REPORT OF PRELIMINARY SURVEY
FOR
FLOOD FORECASTING AND WARNING SYSTEM
IN SABAH AND SARAWAK
MALAYSIA

March 1979

JAPAN INTERNATIONAL COOPERATION AGENCY

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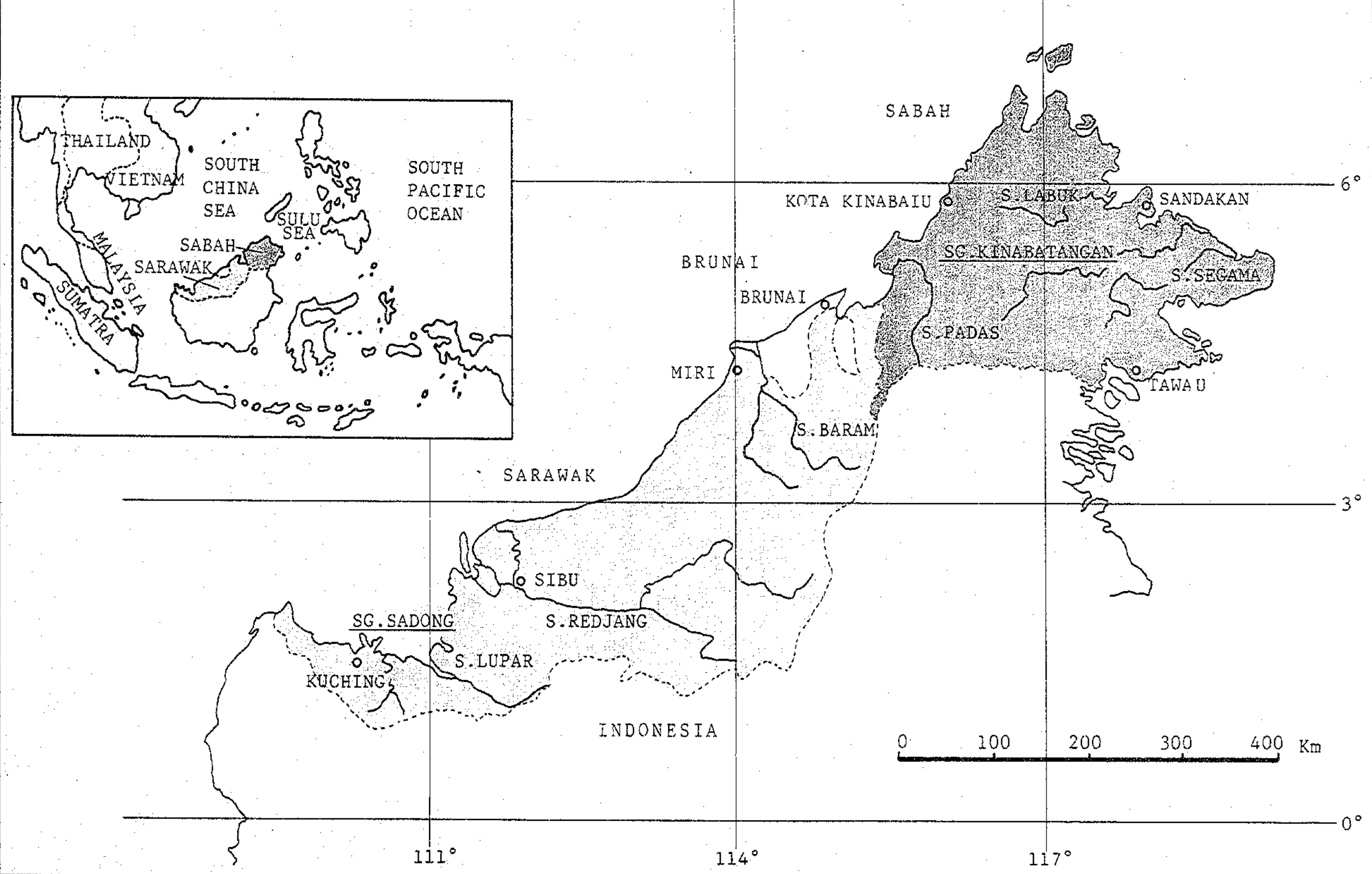
SABAH·SARAWAK General Map



Preface

In response to the request of the Government of Malaysia, the Government of Japan decided to take up a preliminary survey for establishing a flood forecasting and warning system in Sabah and Sarawak, and the Japan International Cooperation Agency conducted the survey by dispatching to Malaysia a 3-man team from November 20 to December 22, 1978.

The survey team conducted a field survey and held discussion with the officials concerned on the project. After further studies made in Japan the team has formulated the present report which is based on the findings of the survey and the discussion.

I hope that this report will prove to be useful for the project and contribute to the socio-economic development in Sabah and Sarawak as well as to the enhancement of the friendly relations between our two countries.

I wish to express my sincere gratitude to the officials concerned in Malaysia for their whole-hearted cooperation extended to the team.

March 1979

Shinsaku Hogen

President
Japan International Cooperation Agency

CONTENTS

PART 1. GENERAL

Chapter 1. Introduction

1-1 Background of Survey

In the peninsular area of Malaysia, flood forecasting and warning service is already in operation by the establishment of a systematized telemetering network in the basins of four large rivers, i.e., the Kelantan, the Trengganu, the Pahang and the Perak. The four networks were established as a joint project of UNDP and WMO implemented during the period from 1971 to 1974.

Establishment of a similar flood forecasting network is urgently called for in Sarawak and Sabah of East Malaysia as these two states are afflicted with heavy flood damage each year during the north-east monsoon lasting from November to March.

This report contains the findings of a preliminary survey conducted for studying a suitable flood forecasting and warning network in the Sadong basin in Sarawak and in the Kinabatangan basin in Sabah.

1-2 Formation of Survey Team

The survey team was organized with the following three experts.

Table 1-1. Formation of Survey Team

Name	Assignment	Affiliation
Kazuhiko Takayama	Telecommunication expert	Senior Engineer, Electricity and Telecommunication Division, Minister's Scretariat, Ministry of Construction
Osamu Machida	Hydrologist	Senior Engineer, International Affairs Division, Planning Bureau, Ministry of Construction
Hideaki Yokouchi	Hydrologist	Senior Engineer, Planning Division, Kanto Regional Construction Bureau, Ministry of Construction

1-3 Itinerary of Survey Team

The team's itinerary is as shown in Table 1-2 below.

Date		Itinerary	Meeting
Nov.20	Mon.	Arrival in Bangkok	
21	Tue.	Meeting with ESCAP	Mr. McCutchan, Mr. Manalac Mr. C. Wang, Mr. E.F. Shulz
22	Wed.		
23	Thu.	Arrival in Kuala Lumpur	
24	Fri.	Discussion with D.I.D. Officials.	Mr. S.H. Thavaraj Mr. Sich Kok Chi Mr. Tan Hoe Tin Mr. Tan King Seng
		Meeting with M.M.S. Officials	Mr. P. Markandan Mr. Abraham David
25	Sat.	Meeting with Telecom. Department	
26	Sun.		
27	Mon.	Arrival in Kuching Discussion with D.I.D. Officials	Mr. Ngo, Mr. Tserng Goong Farm Mr. Then Tiat Kiong Mr. Y. Komori
28	Tue.	Field Survey in the Sadong river basin. (Serian, Gedong, Balai-Ringin, Tebedu).	
29	Wed.	Field Survey (Tebakang, Krusin, Mongkos, Meringgu, Gedong)	
30	Thu.	Field Survey (Mt. Serapi, Siniawan)	
		Discussion with D.I.D. Officials	Mr. Joseph Ting Mr. Tserng Goong Farm Mr. Ten Tiat Kiong Mr. Y. Komori
Dec. 1	Fri.	(National Holiday)	
2	Sat.	Meeting with Officials of SPU, D.I.D., Police, Telecom., M.M.S., Welfare at SPU	
3	Sun.		
4	Mon.	Discussion with D.I.D. Officials	Director Foong Ka Nim Mr. John Tan
		Departure from Kuching	
		Arrival in Kota Kinabalu	
5	Tue.	Meeting with D.I.D. Officials	Director Joseph Yeoh Hoh Hoh Mr. Paul Hii, Mr. Stanley Chin
		Visit to SEPU	Dy. Director
Dec. 6	Wed.	Field Survey in the Kinabatangan river basin	Mr. Paul Hii
		Departure from Kota Kinabalu to Sandakan	

Date		Itinerary	Meeting
		Field Survey in the Kinabatangan river basin (Bukit Garam, Balat, Kuamut, Ulu Kuamut)	Mr. Chin Foo Fah
7	Thu.	Field Survey (Tangkulap)	
8	Fri.	Study at D.I.D. Sandakan	
		Arrival in Kota Kinabalu	
9	Sat.	Meeting with Officials of D.I.D., SEPU, Telecom, M.M.S., Police, Welfare at D.I.D.	Director Joseph Mr. V. Thiagarajah, Mr. Paul Hii, Mr. Stanley Chin (DID), Mr. Vincent Gadalow (SEPU) Mr. A. Malion Hussain(Telecom) Mr. Chong Ah Look (MMS) Mr. Dominic Apin (Police) Mr. Pamloc Mond (WELFARE)
10	Sun.		
11	Mon.	Arrival in Kuala Lumpur	
		Discussion with D.I.D. Officials	Mr. Tan King Seng Mr. Khoo Soo Hock Mr. S. Thirugnanasambanthar
12	Tue.	Preparation for Interim Report	
13	Wed.	Field Survey on the existing flood forecasting system in the Perak river basin.	
14	Thu.	Preparation of Interim Report	
15	Fri.		
17	Sun.	Data arrangement	
18	Mon.	Final discussion with EPU and D.I.D. Officials	
19	Tue.	Data arrangement	
20	Wed.	Departure from Kuala Lumpur Arrival in Manila	
21	Thu.	Discussion at TCS	
22	Fri.	Return to Tokyo	

1-4 Scope of Survey

During its stay in Malaysia, the team conducted the following pleliminary study for a flood forecasting and warning system in the basins of the Sadong and the Kinabatangan with helpful assistance of Malaysian government.

(1) Field reconnassiance survey in the two basins.

(2) Discussions with competent Malaysian authorities on the flood forecasting system.

(3) Collection of available data and information.

(4) Studies on the network of hydrological observation stations and telemetering stations.

(5) Preparation of the survey report.

(6) Collection of information necessary for the next mission on a feasibility study scheduled in 1979.

1-5 Data Collection

The following data and information were collected during the survey period.

<u>Data and Information</u>

Data and Information provided by Typhoon Committee Secretariat

(1) SADONG RIVER IN SARAWAK

* MAP 1/50,000 LAYOUT PLAN OF SADONG & KRANG RIVER IMPROVEMENT PROJECT
* MAP UPPER SADONG FLOOD AREA MAP 1/50,000
* MAP SARAWAK 1/1,000,000
* ISONYETAL MAP OF SARAWAK 1974
* SEASONAL DISTRIBUTION OF RAINFALL 1974
* DETAIL FLOOD AREA AT SERIAN
* FLOOD HYDROGRAPH OF SADONG RIVER 1976
  Serian, Putch, Gedong (9th/Jan.- 21th/Jan.)
* FLOOD INVESTIGATION REPORT FEB./1974

(2) KINABATANGAN RIVER IN SABAH

* TOPOGRAPHY MAP 1/250,000
  Hydrological Stations are marked on the map

* HYDROGRAPH FOR THE 1971 FLOOD
* STAGE DISCHARGE TABLE
  Ulu Kuamut, Tanghulap
* DAILY RAINFALL
  1/2/1971 - 15/2/1971
* DAILY WATER LEVEL
  Ulu Kuamut 4/2/1971 - 11/2/1971
  Tanghulap 4/2/1971 - 15/2/1971

Data and Information provided by DID Kuala Lumpur

* COMPUTER - BASED FLOOD FORECASTING IN PENINSULAR MALAYSIA AIEUAL REPORT NO.1 FOR 1977/78 MONSOON
* MAP COMPUTER - BASED FLOOD FORECASTING NETWORK
* MAP AVERAGE MONTHLY RAINFALL DISTRIBUTION FOR SELECTED STATIONS IN MALAYSIA
* MAP EXISTING AND PROPOSED OBSERVATION STATIONS (SARAWAK)
* SADONG RIVER HYDROLOGICAL STATION AND PERIOD OF RECORDS AVAILABLE
* PROJECT BRIET ON PROPOSED FLOOD FORECASTING AND WARNING SYSTEM IN SABAH AND SARAWAK

Data and Information provided by MMS Kuala Lumpur

* RECORDS OF SURFACE WIND, RAINFALL AND TEMPERATURE (Sandakan, Kuching)
* MONTHLY ABSTRACT OF METEOROLOGICAL OBSERVATIONS 1977

Data and Information Provided by DID Sarawak

* MAP 1/50,000 (1/110/15, 1/110/16, 0/110/3, 0/110/4, 1/110/14, 0/110/2, 1/110/7, 1/110/8, 1/110/12, 1/110/11)
* MAP 1/250,000 (MA-49-10)
* SARAWAK HYDROLOGY BRANCH STAFF ORGANIZATION
* DRAINAGE & IRRIGATION DEPERTMENT ORGANIZATION CHART
* LAND USE TABLE
* FLOOD DAMAGE IN 1963
* SARAWAK FLOOD RECORD 1976
* STAGE DATA (CHART)
  Serian 2/12/1977 - 12/12/77, 20/1/1978 - 28/1/78,
  24/ 3/1978 - 27/ 3/78, 4/4/1978 - 11/4/78
  Gedong 14/2/1978 - 21/ 2/78, 21/3/1978 - 28/3/78
  4/4/1978 - 11/ 4/78, 19/1/1978 - 28/1/78
* HOURLY RAINFALL AT KUCHING AIRPORT DURING SERIAN FLOOD PERIOD
  Jan. 1963, Feb. 1974, Jan. 1976
* TIDE DATA 1974, 1976 KUCHING

* HYDROGRAPH
  - Serian, Krusin - 15/1/1977 - 28/2/1977
  - Tebedu, Tebakang 1/12/1977 - 10/12/1977
  - Monghos, Serian 21/ 1/1978 - 30/ 1/1978
  - Meringgu - 8/ 1/1978 - 28/ 1/1978
* SARAWAK HYDROLOGICAL YEAR BOOK
  1963 - '66, '67 - '68, '69, '70, '71, '72, '73, '74
* PROPOSALS FOR AGRICULTURAL DEVELOPMENT OF THE SANARAHAN AND SADONG - KRANG PADI PROJECT AREAS, SARAWAK: PREFEASIBILITY STUDY
  Volume 1 - 3
* ANNUAL STATISTICAL BULLETIN SARAWAK 1976
* FLOOD MITIGATION REPORT FOR UPPER SADONG BY Y. KOMORI 1978
* SINIAWAN FLOOD WARNING STATION, MARCH 1976

Data and Information provided by DID Sabah

* MAP 1/50,000 4/116/3,4,6 4/117/1,2,3,5 5/116/7,8,10,12,14,15,16
  5/117/5-16 5/118/1,5,6,7,9,10,11,13
* MAP 1/250,000 (JAN. 1968 FLOOD) 1/750,000
* ORGANISATION CHART (AS ON 1st. SEPT., 1978)
* HYDROLOGIC RECORDS OF SARAN TO 1968
* ANNUAL BULLETIN OF STATISTICS SABAH 1976
* STUDY ON TIME LAG OF FLOODS BY DID
* SECTION OF WATER LEVEL STATION
  (Barik Manis, Lamag, Ulu Kuamut, Tangkulap)
* BUDGET OF SARAWAK DID
* POPULATION & CROP STATISTIC
* FLOOD DAMAGE
* TIDE DATA IN SANDAKAN
* ABSTRACT OF METEOROLOGICAL OBSERVATIONS FOR SANDAKAN AIRPORT
* MONTHLY AND ANNUAL RAINFALL DATA 1969 - 1975
  (Tangkulap, Bukit Garam, Kuamut, Ulu kuamut)
* METEOROLOGICAL DATA AT KUAMUT 1969 - 1975
* DAILY RAINFALL DATA
  (Bukit Garam 1968 - 1975, Kuamut 1969 - 1975)
  (Tangkulap 1969 - 1975, Ulu Kuamut 1969 - 1975)
* DAILY EVAPORATION DATA
  Sandakan 1969 - 1976, Kuamut 1969 - 1976
* DAILY MEAN STAGE DATA
  Ulu Kuamut 1969 - 1975, Tangkulap 1969 - 1975)

* HOURLY RAINFALL DATA
  Main Flood during 1971 - 1975
* HOURLY STAGE DATA (CHART)
  Main Flood during 1971 - 1975
  Tangkulap, Ulu Kuamut
  Barik Manis (only 2/1971)

1-6 Recommendations

On the basis of the field survey in the basins of the Sadong and the Kinabatangan and from the findings of analysis of relevant data, the team recommends that due consideration be given to the following.

(1) The field survey disclosed that the establishment of a flood forecasting system in the two basins is feasible mainly from the technical point of view and at the same time highly contributory to the development of the two basin areas. A further detailed study should therefore be made by a second survey team in the near future.

(2) The flood forecasting system should be an appropriate one with due account taken of various aspects including cost-benefit ratio, operation and maintenance etc.

(3) Several new water level stations should preferably be established in both basins.

(4) Flood forecasting and warning system will increase the potentiality of the basin's future development. It is recommended that a comprehensive river basin study be undertaken for efficient development in the basin as soon as possible.

(5) As for hydrological data, observation and data processing have been done well by a rather small number of personnel despite the fact that most of the stations are located in remote places. However, further periodical inspection of the stations is desirable from the view point of gauge reliability.

(6) All personnel to be engaged in actual forecasting service should be given the opportunity to receive technical training in various areas directly associated with their service.

(7) It is recommended that the flood forecasting and warning system will have a configuration briefed below.

(Sadong River Basin in Sarawak)

1) Water level observation stations

6 stations at Krusin, Meringgu, Tebakang, Serian, Gedong, and Kpg. Ensenggi Melangu.

2) Rainfall observation stations

5 stations at Muara Mongkos, Tebakang, Serian, Bedup, and Balai Ringin.

3) Tebakang and Serian stations are to be operated for observation of both water level and rainfall, and Ensenggi Melangu station for tide observation. Bedup and Balai Ringin stations can be included in the future construction plan.

4) Target areas of flood warning

Tebakang, Serian, Tanah Puteh, Sebanban and Gedong.

5) Target points of flood forecasting

Serian and Gedong.

Selection of these points will make it possible to issue warnings 6-12 hours in advance by water stage correlation method or 20 - 30 hours in advance by rainfall-water stage correlation method.

Further study of hydrological data is necessary.

(Kinabatangan River Basin in Sabah)

1) Water level observation stations

7 stations at Tongod, Ulu Kuamut, Tangkulap, Kuamut, Balat, Bukit Garam, and Bilit.

2) Rainfall observation stations

6 stations at Tongod, Ulu Kuamut, Tangkulap, Kuamut, Belat, and Bukit Garam.

3) The 5 stations at Tongod, Ulu Kuamut, Kuamut, Balat, and Bukit Garam will be operated for observation of both water level and rainfall.

4) Target areas of flood warning

Kuamut, Balat, Pintasan, Lamag, and Bilit.

5) Target points of flood forecasting

Balat, Bukit Garam, and Kuamut.

Selection of these points will make it possible to issue warnings 6 - 24 hours in advance.

Further study of hydrological data is necessary.

(8) The proposed telemetering network is shown in Figs. 1-1 and 1-2. Radio propagation tests should be conducted to determine detailed specifications of the radio link shown in these figures.

In selecting the sites of relay stations required for the operation of the network, careful consideration should be given to the construction cost, ease of maintenance service, etc.

(9) Studies should be made to determine whether maintenance service of telemetering facilities is to be undertaken by the State DID or commissioned to the Telecommunication Department.

(10) Since the State DID will be the flood forecasting center in each basin, studies must be made on its organizational makeup, location, availability of space for accommodating the centre's facilities, and operational problems likely to be encountered in future.

Fig. 1-1 Telemetering Network in the Sadong River Basin

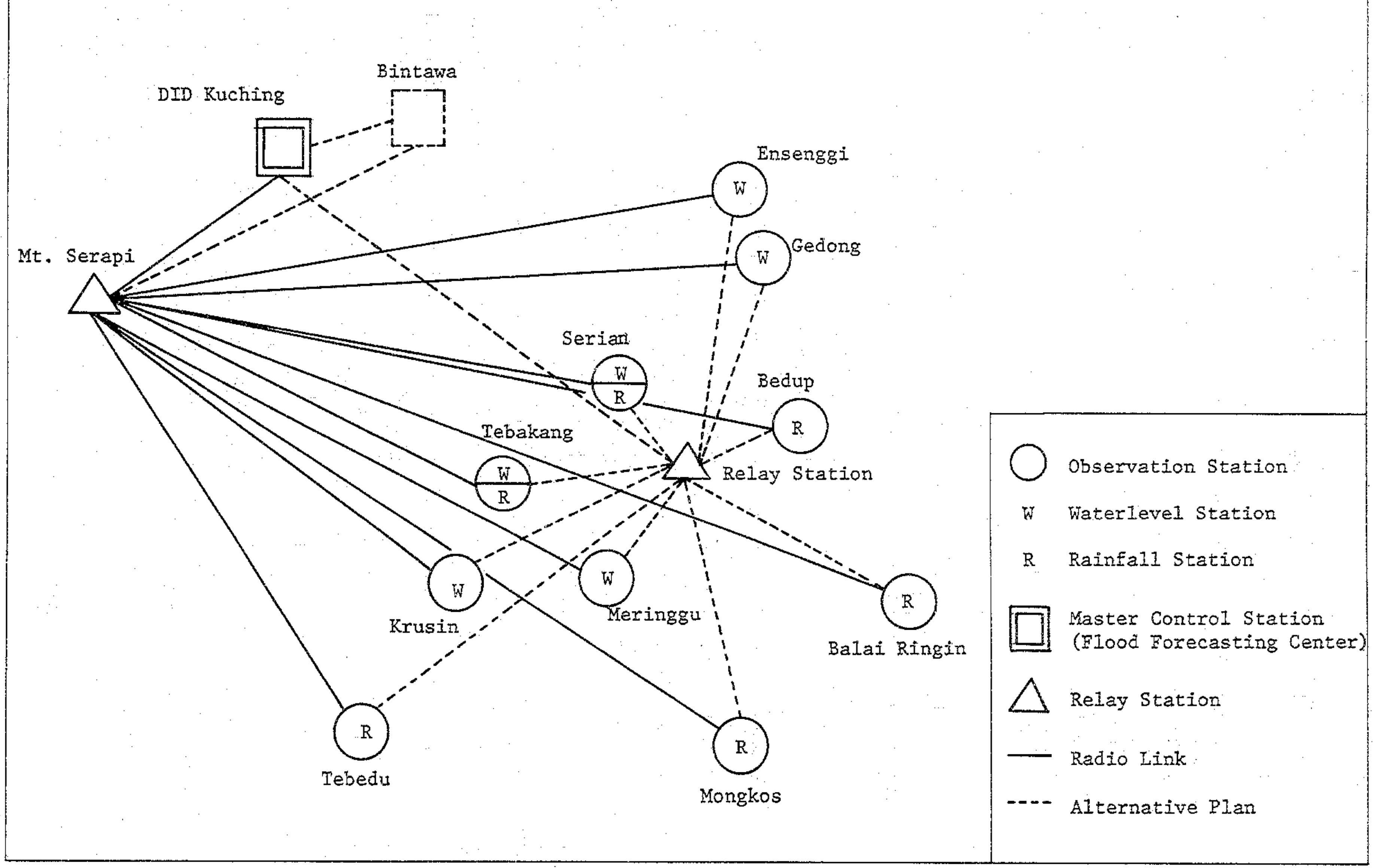
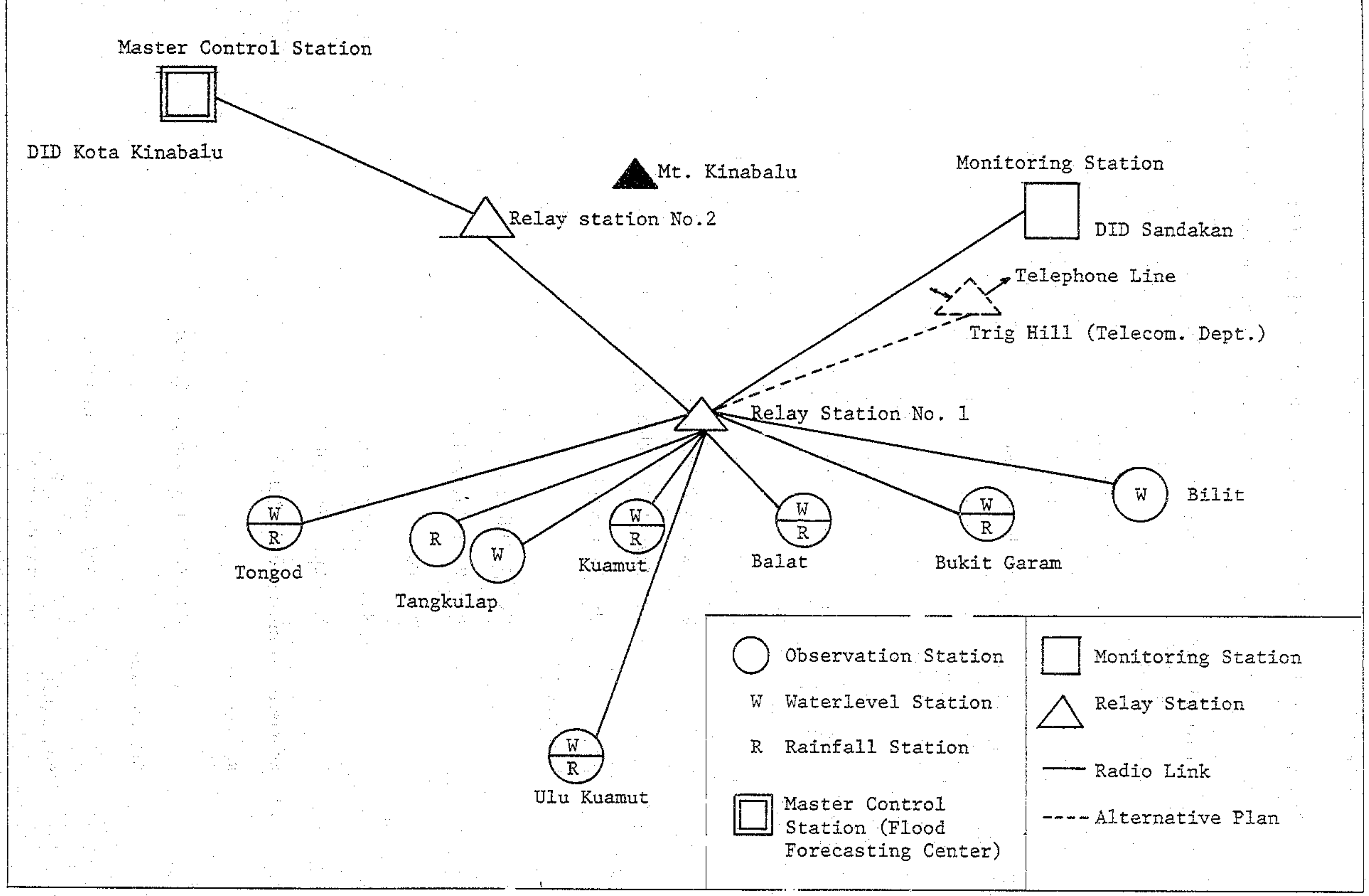


Fig. 1-2 Telemetering Network In The Kinabatangan River Basin



1-7 Acknowledgement

(1) The team feels deeply indebted to the following officials of Malaysian government who offered most helpful assistance during the survey period.

1) Drainage and Irrigation Department (DID)

Federal DID:

Mr. S.H. Thavaraj

Mr. Tan Hoe Tim

Mr. Sieh Kok Chi

Mr. Tan King Seng

DID Sarawak:

Mr. Foong Ka Nin

Mr. Joseph Ting

Mr. John Tan

Mr. Ngo

Mr. Tserng Goong Farn

Mr. Then Thiat Khiong

Mr. Y. Komori

DID Sabah:

Mr. Joseph Yoeh Hoh Hoh

Mr. V. Thiagarajah

Mr. Paul Hii

Mr. Stanley Chin

Mr. Chin Foo Fah

2) Economic Planning Unit (EPU)

Federal EPU:

Mr. Zulkefli Bin A. Hassan

EPU Sarawak

Mr. Amiruddin Bin Hussain

EPU Sabah:

Deputy Director

Mr. Vincent Gadalow

3) Malaysia Meteorological Service (MMS)

Federal MMS:

Mr. P. Markandan

Mr. Abraham David

MMS Sarawak:

Mr. Benedict Chin

MMS Sabah:

Mr. Chong Ah Look

4) Telecom Department (TD)

Federal TD:

Mr. P. P. Jothy

TD Sarawak:

Mr. Paul Foo

TD Sabah:

Mr. A. Malion Hussain

5) Officials of Police and Welfare Authorities

The team also wishes to express its deep gratitude to ESCAP for rendering valuable advice and to the Typhoon Committee Secretariat for providing the assistance of Mr. Hidetomi Oi.

Chapter 2. Existing Flood Forecasting and Warning System in Malaysia

2-1 Flood Forecasting and Warning Facilities

A flood forecasting telemetering system is already established in the basins of four major rivers in the peninsular area (i.e., the Kelantan, the Trengganu, the Pahang, and the Perak). In these basins, rainfall and water level stations are operated automatically for data transmission to the State DID by the telemetering network. All observation stations in each state are under the calling control of the master control station at DID where the data transmitted from each station is printed by typewriter.

Table 2-1 and Fig. 2-1 show the existing telemetering facilities in the four basins.

Table 2-1 Telemetering Facilities

River	Catchment Area (Km^2)	Number of Observation Stations	Location of Master Control Station	Remarks
Perak		Rainfall station 2 Water level station 2	Ipo	Relay station 2
Kelantan	12,200 (Guillemard Bridge)	Rainfall Station 5 Water level station 3	Kota Bharu	Relay station 1
Trengganu	3,300	Rainfall station 4 Water level station 1	Trengganu	Relay station 2
Pahang	19,000	Rainfall station 7 Water level station 4	Kuantan	Relay station 2

Note: The following 8 frequencies within 70 MHZ band are currently used for data transmission.

71.900, 71.950, 72.125, 72.175, 75.475, 75.525, 75.625, and 80.650

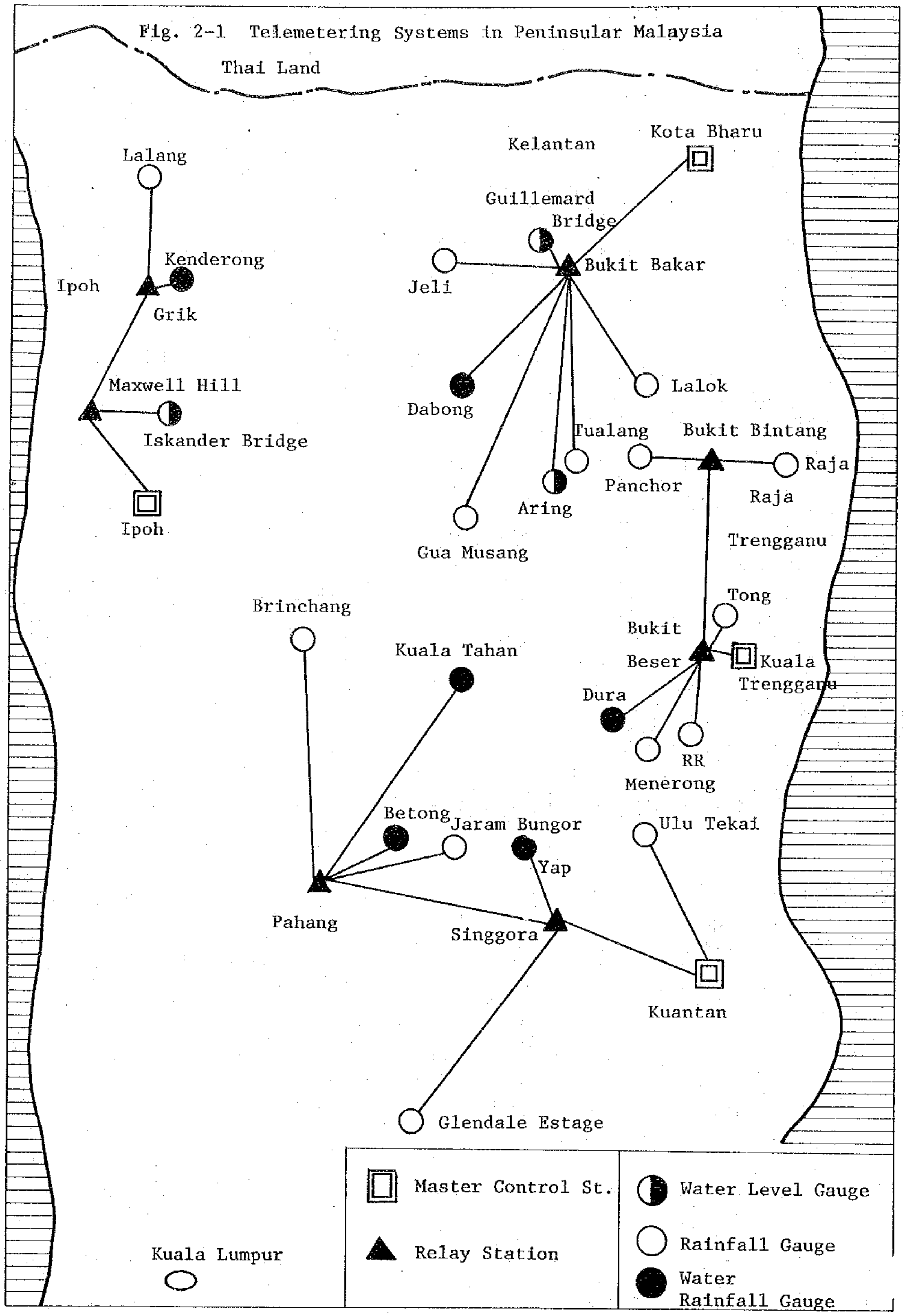
Water level and rainfall data in the Kelantan, Trengganu and Pahang basins are transmitted by the teleprinter line network of Telecom. Department to DID Headquarters in Kuala Lumpur for processing by electronic computer. The Perak river basin is not linked with this teleprinter line network.

The existing telemetering systems are not fully satisfactory. Specifically, the rainfall stations in upstream areas are limited in number and they are located near the mouth of catchment area by reason of the cost and difficulty in construction and maintenance work. Hence, they do not represent average basin rainfall with satisfactory accuracy. The efficiency of the existing systems is also impaired by the fact that only point rainfall can be observed at the stations and by frequent local rainfall in Peninsular Malaysia.

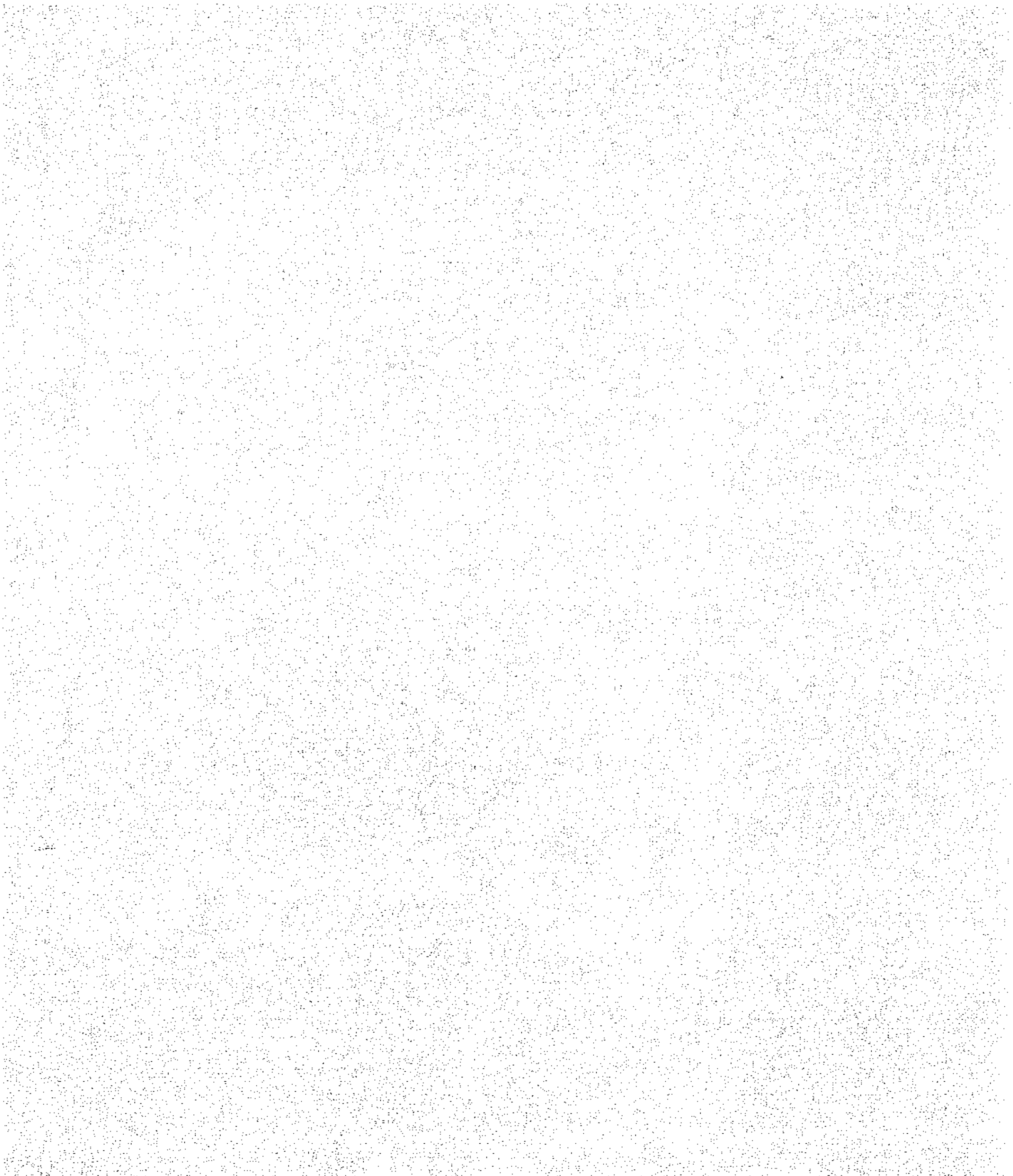
Accordingly, it is said that the "radar data" obtained from the weather radar of Meteorological Service is useful. But the radar data is not used for quantitative analysis as it is qualitative in nature.

DID Headquarters is equipped with a computer system operated for data analysis for flood forecasting by Sacramento method or Pabang method. This computer System is composed of a "Data General Corporation NOVA 1220 with a core capacity of 32 kW (16 bit), " magnetic tape unit, magnetic disk memory, card reader, line printer, teleprinter, etc. Details of this system are given in "Computerbased Flood Forecasting in Peninsular Malaysia" prepared by DID.

Fig. 2-1 Telemetering Systems in Peninsular Malaysia



PART II. SADONG RIVER BASIN (SARAWAK)



Chapter 3. Outline of Sadong River Basin

3-1 Natural Conditions

The Sadong river has a catchment area of 3,460 km^2 lying between Lat. 1° and 1°30'N and between Long. 110° and 111° E. within Sarawak State. Its basin is relatively flat as a whole and Mt. Rawan with an elevation of 900 m is the highest mountain on the waterhsed that forms the Indonesian border line.

The upper Sadong basin is crossed by an arterial road linking Kuching and Simanggan, from which a number of branch roads extend to main Kampongs (chesters) in the basin such as Gedong in the downstream area and Tebakang, Muara Mongkos and Tebedu in the upstream area. These Kampongs are easy of access by car because all the branch roads are well maintained. The largest city in the basin is Serian, and there are found many small villages along the Sadong. Serian is only a 40 minutes' car ride from Kuching, the state capital, so that there is high probablity that the basin will be developed rapidly in future. (See Figs. 3-1 and 3-2)

The basin has a tropical climate featured by high temperature and copious rain. The northeast monsoon season (wet season) lasts from November to March, and 55% of annual rainfall is recorded in this period. Paddy cultivation requires no irrigation in this monsoon season.

Fig. 3-1 Sadong River Basin

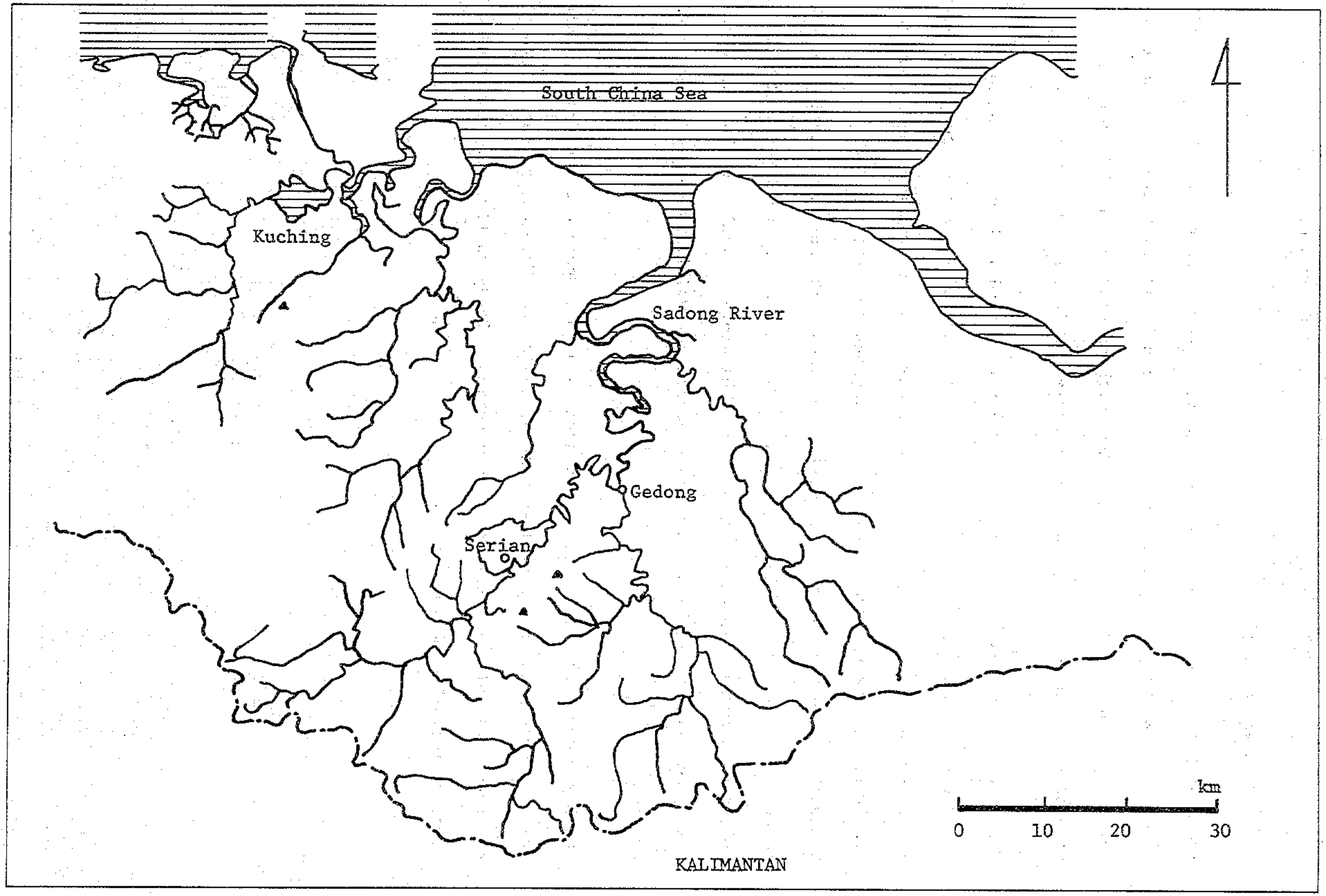
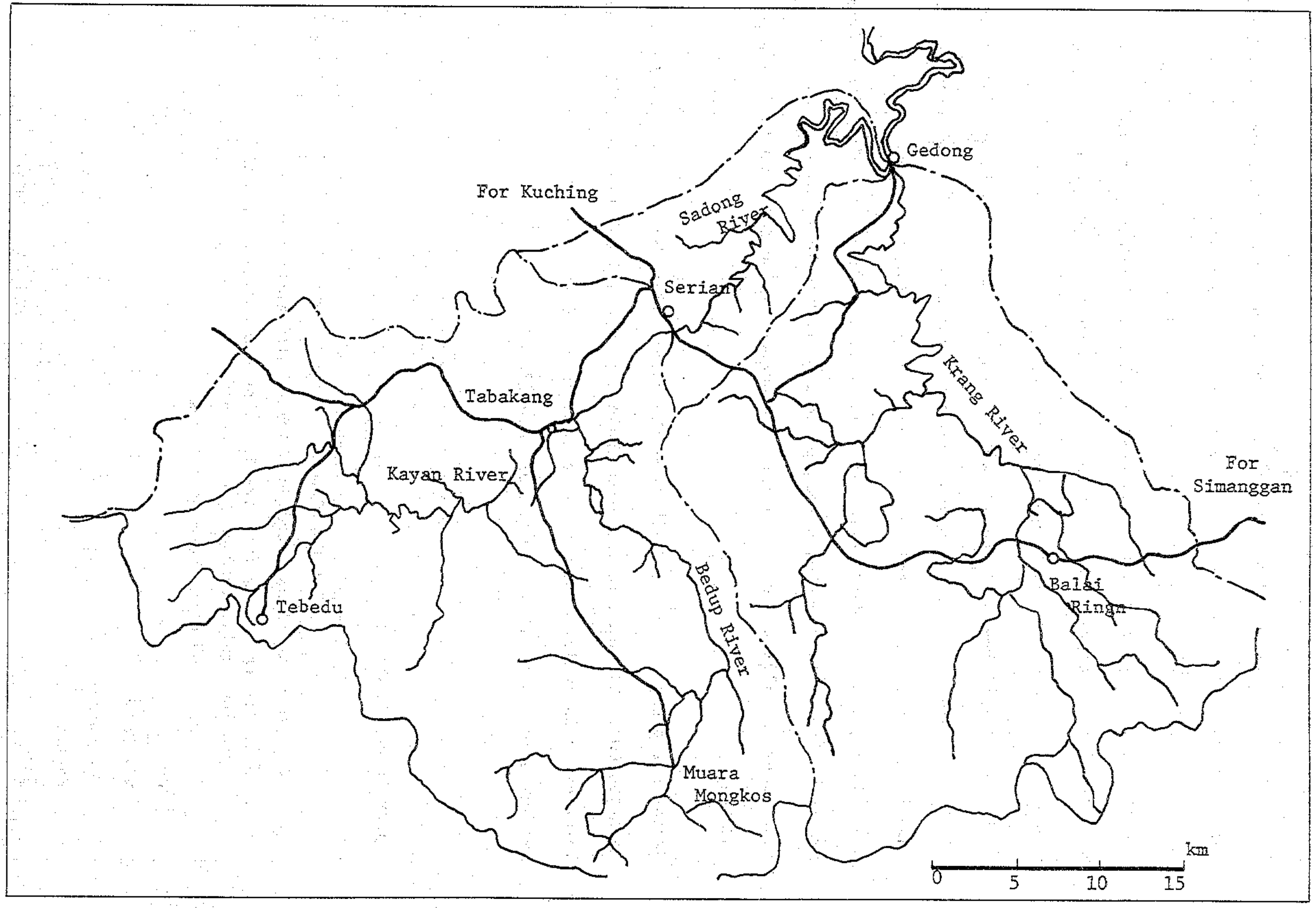


Fig. 3-2 Upper Sadong River Basin



3-2 Socio-economic Conditions

The Kuching - Simanggan road, one of arterial roads in Sarawak, runs through the upper Sadong basin. Serian, the largest city in the basin, is one of the important cities developed along this road. A number of Kampongs are found along the Sadong both upstream and downstream of Serian. By virtue of the well-maintained road network, the land use ratio in the basin is relatively high, especially in the upper basin upstream of Gedong.

Main crops in the basin are paddy, rubber, pepper, and coconut. Special effort is made for increasing paddy production and a number of irrigation programmes have been formulated for this purpose such as the Mid-Sadong Drainage Scheme Stage I, II, III, the Paya Payang Irrigation Scheme, and the Sadong-Krang Padi Project. Pepper is expected to become an important commercial crop as it flourishes in hilly areas. Existing land use condition is shown in Tables 3-1 and 3-2.

Serian has a population of 2,200, and the upper Sadong basin has a population of about 54,000. Simunjan in the downstream area has a population of 630, and the lower basin including Simunjan has a population of about 31,000. Thus, the basin has an estimated total population of about 85,000.

Table 3-1 Land Use

Upper Sadong District

	LAND USE CLASSES	km^2
1.	Settlement and Associated Non-Agricultural Lands	3
2.	Horticultural Lands (mainly miscellaneous cultivation and including small areas of fruit trees).	7
3.	Tree Palm and Other Permanent Crops	179
	Rubber	146
	Oil Palm	-
	Coconut	1
	Pepper	32
	Sago	-

4.	Crop Land	1,126
	Wet Padi	11
	Shifting cultivation	1,115
5.	Improved Permanent Pasture (Not used)	-
6.	Unused Land	55
	Sheet Lalang (Not used)	-
	Other Secondary Growth	55
7.	Swamp Forest	197
	Mixed Swamp Forest	197
	Alan	-
	Padang Paya	-
8.	Dry Forest Land	475
	Hill Forest	457
	Kerangas Forest	14
	Riverain Forest	4
	Beach Forest	-
9.	Swamp (Paya) (including fresh and salt water and mangrove and nipah)	-
10	Unproductive Land (Not used)	-
	All Land Use Classes	2,042

Table 3-2 Land Use

Lower Sadong District

	LAND USE CLASSES	km^2
1.	Settlement and Associated Non-Agricultural Lands	2
2.	Horticultural Lands (mainly miscellaneous cultivation and including small areas of fruit trees)	2
3.	Tree Palm and Other Permanent Crops	137
	Rubber	37
	Oil Palm	-
	Coconut	96
	Pepper	4
	Sago	-
4.	Crop Land	381
	Wet Padi	28
	Shifting cultivation	353

5.	Improved Permanent Pasture (Not used)	-
6.	Unused Land	47
	Sheet Lalang (Not used)	-
	Other Secondary Growth	47
7.	Swamp Forest	805
	Mixed Swamp Forest	748
	Alan	57
	Padang Raya	-
8.	Dry Forest Land	221
	Hill Forest	186
	Kerangas Forest	34
	Riverain Forest	-
	Beach Forest	1
9.	Swamp (Paya) (including fresh and salt water and mangrove and nipah)	7
10.	Unproductive Land (Not used)	-
	All Land Use Classes	160

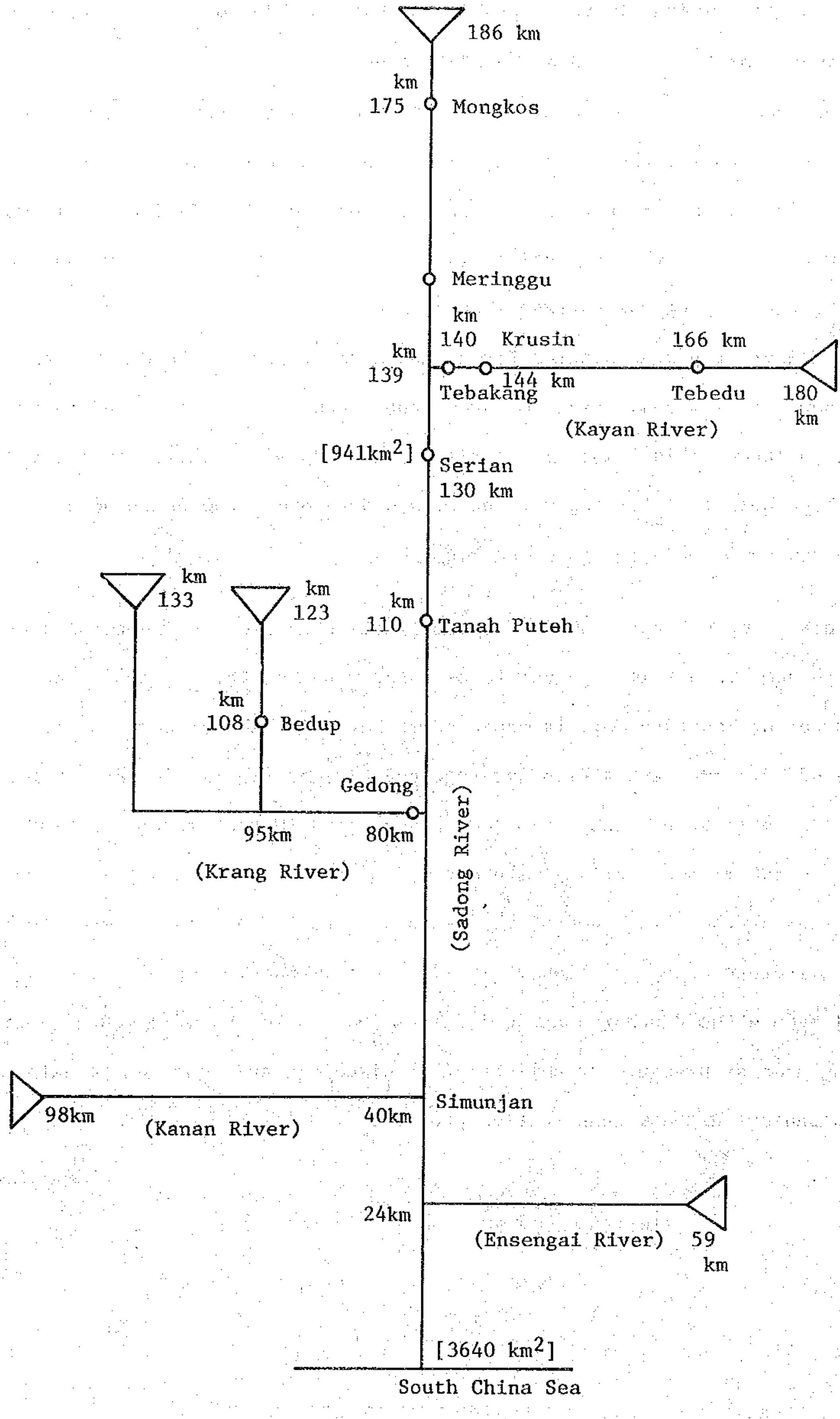
3-3 River Channel

As shown in Fig. 3-3, the Sadong has a length of 186 km and meanders through a flat plain. Its tidal area extends up to Tanah Puteh located 110 km upstream of the estuary. In this 110 km section, the river meanders extremely and presents features of a primary river with mangrove trees growing thickly on both banks. In the king tide season lasting from December to February, which coincides with the wet season, flood water often overflows its banks.

The Sadong has a width of 40 - 60 m at Serian located 130 km upstream of the estuary, and at a point 10 km further upstream, it is joined by two tributaries, the Kedup which has a mild bed gradient (1/3500) and the Kayan which has a sharp bed gradient (1/570).

Since no road is constructed on either bank, boats must be used for observation of the channel. Boats are the most important means of transportation for most of the Kampongs along the Sadong.

Fig. 3-3 Basin Model of the Sadong River



3-4 River Improvement

No river improvement is under way in any part of the Sadong river, but there are two improvement plans under consideration.

One of them is the short-cut plan. The Sadong has a very mild surface slope because of its extreme meandering flow. The distance between Serian and Gedong is only about 16 km in a straight line, but the river channel has a length of 50 km, so that the connection of the two points with a single short cut results in the trebling of the surface slope. Hence, it is planned to shortcut the channel in a number of places between Serian and a point about 7 km downstream of Gedong as shown in Fig. 3-4. Fig. 3-5 shows the cross-section of curved parts to be shortcut under this plan. It is also planned to widen the channel and increase the bank height by filling work between Gedong and Tanah Puteh because even king tide causes flooding of this section.

The other improvement plan is for construction of two flood-control dams. One of the dams is a fill type dam to be constructed on the Kayan at a point 7 km upstream of Tebakang. It is expected to have a height of about 30 m, a reservoir area of 10.6 km^2, and a flood storage capacity of 110 million m^3. Completion of this dam will reduce the maximum discharge in a 10 year return period from 700 m^3/s to 400 m^3/s at Serian. The other dam, to be built at a point about 10 km upstream of the confluence of the Kedup and the Sadong, is expected to have a flood storage capacity of about 70 million m^3. Completion of these two dams will reduce the discharge at Serian from 700m^3/s to 190 m^3/s. Endeavours are being made at present for collection of discharge and other basic data essential to planning this dam construction project.

Fig. 3-4 Proposed Short Cut

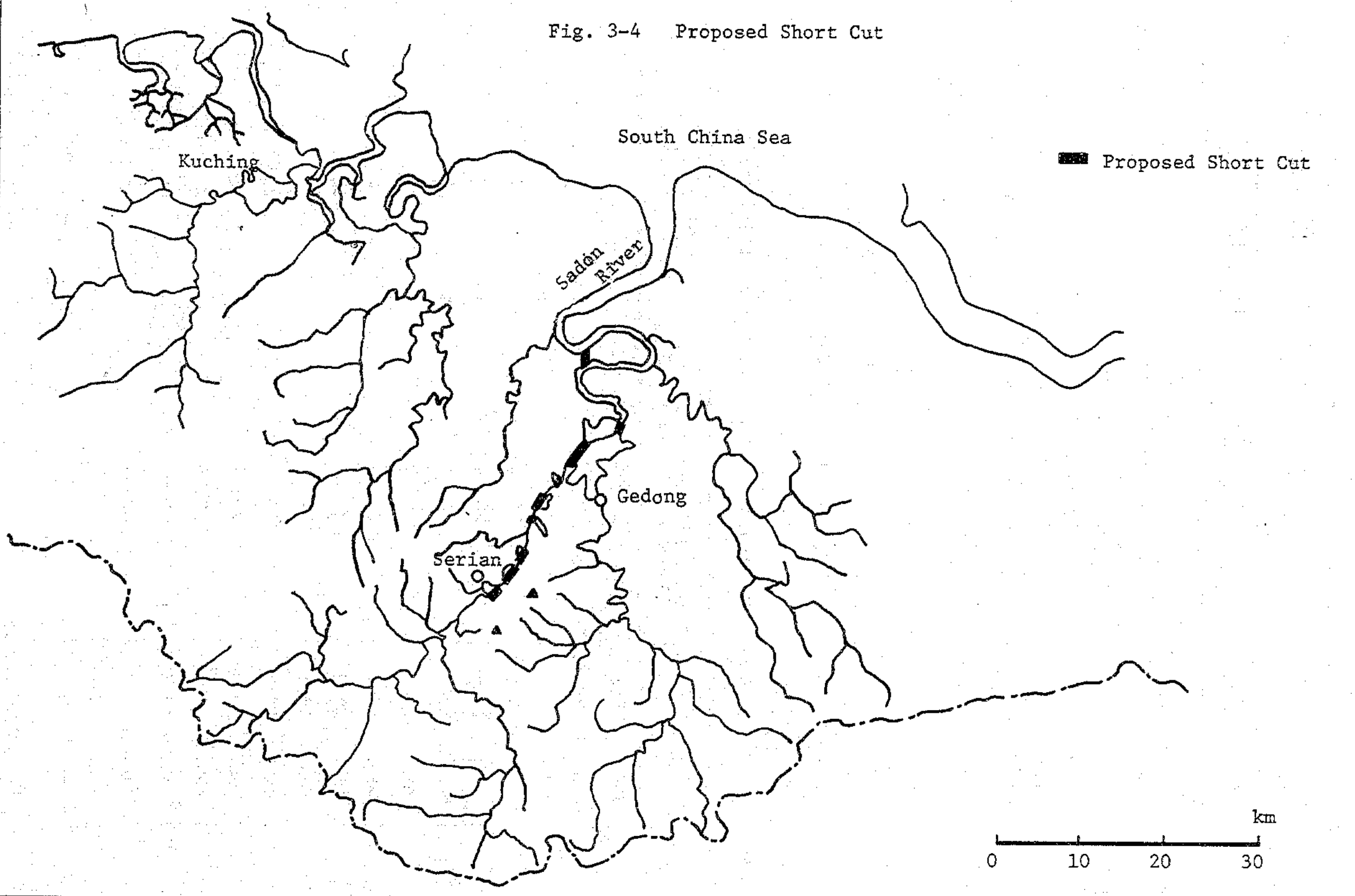


Fig. 3-5 Cross Section of Bunding & Widening

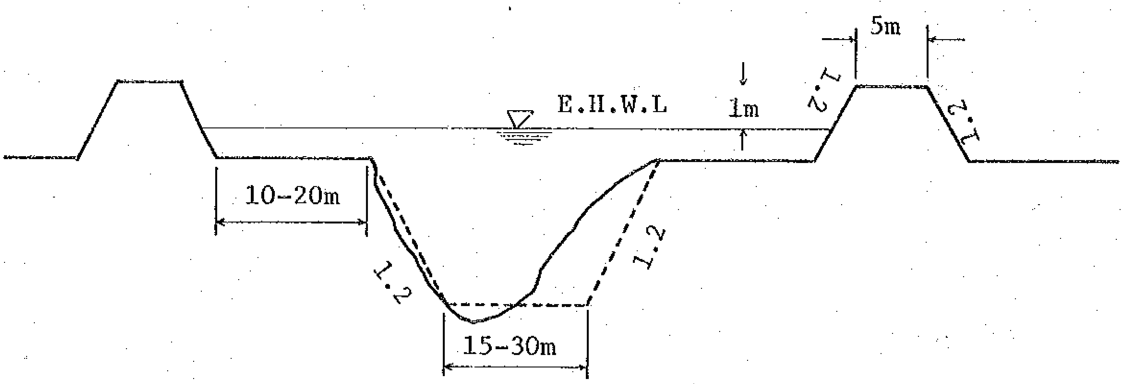
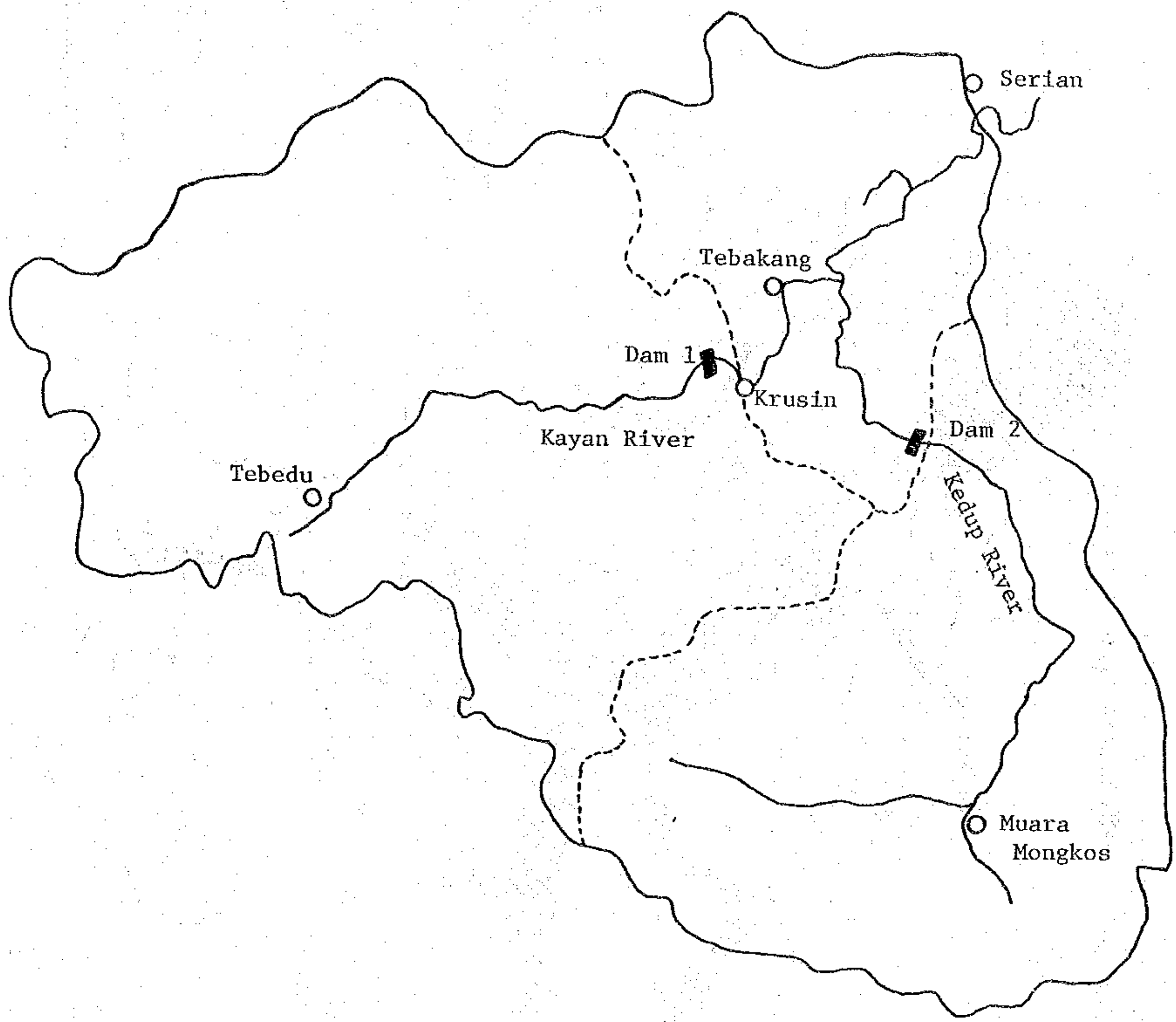


Table 3-3 Data of floot water level

A nual Maximun Water Level at Serian (1962-1977)

Year	Water Level (Above M.S.L. in feet)	Flood Depth feet
Feb. 1962	30.70	4
Jan. 1963	30.74	4
March 1964	27.44	$1\frac{1}{2}$
March 1965	26.74	$\frac{1}{2}$
Jun. 1966	26.54	$\frac{1}{2}$
March 1967	26.54	$2\frac{1}{2}$
Feb. 1968	28.99	3
Dec. 1969	29.74	1
Jan. 1970	27.09	$1\frac{1}{2}$
Feb. 1971	27.49	$\frac{1}{2}$
Jan. 1972	26.74	$2\frac{1}{2}$
Dec. 1973	29.01	$4\frac{1}{2}$
Feb. 1974	30.86	4
Feb. 1975	30.63	6
Jan. 1976	32.01	-
Jan. 1977	——	-

Fig. 3-6 Location of Flood Control Dams.



LEGEND

▬ ------- Dam site
Reservoir

Fig. 3-7 UPPER SADONG FLOOD AREA (1976)

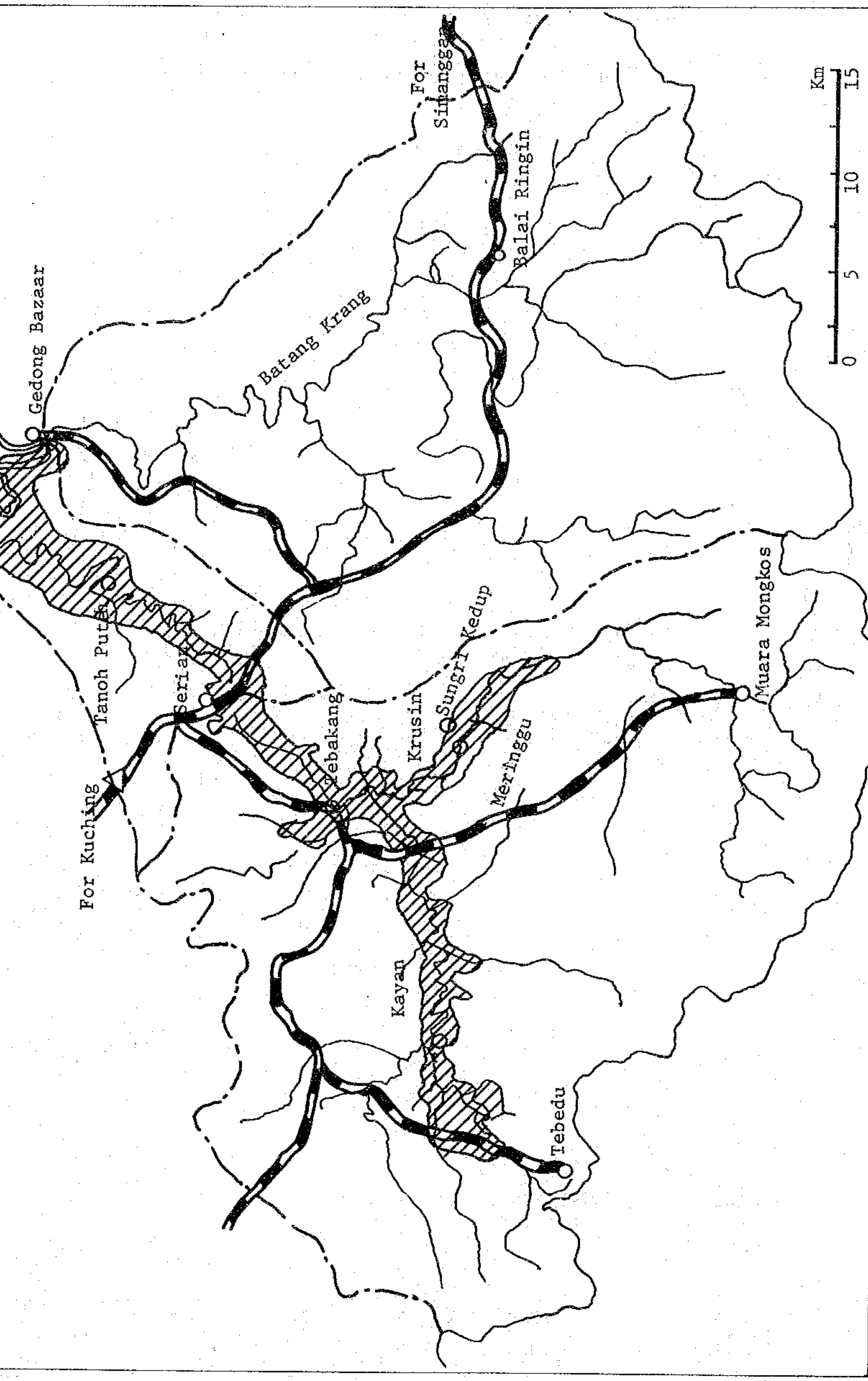
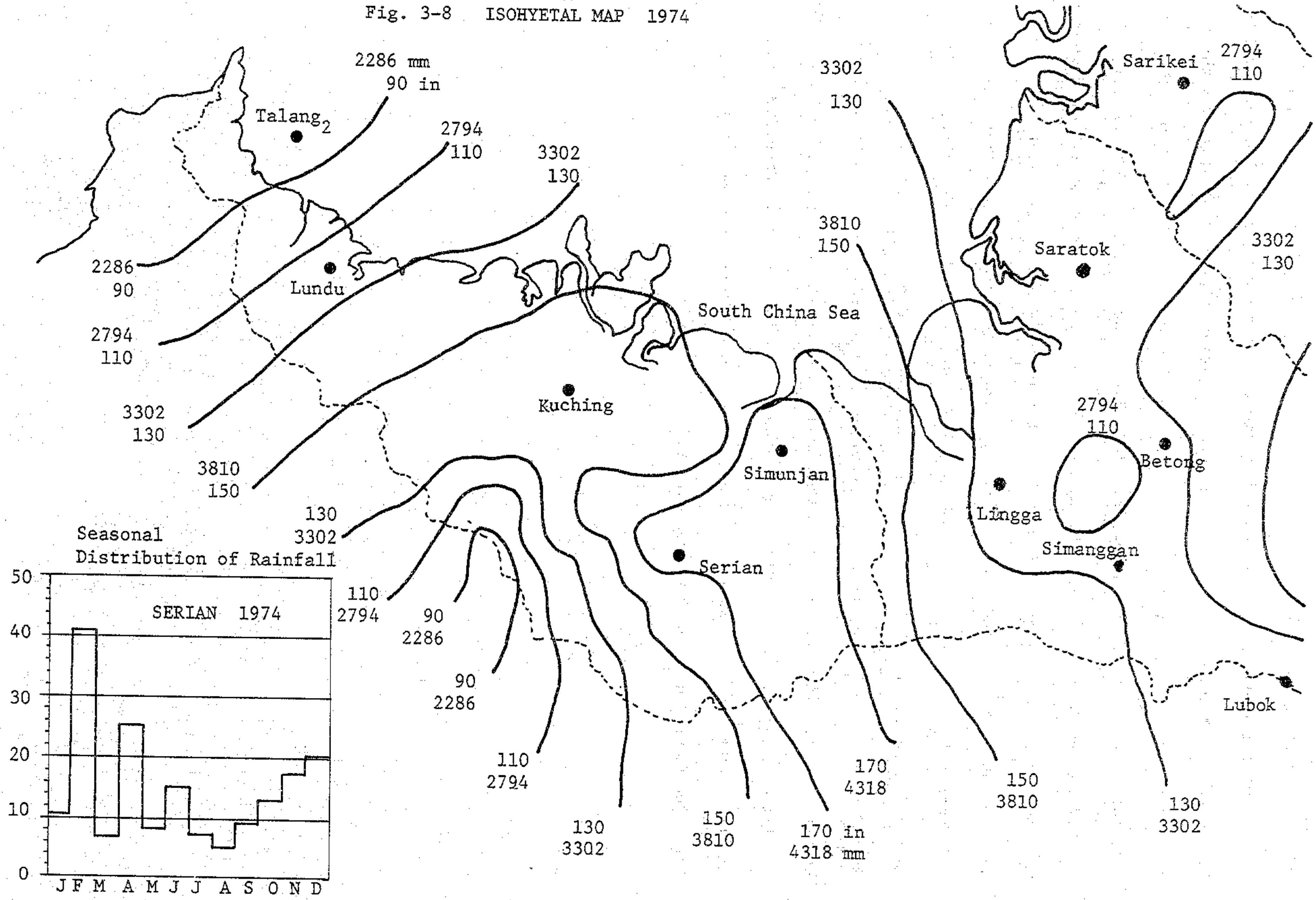


Fig. 3-8 ISOHYETAL MAP 1974



3-5 Flood Damage

Details of flood damage are unknown because no damage survey has been conducted in the past. Judging from the flood data at Serian (Table 3-3) which is the most well-consolidated flood water level data, the flood in January 1976 was the heaviest ever recorded in the basin. This flood inundated the greater part of the Sadong basin, overflowing the Kuching-Simanggan road to a height of 2 feet in Serian area and waterlogging lower areas for about 7 days. It recorded a maximum depth of about 6 feet and incurred heavy damages especially in Serian, Tebakang, and Tanah Putech. The flood in January 1977 was also quite disastrous. It recorded a depth of 4-5 feet in Serian, and incurred an estimated loss of M$464,000 to crops, livestock and properties. Five houses are known to have been washed away by this flood in Tebakang. The upper Sadong flood area in 1976 is shown in Fig. 3-7. The flood in February 1974 was quite destructive, too. It had a depth of more than 4 feet and submerged Serian for about 7 days. Fig. 3-8 shows the isohyetal map for 1974.

Chapter 4. Meteorology and Hydrology

4-1 Meteorology

The Sadong basin is featured by copious rain. The annual rainfall ranges from 3,100 to 5,300 mm, averaging about 4,100 mm. The wet season lasts from November to March, and 55% of the annual rainfall is recorded in this period. Atmospheric temperature ranges from 19 to 36°C, the 24 hour average being about 26°C. The 24 hour mean of relative humidity is about 83%, and the annual evaporation is about 1,400 mm. Tables 4-1 and 4-2 show the meteorological data recorded at Kuching located close to the Sadong basin. Fig. 4-1 shows the monthly average rainfalls in the vicinity of the Sadong basin. The figure indicates that the November - March period records concentrated rainfalls due to the influences of northeast monsoons.

Table 4-1 Records of Mean, Highest and Lowest of Monthly and Annual Rainfall and Raindays.

Station: Kuching Aerodrome
Lat. 1°29'N
Long. 110°20'E
Ht.above M.S.L.26m

	Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)														
Mean	1951-1977	654.9	555.9	336.0	289.2	266.5	199.1	197.9	218.8	260.8	328.6	334.0	460.7	4102.6
Highest	1947-1977	1206.5	1558.4	597.6	457.8	431.7	323.8	445.5	386.8	408.6	561.5	634.4	880.7	5293.4
Year of Highest		1971	1964	1968	1977	1969	1963	1960	1969	1954	1968	1948	1973	1977
Lowest	"	145.8	99.6	166.9	84.6	150.6	114.5	27.4	66.0	96.0	142.7	215.1	263.6	3098.1
Year of Lowest		1974	1959	1974	1974	1965	1969	1958	1967	1976	1965	1965	1974	1972
Number of Raindays														
Mean	1951-1977	25	21	21	19	19	16	16	18	19	23	24	25	247
Highest	1947-1977	30	29	27	25	24	21	24	25	25	29	28	28	279
Year of Highest		1963	1952	Sev.	1961 1970	1949	1962	1953 1968	1958	1975	1949	Sev.	Sev.	1952
Lowest	"	13	17	14	11	14	11	5	10	14	19	16	21	213
Year of Lowest		1974	Sev.	1974	1963	1976	1956	1958	1953	1976	1961 1967	1965	1948	1972

Table 4-2 PERKHIDMATAN KAJICUACA MALAYSIA

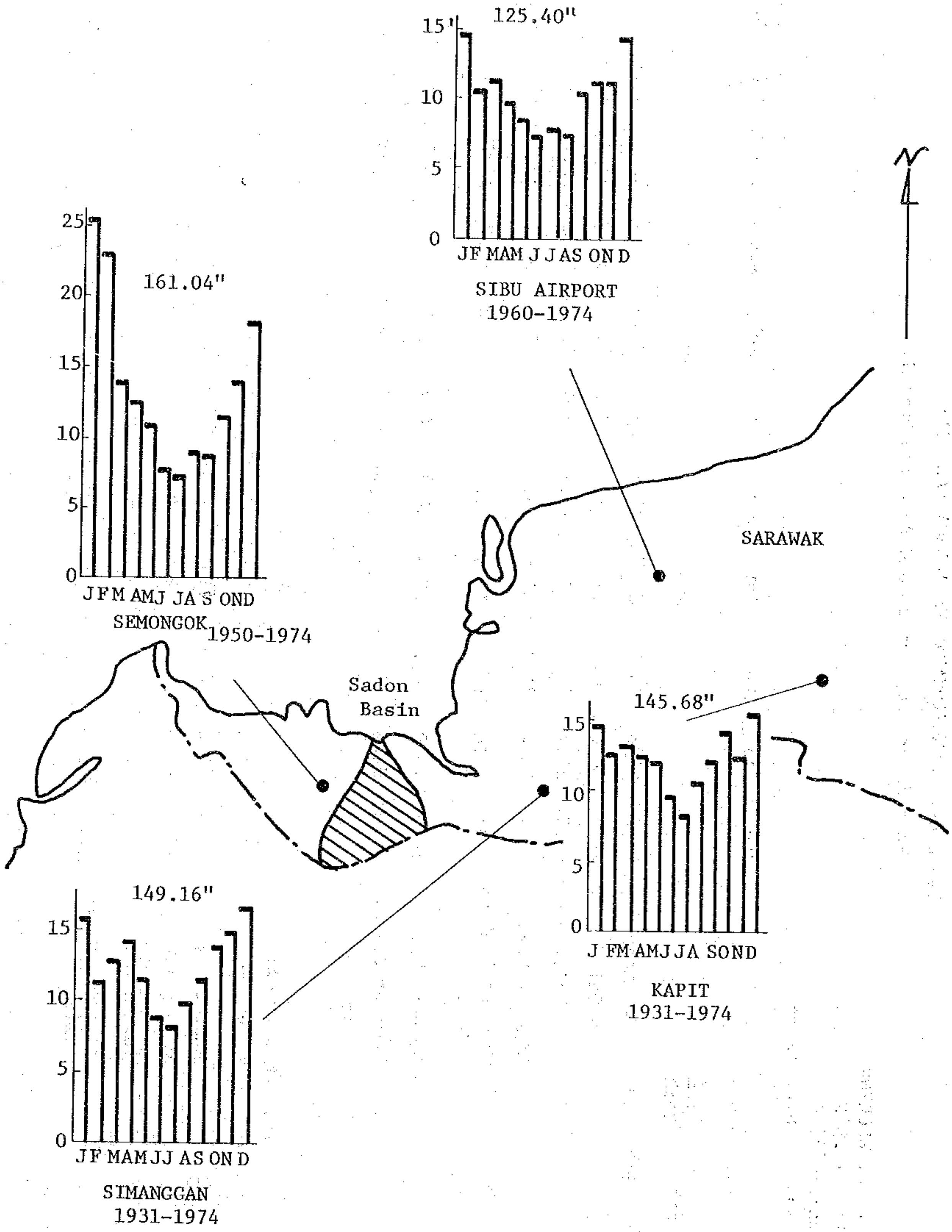
Records of Temperature and Relative Humidity

Station: KUCHING
Lat: 1°29'N
Long: 110°20'E
Ht.above M.S.L. 25.6m

Period	No.of Years	Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1968-1977	10	24 Hr. Mean	25.3	25.6	26.1	26.5	26.8	26.6	26.6	26.3	26.3	25.9	25.8	25.6	26.1
		Mean Daily Max.	29.6	30.0	30.8	32.0	32.6	32.3	32.3	32.1	32.1	31.8	31.4	30.7	31.5
		Mean Daily Min.	22.5	22.7	23.0	23.2	23.3	23.0	22.8	22.8	22.7	22.7	22.7	22.7	22.8
		Highest Max.	33.2	33.4	34.2	35.5	35.3	35.1	35.7	36.0	36.5	34.4	34.3	34.2	36.5
		Year of Highest Max.	1977	1976	1975	1975	1974	1973	1972	1972	1976	1973, 1974	1973	1974	1976
		Lowest Min.	18.9	18.9	20.7	20.4	20.7	20.2	21.0	20.9	20.7	21.0	20.5	20.6	18.9
		Year of Lowest Min.	1974	1968	1977	1971	1969	1976	1977	1969	1974	1976	1968	1975	1968, 1974
		Relative Humidity (%)													
1968-1977	10	24 Hr. Mean	85.9	85.3	83.9	83.9	82.8	81.4	80.6	81.7	81.9	84.2	85.1	85.9	83.5
		Mean Daily Max.	96.6	96.6	96.3	96.5	96.4	95.9	95.5	95.9	95.7	96.5	96.9	96.7	96.3
		Mean Daily Min.	66.4	65.0	62.0	59.3	56.5	56.6	55.4	56.5	56.7	59.1	59.5	63.5	59.7
		Lowest Min.	44	45	45	39	36	38	35	42	29	42	38	42	29
		Year of Lowest Min.	1968, 1974	1968	1975	1971	1973	1972	1972	1970, 1971	1969	1971	1971	1970	1969

Fig. 4-1 Average Monthly Rainfall

(inch)



4-2 Rainfall

Rainfall in the Sadong basin is observed at 15 stations at present. Table 4-3 shows the rainfall stations and their records, and Table 4-4 and Fig. 4-2 show the periods of recordings available and the location of each station. The team visited the stations located at Tebedu, Muara Mongkos, Belai Ringin, and Tebakang. An automatic recording gauge is installed at all these stations, and observation records are generally kept in a satisfactory condition. At some stations where the data are not recorded clearly due to the poor flow of recording. In order to minimize suspension of recording due to poor ink flow or any other causes, it is necessary to install an stand by rain gauge at all stations and increase the frequency of maintenance service especially in the wet season.

Rainfall records at four stations in the upper reaches of the Sadong (Serian, Tebedu, Tebakang, and Muara Mongkos) and those at four stations in the Krang river basin (Bedup, Merang, Simunjan Nonok, and Teb) are shown in Tables 4-5, 4-6, 5-7 and 4-8. These tables indicate that the monthly total rainfall varies largely by station, which suggests the considerable intensity of local rainfalls. It can also be deduced from these tables that rainfall in the neighbourhood of Serian is heavy, and that hilly areas embracing Muara Mongkos are less copious in rainfall than flatland areas. It also appears that the Sadong mainstream basin has a somewhat larger rainfall than the Krang river basin.

Table 4-3 Available Rainfall Station & Records

Name of Station	Station Number	Latitude	Longtitude	Approx Elevation	Period	Remarks
Tarat	1-6	1°12'N	110°32'E	-	9/'62 to date	Autographic
Simunjan	1-18	1°20'N	110°41'E	-	1/36 to date	Standard Gauge
Serian	1-27	1°10'N	110°34'E	40'	12/58 to date	Autographic
Sungai Bedup	1-28	1°05'N	110°38'E	40'	11/58 to date	"
Tebedu	1-31	1°02'N	110°22'E	-	5/63 to date	"
Sungai Pinang	1-32	1°05'N	110°52'E	-	1/64 to date	Standard Gauge
Sungai Merang	1-33	1°15'N	110°38'E	-	1/64 to date	Autographic
Simunjan Nonok	1-35	1°15'N	110°37'E	-	2/64 to date	"
Muara Mongkos	1-39	-	-	-	4/65 to date	"
Balai Ringin	1-40	1°13'N	110°45'E	-	7/58 to date	"
Sungai Teb	1-37	1°13'N	110°38'E	-	2/64 to date	"
Tebakang	1-50	1°08'N	110°30'E	-	12/64 to date	"
Bkt. Mutuh	1-79	1°05'N	110°38'E	-	1/71 to date	Standard Gauge
Sungai Busit	1-80	1°05'N	110°38'E	-	1/71 to date	"
Mid Sadong	1-55	1°21'N	110°41'E	-	3/66 to date	"

Table 4-4 BATANG BADONG HYDROLOGICAL STATION AND PERIOD OF RECORDS AVAILABLE

Type of Station:	Old Station No	Station Name	Approx. Period (Years)	Period of Recoreds Available							
				1931-1940	1941-1950	1951-1955	1958-1960	1961-1968	1968-1970	1971-1975	1976-1977
Rainfall Station	1 - 6	TARAT	15								
	1 - 18	SIMUNJAN	22								
	1 - 27	SERIAN	15								
	1 - 28	SUNGAI BEDUP	15								
	1 - 31	TEBEDU	12								
	1 - 32	SG. PINANG	14								
	1 - 33	SG. MERANG	12								
	1 - 35	SIMUNJAN NONOK	12								
	1 - 37	SUNGAI TEB	12								
	1 - 39	MUARA MONKGOS	11								
	1 - 40	BALAI RINGIN	12								
	1 - 50	TEBAKANG	27								
	1 - 55	MD- SADONG	11								
	1 - 79	SUKIT MATUH	6								
	1 - 80	SUNGAI BUSIT	6 1/2								

Fig. 4-2 Location of Rainfall Stations

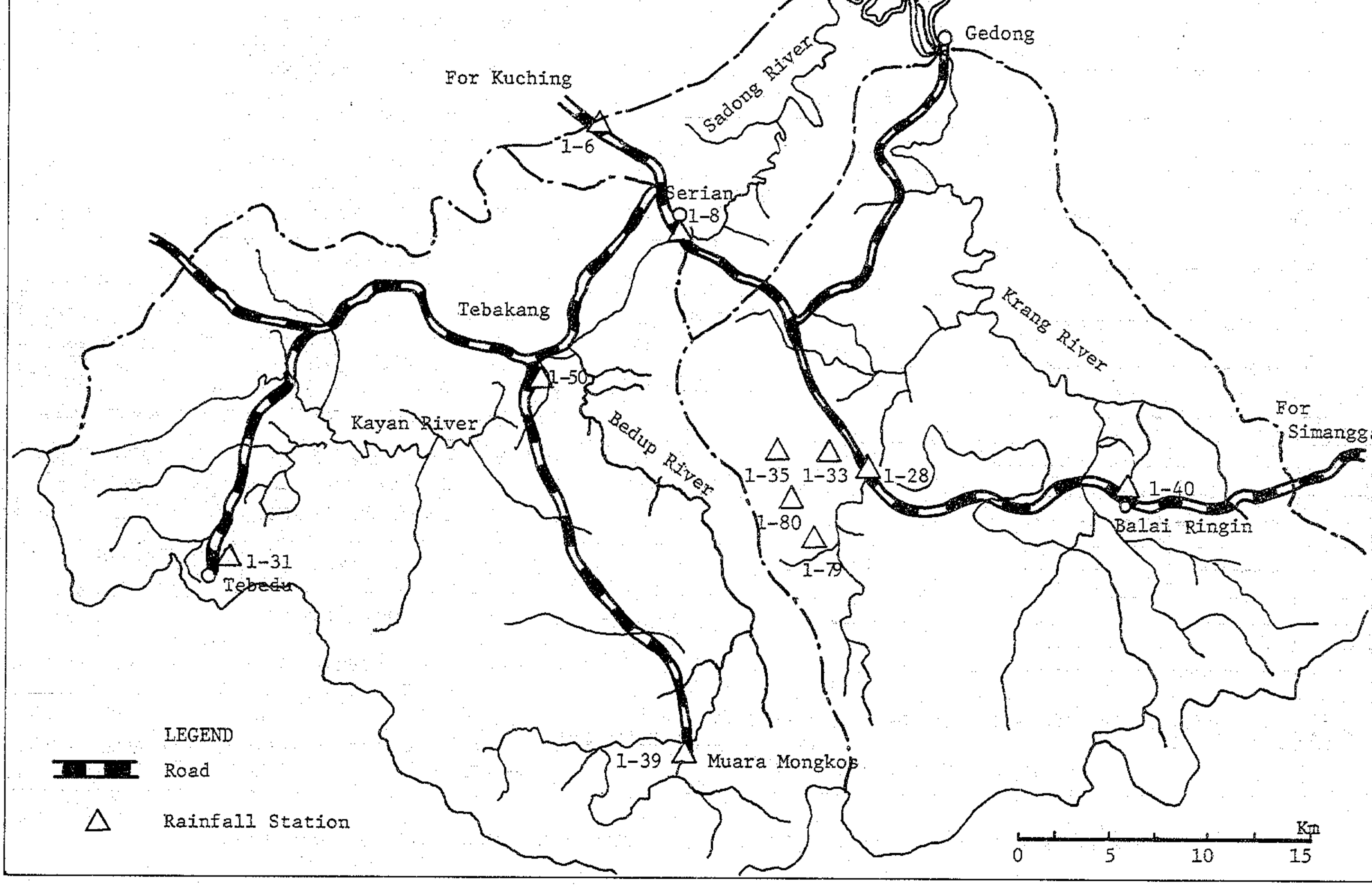


Table 4-6 Rainfall During Flood Period

Basin & station / Period / Day	SADONG RIVER				KRANG RIVER			
	SERIAN	TEBEDU	TEBAKANG	MUARA MONGKOS	BEDUP	MERANG	SIMUNJAN NONOK	TEB
	Feb.,'74 8th-15th	Feb.,'74 8th-15th	Feb.,'74 8th-15th	Feb.,'74 8th-15th	Feb.,'74 8th-15th	Feb.,'74 8th-15th	Feb.,'74 8th-15th	Feb.,'74 8th-15th
1st	10.7	-	-	-	7.6	2.3	7.6	6.4
2nd	164.0	91.9	23.9	96.8	122.4	125.7	131.0	99.1
3rd	136.0	84.3	115.6	67.8	74.2	83.8	77.5	38.1
4th	136.0	82.0	120.9	87.6	105.2	92.7	104.1	116.8
5th	73.7	80.8	76.2	55.9	45.0	35.6	47.0	38.1
6th	41.9	15.0	25.4	29.7	33.8	24.1	30.5	29.2
7th	19.1	19.1	26.7	8.4	15.2	15.2	19.1	14.0
8th	-	33.0	5.8	19.6	0.3	-	-	1.5
TOTAL	581.4	406.1	394.5	365.8	403.7	379.4	416.8	343.2
MONTHLY TOTAL	1039.6	680.0	553.8	684.8	762.3	741.2	783.8	676.7
DAYS	23	17	20	20	24	22	20	25

(mm)

Table 4-7 Rainfall During Flood Period

Basin & Station / Period	Sadong River				Krang River			
	SERIAN	TEBEDU	TEBAKANG	MUARA MONGKOS	BEDUP	MERANG	SIMUNJAN NONOK	TEB
Day	Feb.,'75 22nd-1st	Feb.,'75 22nd-1st	Feb.,'75 22nd-1st	Feb.,'75 22nd-1st	Feb.,'75 22nd-1st	Feb.,'75 22nd-1st	Feb.,'75 22nd-1st	Feb.,'75 22nd-1st
1st	43.9	8.1	2.3	72.4	24.9	22.9	26.7	28.4
2nd	111.8	10.4	71.1	106.5	135.0	128.0	135.0	148.0
3rd	19.1	16.0	76.7	16.5	8.9	9.4	10.2	14.0
4th	-	1.0	10.2	-	0.5	-	1.3	0.5
5th	19.1	-	0.5	10.7	10.9	18.0	35.6	17.5
6th	10.7	-	45.0	19.0	11.9	12.4	10.2	23.6
7th	74.4	-	11.9	0.8	0.9	-	-	1.3
8th	-	-	0.5	1.8	1.3	1.3	1.3	1.5
TOTAL	279.0	35.5	218.2	227.7	193.9	192.0	220.3	234.8
MONTHLY TOTAL	507.5	152.2	442.7	482.6	424.7	418.3	512.6	453.9
DAYS	22	15	23	22	26	21	27	27

(mm)

Table 4-8 Rainfall During Flood Period

Basin / Station / Period	Sadong River				Krang River			
	SERIAN	TEBEDU	TEBAKANG	MUARA MONGKOS	BEDUP	MERANG	SIMUNJAN NONOK	TEB
Day	Jan.,'76 9th-16th	Jan.,'76 9th-16th	Jan.,'76 9th-16th	Jan.,'76 9th-16th	Jan.,'76 9th-16th	Jan.,'76 9th-16th	Jan.,'76 9th-16th	Jan.,'76 9th-16th
1st	20.1	5.3	37.6	0.8	29.2	25.4	22.4	30.5
2nd	3.8	7.4	59.9	138.0	2.5	4.6	6.9	2.5
3rd	221.0	210.0	113.8	59.7	235.0	161.0	197.0	182.0
4th	122.9	78.2	115.6	50.0	95.8	108.0	164.0	89.4
5th	114.0	58.7	101.6	2.8	77.2	57.2	72.6	74.7
6th	18.0	18.5	9.9	6.4	5.6	7.1	6.1	7.1
7th	9.9	5.3	31.8	1.0	6.6	4.6	6.6	7.9
8th	6.1	0.3	10.2	0.3	8.6	12.4	25.4	11.9
TOTAL	515.8	383.7	480.4	259.0	460.5	380.3	501.0	406.0
MONTHLY TOTAL	760.5	473.5	705.1		650.5	588.8	782.1	569.2
DAYS	19	13	22		24	22	24	23

(mm)

Table 4-5 Rainfall During Flood Period

Basin & Station / Period / Day	Sadong River	Krang River
	SERIAN	BEDUP
	Jan.'63 24th-31st	Jan.'63 24th-31st
1st	5.6	4.6
2nd	6.6	6.4
3rd	23.6	3.3
4th	162.0	54.1
5th	122.0	50.0
6th	3.6	4.8
7th	24.9	13.7
8th	11.4	5.1
TOTAL	359.7	142.0
MONTHLY TOTAL	763.5	418.6
DAYS	29	27

(mm)

4-3 Water Level and Discharge

Water level stations are established at Serian, Bedup, Gedong, Krusin, and Merringu. Of these five, Krusin and Merringu are new stations established in 1977 for the purpose of collecting hydrological data for a feasibility study of the two dams. Serian station is the most important of all five stations and has the longest period of recording. It is operated for observation of both water level and discharge and preparation of rating curves. Locations of the five stations are shown in Fig. 4-3, and the period of recording in Table 4-9.

The team visited all the five stations. The four stations at Serian, Bedup, Gedong, and Krusin are accessible by car, but a river route must be taken from Tebakang to reach Merringu station. Serian station, situated at about a 40 minutes' car drive from Kuching, is constructed on the upstream side of a bridge on the Kuching-Simanggan road across the Sadong. At this site, the road has an elevation of about 30 feet but the lower ground has an elevation of 26 feet. The Sadong overflows when its water level rises beyond this ground elevation. Gedong station, situated at about a 25 minutes' car drive from Serian, is constructed at the confluence of the Krang and the Sadong. The water level at this site is under constant influence of tide. Bedup station is constructed on the upstream of the Krang and equipped with a bubble type level recorder.

Krusin and Merringu stations are equipped with a staff gauge installed in 1977 for the dam construction plan. Gauge reading, conducted twice a day at 6:30 and 18:30 hours daily, is commissioned to local employees. During the flood period, gauge reading is conducted at intervals of 3 hours.

Table 4 - 9 Water Level Station & Period of Record Available

Station Name	No	Period	Type	Period of Record Available			
				1961 - 1965	1966 - 1970	1971 - 1975	1976-
Serian	L/1-1	12/'62 to date	Self Recording	—	—	—	—
Bedup	L/1-3	1/64 to date	"	—	—	—	—
Gedong	L/1-29	7/71 to date	"			—	—
Krusin	L/1-38	1/77 to date	Stick Gauge				—
Merringu		1/77 to date	"				—

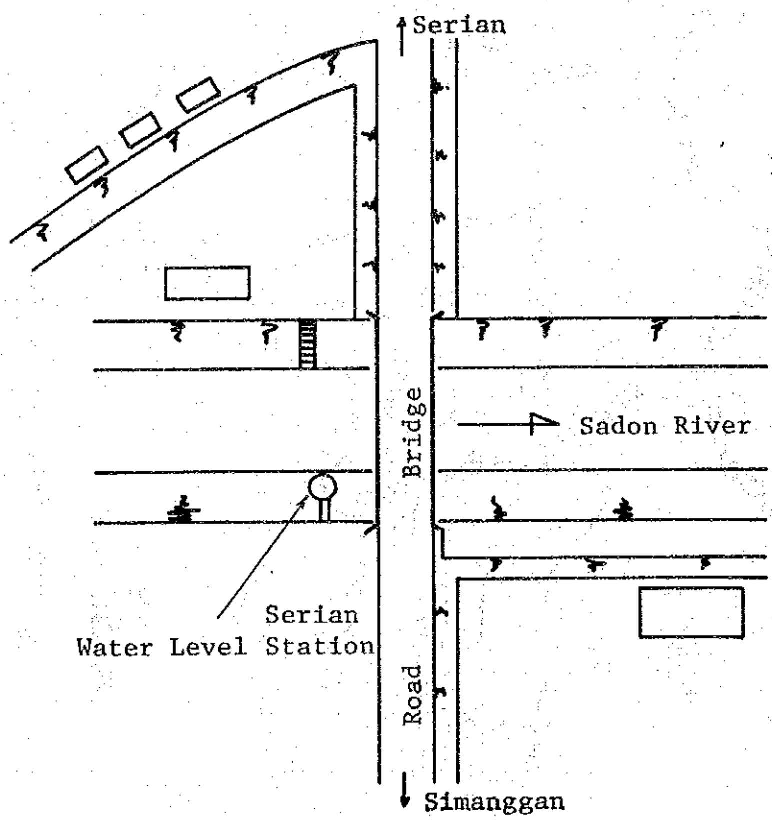
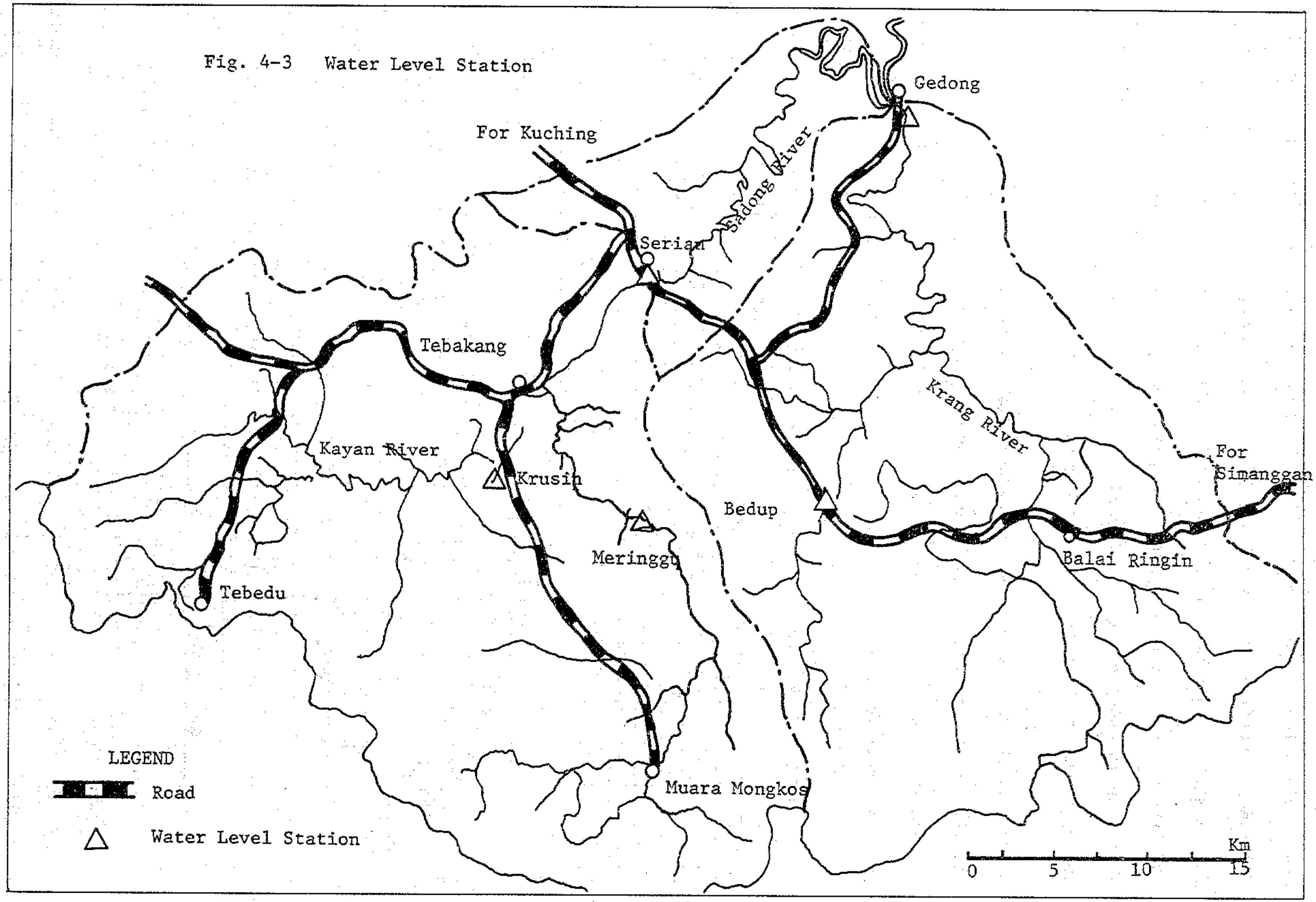


Fig. 4-4 Serian Water Level Station

Fig. 4-3 Water Level Station



Chapter 5. Flood Analysis

5-1 Relationship between Flood Water Level and Rainfall

Flooding of the Sadong mainstream causes the heaviest damage in the upper basin, including Serian. Hence, the proposed flood forecasting and warning system has been studied with top priority given to this area. Flood data for the system planning is also most abundant in this area.

Table 5-1 shows the data of flood water level recorded at Serian since 1962. The rainfall data shown in this table are those recorded at Serian and Muara Mongkos stations which are considered to have produced fairly consolidated rainfall data in the past. The values of 1 day, 2 days, 3 days and 4 days rainfalls are the maximum 1 day, 2 days, 3 days and 4 days rainfalls calculated from each series of rainfall considered to have caused the peak flood water level. On the basis of the data shown in this table, the relationship between the maximum rainfall and the peak flood water level is plotted in Figs. 5-1, 5-2, 5-3, and 5-4. These figures suggest that there exists correlation between each maximum rainfall and peak flood water level. With the accumulation of rainfall and water level data in future, it may become possible to obtain a closer correlation at Serian and analyze the rainfall - water level correlation at Krusin located at a further upstream point.

The above discussion indicates that if the peak rainfall is obtained and the water level at Serian and Krusin at the time of peak rainfall is recorded, the peak water level at each station after time lag can be forecasted. It is therefore hoped that further study will be made in this connection.

Table 5-1 Data of Flood Water Level and Rainfall

Year	Serian Water Level above M.S.L in feet	Serian Rainfall (mm)				Muara Mongkos Rainfall (mm)			
		1 day	2 days	3 days	4 days	1 day	2 days	3 days	4 days
Jan. 1963	30.70	162	284	308	315	-	-	-	-
Mar. 1965	26.74	48	79	103	120	-	-	-	-
Jan. 1966	26.54	76	114	135	154	-	-	-	-
Mar. 1967	26.54	60	111	122	127	-	-	-	-
Jan. 1968	28.99	-	-	-	-	58	104	138	172
Dec. 1969	29.74	-	-	-	-	83	159	177	195
Jan. 1970	27.09	138	141	143	152	36	59	63	63
Feb. 1971	27.49	88	162	219	228	44	57	68	78
Jan. 1972	26.74	90	148	170	195	44	83	104	117
Dec. 1973	29.04	105	126	206	231	42	78	103	133
Feb. 1974	30.86	164	300	436	510	97	165	253	309
Feb. 1975	30.63	112	156	175	175	107	179	196	196
Jan. 1976	32.01	221	344	458	476	161	269	326	333

Fig. 5-1 Maximum Daily Rainfall-Water Level Relation

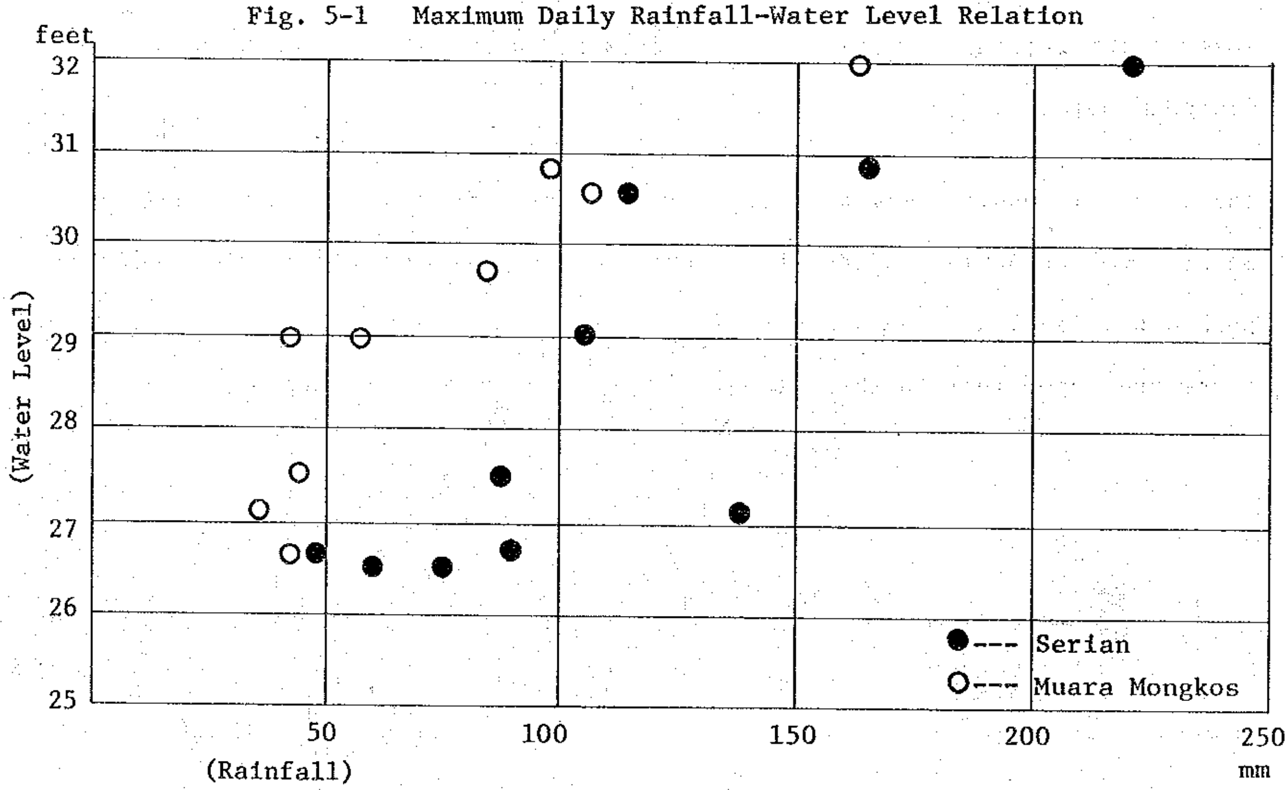


Fig. 5-2 Maximum 2 Days Rainfall-Water Level Relation

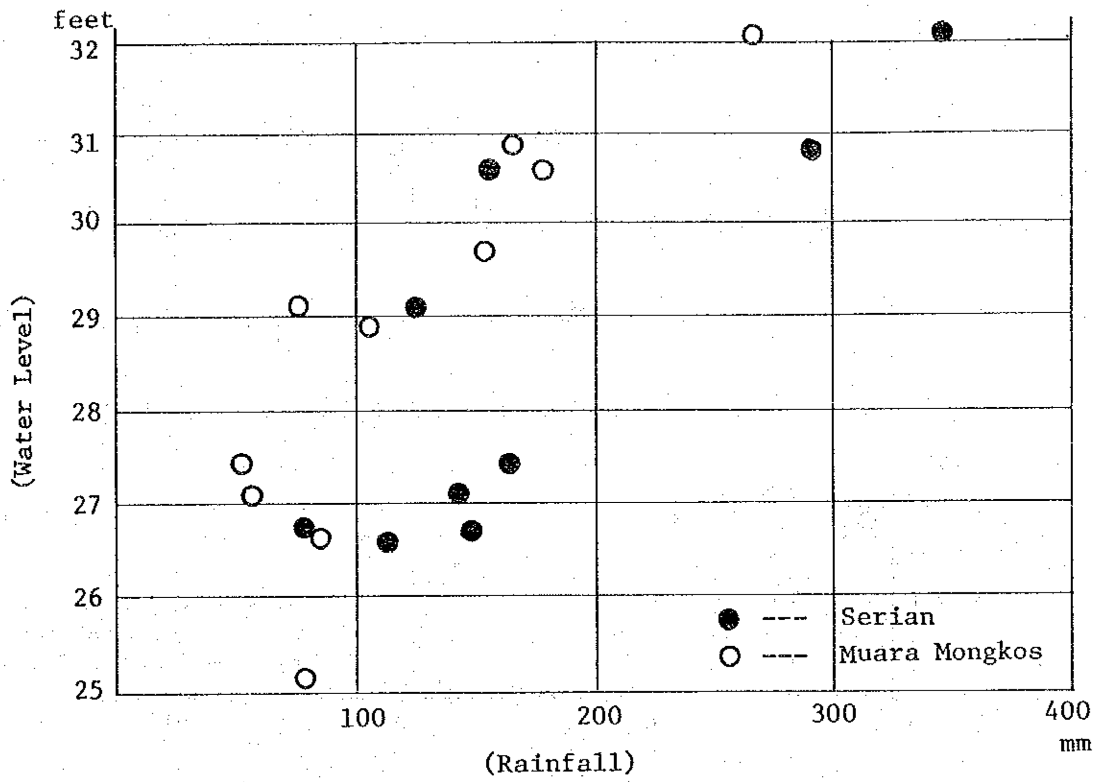


Fig. 5-3 Maximum 3 Days Rainfall-Water Level Relation

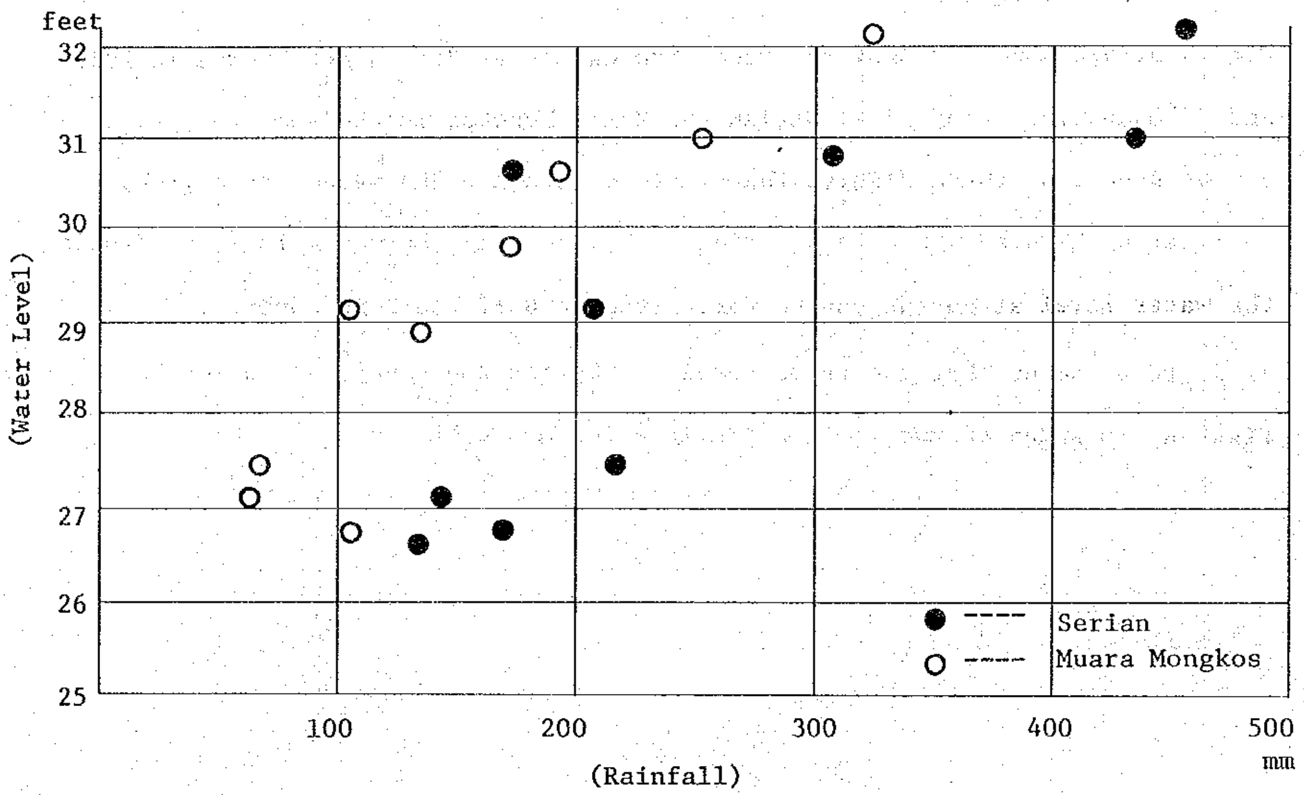
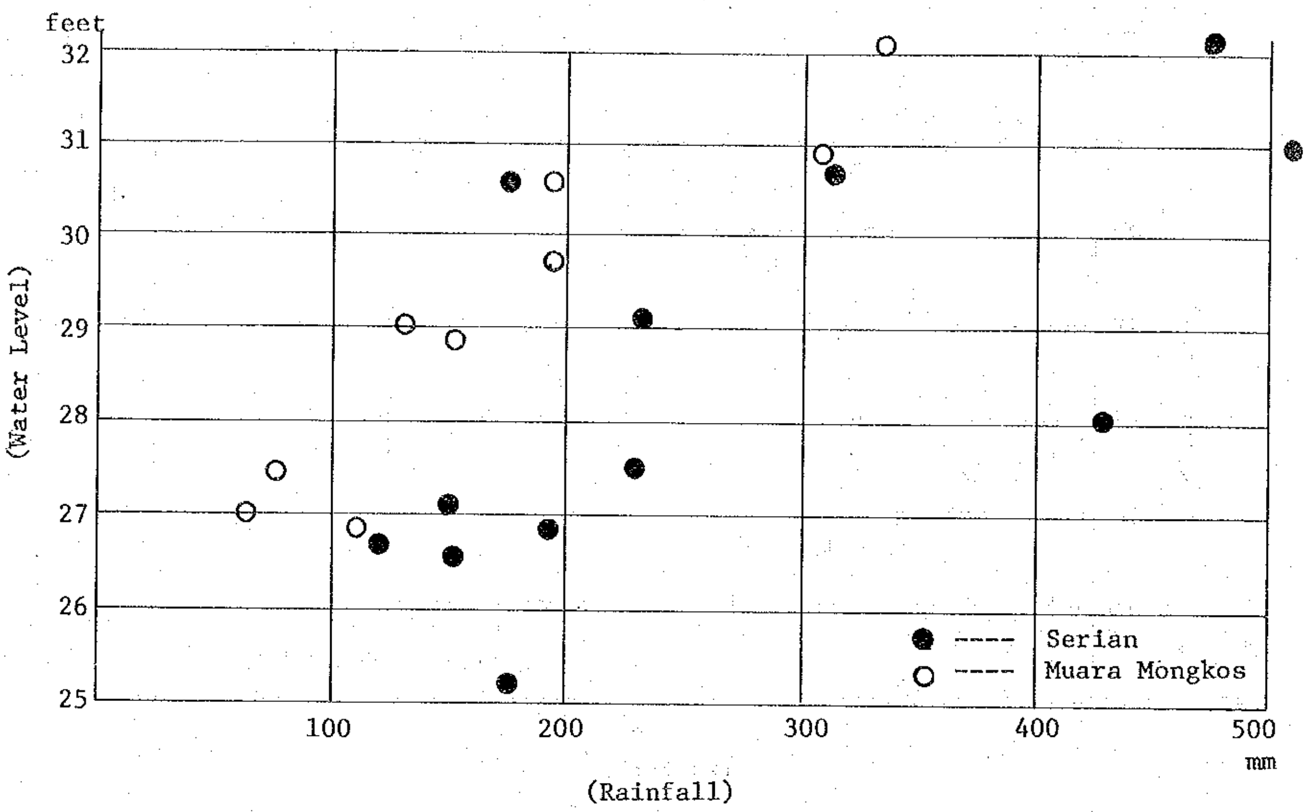


Fig. 5-4 Maximum 4 Days Rainfall-Water Level Relation



5-2 Flood Hydrograph

Fig. 5-5, 5-6 and 5-7 show the flood hydrograph at Serian and Krusin in 1977 and 1978 and the rainfall at Serian and Muara Mongkos in the same two years. It can be seen from these figures that there exists a close water stage (H-H) correlation between Krusin and Serian and by knowing the water level at Krusin, the water level at Serian can be forecasted in 6-12 hours in advance.

It is to be noted that the water levels at Serian and Krusin shown in the figures are gauge values, not their elevation above MSL.

Fig. 5-5 Hydrograph

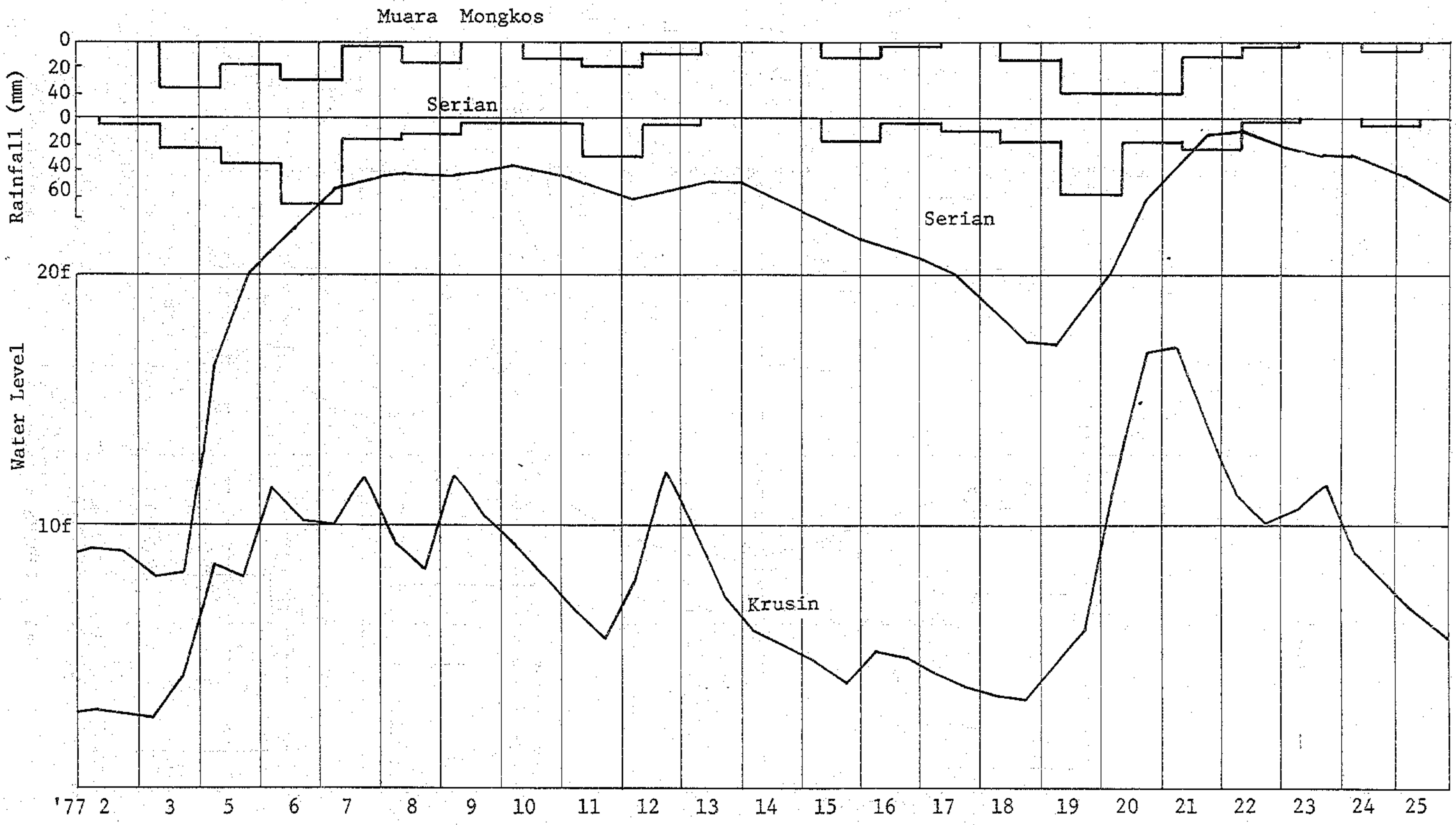


Fig. 5-6 Hydrograph

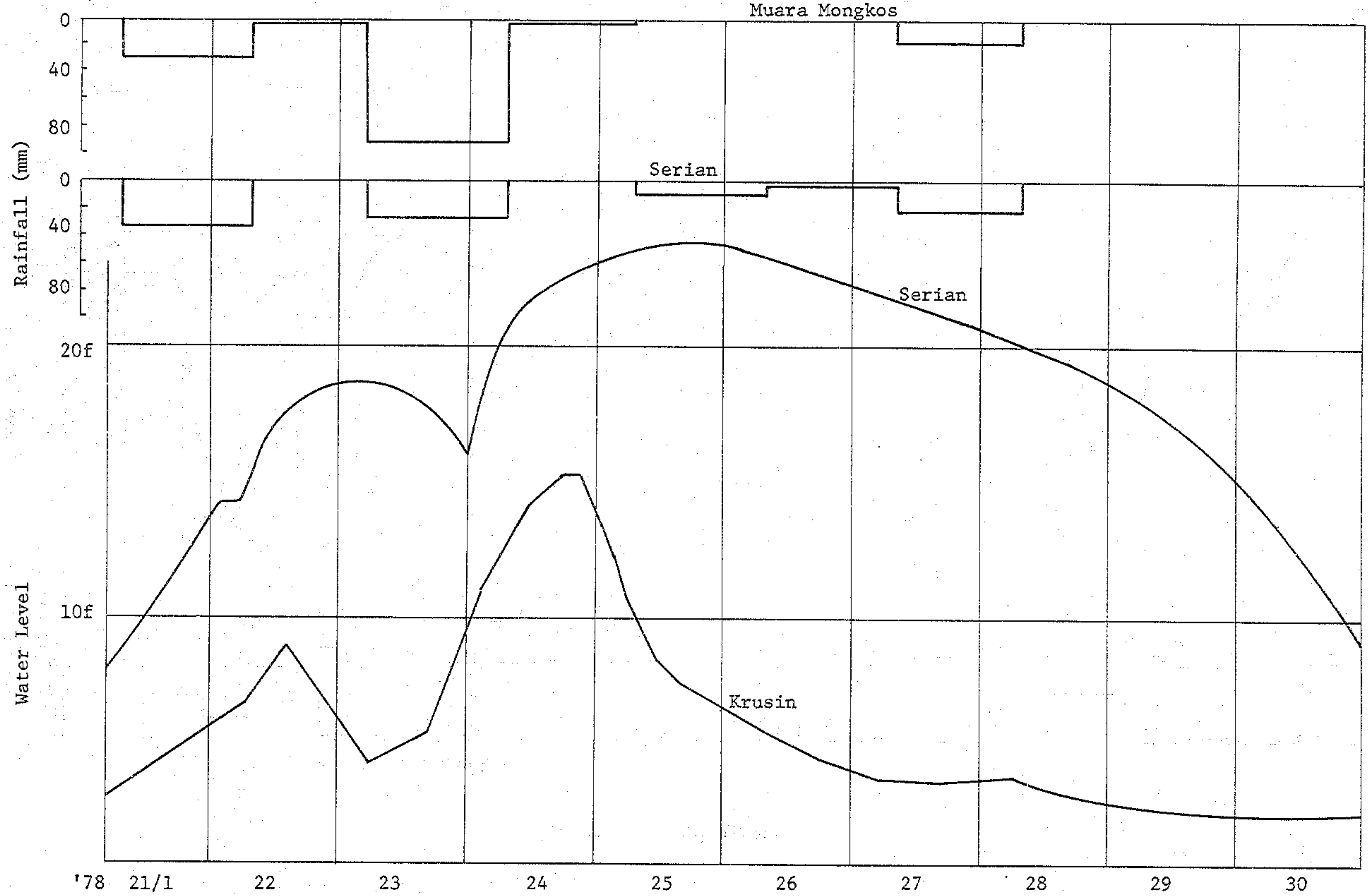
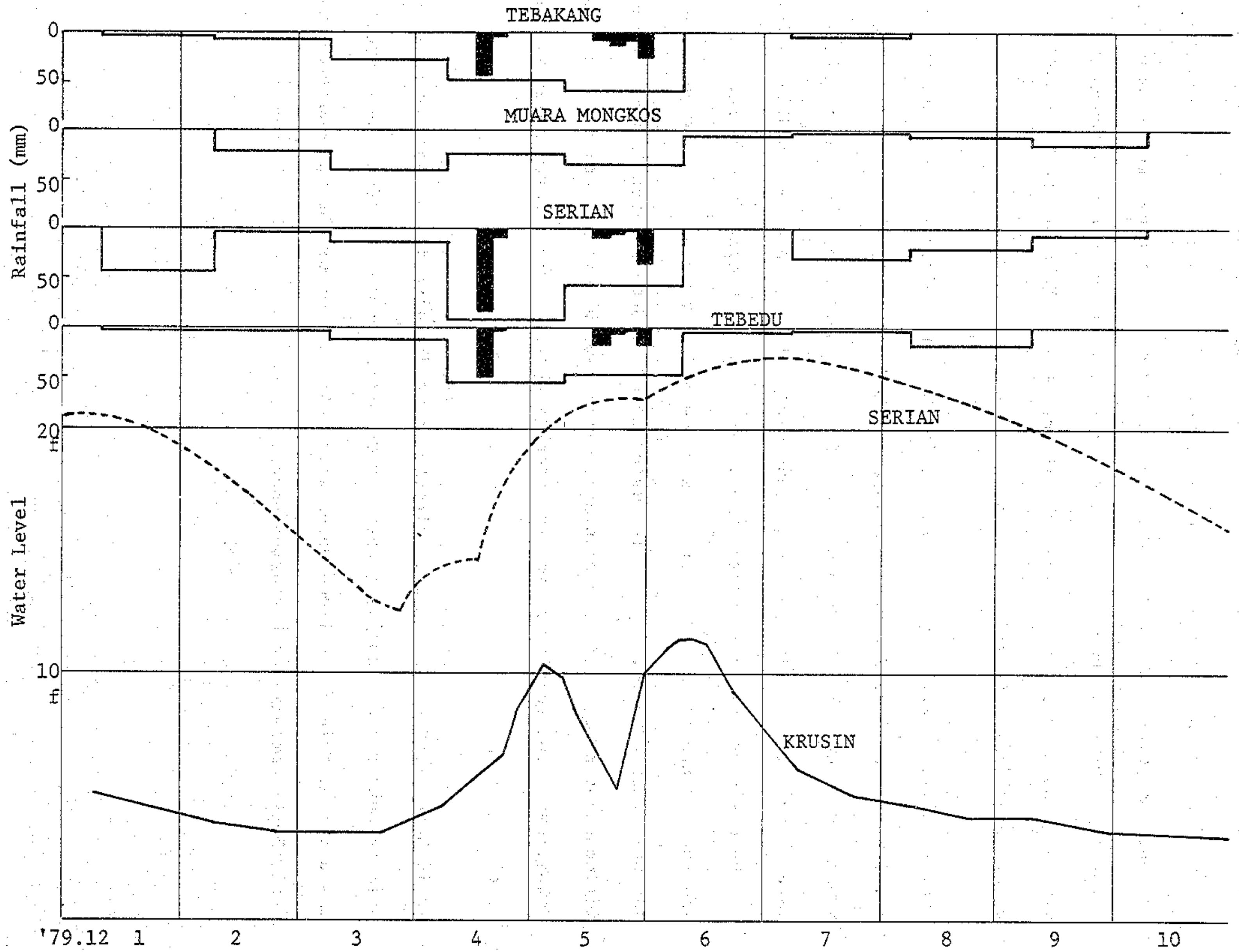


Fig. 5-7 Hydrograph



5-3 Flood Forecasting

From the discussion advanced above, it will be understood that accumulation of rainfall and water level data in future will make it possible to employ the H-H method for forecasting the flood water level at a downstream point from that at an upstream point, and to forecast the water level at the designated point from rainfall. Future accumulation of discharge data and accuracy improvement in discharge observation will also make it possible to forecast both run-off and water level from rainfall.

Specifically, it will become possible, in the first place, to forecast the water level at Serian 6 - 12 hours in advance by H-H method if the water level at Krusin is known. In the second place, if the relationship between rainfall and water level at different points is made clear, it will become possible to forecast, on the basis of rainfall record, the water level at Serian 20 - 30 hours in advance and that at Krusin 15 - 20 hours in advance and at Merringu 30 - 40 hours in advance, respectively. As for the water level at Gedong which is under direct influence of tide, a tide level station will have be established at a further downstream point to clarify the relationship between river water level and tidal level.

It is hoped that effort will be directed toward collection of data so as to be able to make run-off analysis based on rainfall records besides flood forecasting based on the rainfall - flood water level correlation or the up- and down stream water level correlation mentioned above.

Chapter 6. Flood Forecasting and Warning System

6-1 Necessity of Flood Forecasting System

Located close to Kuching, the state capital, and having a large population especially in the neighbourhood of Serian, the Sadong basin is one of important areas in the country with high development potentials. Establishment of a flood for forecasting and warning system in this area is quite meaningful and urgently called for to cover important districts along the Sadong mainstream such as Tebakang, Serian, Tanah Puteh, Sebanban, and Gedong.

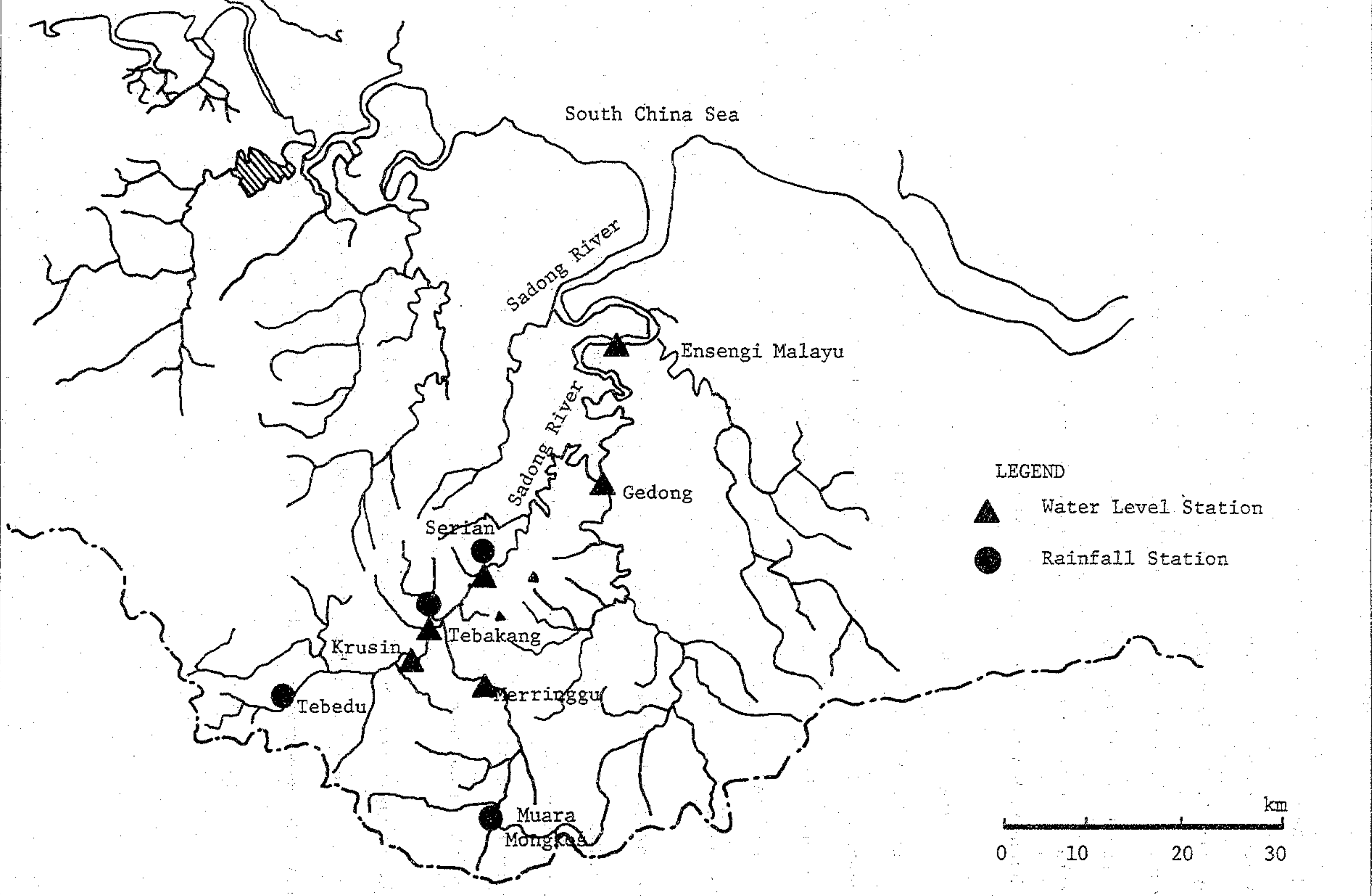
6-2 Target Areas and Points for Flood Warning, and Forecasting Time

For the Sadong basin flood forecasting and warning system, the team selected Tebakang, Serian, Tanah Puteh, Sebanban and Gedong as target areas of flood warning. Further, 5 water level observation points (Krusin, Meringgu, Tebakang, Serian, and Gedong) and 1 tide level station (Ensenggi Malaya) were selected. The network of observation stations is shown in Fig. 6-1.

As for the forecasting time, it is considered possible to forecast a flood by the rainfall-water level method 15 - 20 hours in advance at Krusin, 20 - 30 hours in advance at Serian, and 30 - 40 hours in advance at Merringgu. If the water level correlation method is adopted, it will be possible to forecast a flood at Serian 5 - 10 in advance.

The Krang river, one of the Sadong's tributaries, was excluded from the proposed system. However, it is certainly possible to include it in the system in future when the importance of its basin area calls for flood forecasting service.

Fig. 6-1 Observation Station Net Work



6-3 Telemetering System

The following points must be taken into consideration in planning the telemetering system for the Sadong basin.

- Location of component stations should be selected carefully with consideration given to the construction cost and ease of maintenance service.
- The system should have the same functional capacity as the one already in operation in Peninsular Malaysia, but should be operated according to a method compatible with the situation in the basin.
- It should be so planned as would leave room for future expansion in consideration of possible coverage of adjoining river basins.
- VHF band should be selected for stability, reliability and economy of radio link operation.
- Special care should be exerted in determining the number and locations of relay stations.
- If any of the existing facilities of the Telecom. Department are expedient for the system operation, they should be incorporated in the system.

As stated already, a total of 10 stations comprising 4 water level stations, 2 rainfall stations, 2 water level-cum-rainfall stations, and 2 rainfall stations (future) will be operated in the basin, with the master control station established within DID Kuching (or within Bitwan branch of DID if the space at DID Kuching is not large enough to accommodate the control facilities).

As for the relay station which is indispensable for the network operation, either a new station will be constructed on the summit or side of a mountain near Serian (Plan A), or the TV transmitting station of Telecom. Department on the summit of Mt. Serapi will be used.

Detailed explanation is given below on each aspect of the network.

(1) Water level station

The four selected stations are located at Krusin, Merringu, Gedong, and

Kpg. Ensenggi Melangu. These stations will not present any specific problems in the circuit design, although their suitability should naturally be checked by a prior survey.

(2) Rainfall station

Two stations at Muara Mongkos and Tebedu will be used for the proposed network, and two new stations will be built at Bedup and Belai Ringin for future expansion. These stations are not considered to present any problems, although they will naturally have to be subjected to radio propagation test.

(3) Water level-cum-rainfall station

Two stations at Serian and Tebakang will be used.

(4) Relay station

A relay station is required for the operation of the telemetering network. The following two alternative plans are proposed regarding its location.

Plan A:

This plan is proposed for construction of a new relay station on the summit or side of a mountain near Serian. Its location should be determined by checking the topographic condition on the map as well as by a radio propagation test. If no access road is available, it should be newly constructed, and careful account must be taken of the difficulty involved in the construction and maintenance service. Nevertheless, the proposed site is quite advantageous for circuit design as it is in the approximate center of the whole network.

Plan B:

This plan is proposed for utilizing the existingrelay station of Telecom. Department, and is consequently advantageous in terms of construction work and maintenance service. The station facilities must be installed within the TV transmitting station on the summit by reason of topographic condition.

Since many radio frequencies are used at the existing station, studies must be made to prevent their interference and in addition, responsibilities for maintenance service should clearly delineated hetween Telecom. Department and DID.

If the relay station is constructed under this plan, it must be linked directly with Kuching (or Bintawa) with a VHF circuit. If, again, the master control station is established at Bintawa due to non-availability of sufficient space at DID Kuching, a VHF radio link will have to be established between DID Kuching and Bintawa, with terminal facilities such as typewriters installed at Kuching.

2 radio frequencies in 70 MHZ band will have to alloted to the telemetering network and 1 - 2 frequencies in the same band to the Bintawa - Kuching link.

The telemetering network briefed above is illustrated in Fig. 6-2.

(5) Circuit design

Circuit design of each span is shown in Table 6-1 which indicates that a Signal to Noise ratio (S/N ratio) of more than 30 dB (minimum required S/N) can be assured for each span. However, the ratios shown in the table are the values based on calculation and must be verified by radio communication test in the next survey.

(6) Equipment configuration and estimated construction cost

The equipment configuration at each station is shown in Figs. 6-3, 6-4 and 6-5. Detailed equipment specifications will have to be determined after the next field survey.

Breakdown of approximate construction cost by equipment, housing and antenna pole is shown in Table 6-2. It is to be noted that this table shows only very rough costs which should be corrected after a detailed survey.

Fig. 6-2 TELEMETERING NETWORK IN THE SADONG RIVER BASIN

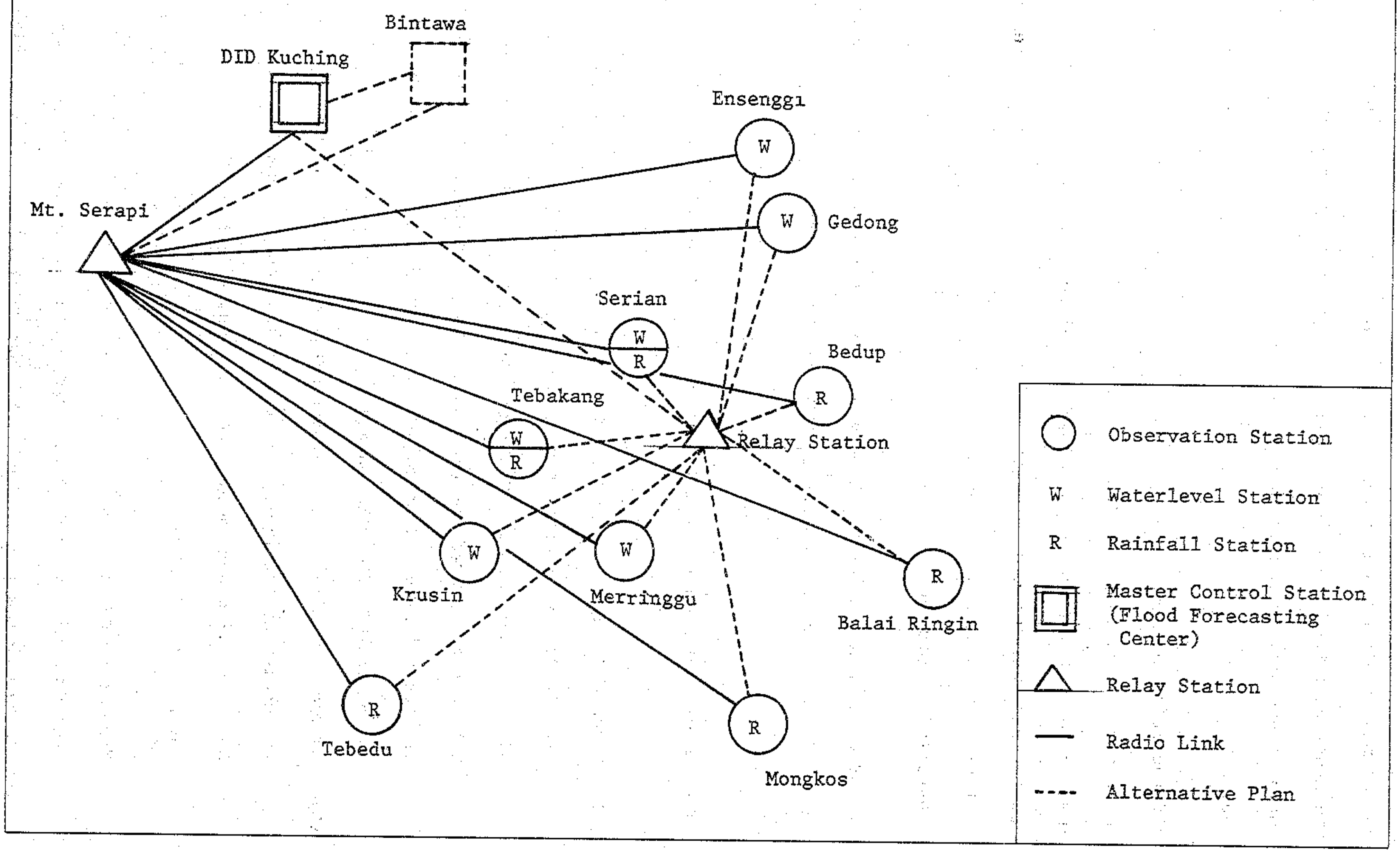


Table 6-1 Circuit Design Table (Sadong River Basin)

Item \ Name of Station	Unit	Serapi-Ensengi (54 km)		Serapi-Gedong (66.5km)		Serapi-Serian (63 km)		Serapi-Tebakan (64 km)		Serapi-Krusin (66 km)		Serapi-Tebedu (65 km)	
Transmitting Power	dBm	40	10W	40	10W	40	10W	40	10W	40	10W	40	10W
Free Space Loss	dB	-103.9		-105.8		-105.3		-105.7		-105.7		-105.6	
Additional Loss	dB	0		0		-15.2		-24.8	15.3+9.5	-25.5	13+12.5	-29	10.5+18.5
Feeder Loss	"	-3.2	10D-2V 40/40 0.04/m	-3.2		-3.2		-3.2		-3.2		-3.2	
Antenna Gain (T)	"	8	3el Yagi	8	3el Yagi	8	3el Yagi	8	3el Yagi	8	3el Yagi	8	3el Yagi
" (R)	"	6	33°(-2dB)	7.5	21°(-0.5dB)	8	"	8	"	8	"	8	"
Receiving Power	dBm	-53.1		-53.5		-67.7		-77.7		-78.4		-81.8	
Received Noise Power	"	-115		-115		-115		-115		-115		-115	
Radio Frequency S/N (C/N)	dB	61.9		61.5		47.3		37.3		36.6		33.2	
S/N Improvement Factor	"	12		12		12		12		12		12	
Standard S/N	"	73.9		73.5		59.3		49.3		48.6		45.2	
Fading Loss	"	-5.4	0.1dB/km	-6.7		-6.3		-6.4		-6.6		-6.5	
S/N at Fading	"	68.5		66.8		53		42.9		42		38.7	
Threshold Level	dBm	-106		-106		-106		-106		-106		-106	
Threshold Margin	LB	52.9		52.5		38.3		28.3		27.6		24.2	
Threshold Margin at Fading	dB	47.5		45.8		32		21.9		21		17.7	

Item \ Name of Station	Unit	Serapi-Meringgu (71 km)		Serapi-Mongkos (83 km)		Serapi-Bedup (73.5km)		Serapi-Tanah Putch (64 km)		Serapi-Balai Ringin (85km)	
Transmitting Power	dBm	40	10W	40	10W	40	10W	40	10W	40	10W
Free Space Loss	dB	-106.3		-107.7		-106.6		-105.4		-107.9	
Additional Loss	dB	-41.5	26+15.5	-25.2	17+8.2	-20.5		0		-17.5	
Feeder Loss	"	-3.2		-3.2		-3.2		-3.2		-3.2	
Antenna Gain (T)	"	8	3el Yagi	8	3el Yagi	8	3el Yagi	8	3el Yagi	8	3el Yagi
" (R)	"	11	5el Yagi	8	"	8	"	8		8	
Receiving Power	dBm	-92		-80.1		-74.3		-52.6		-72.6	
Received Noise Power	"	-115		-115		-115		-115		-115	
Radio Frequency S/N (C/N)	dB	23		34.9		40.7		62.4		42.4	
S/N Improvement Factor	"	12		12		12		12		12	
Standard S/N	"	35		46.9		52.7		74.4		54.4	
Fading Loss	"	-7.1		-8.3		-7.4		-6.4		-8.5	
S/N at Fading	"	27.9		38.6		45.3		68		45.9	
Threshold Level	dBm	-106		-106		-106		-106		-106	
Threshold Margin	LB	14		25.9		31.7		53.4		33.4	
Threshold Margin at Fading	dB	6.9		17.6		24.3		47		24.9	

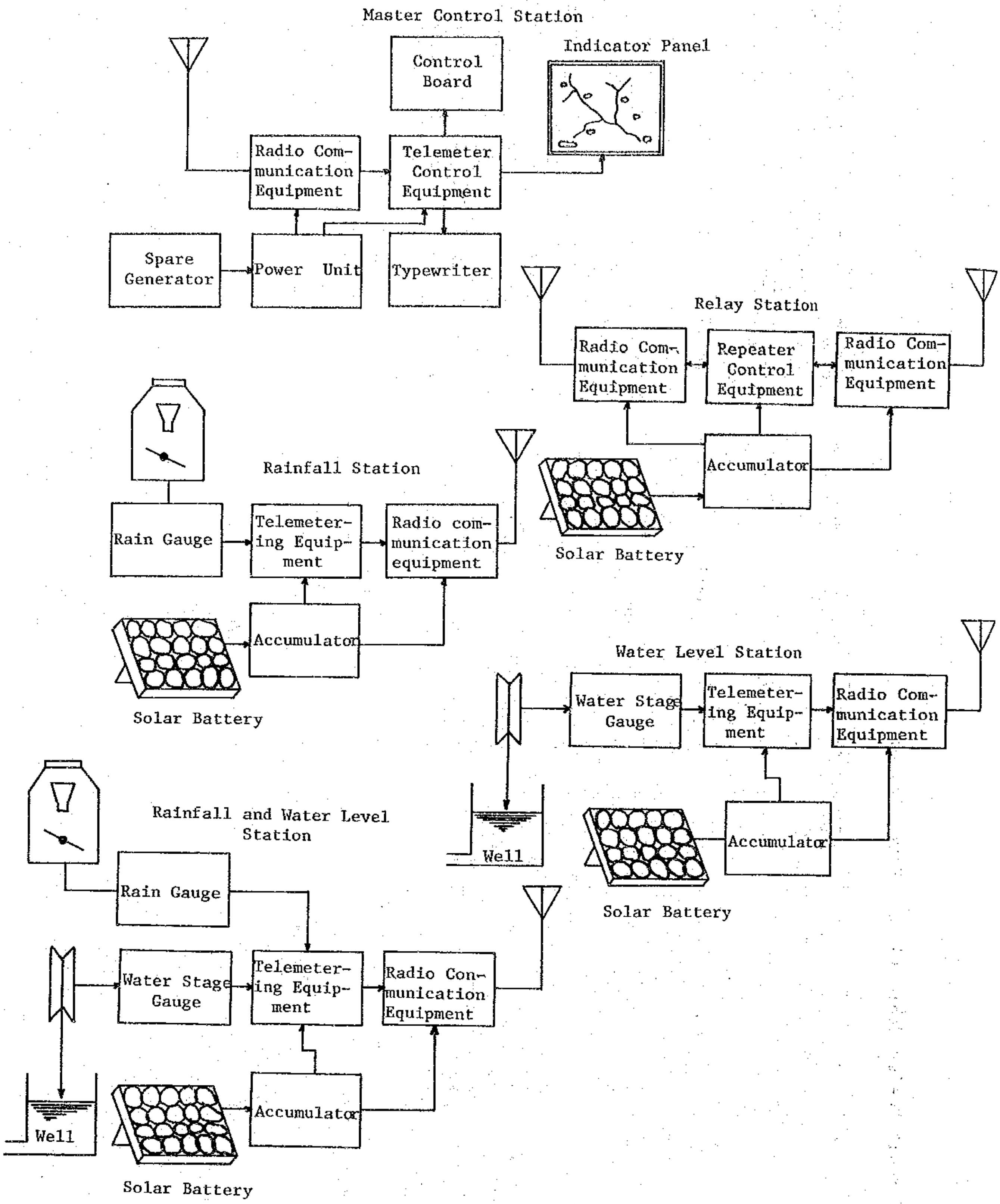
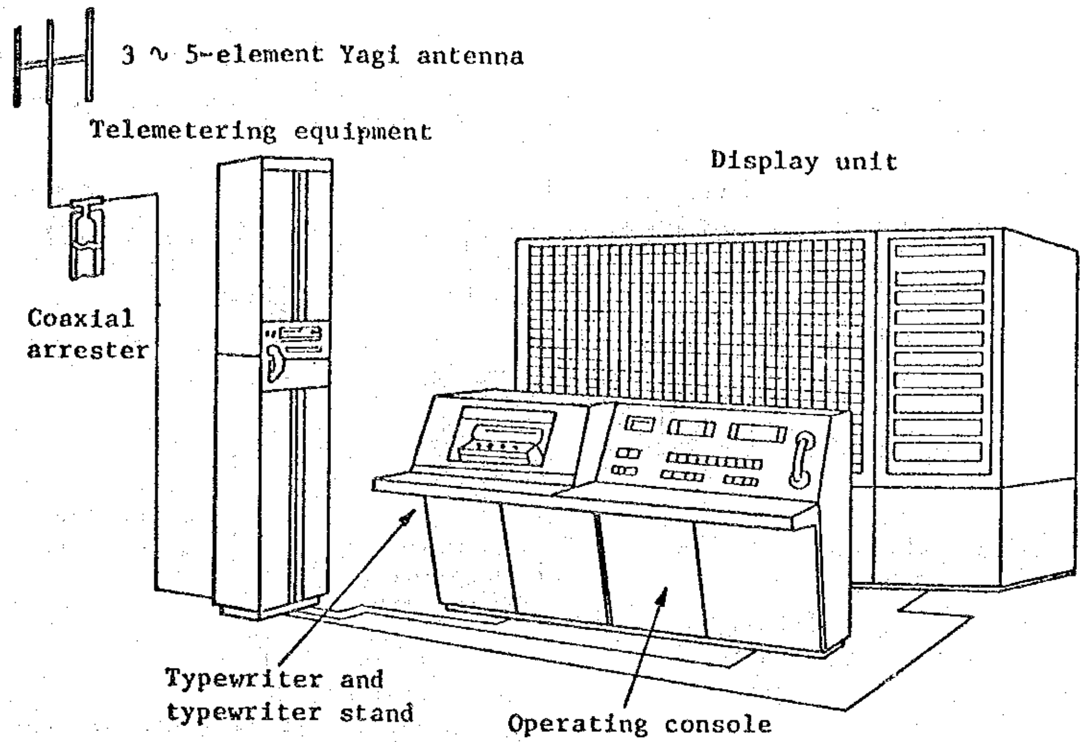
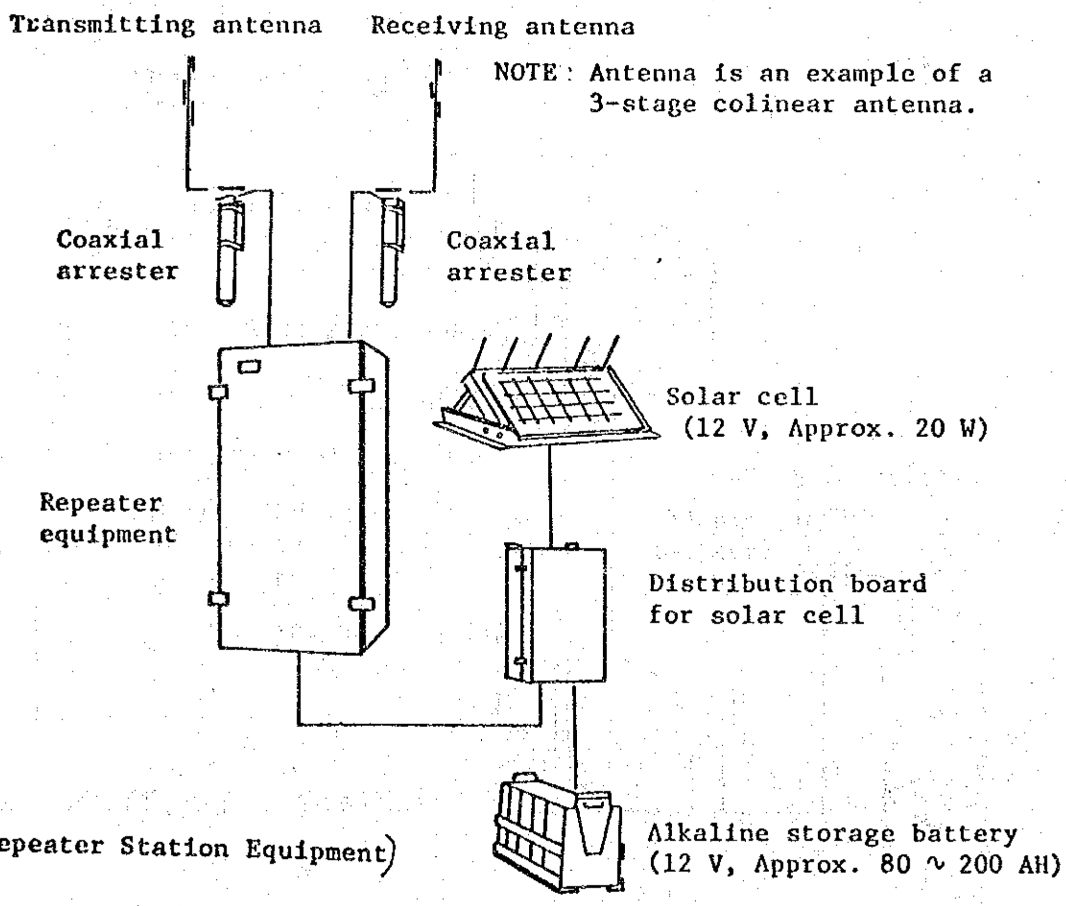


Fig. 6-3 Equipment Configuration

Fig. 6-4 Equipment - 1

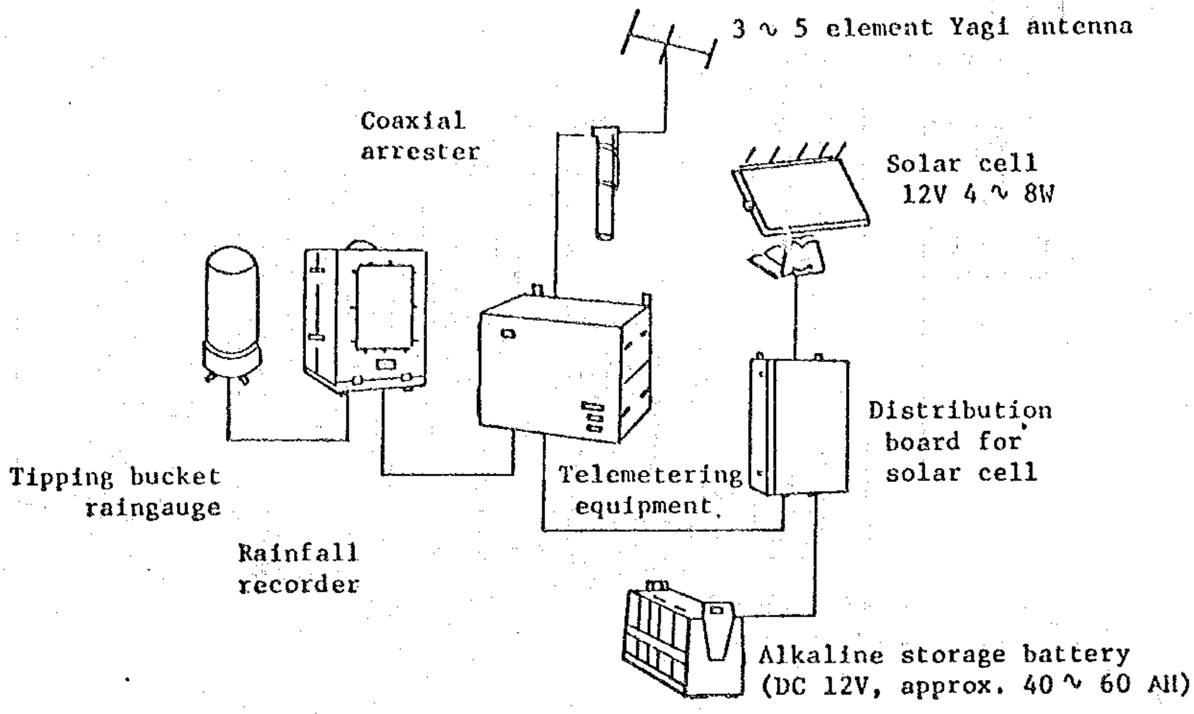


(Master Station Equipment)

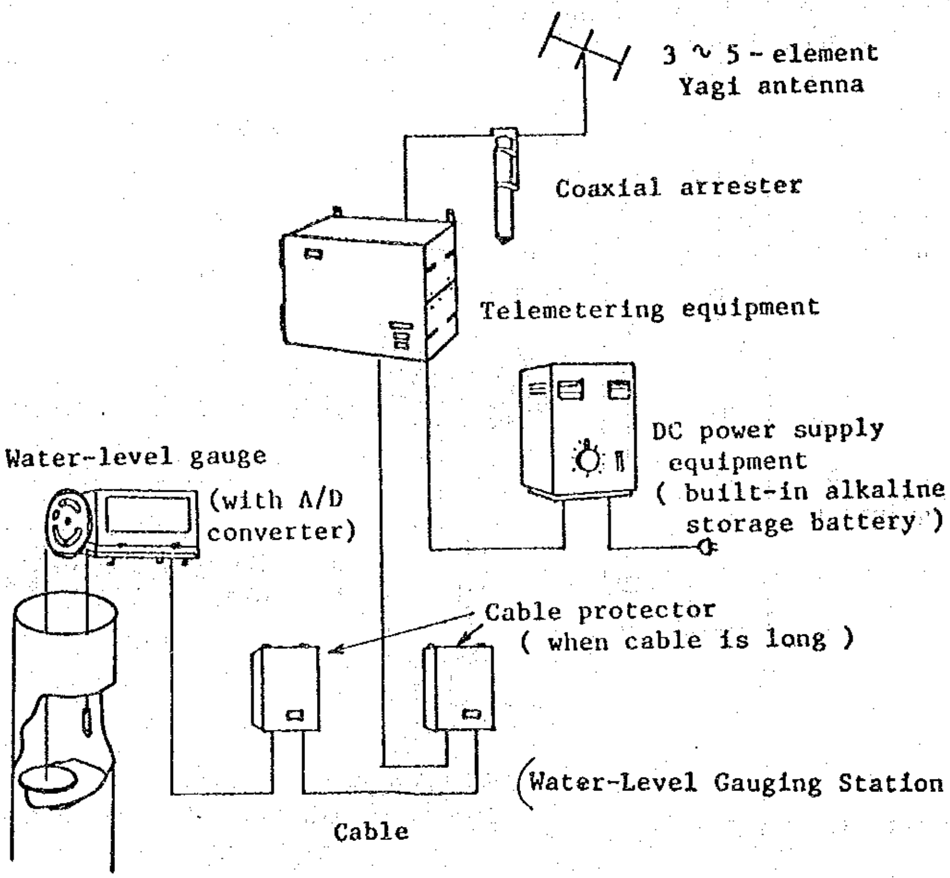


(Repeater Station Equipment)

Fig. 6-4 Equipment - 2



(Rainfall Gauging Station Equipment)



(Water-Level Gauging Station Equipment)

Table 6 — 2

Approximate Construction Cost of Telemetering Facilities (Sadong River Basin)

us.$

Station	Number	Equipment	Housing	Antenna Pole	Total	Rewarks
Master Control Station	1	269,000	10,000	5,000	284,000	DID in Kuching
Repeater Station	1	76,000	15,000	4,000	95,000	
Water Level Station	4	132,000	28,000	16,000	176,000	
Rainfall Station	4	100,000	20,000	16,000	136,000	
Water Level and Rainfall Station	2	80,000	14,000	8,000	102,000	
Total		657,000	87,000	49,000	793,000	

(1) Notes: 1. Calculation was worked out on the assumption that the master control station will be established at DID Kuching.

2. Cost of relay station is that of a new one, but excludes the construction cost of a maintenance road.

6-4 Required Future Studies

In addition to continued collection, consolidation and analysis of rainfall and water level data, the following studies and analyses must be conducted in order to set the network construction plan afoot.

- Profile levelling to obtain H-H correlation between respective water level stations, and cross-sectional levelling at each observation station and at each point for flood warning.
- Survey for selecting the locations of observation stations.
- Selection of suitable observation equipment and studies on observation method in order to obtain accurate and reliable data.
- Studies on the method of data transmission, collection and analysis.
- Studies on the method of giving flood warning and target areas for flood forecasting.
- Studies on the system administration and management.
- Estimation of the construction cost.

6-5 Effects of Flood Forecasting System

Operation of the proposed flood forecasting and warning system in the Sadong basin will yield the following effects.

- Alleviation of flood disasters including loss of human lives and damage of properties.
- Reduction of traffic congestion through prior announcement of isolated road sections.
- Higher development potential of the whole basin.
- Greater welfare and better livelihood for the people in the basin.

Chapter 7. Administration, Management and Maintenance

7-1 DID Organization

Fig. 7-1 is the present organizational chart of DID, Sarawak. The Sadong belongs to the first block, and Hydrological Department of DID's Planning and Design Branch undertakes the collection and analysis of hydraulic and hydrological data as well as flood forecasting service (See Fig. 7-2).

It is likely that the Sadong basin flood forecasting system will be placed under the control of this Hydrological Department and if so, it will be necessary for the department to increase its staff members for satisfactory maintenance of the system so that efficient flood forecasting service will be ensured.

7-2 Management and Maintenance

Full utilization of this flood forecasting system presupposes satisfactory routine management and maintenance service. Especially in the flood season when the equipment are prone to develop troubles, maintenance and inspection service must be carried out with greater care and at shorter intervals than in other seasons. The maintenance service may be performed once or twice a month in non-flood seasons, but should be conducted once or twice a week throughout the flood season to prevent the occurrence of missing observation record.

Fig. 7-1 Drainage & Irrigation Department Organization Chart

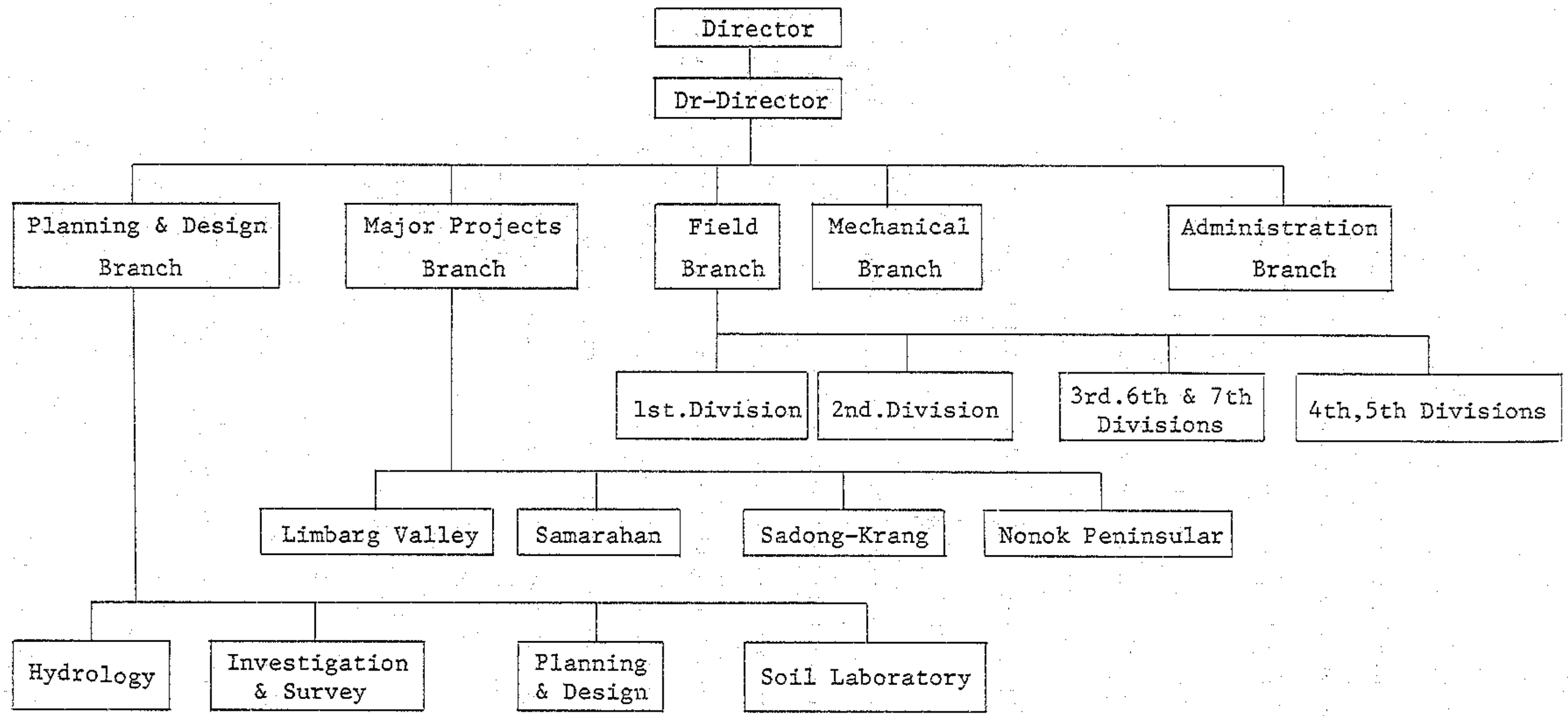
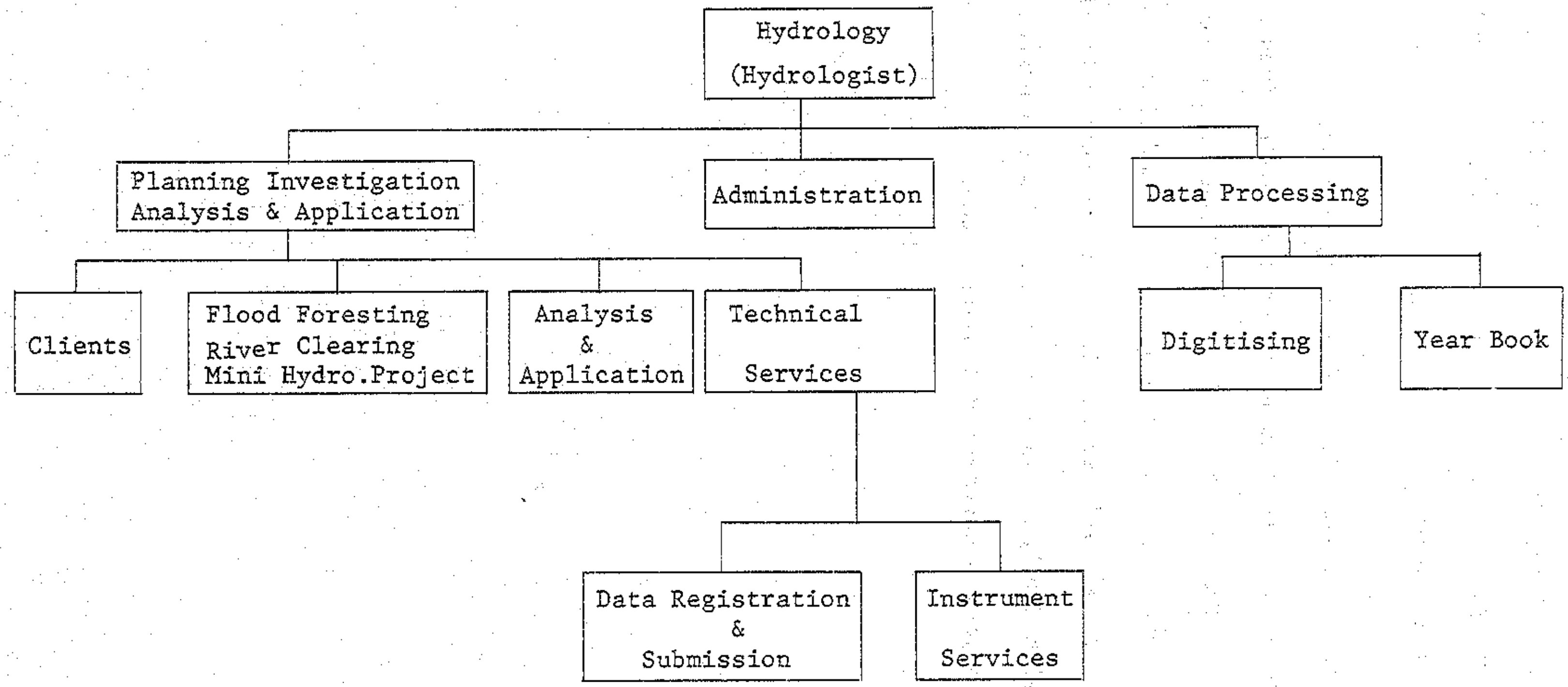


Fig. 7-2 Hydrological Department Organization Chart



(As of Aug. 1978)

Chapter 8. Recommendation and Conclusion

The Sadong river basin is located close to Kuching, the capital of Sarawak State. The basin has a large population and there are a number of schemes now under planning for its development. It is probable that the basin will pursue a steady course of development in future.

Establishment of a flood forecasting and warning system in the basin will yield immense and multiple effects such as protection of human lives and properties from flood disasters, stabilization of people's livelihood, and enhancement of the overall basin development. It is therefore recommended that a further detailed survey be conducted at the earliest possible date so that a flood forecasting system compatible with the basin will be instituted and operated with account taken of its satisfactory management and maintenance.

PART III. KINABATANGAN RIVER BASIN (SABAH)

Chapter 9. Outline of Kinabatangan River Basin

9-1 Natural conditions

The Kinabatangan river basin is located in the central part of the east coast area of Sabah State, lying between Lat. 4°30' and 5°45'N and between Long. 116°25' and 118°40'E. The Kinabatangan is the largest river in Sabah having a catchment area of about 17,000 km^2 and its maintstream has a length of 500 km. The basin is 250 km from east to west and 40 - 100 km from south to north. The Milian river rising in the mountainous area in the western part of the basin and the Kuamut river flowing from the southern mountainous area join at Kuamut in the centre of the basin to form the Kinabatangan mainstream which flows eastwards in a meandering direction through the flat and extensive alluvial plain, passing by a number of towns and villages such as Balat, Pintasin, Lamag, Bilit and Sukau, and empties into Sulu Sea at a point 40 km to the east-southeast of Sandakan.

In the upper basin, many rivers rising from Mt. Trusmad (El.2,600 m) and other mountains with a height of 500 - 2,000 m flow down to join the Millian and the Kuamut. The mid-stream basin is a flat plain covered with forests through which the Kinabatangan flows in an extreme meandering direction. The lower basin embraces many swamp areas and the Kinabatangan branches off into many tributaries through the deltas formed near its estuary before draining itself into the sea.

The bed slope is very mild and estimated to range from 1/20,600 to 1/40,000 in the middle and lower basins. Hence, the Kinabatangan is extremely susceptible to tide and its water level is affected by tide even at Lamag which is as far as about 200 km upstream of the estuary. Due to its mild bed slope and extreme meandering, the flood flow has a very low velocity and inundates the extensive flat plain along the channel.

The geology of the basin consists of bedrocks of sandstone and mudstone which are overlain by different sedimentary soils. The acid soil in the coastal area and the peat soil in the swamp area are not suited for farming operation, but the clayey alluvial soil and humus forest soil in the mid-stream basin are suited for agricultural development.

As regards vegetation, the whole basin is covered with tropical forest and felling of forest trees is conducted in many parts for export of timber.
The basin has a tropical climate featured by high temperature and high relative humidity. The wet season brought about by the northeast monsoon lasts from November to March, and the annual rainfall is as large as 2,000 - 3,000 mm.

9-2 Socio-economic Conditions

The Kinabatangan basin occupies the southern half of Sandakan Residency in the eastern part of Sabah State. Sandakan Residency accounts for as large as 1/3 of the total area of Sabah, but it is at the lowest stage of development when compared with the three other residencies, i.e., Interior Residency, West Coast Residency and Tawau Residency.

The Kinabatangan basin covers more than half of Sandakan Residency. However, its entire area being enveloped with natural forests, the basin is still left intact except that its forest resources are being developed.

The Kinabatangan river is the principal means of transportation in the basin, and the only means of overland traffic is the paved road linking Sandakan and Lamag in the central part of the basin.

According to the 1970 census, the Kinabatangan basin has a population of 14,177, which accounts for only 2.2% of the total population of Sabah State (653,264 persons). Indigenous people consisting mainly of the Orang Sugai race account for about 80% of the basin's population, numbering 11,283 persons. During the period from 1951 to 1971, the population of Sabah State increased by 1.96 times (=653,264/334,141), but that of the Orang Sungai race who inhabit in Sabah increased only by 1.29 times (=17,687/13,697).

Main crops are rubber, coconut, oil palm and paddy.

Fig. 9-1 KINABATANGAN River

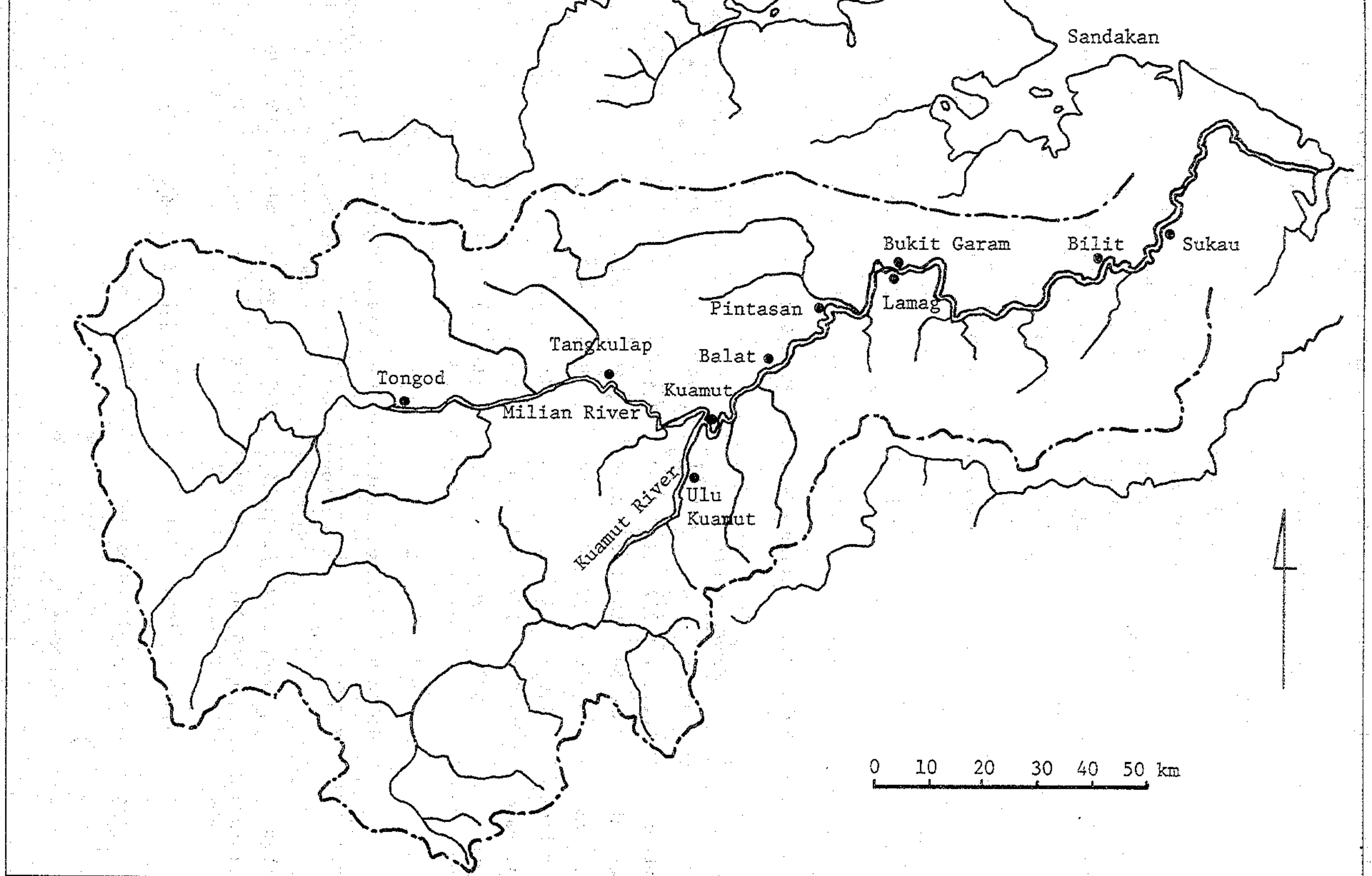


Table 9-1 Population & Crop Statistic in the Kinabatangan River Basin (1976)

Population			-14,177
Crops	- Wet Padi	305 acres	
	- Dry Padi	3280 "	
	- Rubber	2068 "	
	- Coconut	2266 "	
	- Oil Palm	8532 "	
	- Maize	500 "	
	- Coffee	30 "	
	- Fruits	61 "	
	- Other crops	1500 "	
	Total:		18,542 acres

Table 9-2 Estimated Area of Main Crops

(Acres)

	Sabah State			Sandakan District			Kinabatangan Area
	1970	1976	1976/1970	1970	1976	1976/1970	1976
Rubber	262,097	267,202	1.02	19,498	22,749	1.17	2,068
Coconut	136,139	133,072	0.98	12,489	17,846	1.43	2,266
Wet Padi	76,689	77,306	1.01	370	955	2.58	305
Dry Padi	27,041	44,221	1.64	4,050	8,150	2.11	3,280
Oil Palm	94,968	171,598	1.81	45,146	70,465	1.56	8,532
Cocoa	9,932	29,036	2.92	730	1,113	1.52	-

Table 9-3 Classification of the Forest Reserves

(in Acres)

	Total	Protection Forest	Commercial Forest	Domestic Forest	Amenity Forest	Mangrove Forest
Sabah	7,062,612	1,062,547	5,719,968	34,265	50,389	186,326
Sandakan(South)	1,040,391	12,305	937,939	(392)	10,674	79,081

(1 acre = 0.004046 km^2)

In 1976, the cultivated land area in the basin was 8,532 acres for oil palm, 3,280 acres for dry paddy, 2,266 acres for coconut, 2,068 acres for rubber, and 305 acres for wet paddy. The cultivated area of these main crops excepting rubber increased by 1.4 - 2.6 times during the period from 1970 to 1976 (Table 9-2).

Timber production is the largest industry in the Kinabatangan basin. Of the total timber export from Sabah State, which amounts to M$,212,950,000 (FOB 1976), a considerably large portion is accounted for by the Kinabatangan basin. Although administrative measures are taken for designation of forest reserve, it is likely that changes will take place in the run-off the Kinabatangan with the increase of cutting area.

None of the towns in the basin are covered by the electric power supply service of Sabah Electricity Board. Kerosene lamps are used for illumination in all towns except Bukit Garam and few other towns equipped with an isolated power plant. Public water supply network is not yet established in the basin, so that rain and river water is used as drinking water.

GDP in Sabah State amounts to M$1,529 million in total and M$2,340 per capita. Per capita GDP in the Kinabatangan basin seems to be considerably lower than the average of Sabah State (See Table 9-4).

9-3 River Channel

The Kinabatangan is the largest river in Saba State having its estuary on the east coast of the state and a catchment area of about 17,000 km^2. As shown in Fig. 9-1, two main tributaries, the Milian and the Kuamut (catchment area: 9,270 km^2) join in the upper basin to form the Kinabatangan which then flows eastward in the flat forestland area in the mid-stream basin and divides itself into a number of branch rivers near the east coast before emptying into Sulu Sea.

The upper Milian basin and the Kuamut basin are hilly areas with an elevation of 500 - 2,000 m, but other parts of the Kinabatangan basin are flat alluvial plains

Table 9-4 Sabah - Gross Domestic Product By Industrial Origin At Factor Costs in Current Prices

(M$ Million)

	1967	1968	1969	1970	1971	1972	1973	1974	1975
TOTAL G.D.P. @ FACTOR COST	602	645	713	743	787	879	1,250	1,494	1,529
1. Agriculture, Livestock, Forestry and Fishery......	332	351	397	406	417	445	742	894	750
(a) Agriculture and Livestock	93	108	122	122	125	139	191	258	289
(b) Forestry and Logging..	210	218	252	259	265	272	513	595	411
(c) Fishery	29	25	23	25	27	34	38	41	50
2. Mining and Quarrying......	1	1	1	2	3	4	4	8	114
3. Manufacturing	13	13	15	16	21	28	35	39	43
4. Construction	20	25	27	30	33	41	47	90	85
5. Electricity and Water	6	7	9	10	10	11	13	14	16
6. Transport and Communication	26	29	31	37	42	48	53	64	82
7. Wholesale and Retail Trade	67	71	75	79	84	90	109	114	123
8. Banking and Insurance	7	8	9	9	9	10	11	16	19
9. Ownership of Dwellings ...	41	44	46	47	49	52	55	59	71
10. Public Administration and Defence	35	37	39	40	47	60	67	77	82
11. Services	54	59	64	67	72	90	114	119	144

(Annual Bulletin of Statistics 1976)

covered with forests. Towns and villages each comprising 20 - 1,000 households are found along the river channel. People living in these towns and villages resort to small boasts navigating on the Kinabatangan for the supply of foodstuffs, daily necessities including kerosene, agricultural machinery and materials, etc. Despite the constant exposure to flood damage, the people in these riverine towns and villages are forced to live in elevated-floor type houses built near the river banks because the goods transported by boats must be carried by manpower to their houses and their daily lives are heavily dependant upon the Kinabatangan.

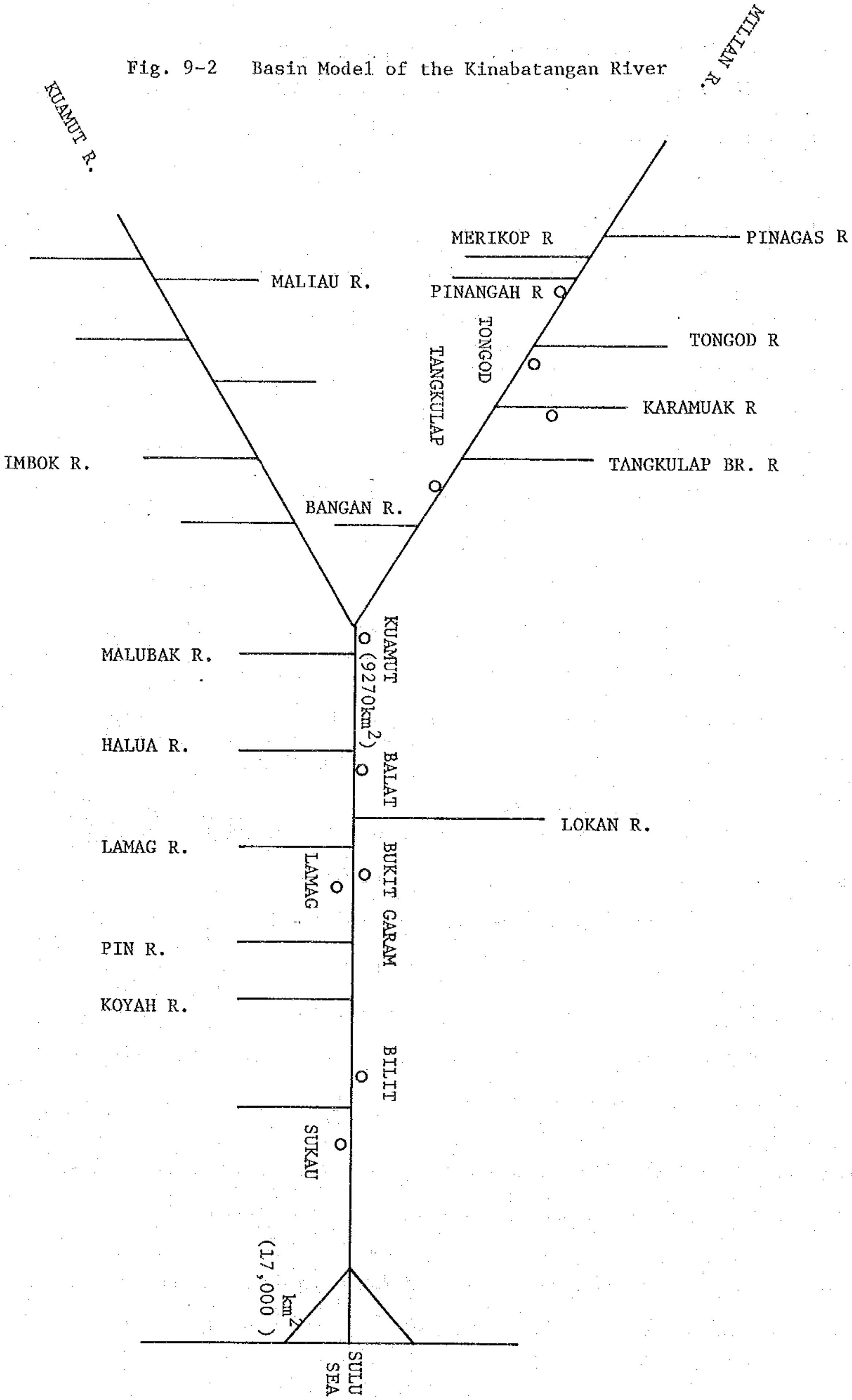
The lower basin embraces many swamps especially near the coast where the basin turns into a low-lying swamp area with mangrove trees growing thickly on both banks. The bed slope between the mid-stream section and the estuary is very mild, estimated to be 1 : 40,000 or milder. Hence, the river meanders extremely and overflows both banks even by a slight increase in the water level. This mild bed slope in the mid-stream and lower basins makes the velocity of flood, flow rather small and incurs a conspicuous tidal effect which is observed even at Lamag and Pintasan located more than 200 km upstream of the estuary.

River improvement work is not undertaken in any part so that the Kinabatangan still remains a natural river along its entire channel. As for the natural environment along the channel, contamination of river water is not observed yet although felling of forest trees for timber production is conducted on a considerably large scale in the mid-stream and lower basins. There is probability that the future logging operation will incur some changes in the run-off structure of the river.

The basin is covered with natural forests which provide habitat for various kinds of wild life such as alligator, wild pig, Oran Utan, and hornbill.

The Kinabatangan is subjected to considerable erosion and deposition. Trees on the river banks are often washed away as a result of the bank erosion.

Fig. 9-2 Basin Model of the Kinabatangan River



The Kinabatangan has a width of about 200 m at Bukit Garam located along the mid-stream section. The Milian has a width of 100 m in the lower basin and 70 - 80 m at a point about 30 km upstream from the confluence with the Kinabatangan. The Kuamut has a width of about 100 m in the lower basin, becoming narrower towards the upper reaches but with a number of sections embracing shoals and islands and having a width of more than 200 m. The mainstream and tributaries are used for navigation, fisheries, timber transportation as well as domestic water. The team often observed several hundred logs measuring 2 - 5 feet in diameter and 30 feet in length towed down the channel by a boat.

9-4 Flood Damage

In the wet season lasting from November to March, the northeast monsoon causes inundation of minor scale along the channel practically every year, bringing about a serious flood once in about several years, which inflicts a heavy damage on the riverine inhabitants. All towns and villages in the basin are susceptible to flood damage because they are situated along the river channel. Especially, Kuamut, Balat, Pintasan, Lamag, and Kampongs downstream of Lamag are frequently afflicted with flood disasters. Details of flood damage are not known because no relevant survey has been conducted in the past. The heaviest recorded in the last 10 years are the floods in 1971 and 1977, and these two floods are said to have inflicted a destructive damage on the riverine inhabitants. Table 9-5 is the record of flood damages of the Kinabatangan prepared by DID Sabah Office for the last 10 years.

9-5 Basin Development Plan

In pursuit of its national economic development, the Malaysian government has completed two economic programmes, the First Malaysia Plan (1965 - 1970) and the Second Malaysia Plan (1971 - 1975), and is currently pushing forward the Third Malaysia Plan (1976 - 1980). Economic development of Sabah State as envisaged by this Third Plan has two main targets. One is to increase the production of

Table 9-5 Flood Damage - Kinabatangan

<u>1967</u>

193 houses washed away
700 houses damaged
8000 people affected
Total damages estimated $200,000.00

<u>1968</u>

Kinabatangan flooded - extent of damages not known

<u>1971</u>

Kuamut under 15' of water
Flood damages estimated $100,000.00

<u>1974</u>

Lamag under 3' of water - extent of damages not known

<u>1976</u>

Sungai Kinabatangan flooded
13 lives lost

<u>1977</u>

Sungai Kinabatangan flooded riverine villages, namely Batuputeh, Bilit Sukan and Abai, affecting 100, 50, 30 and 20 houses respectively
60 families evacuated
30 houses washed away
Bukit Garam under 8' of water
Kuamut under 4' of water
Overall actual flood damage must be assumed to be far greater

main crops such as palm oil, cocoa and coconut to break out of the present pattern of economy which depends solely on timber production, and the other is to solve the problem of income differentials between different races and different social strata. By the implementation of the First and Second Malaysia Plan, GNP increased from M$494 (1965) to M$1,524 (1975) (Table 9-6), but the income disparity between races is still quite large. In particular, the greater part of indigenous population are employed in low-paying jobs. Hence, the Third Malaysia Plan is aimed specifically at readjustment of social structure and elimination of income disparity in addition to overall economic growth and expansion. Development of the Kinabatangan basin is urgently called for as more than 90% of the basin's total population is accounted for by indigenous people engaged in low-income jobs and timber production is virtually the only industry in the whole basin area.

Development expenditure of Sabah State has been on the steady increase, growing from M$94 million (1970) to M$150 million (1975). In 1975, more than half of the development expenditure was appropriated for infrastructural improvement, with M$54 M$54 invested in the road construction/improvement sector, M$32 million in the land development sector, and M$8.5 million in the paddy production sector (See Table 9-7).

Table 9-6 Economic Growth in Sabah, through Economic Plan

	First Malaysia Plan		Second Malaysia Plan		Third Malaysia Plan	
	1965	1970	1971	1975	1976	1980
GNP	million M$ 494	million M$876		M$1524		
(Annual expansion)	(10.5%)		(11.7%)			
Population	544,944	653,604		768,331		
(Annual expansion)	(3.7%)		(3.3%)		(3.2%)	
Income per Capita	M$ 891	M$1340		MS1984		M$2563
	(8.5%)		(8.2%)		(5.2%)	

Table 9-7 State Development Expenditure (Actual)

(M$'000)

Nature of Expenditure	1970	1971	1972	1973	1974	1975
TOTAL	94,032	96,592	117,658	93,084	124,263	160,517
Investment	-	-	-	900	2,800	10,000
Power	-	-	-	264	951	600
Housing	3,950	3,044	2,724	2,000	4,500	-
Commerce and Industry	3,350	900	17,393	7,389	2,681	4,914
Medical and Health	3,453	2,873	1,829	-	-	-
Social Welfare	-	-	116	294	706	635
Surveys	77	103	193	162	38	47
Forest Inventory and raining	885	863	475	270	213	3
Agriculture Research and Training	1,111	3,287	3,729	3,307	4,068	4,551
Drainage and Irrigation ...	2,857	2,775	2,829	2,555	2,958	4,376
Road and Bridge	15,336	24,063	30,035	34,235	40,374	53,868
Water Supplies	2,233	5,313	4,391	3,844	5,403	7,132
Goverment Buildings (Other than Housing)	-	-	-	-	-	-
Public Works Plants and Working	750	672	1,237	359	1,667	1,715
Government Housing	210	96	71	36	-	119
Sabah Railways	2,199	3,658	874	656	1,951	2,509
Marine	703	2,419	1,091	1,135	9,495	3,260
Community Services	841	950	774	856	3,750	6,035
Local Authorities	3,299	3,390	-	-	-	-
Agriculture Extension and Credit	8,443	2,818	2,276	2,232	2,744	2,353
Land Development	14,868	18,550	-	-	-	-
Lands	204	1,276	1,030	939	905	1,303
State Buildings	2,981	6,108	-	3,440	2,649	3,553
Forests	125	590	1,126	1,653	1,099	1,773
Veterinary	825	1,417	-	647	713	1,117
Fisheries	712	297	467	344	310	228
Miscellaneous	18,509	1,790	2,036	551	1,589	3,431
State Water Supplies	3,015	-	-	-	-	-
Crop Research	1,719	-	-	-	-	-
Civil Aviation	1,377	533	16	2	-	-
Contingencies Reserve	-	-	-	-	40	40CR

Ports	-	179	360	1,676	-	-
Rubber Fund Board	-	1,100	3,860	1,200	2,900	2,550
Sabah Padi Board	-	7,133	8,063	4,235	4,594	8,511
Television Sabah	-	395	147	-	-	-
Local Government and Fire Fighting Services.......	-	-	4,558	2,202	1,639	3,048
Culture, Youth and Sports	-	-	370	329	302	539
Veterinary Services	-	-	779	172	249	415
Sabah Land Development Board	-	-	21,800	15,200	22,975	31,972
State Buildings...........	-	-	3,009	-	-	-

Source: Accountant-General.
Annual Bulletin of Statistics
Sabah 1976

In the Crop Development Programme of Sabah State, shown in Table 9-8, special emphasis is placed on the accelerated production of oil palm, cocoa, coconut, and rubber.

Table 9-8

SABAH CROP DEVELOPMENT PROGRAMME, 1976-1980 (Acres)

	Settlement Schemes	Development Cooperatives	Estates	Others	Total
Oil Palm	42,133	6,000	25,000	1,867	75,000
Cocoa	9,519	500	8,920	6,061	25,000
Coconut	7,068	1,500	200	4,000	12,768
Rubber (high yielding)	168	2,000	3,500	21,500	27,168
Padi:					
First Crop	220	—	—	8,150	8,370
Second Crop	—	—	—	10,250	10,250
Fruit Trees	481	—	—	9,519	10,000
Coffee	590	—	—	200	790
Pasture	—	—	—	10,000	10,000
Other Crops	386	—	—	22,114	22,500
Fish Ponds	—	—	—	1,500	1,500
TOTAL	60,565	10,000	37,620	95,161	203,346

(THIRD MALAYSIA PLAN)

In the Land Development Programme incorporated in the Third Malaysia Plan, public sector is given greater importance than private sector, the former covering an total acreage of 126,450 as against 76,881 of the latter.

In the aspect of agricultural development, the Minor Settlement Scheme covering a project area of 2,000 acres in the mid-stream Kuamut basin has been in operation since 1970 for increased production of mainly coconut and cocoa, and settlement has been completed in an area of about 500 acreas. A 750 ha paddy field area was developed in the vicinity of Bukit Garam under a programme conducted between 1972 and 1976, but it is now abandoned due to a number of floods that inundated the whole area. Regarding the private sector development, the team learned that an area of 11,000 acres near Bukit Garam was planned to be developed for oil palm production.

As for the overall basin development, a preliminary survey has already been conducted for the construction of a multi-purpose dam with a height of 40 m on the Kinabatangan mainstream near Balat. This dam is planned to be operated for flood control, irrigation and power generation for the purpose of overall development of the mid-stream and lower basins of the Kinabatangan.

TABLE 9 – 9

SABAH LAND DEVELOPMENT PROGRAMME (THIRD MALAYSIA PLAN)

PUBLIC SECTOR	ACREAGE	PRIVATESECTOR	ACREAGE
Sabah Land Development Board	51,565	Estates	34,120
Rubber Fund Board	35,000	Land Cooperatives	10,000
Sabah Padi Board and Drainage & Irrigation Department	18,400	Land Development Companies on Joint – venture basis	20,000
Department of Agriculture	10,000	Smallholders	12,761
Department of Veterinary & Animal Husbandry	10,000		
Department of Fisheries	1,500		
TOTAL	126,465	TOTAL	76,881

Chapter 10. Meteorology and Hydrology

10-1 Meteorology

The Kinabatangan basin lies between Lat. 4°30' and 5°45'N and has a tropical climate. The northeast monsoon season, which starts in October - November and lasts until February - March, brings about lots of rain in the entire basin. Rainfall in the southwest monsoon season, which lasts from April - May to September - October, is relatively small. Fig. 10-1, showing the monthly rainfall at Sandakan, indicates that the January - February period records a concentrated rainfall each year.

Meteorological stations are established at Sandakan (Malaysia Meteorological Service) and Kuamut (DID).

According to the 1969 - 1975 records at Kuamut situated in the centre of the Kinabatangan basin (Annex 12), the annual rainfall is subject to a large fluctuation, ranging from 1,727 to 3,387 mm, with the average being 2,610 mm; the temperature is 21 - 23°C for mean daily minimum, 30 - 32°C for mean daily maximum, and 25°C for mean; the relative humidity is 30 - 42% for mean daily minimum, 90 - 96% for mean daily maximum, and 80 - 83%; sunshine hours are 5 - 6 hours; and annual evaporation is 1,300 - 1,650 mm.

On the other hand, the 1968 - 1977 records at Sandakan situated a little off the basin indicate that the temperature is 22.9°C for mean daily minimum, 31.2°C for mean daily maximum, and 26.8°C for mean; the relative humidity is 63.6% for mean daily minimum,97.3% for mean daily maximum, and 83.4% for 24-hour mean; the annual rainfall (1951-1977) is 3,066 mm.

Thus, the two places are just about the same in climatic condition.

Fig. 10-1 MONTHLY RAINFALL AT SANDAKAN

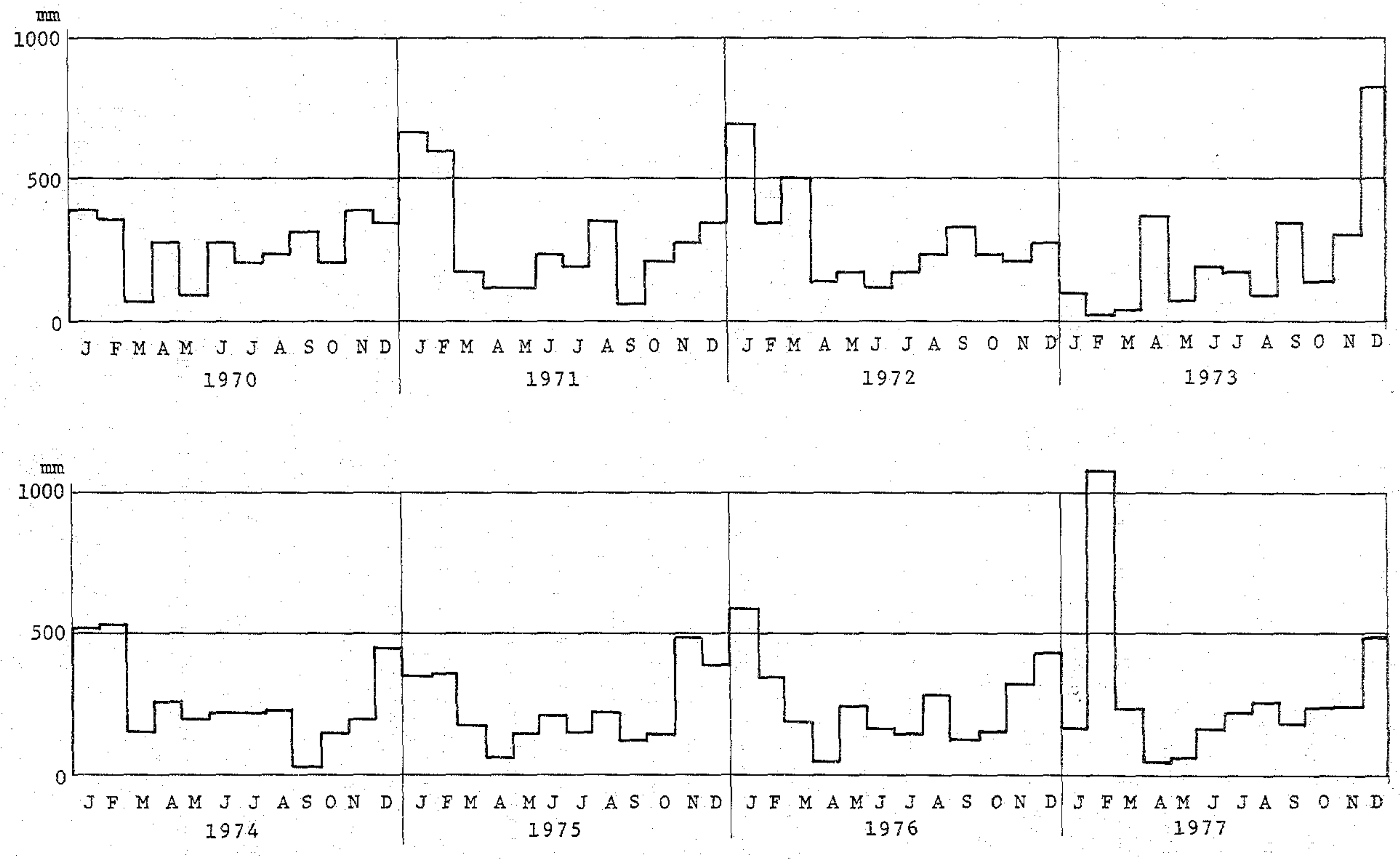


Table 10-1 Records of Mean, Highest and Lowest Monthly and Annual Rainfall and Raindays

Station: Sandakan
Lat: 5°54'N
Long: 118°04'E
Ht. Above M.S.L: 12m

	Period	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Rainfall(mm)														
Mean	1951-1977	453.5	286.8	195.3	113.9	141.4	186.7	179.9	231.7	231.7	243.7	337.5	464.7	3066.8
Highest	1947-1977	1094.0	1079.3	556.4	374.3	366.0	366.0	436.3	381.0	446.5	430.2	660.3	827.9	3793.9
Year of Highest		1963	1977	1954	1973	1961	1952	1972	1968	1957	1961	1967	1973	1956
Lowest	"	105.7	26.7	43.9	0.3	14.7	58.7	55.6	93.7	32.3	59.7	148.8	185.9	2193.7
Year of Lowest		1949	1973	1973	1969	1957	1968	1956	1973	1974	1969	1953	1963	1969
Number of Raindays														
Mean	1951-1977	21	16	13	10	12	14	14	17	16	18	20	23	196
Highest	1947-1977	31	24	21	19	22	21	21	22	24	25	27	27	221
Year of Highest		1963	1977	1965	1950, 1970	1966	1966	1972	1975	1957	1977	1970	Sev.	1956
Lowest	"	11	3	4	1	5	8	7	9	8	12	13	15	162
Year of Lowest		1973	1973	1973	1969	1977	1948, 1972	1958	1953	1971	1969	1964	1947	1973

Table 10-2 PERKHIDMATAN KAJICUACA MALAYSIA

Records of Temperature and Relative Humidity

Station: SANDAKAN
Lat: 5°54'N
Long: 118°04'E
Ht. above M.S.L.: 11.9 m

Period	No. of Years		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Temperature (°C)															
1968-1977	10	24 Hr. Mean	26.0	26.2	26.9	27.4	27.5	27.2	27.1	26.9	26.9	26.9	26.6	26.3	26.8
		Mean Daily Max.	29.3	29.5	30.3	31.5	32.3	32.2	32.3	32.2	32.0	31.6	30.8	30.0	31.2
		Mean Daily Min.	22.7	22.6	23.1	23.7	23.2	23.0	22.7	22.6	22.8	22.9	22.9	22.9	22.9
		Highest Max.	32.1	32.6	32.6	34.0	36.2	35.1	35.6	34.8	34.7	34.9	33.7	33.0	36.2
		Year of Highest Max.	1972	1973	1970	1969	1969	1973	1972	1973	1974	1971	1974	1976	1969
		Lowest Min.	19.4	19.4	20.2	21.6	21.4	20.9	20.2	20.4	21.2	21.1	20.5	20.7	19.4
		Year of Lowest Min.	1968	1968	1968	1971, 1975	1971	1968	1973	1971	Sev.	1973	1968	1975	1968
Relative Humidity (%)															
1968-1977	10	24 Hr. Mean	84.7	83.3	81.6	81.5	82.8	82.9	82.3	82.7	83.7	83.8	85.2	86.2	83.4
		Mean Daily Max.	97.2	96.8	96.3	97.0	97.3	97.3	97.3	97.3	97.6	97.4	97.8	97.7	97.3
		Mean Daily Min.	69.7	68.6	65.2	62.1	60.3	60.5	59.0	59.7	61.3	62.1	65.7	69.5	63.6
		Lowest Min.	52	50	41	46	43	40	38	45	46	43	49	51	38
		Year of Lowest Min.	1975	1971	1973	1969, 1974	1969	1977	1968	1968	1970	1971	1968, 1974	1976	1968

10-2 Rainfall

Rainfall in the Kinabatangan basin is observed at the stations in Kuamut, Ulu Kuamut, Tongod, Tangkulap, and Lamag (moved to Bukit Garam in 1977). In the peripheral area of the basin, rainfall is observed at DID's stations at Telupid and Sook as well as at the meteorological observatory of Malaysia Meteorological Service located in Sandakan. The locations and periods of recordings of these stations are shown in Fig. 10-2 and Table 10-3.

Mean annual rainfall during the period from 1969 to 1975 shows a considerable fluctuation by place, registering 2,949 mm at Sandakan, 2,610 mm at Kuamut, 3,445 mm at Lamag, 2,501 mm at Tangkulap, and 2,939 mm at Ulu Kuamut. The overall average of the basin's rainfall is estimated to be about 3,000 mm.

As shown in Fig. 10-3, distribution of mean monthly rainfall shows no appreciable differences by season except at Sandakan. According to the rainfall records at Sandakan for the last 30 years, the maximum monthly rainfalls in the northeasterly monsoon season are 838 mm (December), 1,074 mm (January) and 1,079 mm (February). The maximum daily rainfall recorded in the last 9-year observation data at Sandakan is 464.5 mm (December 27, 1973).

Rainfall data are compiled and printed up to 1968, but the records for the last 10 years are not yet published. Annex 10 (Daily Summary of Hourly Rainfall at Different Stations) shows the hourly rainfall and daily rainfall at different stations during the floods of February 1971, March - April 1971, February 1974, February - March 1975, and October - November 1975. Table 10-4 shows the hourly rainfall and peak water level at different stations. This table includes many missing records and indicates that there is no rainfall correlation between respective stations.

Annex 11 is an isohyetal map.

Fig. 10-2 KINABATANGAN RIVER BASIN HYDROLOGICAL OBSERVATION STATIONS

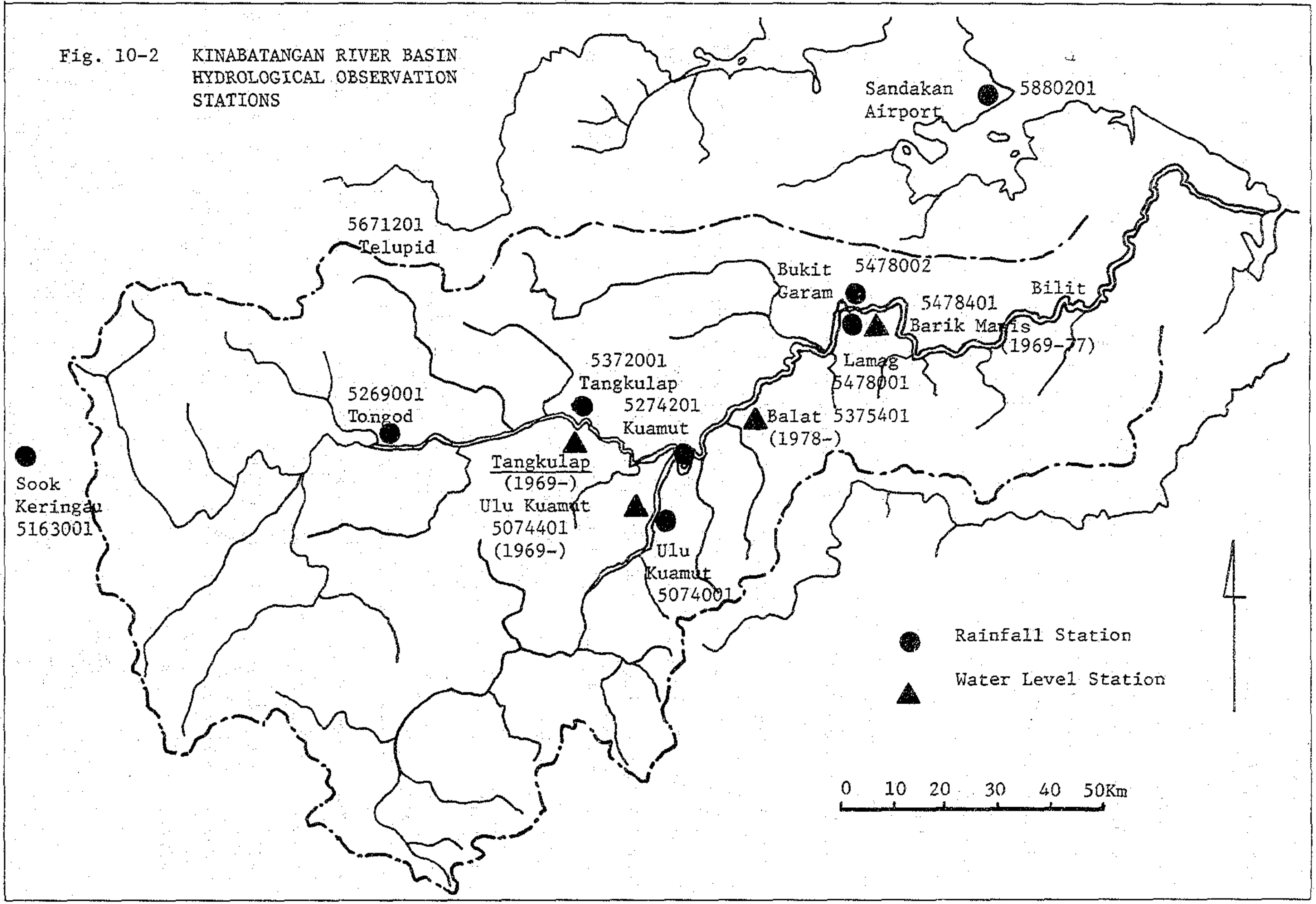


Table 10-3 Rainfall Stations and Records

Station	Station Number	Location		Approximate Elevation	Period of Record	Basin	Remarks
		N	E				
KUAMUT	5274201				1969-to date	Kinabatangan	Principal Station
LAMAG	5478001	5°28'	117°48'	20	1968-1974	Kinabatangan	Principal Station
TANGKULAP	5272001	5°18'	117°17'	100	1953-to date	Kinabatangan	Secondary Station
ULU KUAMUT	5174001				1969-to date	Kinabatangan	Secondary Station
SANDAKAN AIRPORT	5880201	5°53'50"	118°03'30"	39	1967-to date	Kinabatangan	Principal Station
SOOK KERINGAU	5163001 (5163002)	5 08'40"	116°18'10"	800	1965-to date	Padas river	Principal Station
PANIMBANAN	5873201	5°51'50"	117°23'20"	15	1963-to date	Labuk river	Principal Station
BILIT		5°29'	118°12'	10	1953-1959	Kinabatangan	
TELUDID	5671201	5°38'30"	117°27'30"	200	1964-1974	Labuk river	
BUKIT GARAM	5478002				1974-to date	Kinabatangan	
TONGOD	5269001				1977-to date	Kinabatangan	

Fig. 10-3 Mean Monthly Rainfall

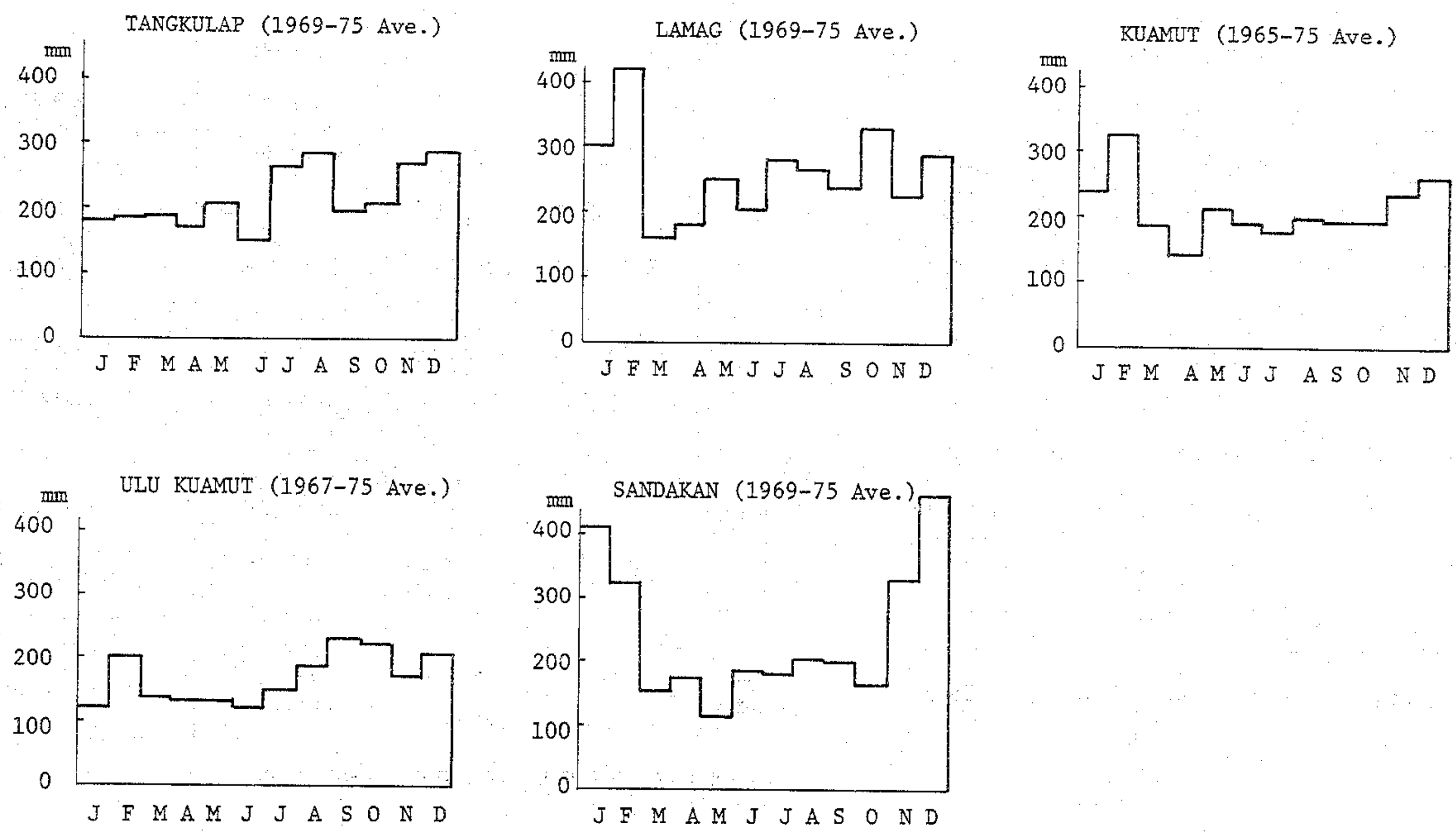


Table 10-4 Peak Water Level - Daily Rainfall

(Rain. mm., Water level: feet)

	Station	1971 February 1	2	3	4	5	6	7	8	9	10	11	1972 March 30	31
Rain	Ulu Kuamut	2	2	0	2	7	18	22	8	10	4	1	-	-
	Lamag	-	-	-	-	-	-	-	-	-	-	-	-	-
	Tangkulap	0	0	0	0	0	0	0	0	0	0	0	26	-
	Kuamut	-	2	8	0	99	125	-	-	-	-	-	0	13
Peak W.Level	Ulu Kuamut							45'	42'					12.9'
	Tangkulap		31.5'									62.5'		20'
	Barik Manis				43.6'	42.3'			41.8'		51.8'			-

	Station	1972 April 1	2	3	4	5	6	7	1974 February 12	13	14	15
Rain	Ulu Kuamut	-	-	-	-	-	-	-	6	39	8	12
	Lamag	-	-	-	-	-	-	-	563	167	24	11
	Tangkulap	-	-	-	-	-	-	-	47	83	3	9
	Kuamut	2	0	0	0	0	0	0	105	63	8	3
Peak W.Level	Ulu Kuamut				8.6'					8.08'		
	Tangkulap	28.2'								30'		
	Barik Manis	-								-		

	Station	1975 February 20	21	22	23	24	25	26	27	28	March 1	2	3
Rain	Ulu Kuamut	25	16	6	25	111	12	28	17	10	94	13	
	Lamag	257	-	-	-	-	-	-	-	-	-	-	
	Tangkulap	128	11	13	3	32	2	0	36	7	78	73	
	Kuamut	39	8	3	35	37	6	13	1	48	81	25	
Peak W.Level	Ulu Kuamut					25.6'							
	Tangkulap							35.5'					33.1'
	Barik Manis												

	Station	1975 October 28	29	30	31	November 1	2	3	4	5	6	7
Rain	Ulu Kuamut	68	6	24	32	8	0	1	0	46		
	Lamag	30	35	0	57	0	1	0	0			
	Tangkulap	0	0	0	0	0	0	0	11			
	Kuamut	-	-	-	15	2	0	4	0			
Peak W.Level	Ulu Kurmut										18.5'	
	Tangkulap											19.5'
	Barik Manis											

10-3 Water Level and Discharge

For water level and discharge observation in the basin, DID has 3 water level and discharge stations established at Barik Manis situated in the mid-stream section of the Kinabatangan mainstream (moved to 1978 to Balat, about 40 km upstream of Barik Manis, to avert tidal effect), Ulu Kuamut along the Kuamut, and Tangkulap on the Milian. Water level is observed using the pressure type Stevens Recorder (manufactured in the U.S.A.). This type of gauge is inferior to the float type gauge in both accuracy and durability, so that it is desirable to replace it with a float type gauge. Discharge observation is made periodically using mainly a current meter for preparation of rating curves (Annex 13). At Bukit Garam and Lokan Bridge, water elvel observation by staff gauge recording was started not long along for floods only.

Since none of the water level stations in the basin have been covered by surveying of gauge datum, the relationship between respective stations in terms of elevation is not known.

Water level and discharge records for the last 10 years have not yet been consolidated for publication.

Flood water levels exceeding 15 feet in gauge height as recorded at water level stations at Barik Manis, Tangkulap and Ulu Kuamut are shown in Fig. 11-1. As seen in this figure, small floods are not necessarily concentrated in the northeast monsoon season (November to February) but occur throughout the year. However, heavy floods are recorded in the January - February period.

Table 10-4 shows the peak water levels and daily rainfalls recorded during heavy floods including those of February 1971 and February 1975. A detailed study must be made in future to obtain the correlation between rainfall and run-off and the rainfall correlation between stations.

Table 10-5 Water Level Stations

Station	Location	Number	Period	remarks
Barik Manis	Kinabatangan River	5478401	1969-1977	Principal Station
Balat	Kinabatangan River	5375401	1978-to dato	〃
Tangkulap	Milian River	5373401	1969-to dato	〃
Ulu Kuamut	Kuamut River	5074401	1969-to dato	〃
Bukit Garam II	Kinabatangan River	5478401	1977-to dato	Staff gauge reading for flood only
Lokan Bridge	Lokan River	5575401	1978-to dato	〃

Chapter 11. Flood Analysis

11-1 Flood Records and Damages

Minor-scale flooding of the Kinabatangan occurs frequently as shown in Fig. 11-1, and serious ones imposing heavy damage on the riverine inhabitants occur every several years as shown in Table 9-5.

The heaviest of the floods recorded in the last 10 years are those of February 1971 and 1977, which inundated Kuamat, Bukit Garam and other Kampongs and washed away many houses, causing great damage to crops and properties. No detailed data are available concerning the damage caused by these two floods. However, the record of the 1971 flood indicates that the peak water level at Ulu Kuamut on the Kuamut reached 45 feet (gauge measure), which means that the water level rose by nearly 40 feet because the ordinary water level at that place is less than 10 feet. At Tangkulap, too,the peak water level recorded as high a value as 62 feet, which means that the water level rose by nearly 50 feet. The peak water level at Barik Manis is not known because the water level gauge went out of order during the flood. Judging from the traces of houses washed away by flood water, it is probable that the water level at Barik Manis rose more than 30 feet above the ordinary level.

Hydrological data currently available are the daily observation data recorded at Tangkulap (water level), Ulu Kuamut (water level), Kuamut (rainfall), Tangkulap (rainfall), Tangkulap (rainfall), Ulu Kuamut (rainfall), and Bukit Garam/Lamag (rainfall). These data are shown in the following annexes.