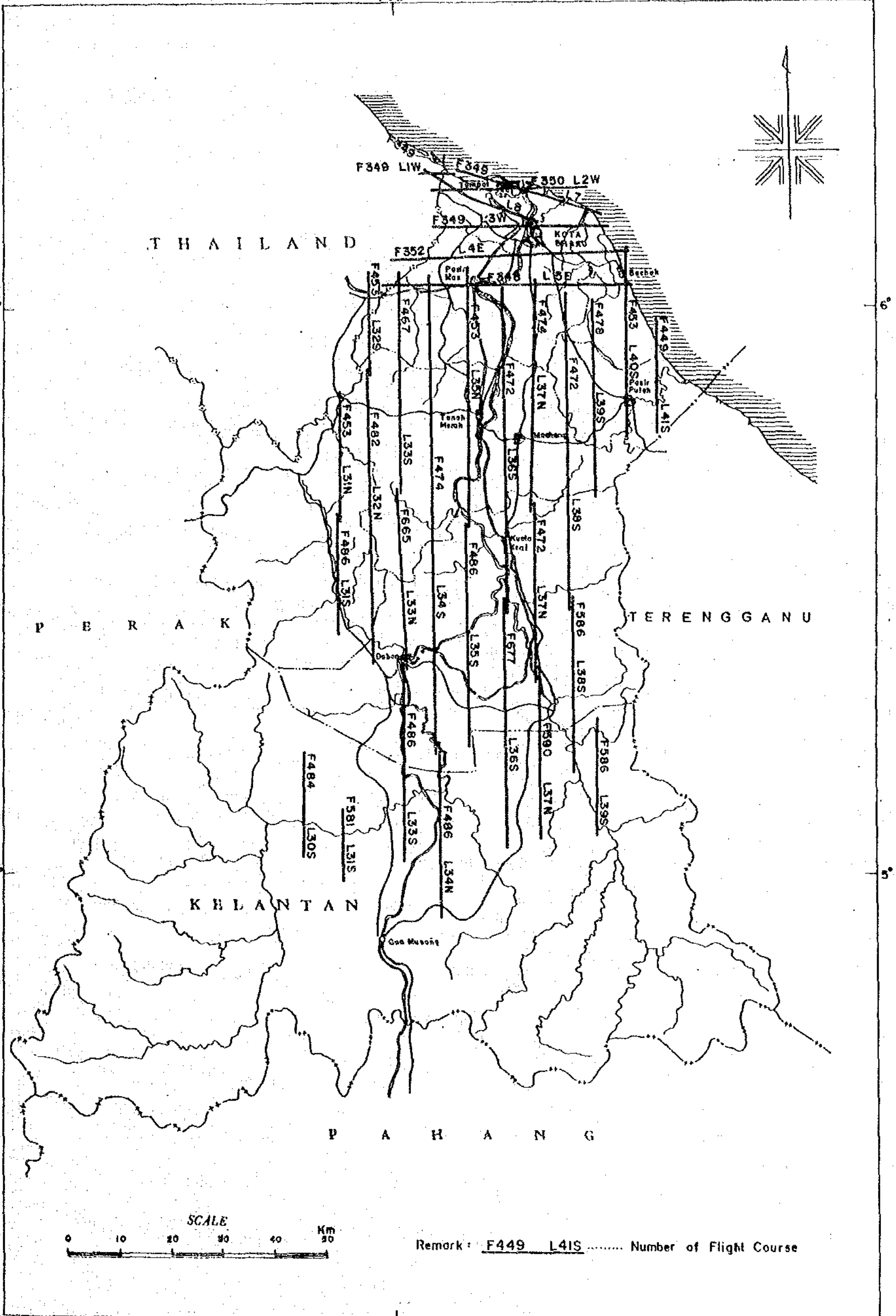

Fig.I.2.3

Index of Aerial Photographs

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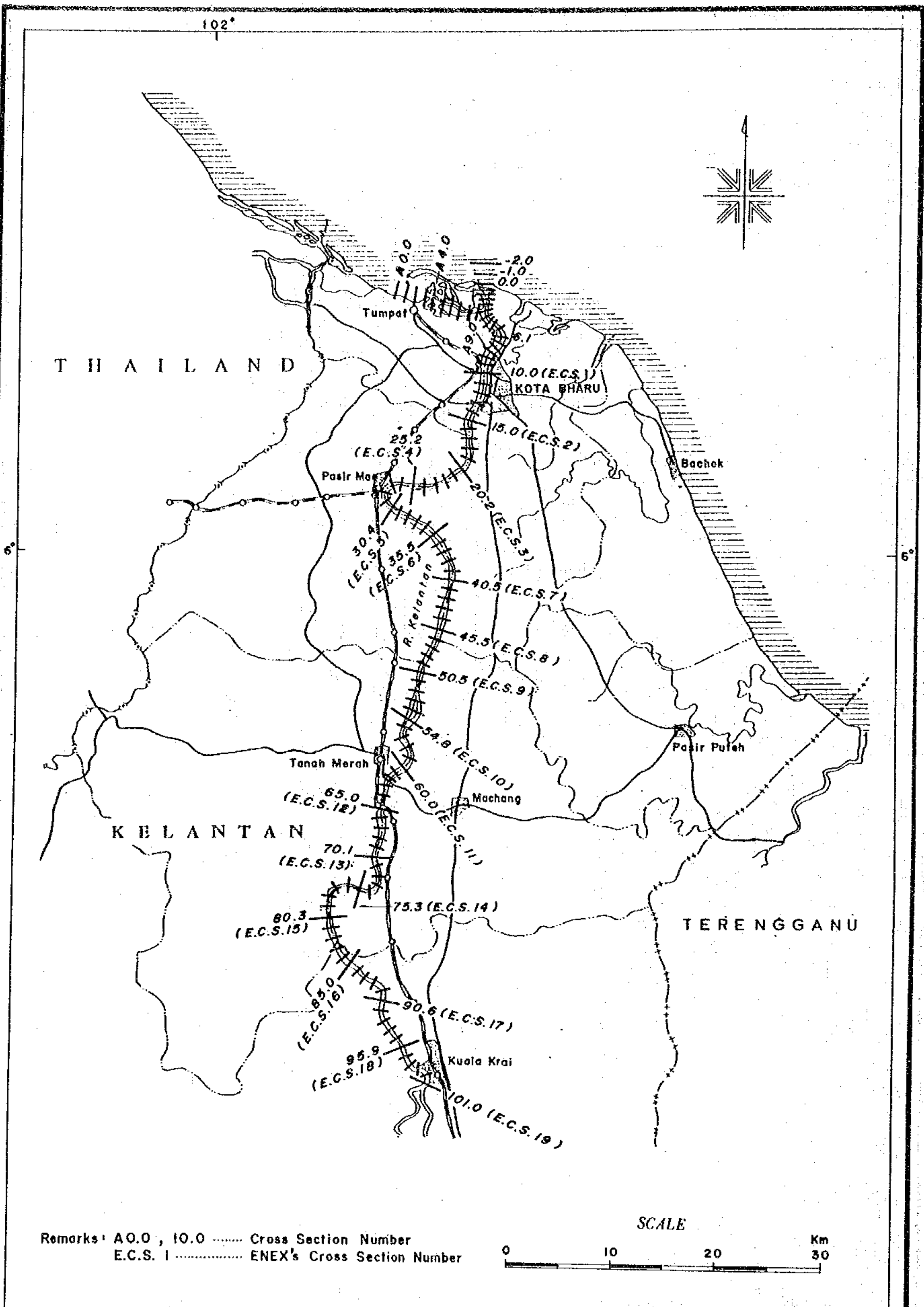

Fig.I.2.4

Index of River Cross-sections

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ANNEX II

HYDROLOGY

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II. HYDROLOGY

1. INTRODUCTION

The objective of hydrological investigation is mainly divided into five categories; namely,

(i) To clarify the physical aspect of hydrological behaviour in the basin,

(ii) To assess the historically large flood and its damage,

(iii) To prepare the river basin model to evaluate the appropriate scale of structures for flood mitigation and their combination,

(iv) To estimate the magnitude of probable flood peak discharge for various return periods at flood prone river stretches, and

(v) To estimate the spillway design flood of storage dams.

A river basin model for the upstream reach comprising about 94% of the catchment area of the Kelantan River basin was prepared to assess the physical aspect of hydrological behaviour in the upstream basin. The runoff parameters were calibrated on the basis of the hourly rainfall and hourly water level records at the representative stations during the floods in 1983, 1984 and 1986.

The probable flood peak discharge at Guillemard Bridge was regarded as the largest among simulated peak discharges by enlarging the hyetographs during the above floods.

The model clarified the magnitude of probable flood at Guillemard Bridge and the concurrent probable floods at storage damsites. The above peak discharges at Guillemard Bridge are regarded as the "INFLOW" into the coastal plain. The probable inundation depth in the coastal plain is evaluated on the basis of the relationship between the above "INFLOW" and the recorded inundation depth in the coastal plain.

Whilst the probable maximum floods for storage dams were estimated on the basis of the probable maximum precipitation by using the river basin model. They are less reliable because of sparse rainfall data in the upstream basin. The magnitude of probable maximum flood was then compared with the 200-year probable flood and recorded maximum flood at storage damsites. The largest flood peak discharge among the above three floods was adopted to the spillway design flood.

2. HYDROMETEOROLOGICAL DATA

2.1 General

The long-term hydrometeorological data in the State of Kelantan are collected from DID and MMS, and those in the selected station in the neighbouring states of Perak, Pahang and Terengganu are abstracted on the basis of National Water Resources Study (JICA, 1982) and Feasibility Study on Nenggiri Dam (ELC, 1986). The hydrometeorological data are summmarized in Fig.II.2.1.

2.2 Rainfall

The rainfall data at 98 stations in the State of Kelantan are stored in the computerized data bank of DID. Of 98 stations, 38 stations were abandoned to measure records and the remaining stations have been managed by DID, NEB, KADA and so on.

The observation of rainfall in the State of Kelantan commenced in 1938 at a few plantations. The installation of rainfall gauge was then eagerly carried out by DID. The number of rainfall stations is, however, limited in the upstream basin of the Kelantan River, while those in the coastal plain are densely installed.

The details in rainfall characteristics are described in Chapter IV.

2.3 Temperature

The mean annual temperature at Kota Bharu is 26.7°C on an average. There is a slight seasonal change ranging from 25.5°C on January to 27.9°C on May. The variation of temperature depends upon a diurnal change ranging from 23°C at 6 o'clock in the morning to 30°C at 2 o'clock in the afternoon.

According to the data at Tanah Rata meteorological gauging station 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.

The data of above stations show that the temperature gradient in the State of Kelantan is estimated at about 0.6°C/100 m on the basis of the altitudes of 5 m a.m.s.l at Kota Bharu and 1,470 m a.m.s.l at Tanah Rata. While the seasonal change of monthly annual temperature reduces at higher altitude, the diurnal change is more significant at the hinterland.

2.4 Relative Humidity

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%, and there is a slight seasonal change ranging from 79% on March to 86% on November. As for Tanah Rata station, the annual mean relative humidity is 87%, and the monthly mean varies from 83% on February to 90% on November.

2.5 Sunshine Hours

Daily sunshine hours have been recorded at 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.

While the seasonal change of monthly mean daily sunshine hours is slight at Tanah Rata for the range from 3.41 hours on November to 5.78 hours on March, those data at Kota Bharu show that the maximum of 8.99 hours on April is about two times the minimum of 4.36 hours on November.

The annual sunshine hours are estimated at about 1,700 hours at Tanah Rata and about 2,500 hours at Kota Bharu. The gradient of sunshine hours is roughly estimated at 55 hours/100m/year, although there is a seasonal variation between stations ranging from 0.95 hours per day on November to 3.78 hours per day on April.

2.6 Surface Wind Velocity

Average surface wind velocity is relatively low ranging from 0.24 m/s at Kg. Lalok and 1.1 m/s at Tanah Rata. The highest 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.

2.7 Evaporation

Pan evaporation data have been collected by DID and NEB in and around the State of Kelantan.

Pan evaporation amount tends generally to decrease at higher altitude. The data show the annual pan evaporation amount of 961 mm at Tanah Rata which locates at 1,470 m a.m.s.l and 1,749 mm at Kota Bharu of 5 m a.m.s.l.

The variation of pan evaporation amount shows that its gradient in the Kelantan River basin is estimated at 20 mm/100 m/year although there are significant differences among the stations below 200 m a.m.s.l due to the difference of equipment of black-painted pan by DID and ordinary pan by NEB.

2.8 Tide Level

Tide table in the Peninsular Malaysis is published by the Department of Survey and Mapping (DMS). The tide table comprises the tidal data at twelve tidal Stations. Among the stations, Geting locating at the river mouth of the Golok River is the nearest station from the river mouth of the Kelantan River. The details of the station are described as follows.

1. Location : Latitude 06°13'36"N
   Longitude 102°14'54"E

2. Datum level of Tidal Heights : 0.534 m below MSL

3. Tides : The inequality is quite remarkable so that one high and one low water occurs mostly in a day.

Tropic Rise	: 1.01 m
Equinoctical Rise	: 0.80 m
Tropic Range	: 0.952 m
Mean High Water Interval	: 7 h 41 min.

4. Note : The North East Wind caused by the low atmospheric pressure, raises the sea level to about 40 cm.

The above data is based on the datum level adopted for tidal predictions of Indian Spring Low Water (ISLW). The data is then adjusted referring to MSL at Kuala Terengganu in order to set at the equivalent datum level with the topographic survey. The adjusted datum level and the tidal range at Geting are illustrated as shown in Fig.II.2.2.

2.9 Sedimentation

The sediment deposit volume in the reservoir of storage dams are estimated based on the other schemes in and around the Kelantan river basin.

(1) The Kelantan River Basin Study (ENEX,1978)

The sediment deposit volume of 100 m^3/km^2/year in the reservoir was estimated on the basis of the geomorphological study on the upper layer of coastal plain assuming that the layer was formulated by the transported sediment for 6,000 years. While the discharge measurement data of 60 samples showed the 140 m^3/km^2/year at Guillemard Bridge. The Study concluded the specific sediment rate at Dabong Dam site was 110 m^3/km^2/year.

(2) Ringlet Falls Reservoir in Camelon Highland

Sediment deposited in the reservoir has been measured for eight times from 1963 to 1986. The average sediment deposited in the reservoir was 168 m^3/km^2/year. The measurement, however, has been carried out for the upstream part of the reservoir which covers about 30 % of the surface area of the reservoir.

(3) Feasibility Study on Lebir Dam (JICA,1987)

The sediment deposited in the reservoir was estimated based on the above data and Kira's empirical formula. Kira's formula is set up by using actual measurement data of 157 reservoirs in Japan, 58 in U.S.A., 47 in India and 14 in other countries. The average annual sediment volume in the reservoir was estimated at 410 m^3/km^2/year.

(4) Feasibility Study on Nenggiri Dam (ELC,1986)

The annual suspended sediment load of 510 m^3/km^2/year was estimated based on the monthly suspended sediment loads for the period from 1972 through 1985. The total sediment deposit volume of more than 1,000 m^3/km^2/year including bed load was applied to the determination of MOL.

(5) The Feasibility Study on Keyir Dam (SMEC,1970)

The annual suspended sediment load of 100 m^3/km^2/year was estimated on the basis of the study on Pahan River Basin.

In this Study, the average annual sediment deposit volume of 410 m^3/km^2/year is applied to determine MOL for the reservoir of storage dams considering that the largest value adopted to the other schemes and the value of more than 1,000 m^3/km^2/year for Nenggiri Dam is more conservative than the curves fitted to other shemes.

3. RIVER BASIN MODEL

3.1 General

The Kelantan River basin is characterized by the periodic extreme flooding and drought. Difficulties of flood mitigation are in the vast coastal plain and the relatively low flow capacity of river channel.

To cope with such difficulties for the measure of flood mitigation, the appropriate hydrological procedures are required to enable to assess the scale of flood and the combination of structures for flood mitigation.

In the Study, the hydrological model for the Kelantan River basin is configurated so as to select the optimized plan for flood mitigation. The objectives to establish such a hydrological model are enumerated into three categories; namely,

(i) To clarify the physical aspect of hydrological behaviour in the basin,

(ii) To assess the historically large flood and its damages, and

(iii) To assess the appropriate scale of structures for flood mitigation and their combination.

3.2 River Basin Model

3.2.1 Configuration

The model comprises the upper reaches of the Kelantan River down to Guillemard Bridge. The model comprises a catchment area of 12,080 km^2, and this area is divided into 26 sub-basins and 15 river stretches as shown in Fig.II.3.1.

This model is available mainly to assess the physical aspect of hydrological behaviour in the upstream basin and also the appropriate scale of structures for flood mitigation.

3.2.2 Basic Concept of the Model

(1) Base and sub-base points

Base points are to evaluate flood probability and to assess the rate of flood mitigation by the combination of flood mitigation structures.

The water level gauging station at Guillemard Bridge is regarded as the base point taking its relatively longer period of water level records in the Kelantan River basin into considerations.

Sub-base points are the ones to evaluate the discharge and also to assess the flood routing by storage dams. These points are set to imply the following conditions:

- Immediately upstream and downstream at the confluence with tributaries,

- Proposed storage damsites,

- Beginning and end points of river stretches divided taking flow capacity and riverbed gradient into considerations, and

- Existing water level gauging stations.

The configuration of hydrological model for the upstream basin is shown in Fig.II.3.2.

(2) Rainfall gauging station

Fourteen rainfall gauging stations are selected for the upstream model under the following considerations:

(i) Relatively longer period of rainfall records,

(ii) Both daily and hourly rainfalls are recorded, and

(iii) Areas of Thiessen's polygon are equally distributed.

The location of selected rainfall gauging stations and Thiessen's polygon are shown in Fig.II.3.3. The areas of each Thiessen's polygon are enumerated in Table II.3.1, and the areas of these polygons contributed to each sub-basin are listed in Table II.3.2.

(3) Runoff coefficient

Runoff coefficient is derived from the relationship between the volume of direct runoff during flooding and the accumulated rainfall depth.

In the Study, the flood hydrographs in 1983 and 1984 are adopted to estimate the runoff coefficient since both hourly water level data at Guillemard Bridge and hourly rainfall records in the upstream basin are available.

Shown in Fig.II.3.4 are the data of accumulated rainfall depth against the direct runoff depth assuming that the base flow is equivalent to the initial runoff immediately before the rising limb of flood hydrograph.

The data show the runoff coefficient of 0.55 is adequate until the accumulated rainfall depth reaches 200 mm, while it changes from 0.55 to 1.0 beyond the accumulated rainfall depth of

200 mm.

(4) Duration of probable rainfall

Although monsoon rainfall occurs intermittently throughout the rainy season as attached in Appendix, the duration of probable rainfall is required to define for establishing the comprehensive river basin model. The duration of probable rainfall can be roughly estimated by the calculation of travelling time of flood. As given in Appendix, the result varies ranging from 1.4 to 5.4 days. The in-depth study is then carried out as described below.

The duration of probable rainfall is defined on the basis of the relationship between the volume of direct runoff (V_Q) and the accumulated effective rainfall depth (V_R). Flood hydrographs in December 1983, December 1984 and November 1986 are adopted to estimate the volume of direct runoff, while the accumulated effective rainfall depths for the period of three to seven days as given in Tables II.3.3 to II.3.5 are calculated by the following equation:

$$V_R = f \cdot R \cdot A \qquad (R \leq Rsat) \ldots\ldots\ldots \text{(Eq.3.1)}$$

$$= [\, R - (1-f) \cdot Rsat \,] \cdot A \qquad (R > Rsat) \ldots\ldots\ldots \text{(Eq.3.2)}$$

where, V_R = volume of accumulated effective rainfall (m^3)
f = runoff coefficient (= 0.55)
R = accumulated basin mean rainfall (m)
A = catchment area (= 12,080 million m^2)
Rsat = accumulated rainfall depth when the catchment is fully saturated (= 0.2m).

Shown in Fig.II.3.5 (above) is the result of above calculation. The ratio of V_Q/V_R on an arithmetic average varies ranging from 1.553 for three days to 0.880 for seven days. Of five durations of rainfall, the rate of five-day rainfall is nearest to 1.0.

Furthermore, the relationship between the peak discharges of annual maximum flood at Guillemard Bridge and the basin mean rainfall depth for various durations are also calculated as shown in Table II.3.6. The duration of 5-day having the highest correlation coefficient is regarded as the optimum duration of design rainfall as shown on Fig.II.3.5 (below).

The five-day rainfall is therefore defined as the duration of probable rainfall.

(5) Base flow

The mean annual runoff of 600 m^3/sec has been observed at Guillemard Bridge for the period from 1960 to 1986. Its specific discharge is estimated at 0.05 $m^3/sec/km^2$. The above specific discharge is defined as the base flow at sub-basin during flooding.

3.3 Runoff calculation

3.3.1 Method

Storage function method is applied to the runoff calculation.

3.3.2 Runoff calculation from sub-basin

Flood runoff from sub-basin is calculated by the following equations:

$$S = K\ Q^{P} \quad \text{(Eq.3.3)}$$

$$dS/dt = (1/3.6)\cdot f\cdot r\cdot A - Q \quad \text{(Eq.3.4)}$$

where, S = storage volume in the sub-basin (m^3)
Q = runoff from sub-basin (m^3/s)
K = constant
P = constant
t = time (sec)
f = runoff coefficient
r = basin mean rainfall (mm/hr)
A = catchment area (km^2)

in which, the constants of K and P are estimated by the following empirical formula:

$$K = 119 \cdot I^{0.3} \quad \text{(Eq.3.5)}$$

$$P = 0.175 \cdot I^{-0.235} \quad \text{(Eq.3.6)}$$

where, I = average riverbed gradient.

Finally, flood runoff is adjusted taking lag time into considerations. The lag-time is roughly estimated by the following empirical formula:

$$Tl = 0.0470\ L - 0.56 \quad (L > 11.9\ km) \quad \text{(Eq.3.7)}$$

$$= 0.0 \quad (L \leq 11.9\ km) \quad \text{(Eq.3.8)}$$

where, Tl = lag time (hours)
L = river length (km).

3.3.3 Flood routing through river channel

In case that the riverbed gradient is rather gentle or the water level is affected by the backwater due to the relatively higher water level in the main stream, the flood runoff generally retards through the river channel.

The storage function of river channel is initially estimated by the river cross section, riverbed gradient and river length.

The flood runoff through river channel is calculated by the following equation:

$$S = K \cdot O^P - Tl \cdot O \quad \text{(Eq.3.9)}$$

$$dS/dt = I - O \quad \text{(Eq.3.10)}$$

where, S = storage volume along river channel (m^3)
K = constant
P = constant
Tl = lag time (hrs)
I = inflow (m^3/s)
O = outflow (m^3/s)

in which, the constants of K and P are estimated by the trial-and-error method on the basis of the observed flood hydrographs.

The lag time (Tl) is estimated by the following empirical equation:

$$Tl = 7.36 \times 10^{-4} \cdot L \cdot I^{-0.5} \quad \text{(Eq.3.11)}$$

where, Tl = lag time (hrs)
L = length of river channel (km)
I = average riverbed gradient.

3.3.4 Flood routing by storage dam

Natural retardation effect of storage dam is calculated on the basis of the reservoir water level and its storage volume by the following equation:

$$dS/dt = I - O \quad \text{(Eq.3.12)}$$

where, S = reservoir storage (m^3)
I = inflow into reservoir (m^3/s)
O = outflow from spillway (m^3/s)

in which, the outflow from spillway is calculated by the following equation:

$$O = C\ B\ H^{1.5} \quad \text{(Eq.3.13)}$$

where, O = outflow from spillway (m^3/s)
C = constant (= 1.9)
B = width of spillway crest (m)
H = water depth above crest (m).

3.4 Recorded Flood Hydrograph

In the catchment area of 12,080 km^2 at Guillemard Bridge, there are six water level gauging stations as enumerated below:

Station	River	C.A.(km^2)	Remarks
1. Chegar Atas	Nenggiri	3,740	1972 - 1986
2. Bertam	Nenggiri	3,956	1976 - 1986
3. Dabong	Galas	7,480	1975 - 1986
4. Tualang	Lebir	2,480	1976 - 1983
5. Kuala Krai	Kelantan	11,127	1978 - 1986
6. Guillemard Bridge	Kelantan	12,080	1941 - 1986

Of six water level gauging stations, five stations except Chegar Atas are managed by DID, while Chegar Atas is managed by NEB since 1972.

So as to calibrate the parameters of river basin model, the flood hydrographs at five stations except Bertam are adopted since Bertam station locates about 15 km downstream from Chegar Atas and the data at Bertam are less reliable than those at Chegar Atas.

As for Kuala Krai station, there are no data of discharge measurement. The rating curve is estimated by the non-uniform flow calculation.

The annual maximum peak discharges at Chegar Atas, Dabong and Tualang are enumerated as given in Table II.3.7. Those at Guillemard Bridge are also enumerated in Table II.3.8.

Frequency analysis is carried out on the basis of the annual maximum peak discharge at Guillemard Bridge since those data at the other stations are limited.

Shown in Fig.II.3.6 is the plotting position of the data. Although three methods, i.e. (i) Gumbel (ii) Iwai and (iii) Log-Pearson Type III, are applied to the frequency analysis, there is no significant difference among them. Gumbel distribution, which is recommended by DID to apply to frequency analysis in the Peninsular Malaysia, is finally adopted to the Study.

Probable peak discharges at Guillemard Bridge are estimated as follows:

Return Period (years)	Probable Peak Discharge (m^3/s)
200	20,700
100	18,500
50	16,300
30	14,700
20	13,400
10	11,000
5	8,700
2	5,100

3.5 Calibration of Runoff Parameter

Three observed flood hydrographs are adopted to the calibration of runoff parameter, that is;

No.	Flood	Peak Discharge at Guillemard Bridge (m^3/sec)
1	December,1983	12,007
2	December,1984	7,744
3	November,1986	6,901

Both observed hourly rainfall and hourly water level records are available for the period of above flooding, although hourly rainfall records are missing at a few rainfall stations. The isohyetal maps of the above monsoon rainfalls are shown in Figs.II.3.7 to II.3.9.

In case that the hourly rainfall records are missing, the hyetograph of the rainfall station having the highest correlation coefficient among the stations is applied.

As for the constant of P in the equation of runoff calculation, the arithmetic average of 0.5 is applied to avoid the lengthy calibration.

The runoff coefficient at sub-basin is divided into two values, i.e. 0.40 for the catchment of the Nenggiri Dam and 0.65 for the other sub-basin. The weighted average of runoff coefficient is equivalent to 0.55 over the whole catchment area at Guillemard Bridge.

The results of calibration are summarized in Table II.3.9 for sub-basin and Table II.3.10 for river channel. The observed and simulated hydrographs are shown in Fig.II.3.10.

4. RAINFALL ANALYSIS

4.1 General

The objectives of rainfall analysis are to estimate the following conditions:

(i) To assess the physical aspect of monsoon rainfall,

(ii) To assess the annual maximum daily rainfall depth for various durations, and

(iii) To estimate the probable maximum precipitation for the spillway design flood of storage dams.

4.2 Annual Basin Mean Rainfall

The isohyetal map of annual mean rainfall depth as shown in Fig.II.4.1 is prepared to estimate the annual basin mean rainfall.

The annual rainfall depth at representative 20 rainfall stations in the State of Kelantan is enumerated in Table II.4.1.

The data show that the annual basin mean rainfall of 2,700 mm on an average has been recorded in the State of Kelantan. The heaviest annual mean rainfall of 3,214 mm has been recorded at Kg. Jeli station where the Pergau and Golok rivers originate, while the relatively smaller annual mean rainfall of about 2,200 mm has been recorded in the hinterland at the Galas and Nenggiri river basins.

The monthly mean rainfall depth in the State of Kelantan is summarized in Table II.4.2 and Fig.II.4.2.

The data show 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.

4.3 Annual Maximum Daily Rainfall

Annual maximum daily rainfall depth for the duration of one to five days is given in Tables II.4.3 to II.4.6.

The frequency analysis of annual maximum daily rainfall depth for each duration is carried out by Gumbel Method. The results of analysis are enumerated in Tables II.4.7 and II.4.8.

4.4 Depth - Area Analysis

Whilst probable rainfalls for the duration from one to five days are obtained based on the daily rainfall data at fourteen stations, these probable rainfall depth should be converted to basin mean rainfall depth corresponding to the area of Thiessen's polygon for each rainfall station.

The rate of conversion from point rainfall to basin mean rainfall is therefore estimated by the depth-area relationship which is derived from the isohyetal map of relatively heavier monsoon rainfall records.

The rainfall records adopted in the depth-area analysis are listed below:

Date	Max. Point Rainfall (mm/day)
Jan. 6, 1967	607
Mar. 25, 1973	315
Nov. 15, 1979	230
Dec. 15, 1982	320
Dec. 20, 1984	273
Nov. 27, 1986	555

Shown in Fig.II.4.3 is the relationship between daily rainfall depth and area. The data show that the heavier daily point rainfall indicates the lower rate of conversion to basin mean rainfall depth.

In the Study, the rate of conversion from point probable rainfall depth to basin mean rainfall is defined as the envelope curve which is the trace of the depth-area curves of November 27, 1986 and January 6, 1967. In case that point rainfall is converted to basin mean rainfall beyond 1,000 km^2, the value of 0.38 at 1,000 km^2 is applied.

4.5 Hourly Rainfall Pattern

Hourly rainfall records more than 300 mm per day are adopted to estimate the hourly rainfall hyetograph for relatively heavier monsoon rainfall. The adopted records are given in Table II.4.9.

4.6 Probable Maximum Precipitation (PMP)

The one day probable maximum precipitation is estimated by Hershfield's method recommended by World Meteorological Organization (WMO) for the area having sparse rainfall data.

Since the records of less than ten years should not be used for the above method, the records at six stations are applied to the method.

The results are given below. The adjustment factor of 1.16 for the observation period of 24 hours is multiplied, and the ratio of PMP to the 100-year probable rainfall is regarded as the maximization factor as shown below:

Station	PMP (mm)	Maximization Factor
Kuala Pertang	1,489	2.875
Lubok Bungor	1,493	3.225
Dabong	883	2.941
Bertam	817	3.215
Kuala Krai	1,669	3.470
Machang	2,067	3.100
Average		3.138

The maximization factor of 3.138 for 100-year probable point rainfall is applied to the estimation of point PMP for the remaining stations.

The point PMP is converted to basin mean PMP by multiplying the conversion factor as described in Section 4.4.

As well as the maximization factor for point PMP, those for basin mean PMP are calculated as given in Table II.4.10. The above factor is applied to the 100-year probable point rainfall for the duration of more than one day:

The basin mean 5-day PMP is estimated by the following procedures:

(i) The one day PMP is arranged at third day at the centre of duration.

(ii) The difference between one-day and two-day PMP is arranged at second day.

(iii) As well as the arrangement of second day, the difference between two-day and three-day PMP is arranged at fourth day.

(iv) Finally, the difference between three-day and five-day PMP is arranged at first and fifth days.

The adopted PMP for the duration of five (5) days is summarized in Table II.4.11.

As for PMP hyetograph, the arithmetic average of recorded hourly rainfall as described in Section 4.5 is applied to the third day, while the uniformly distributed hyetograph is assumed for the remaining days.

5. FLOOD ANALYSIS

5.1 General

The objective of flood analysis lies in the following items:

(i) To estimate the magnitude of probable flood peak discharge for various return periods,

(ii) To assess the flood peak discharges at respective storage damsites which correpond to the return period at Guillemard Bridge, and

(iii) To estimate the spillway design flood of storage dams.

5.2 Water Level Gauging Station

(1) Chegar Atas

The water level gauging station at Chegar Atas having a catchment area of 3,740 km^2 locates at the Nenggiri River. The observation of water level commenced in 1972 and has been managed by NEB. Discharge measurements are carried out a few times per month by NEB. The water level recorder of a depth-pressure type is installed.

(2) Bertam

The water level gauging station at Bertam having a catchment area of 3,956 km^2 locates at Bertam Bridge across the Nenggiri River. The station locates about 15 km downstream of the Chegar Atas station. Comparing with the specific discharges of Chegar Atas and Bertam stations, the water level data at Bertam are less reliable than those of Chegar Atas. The station is settled in 1976, and discharge measurements to establish an accurate rating curve have been carried out by DID.

(3) Dabong

The water level gauging station at Dabong having a catchment area of 7,480 km^2 locates immediately downstream of the confluence of the Galas and Pergau rivers. The observation of water level commenced in 1975. Discharge measurements have been carried out a few times per month by DID.

(4) Tualang

The water level gauging station at Tualang having a catchment area of 2,480 km^2 locates at middle reaches of the Lebir River. The observation and discharge measurement commenced in 1976 by DID. However, the cable of a depth-pressure gauge was broken by floating logs during the flood in 1984.

(5) Kuala Krai

The water level gauging station at Kuala Krai having a catchment area of 11,127 km^2 locates immediately downstream of the confluence of Galas and Lebir Rivers, where the Kelantan River originates. The function of Kuala Krai station is to observe the rising limb of flood discharge and to evaluate the propagation time down to Kota Bharu. The propagation time of flood peak from Kuala Krai down to Kota Bharu is known empirically at about eight hours. The Kuala Krai station therefore takes an important role on the flood forecasting and warning system for the downstream reach. The observation of water level commenced in 1978. The discharge measurement, however, has not been carried out.

(6) Guillemard Bridge

The most reliable data among the hydrological data are the water level records at Guillemard Bridge. The water level gauge of floating type is installed at the downstream side of Guillemard railway bridge. Its catchment area is 12,080 km^2. The annual maximum water level had recorded for the period from 1941 to 1959. Then the automatic water level recorder was installed in 1960. Discharge measurements are carried out by DID a few times a month.

(7) Kota Bharu

The water level gauging station at Kota Bharu locates at the right bank of the Kelantan River. The location is about 11 km upstream from the river mouth. For the range of low flow, the water level is influenced by the tidal effect of the South China Sea, while the high flow is recorded fairly good because the diurnal tidal range at the river mouth is not so high.

5.3 Regional Runoff

Mean annual runoff at water level gauging stations is enumerated in Table II.5.1. The regional specific yield of mean annual runoff is 40 $l/sec/km^2$. The annual runoff/rainfall ratio on a weighted average is estimated at 0.55, while those values vary ranging from 0.45 at Chegar Atas to 0.59 at Guillemard Bridge.

5.4 Probable Flood at Guillemard Bridge

5.4.1 Probable Flood Hydrograph

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