No. 8

GOVERNMENT OF MALAYSIA

KINABATANGAN RIVER BASIN DEVELOPMENT PROJECT

SUPPORTING REPORT

HYDROLOGY
GEOLOGY
DAM
FLOOD CONTROL
AGRICULTURE AND IRRIGATION
HYDRO POWER
SOCIO-ECONOMIC BACKGROUND
PROJECT ECONOMY

MARCH 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

GOVERNMENT OF MALAYSIA

KINABATANGAN RIVER BASIN DEVELOPMENT PROJECT

SUPPORTING REPORT

HYDROLOGY
GEOLOGY
DAM
FLOOD CONTROL
AGRICULTURE AND IRRIGATION
HYDRO POWER
SOCIO-ECONOMIC BACKGROUND
PROJECT ECONOMY

MARCH 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

I . HYDROLOGY

I. CONTENTS OF HYDROLOGY

LIST OF TABLES

LIST OF FIGURES

Page

1. GENERAL

Hydrological studies were conducted in order to clarify hydrological conditions in the Kinabatangan River Basin, based on the data collected during this study period.

The scope of the study covers meteorology, rainfall, run-off, flood analysis and sediment with regard to the Kinabatangan River and the Basin.

These analysis are indispensable to formulation of the project.

2. PRESENT CONDITION

2.1 CLIMATE

Sabah is located in tropical climate zone. It is situated in the midst of the Southeast Asia monsoon area. The northeast monsoon begins in November and lasts until March, and the southwest monsoon prevails from May until August. The rainy season of the west coast of Sabah is, generally speaking, at the time of southwest monsoon season and the east coast is at the time of northeast monsoon season, though the seasonal difference in rainfall is not very clear.

2.1.1 Rainfall

There are being maintained 28 rainfall stations, as are shown in Table I-1, in and around the Kinabatangan River Basin. Rainfall observation condition is not satisfactory in respect of duration of records and the number of the stations, especially inside the Basin. The station locations and recorded period are summarized in Figs. I-1 and I-2. According to the existing rainfall data of 8 representative stations selected taking their location and the record existence into consideration, yearly rainfall is as much as 2,500 to 3,000 mm (refer to Table I-2), and its monthly distribution is shown in Fig. I-3.

2.1.2 Temperature and Humidity

Temperature and humidity are observed at 4 stations as shown in Table I-3. According to the Table, the hightest daily mean temperature occurred in May. However, the difference in daily mean temperature is relatively small throughout a year, i.e. 27°C at Sandakan in the coastal side and 25°C at Kuamut in the mountain side. Variation of hourly temperature within a day in May is relatively large, ranging from a maximum of 32°C to a minimum of 23°C at Sandakan and from 34°C to 22°C at Kuamut in May (refer to Table I-4 and Fig. I-4). Daily mean of relative humidity is about 80%; it is almost equal throughout the year and slightly higher at Kuamut, mountain side, than at Sandakan, coastalside (refer to Table I-5 and Fig. I-5).

2.1.3 Sunshine and Evaporation

Sunshine hours and evaporation are observed at 2 and 4 stations respectively as shown in Table I-3. The yearly sunshine hours total about 2,400 hours and insolation ratio is 27% (refer to Table I-6 and Fig. I-6). The yearly total evaporation ranges from 1,500 to 1,800 mm (1,600 mm at Kuamut and 1,770 mm at Sandakan), and the maximum monthly evaporation reaches 150-170 mm in April to June (refer to Table I-7 and Fig. I-7).

2.2 RUN-OFF, SEDIMENT AND FLOOD

2.2.1 Run-off

There are 4 water stage gauging stations in the project area; namely, Ulu Kuamut, Tangkulap, Balat and Barik Manis. Ulu Kuamut and Tangkulap stations were established in 1969, Balat in 1978 and Barik Manis in 1979. Water stage observation has been conducted at each station since establishment. The water stage data are shown in Fig. I-8 and Table I-8. These stations are being operated and maintained by the Drainage and Irrigation Department (DID) of Sabah. Discharge measurement has also been conducted at each of these stations, and the data except those obtained at Barik Manis which comes under tidal influences, have already been incorporated into the discharge rating curves prepared by the DID. As a result of their evaluation based on the data of discharge measurement, however, the discharge rating curve pertaining to Ulu Kuamut has been found less reliable because the stream velocity is beyond the extent permissible to measurement. Discharge rating curves for Tangkulap and Balat have also been evaluated and prepared based on the existing data of discharge measurement (refer to Fig. I-9).

Based on the water stage record and the discharge rating curve at Tangkulap, daily mean discharge is about 200 m^3/s during the ten years from 1970 to 1979. At Balat the discharge will be estimated at 350 m^3/s when the figure at Tangkulap is multiplied by the ratio of catchment area.

2.2.2 Sediment

The river water running down the Kinabatangan shows brownish, apparently containing much mud and fine sand, and its sediment load consists mostly of wash and suspended loads. The yearly amount of sediment load at Tangkulap, as estimated from the sediment load observation data by DID, would be approximately 8.6×10^5 m^3/year, and the specific sediment load, 140 $m^3/km^2/year$, as shown in Table I-9 and Fig. I-10. The dam project in the Padas River of the West Coast, however, has adopted the specific sediment load of greater than 200 $m^3/km^2/year$.

2.2.3 Flood

According to the reconnaissance survey, recent big floods occurred in 1963, 1968, 1971 and 1981. During these floods, flood inundation continued for about one month and caused heavy damage respectively. From existing water stage record, annual maximum floods during ten years from 1970 to 1981, the record obtainable period, have been picked up and the peak discharges were estimated from water stage records and the discharge rating curve at Tangkulap, as shown in Table I-10. It will be known from this Table that the maximum flood during these twelve years occurred in February 1971, and the maximum daily mean discharge reached to 3,020 m^3/s at Tangkulap, and 5,250 m^3/s at Balat when multiplied by the ratio of catchment area.

2.3 TIDAL STAGE

Tidal stage of the Sulu Sea is being recorded at the Sandakan Port gauging station. The mean sea level recorded at this station is as shown in Fig. I-11.

The datum level of topographic maps of Sabah is based on the mean sea level at Labuan Station and, as will be known from Fig. I-11, the mean tidal stage at Sandakan is 40 cm lower than that at Labuan.

3. FLOOD CONTROL

3.1 STANDARD PROJECT FLOOD

3.1.1 Methodology

The standard project flood is usually estimated on the basis of rainfall data, the observed discharge and specific discharge, etc.

The estimation founded on the rainfall data will be taken when the rainfall observation condition is satisfactory in respect of duration of records and number of the stations in the basin. The observed discharge and the specific discharge be used when the available rainfall data are insufficient to warrant a fair estimation of the standard project flood.

In the Kinabatangan River Basin, there are only 10 rainfall gauging stations which are scattering along the river course, and the rainfall data available therefrom are all of daily basis. Rainfall in tropical zone is generally characterized by its concentration in a narrow area during a short duration of time. Taking the abovementioned into consideration, the rainfall data so far obtainable in the river basin fail to provide enough basis for estimation of the standard project flood.

Accordingly, the observed discharge and specific discharge will be applied to the estimation of the standard project flood.

Observed flood discharge data is available at Tangkulap in the basin. The standard project flood at Balat damsite which is one of the essentials to determine the scale of proposed reservoir can be estimated upon the flood discharge observed at Tangkulap.

The standard project flood at other sites in the basin, i.e. Barik Manis and the estuary, has been estimated on the basis of specific discharge in due consideration of the runoff characteristics in the basin.

3.1.2 Standard Project Flood Estimate

The scale of the standard project flood has been fixed at 20-year return period as mentioned in "Flood Control" Sector.

The proposed standard flood discharge at Balat damsite, Barik Manis and the estuary is 5,400, 6,000 and 6,000 m^3/s, respectively. The distribution of standard project flood and their hydrographs are shown in Figs. I-12 and I-13. Furthermore, hydrograph in the drainage area between Balat and Barik Manis are also shown in Fig. I-14.

The proposed discharges are based on the findings obtained through the process as elabolated below.

Balat Damsite

The standard project flood discharge has been estimated by multiplying 1.74, i.e. the ratio of the catchment areas of Tangkulap and Balat. The probable discharge at Tangkulap was calculated by Hazen method, based on the annual maximum daily discharge in the last eleven years from 1970 to 1980. The distribution of estimated probable discharge is shown in Fig. I-15.

The above ratio is verified to be adoptable for the estimation of the Balat discharge on the ground of the following studies.

- Tangkulap is located in Milian River basin. The catchment area of Milian River basin consists of a large part of the catchment area of upperbasin from Balat damsite.

- Storm rainfall depth in upperbasin from Balat damsite will be expected to be an uniform depth in both Kuamut and Milian basins, when a bigger storm is occurred in the basin.

- The frequency of simultaneous occurrence of the peak discharge between Milian and Kuamut rivers is appreciably high, considering the frequency in occurrence of daily peak river stage recorded at both Ulu Kuamut and Tangkulap gauging stations.

The hydrograph of 1971's flood, which has been verified to be the maximum flood in this decade, was applied for the model hydrograph of standard project flood because this hydrograph shows the longest duration among all of flood hydrographs which has been obtained from the water stage records since 1971 and it is warranted be fully safety for determining the scale of proposed reservoir (refer to Fig. I-16 and I-17).

Barik Manis

Barik Manis is located at about 70 km downstream from Balat damsite. The topographic features of the basins above and below Balat damsite are quite contrasting: while the upstream basin is mountainous, the downstream is made of a flood plain. Therefore, if the standard project flood at Barik Manis should be determined simply by applying the area-wise ratio without paying due attention to such difference in the topographic features between the upstream and the downstream of Balat damsite, the value might happen to be excessively high far beyond the safety limit.

Due to a lack of data for determining the standard project flood discharge at Barik Manis, it was estimated from the specific discharge and catchment area of upstream from Barik Manis.

Fig. I-18 shows the relationship between the specific discharge and the catchment area in which the standard project flood at Barik Manis has been arrived at. Data plotted thereupon consist of the 20-year probable discharges of 10 rivers in Sabah which have been quoted from the report; "National Water Resources Study, Malaysia" which presents run-off characteristics similar to those observed in the Kinabatangan River Basin.

Estuary

The gradient of the river course below Barik Manis is still milder than that thereabove and, for the length of about 190 km from Barik Manis to the estuary, the stream gradient is between 1:15,000 and 1:20,000.

Between Barik Manis and the estuary, a 3,840 km^2-wide basin is spreading and the peak discharge therefrom is anticipated at about 700 m^3/s if the specific discharge at Barik Manis will be applied for.

However, it is assumed that this-much peak discharge will be dissipated in the flood prone area so that the peak discharge at the estuary would not be much higher than that at Barik Manis. Therefore, the peak discharge at the estuary is assumed to be equal to that at Barik Manis.

3.2 DESIGN FLOOD ESTIMATE

Design flood estimation at respective sites in the basin has been made on the basis of the expected results obtainable from the optimum flood control measures and proper operations of the outflow facilities equipped with the dam (refer to "Flood Control" and "Dam" Sectors).

Firstly, 5,400 m^3/s inflow to Balat dam reservoir will be regulated to 900 m^3/s when flown out of it.

Successively, 600 m^3/s run-off from the basin spreading between the dam and Barik Manis will be added up to the dam-regulated 900 m^3/s to make the design flood discharge of 1,500 m^3/s at Barik Manis.

As no increase of discharge is anticipated between Barik Manis and the estuary, the design flood discharge at the estuary will remain at 1,500 m^3/s, the same value as that at Barik Manis.

Distribution of the design flood discharge among respective sites is shown in Fig. I-19 and their hydrographs, in Fig. I-20.

3.3 DESIGN FLOOD FOR DAM

3.3.1 Methodology

Since no definite criteria have so far been established in Malaysia for determining the design flood for dam, it has been customarily calculated in due consideration of the probable maximum flood (PMF) pertaining to the subject dam.

Due to the lack of sufficient data for estimation of PMF the following considerations which have been successfully adopted in the past for similar purposes with many dams have been conveniently used for estimation of the design flood for the proposed Balat dam.

The design flood for the dam shall be what has the biggest value among the following three cases:

1) Past maximum flood discharge
2) Flood discharge of 200-year probability (1.2 times bigger in case of an earth-fill dam)
3) Regional specific discharge (Creager's Curve)

3.3.2 Design Flood Estimate

The design flood discharge to be adopted for determining the capacity of a spillway of the proposed Balat dam has arrived at 15,500 m^3/s which is the biggest in value among the three cases referred to in the preceding paragraph. The adopted 15,500 m^3/s of the inflow to Balat dam reservoir will be equal to the outflow without regulation of the proposed reservoir because of the huge inflow hydrograph compared with the flood control capacity proposed in the reservoir.

Computation result of each one of them will be explained in the below:

<u>Past Maximum Flood Discharge</u>

The maximum flood discharge ever recorded in the past at Tangkulap is 3,103 m^3/s, which was obtained in February 1971. When this value at Tangkulap is multiplied by the corresponding ratio of catchment area (1.74), the past maximum flood discharge at Balat damsite would be 5,400 m^3/s.

<u>Flood Discharge of 200-year Probability x 1.2</u>

As peak discharge of the 200-year probability at Tangkulap is 4,900 m^3/s, that at Balat damsite would be 8,500 m^3/s, that is the sum obtainable through multiplication of Tangkulap value by the area ratio of 1.74.

Since Balat dam is an earth-fill type, 8,500 m^3/s will have to be multiplied by 1.2 and the answer given is 10,200 m^3/s.

Regional Specific Discharge (Creager's Curve)

"National Water Resources Study, Malaysia" presents the "Design Flood Envelop Curve" (see Fig. I-21) and when the relevant data will be plotted, as shown Fig. I-21, in the relationship between the catchment area of the dam (including those existing, under construction and proposed) in Malaysia and their design flood discharges, the design flood discharge for Balat dam obtainable through application on Creager's Curve (C=45) would be 15,500 m^3/s. The adopted value of C=45 is similar to the actual precipitation in the Kinabatangan River Basin.

3.4 FLOOD CONTROL EFFECT

The flood control effects on the inflow other than the 20-year return period such as the 5-, 10-, 30-, 50- and 100-year return period have been studied by using the flood control capacity of $4.665 \times 10^9 m^3$ provided with Balat reservoir.

The hydrographs of the respective return periods are shown in Fig. I-22. The reservoirs' control effects on the inflows resulting from the floods of the respective return periods are shown in the relations between the inflow and outflow discharges to and from the reservoir in Table I-11 and Fig. I-23.

As may be readily understood, inflow of floods in magnitude over the 20-year probability will lead to overtopping, giving damages in the beneficiary area.

4. WATER UTILIZATION

4.1 DESIGN FLOW REGIME

The river flow in 1970 which has a volume corresponding to the 5-year return period has been adopted as a design flow regime for water utilization, while the 1975 year flow which coincides with an average flow for the last 10 years, as a design flow regime for estimation of hydro power generation. The respective flow regimes are presented in Figs. I-24 and I-25.

The respective flow regimes are set up at Balat damsite, being founded on the proportion of the catchment area to the discharge at Tangkulap. The serial 3-stage tank model has been used to supplement the interruptions in the flow discharge data.

4.2 WATER UTILIZATION

Water utilization in the basin is meant for irrigation water use and vested right water.

Irrigation Water Requirement

Irrigation water use proposed in "Agriculture and Irrigation" Sector will be projected in the below:

Month	Jan	Feb	Mar	Apr	May	Jun
Flow discharge						
A	8.7	7.1	44.0	49.6	56.5	43.7
B	7.1	3.5	42.7	22.9	59.4	27.6

Month	Jul	Aug	Sep	Oct	Nov	Dec
Flow discharge						
A	33.3	21.8	41.0	5.0	31.2	12.7
B	32.3	45.7	41.8	25.5	34.0	15.8

Note: "A" stand for the former half-monthly discharge and "B" for the latter half-monthly discharge.

Vested Right Water

Vested right water in the basin includes the river water for navigation, existing irrigation and domestic use.

However, consumption of the river water for irrigation purpose and domestic use is extremely small, and the vested right water comprises almost entirely of the volume of the river water made available for navigation.

Necessary river discharge for navigation has been sought in its absolute quantity in terms of the maximum draft of the vessels servicing along the downstream and is identified at about 150 m^3/s.

Out-flow operation of the dam will be planned to flow down 150 m^3/s as long as the river flow exceeds 150 m^3/s, and otherwise it would be in line with the present flow regime.

The maximum drafts of various kinds of boat are estimated as follows:

River fishing boats	......	0.5 m
Passenger boats	....	0.9 m
Cargo boats	......	3.0 m
Tag boats	......	1.5 m

4.3 WATER REQUIREMENT

Water requirement for irrigation is estimeted at 120 x $10^6 m^3$, as is shown in Fig. I-26, which will be obtained by dam operation.

5. SEDIMENT STORAGE

The annual sediment load at Tangkulap, that is 140 m^3/km^2/year, may be adopted as an approximate specific sediment load of the reservoir.

On the other hand, sediment load adopted for the reservoirs in other river basins which resemble this basin, for instance, the dam project in the Padas River on the West Coast, is about 200 m^3/km^2/year.

200 m^3/km^2/year has been adopted in this study to keep an ample safety margin in design criteria.

Sediment storage in the reservoir will amount to 214 x 10^6 m^3 in case of 200 m^3/km^2/year of specific sediment load from the dam's upstream area extending over 10,730 km^2 during the period of 100 years.

T A B L E

Table I-1(1) EXISTING RAINFALL OBSERVATION STATIONS

Station No.	Station Name	Coordinate		Elevation (T.B.M. m)	Date of Establishment	Administration Office
		Lat.	Long.			
5269001	Tongod	5°16'05"	116°58'05"	50	Jun, 1978	J.P.T.
5372001	Tangkulap	5°18'15"	117°16'40"	80	Aug, 1969	J.P.T.
5274201	Kuamut	5°13'20"	117°29'10"	20	May, 1969	J.P.T.
5074001	Ulu Kuamut	5°04'55"	117°26'30"	40	Oct, 1969	J.P.T.
5478001	Lamag	5°28'40"	117°49'10"	10	Oct, 1968	J.P.T.
5478002	Bukit Garam	5°29'45"	117°50'05"	30	Jun, 1974	J.P.T.
5678001	Bode Estate	5°38'	117°51'	18	Jan, 1953	L.D.G.
5777001	Ulu Dusan	5°47'25"	117°45'45"	15	Jan, 1971	J.P.
5880201	Sandakan	5°53'50"	118°03'30"	12	Aug, 1967	P.K.M.
5979001	Sandac R. Estate	5°54'	117°59'	18	Jan, 1971	L.D.G.
5384001	Litang R. Estate	5°19'	118°29'	183	Jan, 1951	L.D.G.
5485001	Kretam/Binuang	5°29'	118°34'	75	Jan, 1963	L.D.G.
5487001	Tomanggong Estate	5°26'	118°37'	30	Feb, 1963	L.D.G.
	Beluran	5°53'	117°33'	7		L.D.G.
5083002	Lahad Datu Agr. St.	5°03'	118°18'	6	Aug, 1959	J.P.

Note: J.P.T. : JAPATAN PALIT DAN TALI AIR J.P. : JAPATAN PERTANIAN
P.K.M. : PERKHIDMATAN KAJICUACUA MALAYSIA L.D.G. : LADANG

Table I-(2) EXISTING RAINFALL OBSERVATION STATIONS

Station No.	Station Name	Coordinate		Elevation (T.B.M. m)	Date of Establishment	Administration Office
		Lat.	Long.			
4764001	Sapulut	4°42'10"	116°28'55"	280	May, 1978	J.P.T.
5163001	Sook	5°08'30"	116°18'20"	350	Jan, 1965	J.P.T.
5364001	Tulid	5°20'	116°26'	366	Jan, 1953	J.P.
5462001	Apin Apin	5°28'35"	116°16'00"	350	Jan, 1962	J.P.T.
5768001	Tampias	5°42'40"	116°51'35"	220	May, 1978	J.P.T.
5671201	Telupid	5°38'30"	117°07'30"	60	Jan, 1964	J.P.T.
	Bilit	5°29'	118°12'	7		L.D.G.
5980002	Friendly R.Estate	5°55'	118°01'	18	Jan, 1962	L.D.G.
	Pinagah					L.D.G.
4474001	Kalabakan	4°25'	117°29'	12	Jan, 1959	L.D.G.
4373001	Table Estate	4°22'	117°20'	12	Jan, 1961	L.D.G.
5980001	Friendly R.Estate	5°55'	118°00'	18	Jan, 1951	L.D.G.
5083001	Lahad Datu Air Field	5°02'	118°20'	6	Jan, 1959	J.P.

Note: J.P.T. : JAPATAN PALIT AND TALI AIR
P.K.M. : PERKHIDMATAN KAJICUACUA MALAYSIA
J.P. : JAPATAN PERTANIAN
L.D.G. : LADANG

Table I-2 MONTHLY MEAN RAINFALL

Unit: mm

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sandakan	414.6	334.7	154.3	130.3	129.5	192.4	190.0	224.4	205.7	201.8	384.2	469.5	3,031.4
Bode Estate	397.6	263.0	173.3	73.4	194.2	175.4	181.4	214.9	228.7	214.0	175.3	306.2	2,597.4
Tamanggong Estate	423.1	342.3	160.6	140.9	243.7	210.3	184.2	182.8	257.7	277.5	307.1	396.1	3,126.3
Bilit	(294.7)	(131.5)	(92.3)	(130.9)	(155.6)	(152.0)	(178.1)	(195.4)	(222.5)	(210.4)	(245.0)	(213.8)	(2,191.6)
Lamag/ B.Garam	439.0	293.0	131.0	291.3	201.0	229.0	281.8	242.8	271.3	293.3	152.0	308.3	3,133.8
Kuamut	319.5	303.5	195.9	201.9	221.4	231.0	222.4	225.6	228.8	252.9	306.6	311.2	3,020.7
Ulu Kuamut	(123.0)	(173.7)	(137.8)	(133.0)	(88.7)	(124.8)	(146.5)	(187.0)	(230.3)	(255.7)	(184.3)	(147.0)	(1,931.8)
Tangkulap	187.4	190.8	206.3	209.3	210.8	152.2	278.4	286.5	199.6	195.2	285.3	285.3	2,687.1
Pinagah	196.5	184.2	141.7	160.8	194.2	207.9	181.8	220.1	251.1	240.2	263.4	214.0	2,455.9
Sapulut	179.1	174.2	206.0	318.3	335.2	264.3	234.5	252.0	261.9	288.7	258.5	194.4	2,967.1

Note: Values with ( ) are less dependable because of short duration and interruption of observation record.

Table I-3 EXISTING CLIMATOLOGICAL OBSERVATION STATION

Station No.	Station Name	Coordinate		Item of Observation					Administration Office
		Lat.	Long.	Temperature	Humidity	Sun Shine	Wind	Evaporation	
5274201	Kuamut	5°13'20"	111°29'10"	o	o			o	J.P.T.
5880201	Sandakan	5°53'50"	118°03'30"	o	o	o	o	o	P.K.M.
5671201	Telupid	5°38'30"	117°07'30"	o	o			o	J.P.T.
5777201	Ulu Dusan	5°47'25"	117°45'45"	o	o	o		o	P.K.M.

Note: J.P.T. : JAPATAN PALIT AND TALI AIR
P.K.M. : PERKHIDMATAN KAJICUACUA MALAYSIA

Table I-4 MONTHLY MEAN TEMPERATURE

Unit: °C

Station Name	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kuamut	Max	32.2	32.3	32.6	33.4	34.3	33.7	33.5	33.9	33.4	33.8	33.1	32.8
	Mean	24.4	24.5	24.8	25.5	25.6	25.3	24.8	25.1	24.6	25.4	25.4	25.2
	Min	21.5	21.7	22.2	22.5	22.2	22.3	22.0	21.8	22.4	22.2	22.2	22.1
Sandakan	Max	29.3	29.0	30.0	31.2	32.2	31.7	31.8	32.0	32.0	31.4	30.7	29.8
	Mean	26.0	26.0	26.7	27.3	27.3	26.9	26.8	26.7	26.8	26.7	26.4	26.2
	Min	22.8	22.7	23.1	23.3	23.2	23.3	22.9	22.6	22.8	22.9	22.9	23.0
Telupid	Max	30.6	31.3	32.6	34.2	34.3	35.5	33.7	33.8	33.8	33.0	32.9	31.7
	Mean	25.4	25.4	26.5	27.4	27.4	26.9	26.7	27.0	27.2	26.9	26.7	26.1
	Min	21.1	23.4	21.6	22.1	22.1	21.4	21.2	20.9	21.4	21.3	21.5	21.3
Ulu Dusan	Max	29.0	30.1	30.8	32.2	32.4	32.3	32.1	32.5	32.1	32.1	31.4	30.8
	Mean	26.0	26.0	26.6	27.7	28.2	27.7	27.5	27.7	27.7	27.6	27.1	26.7
	Min	22.8	21.6	21.6	22.2	22.3	22.5	22.1	22.2	22.1	22.3	22.4	22.3

Table I-5 MONTHLY MEAN RELATIVE HUMIDITY

Unit: %

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kuamut	85.1	85.6	84.3	82.8	83.3	83.3	84.2	80.5	84.1	81.5	80.9	82.6
Sandakan	78.1	77.5	75.9	75.8	77.0	76.8	76.7	77.6	78.0	77.8	79.1	79.9
Telupid	79.1	77.9	74.9	72.9	73.9	74.8	76.7	73.7	73.3	75.9	75.9	77.1
Ulu Dusan	79.1	72.9	74.5	75.7	74.6	74.8	74.9	74.0	75.1	75.2	77.3	77.8

Table I-6 MONTHLY MEAN SUNSHINE RATIO

Unit: %

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sandakan	21.9	21.3	30.8	33.5	33.7	28.3	29.9	27.1	25.0	25.5	23.6	18.7
Ulu Dusan	21.6	19.6	27.8	31.6	33.6	27.7	29.1	30.1	26.0	27.7	25.5	19.9

Table I-7 MONTHLY MEAN EVAPORATION

Unit: mm

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kuamut	115.7	104.9	123.3	148.4	154.0	143.3	135.1	127.0	142.8	145.5	127.5	115.5
Sandakan	139.4	147.1	167.2	145.1	168.0	149.9	152.6	158.5	138.1	144.4	126.4	121.9
Telupid	105.8	108.7	146.2	171.2	155.0	135.2	135.9	135.1	138.1	128.3	116.3	112.5
Ulu Dusan	112.0	105.7	126.0	145.7	159.7	144.5	159.7	162.5	141.7	142.7	121.2	122.9

Table I-8 EXISTING WATER STAGE OBSERVATION STATIONS

Station No.	Station Name	Coordinate		Date of Establishment	Administration Office
		Lat.	Long.		
5074401	Ulu Kuamut	5°04'55"	117°26'30"	Jun, 1969	J.P.T.
5373401	Tangkulap	5°18'15"	117°19'05"	Dec. 1969	J.P.T.
5375401	Balat	5°18'35"	117°35'50"	May, 1978	J.P.T.
5478401	Barik Manis	5°29'35"	117°52'40"	Apr, 1979	J.P.T.

Note: J.P.T. : JAPATAN PALIT AND TALI AIR

Table I-9 SEDIMENT LOAD

Tangkulap

Year	Sediment
1970	5.97×10^5 m^3
1971	17.20 x "
1972	11.15 x "
1973	4.93 x "
1974	7.01 x "
1975	6.79 x "
1976	5.79 x "
1977	14.90 x "
1978	5.50 x "
1979	6.94 x "
MEAN	8.62×10^5 m^3

Specific sediment load per year : Qs

$Qs = 8.62 \times 10^5\ m^3 / 6165\ Km^2 = 140\ m^3/Km^2$ /Year

Table I-10 ANNUAL MAXIMUM FLOODS

Tangkulap

Date	H (m)	H' (m)	Q (m^3/s)	H max(m)	H' max (m)	Q max(m^3/s)
1970. 1.23			(739.3)			(751.1)
1971. 2.10	31.07	18.75	3020.2	31.23	18.91	3068.6
1972. 9.23	23.08	10.76	1094.2	23.28	10.96	1130.7
1973. 9.28	23.51	11.19	1173.4	23.58	11.26	1186.6
1974. 5.24	23.27	10.95	1128.8	23.40	11.08	1152.9
1975. 2.26	22.93	10.61	1067.2	23.16	10.84	1108.7
1976. 1.27	23.74	11.42	1217.0	23.78	11.46	1224.6
1977. 2.10	24.32	12.00	1330.3	24.48	12.16	1362.5
1978.12.11			(628.4)			(638.5)
1979.11.10		10.35	1021.1			1037.4
1980. 1. 6	23.43	11.11	1201.8			1221
1981. 1.18	29.61	17.29	2595.0			2637

Note: H : Daily Mean Water Stage.
H': Daily Mean Water Stage from Gauge Zero (Gauge Zero Height: 12.32 m).
Q : Daily Mean Discharge. H max, H' max : Instantaneous Water Stage.
Q max : Instantaneous Discharge.

Values of ( ) are obtained from Tank Model method Calculation result.

2637 m^3/s of 1981.1.18 flood was the maximum recorded during the period from 1981.1.1 to 1981.9.30.

Table I-11 FLOOD DISCHARGE UNDER "WITH" AND "WITHOUT" THE DAM RESERVOIR

Unit: m^3/s

Return Period (1/Year)	1/5	1/10	1/20	1/30	1/50	1/100
Balat Dam						
Inflow Discharge	3,500	4,350	5,400	5,800	6,450	7,300
Outflow Discharge	600	700	900	2,600	3,700	4,900
Flood Control Effect	2,900	3,650	4,500	3,200	2,750	2,400
Barik Manis						
Without Dam	3,890	4,840	6,000	6,450	7,170	8,110
With Dam	990	1,190	1,500	3,250	4,420	5,710
Flood Control Effect	2,900	3,650	4,500	3,200	2,750	2,400

F I G U R E

Fig. I-1 LOCATION OF RAINFALL AND WATER STAGE OBSERVATION STATIONS

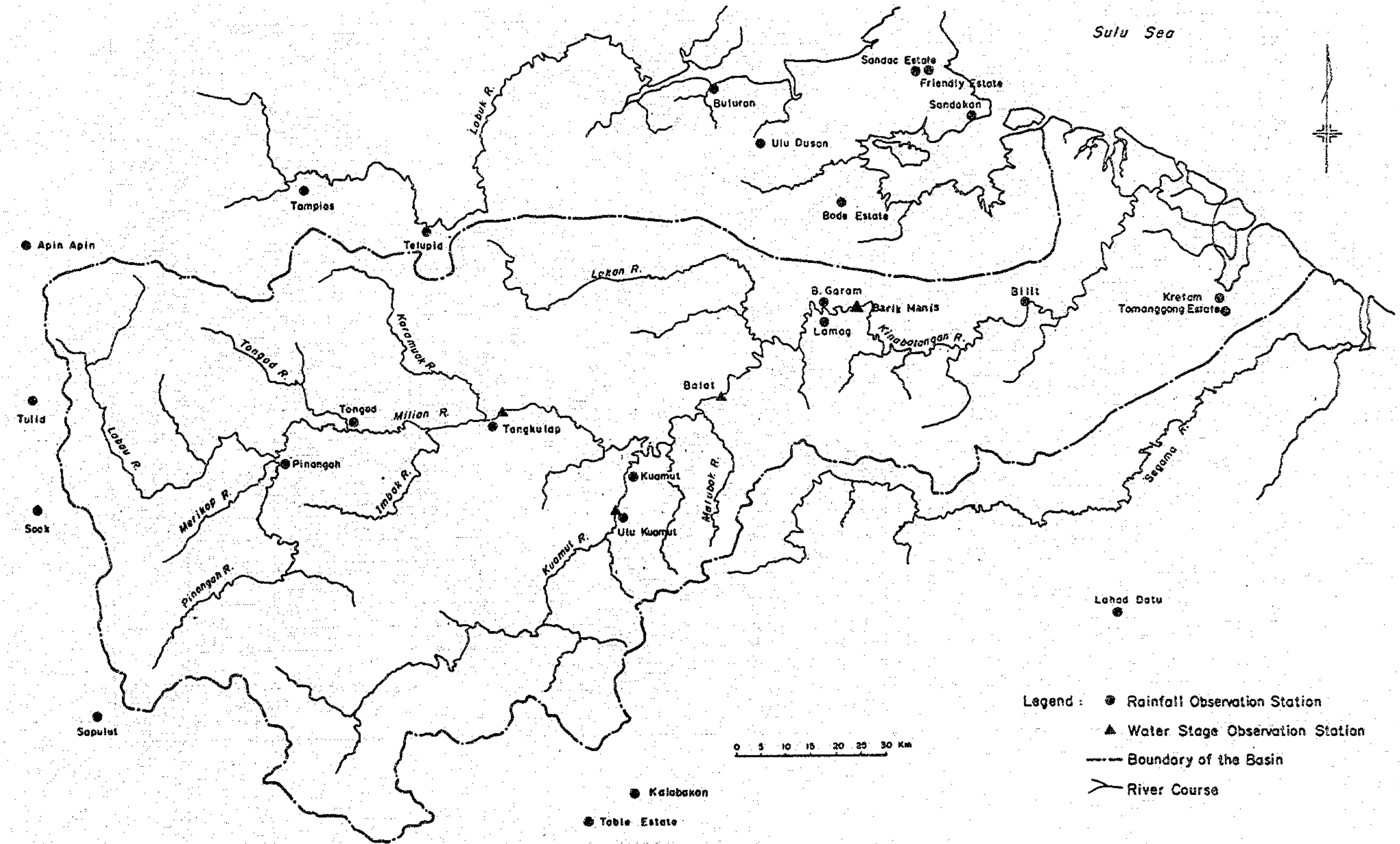


Fig. I-2 EXISTING RAINFALL DATA

Station No.	Station Name	Data Existing Condition																																	
		'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80
5269001	Tongod																																		Δ	Δ	Δ
5372001	Tangkulap																									Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
5274201	Kuamut																									o	o	o	o	o	o	o	o	o	o	o	o
5074001	Ulu Kuamut																									Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
5478001	Lamag																									o	o	o	o	o	o						
5478002	Bukit Garam																															Δ	Δ	Δ	Δ	Δ	Δ
5678001	Bode Estate									Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ													
5777001	Ulu Dusan																											o	o	o	o	o	o	o	o	o	o
5880201	Sandakan																							o	o	o	o	o	o	o	o	o	o	o	o	o	o
5979001	Sandac Estate																		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
5384001	Litang Estate							Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	o	o	o	o	o	o	o	o	o	o	o	o									
5485001	Kretam/Binuang																			o	o	o	o	o	o	o	o	Δ									
5487001	Tomanggong Estate																					o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
	Buluran																o	o	o	o	o	o	o	o	o	o	o										
5083002	Lahad Datu Agr.																									Δ	Δ	Δ	Δ	Δ	Δ	Δ					
4764001	Sapulut																				o	o	o	o	o	o	o	o	o	o	o	o				Δ	Δ
5163001	Sook																									Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
5364001	Tulid									Δ	Δ	Δ	Δ	Δ	Δ	Δ	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
5462001	Apin Apin																									o	o	o	o	o	o	o	*	*	*	*	Δ
5768001	Tampias																																		*	*	Δ
5671201	Telupid																			o	o	o	o	o	o	o	o	o	o	o							
	Bilit								Δ	Δ	Δ	Δ	Δ	Δ	Δ																						
5980002	Friendly Estate																									Δ	Δ	Δ	Δ	Δ	Δ	Δ					
	Pinangah									Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ																				
4474001	Kalabakan															Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ		Δ	Δ	Δ	Δ	Δ	Δ	Δ	*	*	*	*	*
4373001	Table Estate																	Δ	Δ	Δ	Δ	Δ	Δ	Δ		Δ	Δ	Δ	Δ	Δ	Δ	Δ	*	*	*	*	*
5980001	Friendly Estate																	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
5083001	Lahad Datu A.																o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o

Note: o : Daily Rainfall, Δ : Monthly Rainfall, * : Data not yet available

Fig. I- 3 MONTHLY MEAN RAINFALL

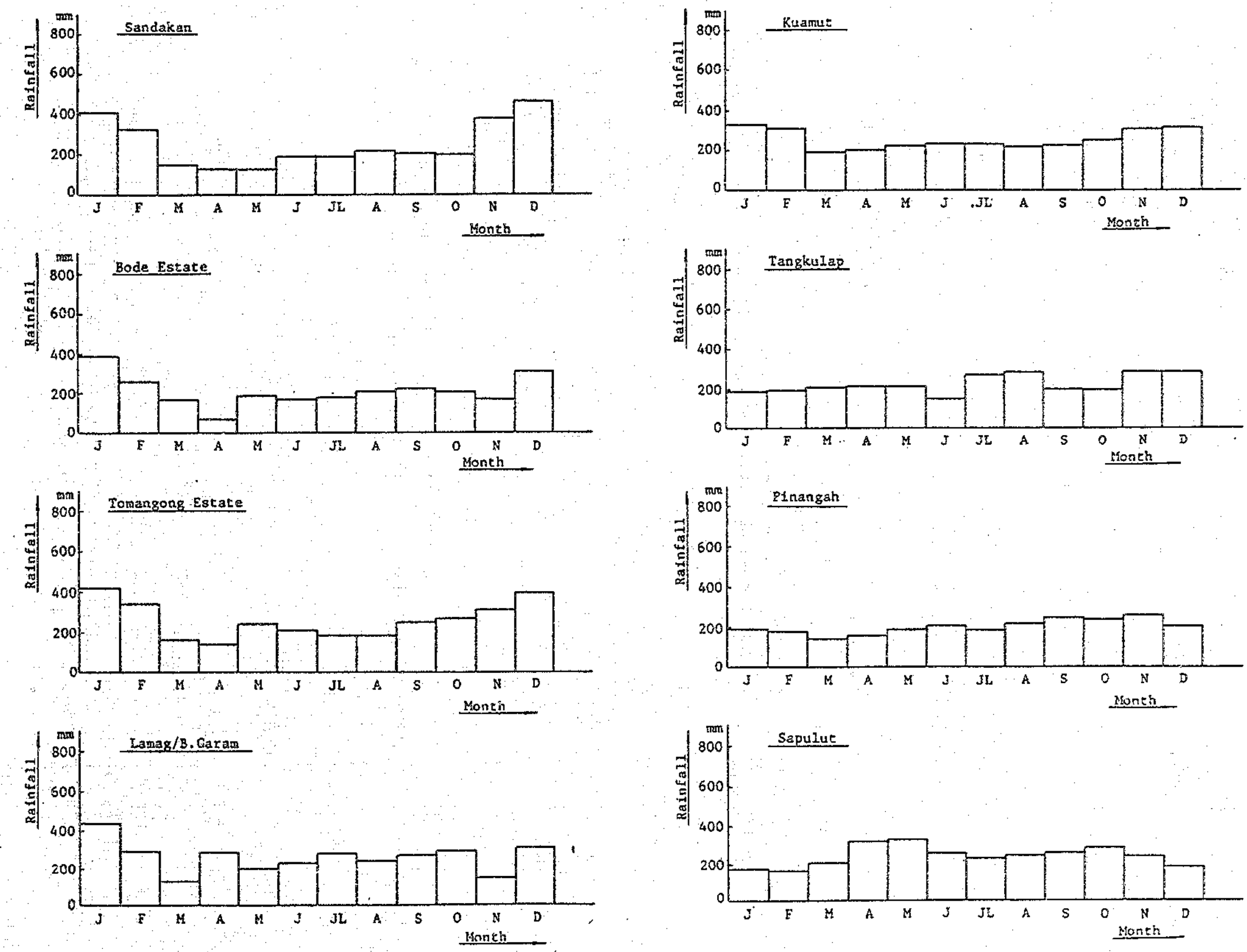


Fig. I-4 MONTHLY MEAN TEMPERATURE

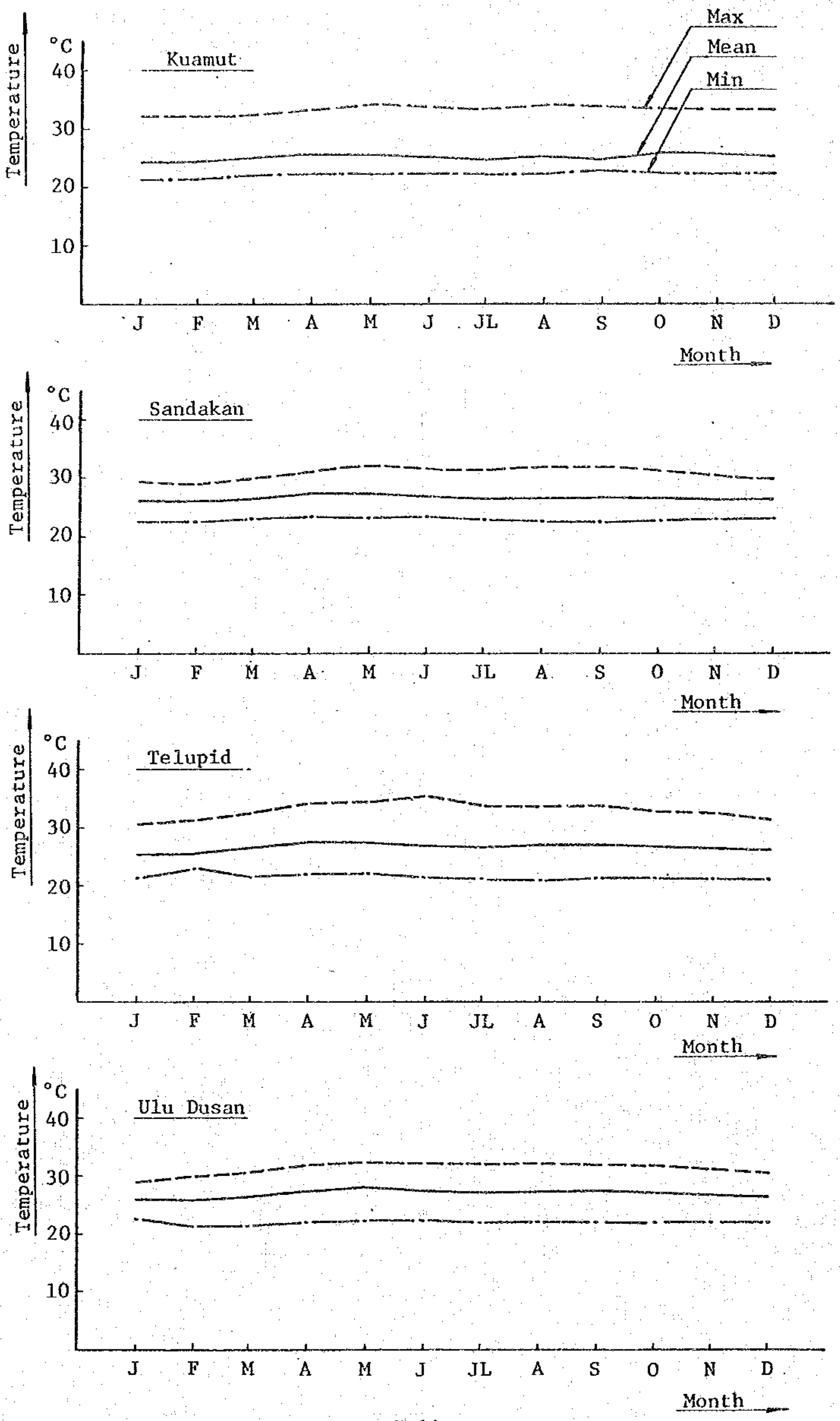


Fig. I-5 MONTHLY MEAN RELATIVE HUMIDITY

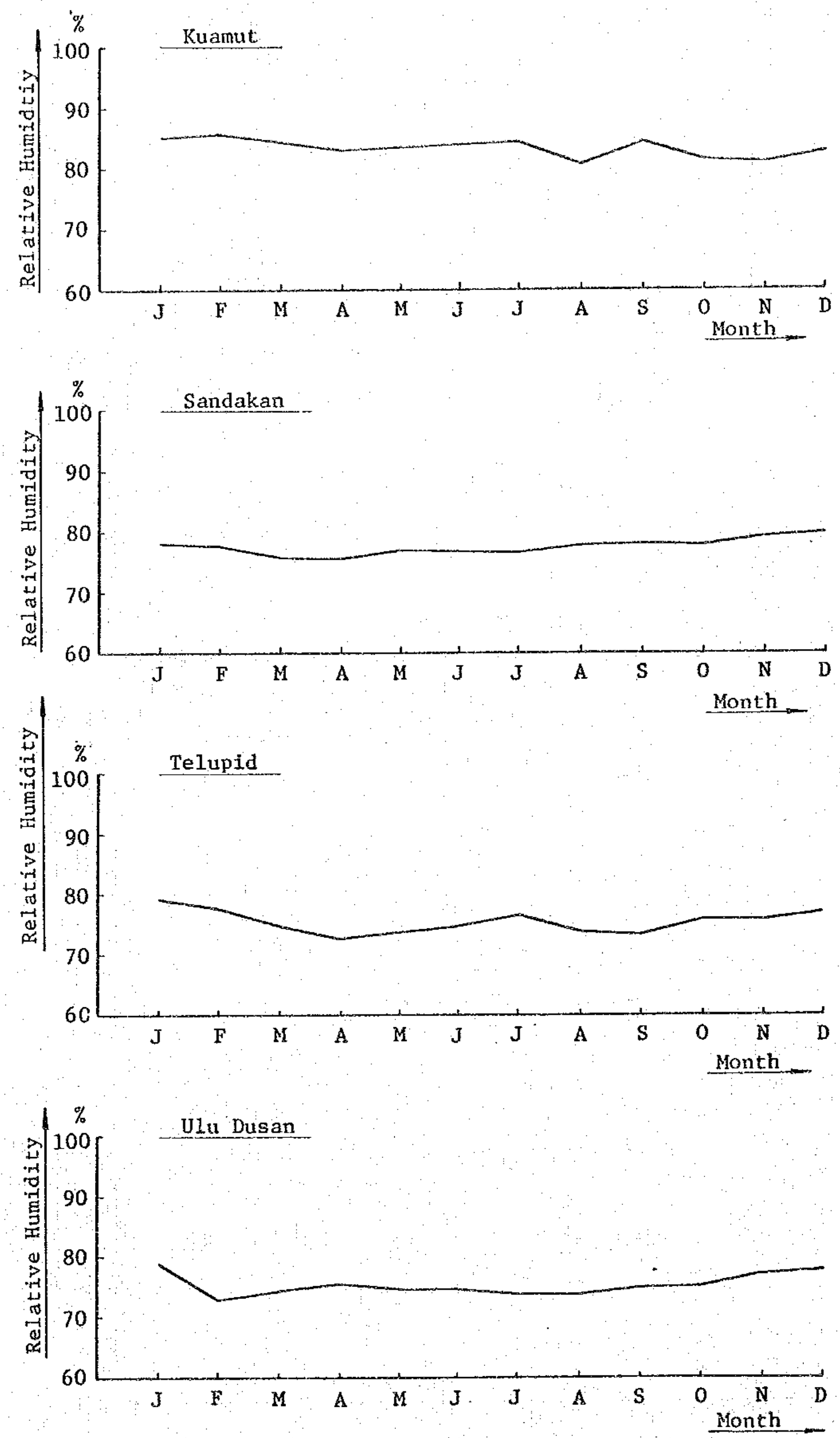
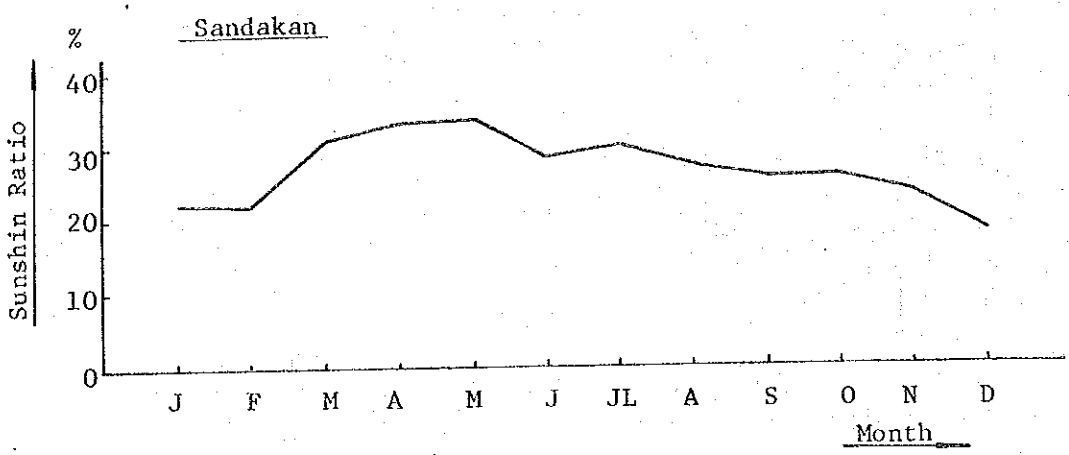


Fig. I-6 MONTHLY MEAN SUNSHINE RATIO



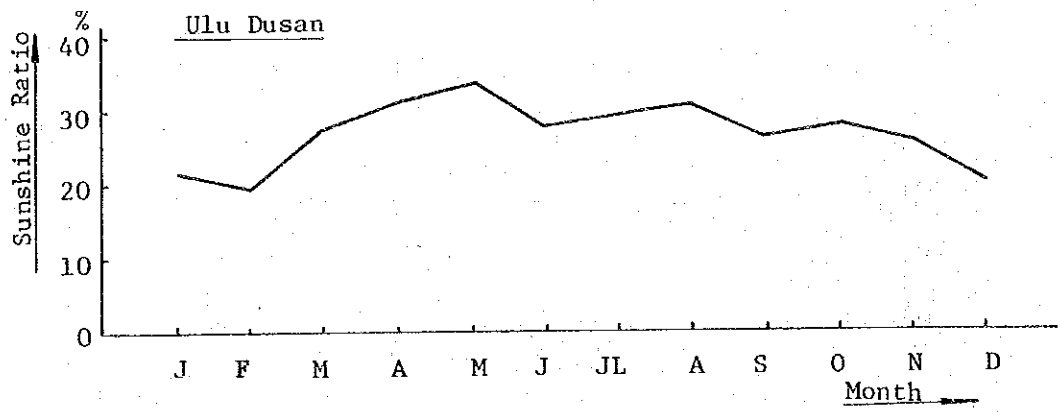
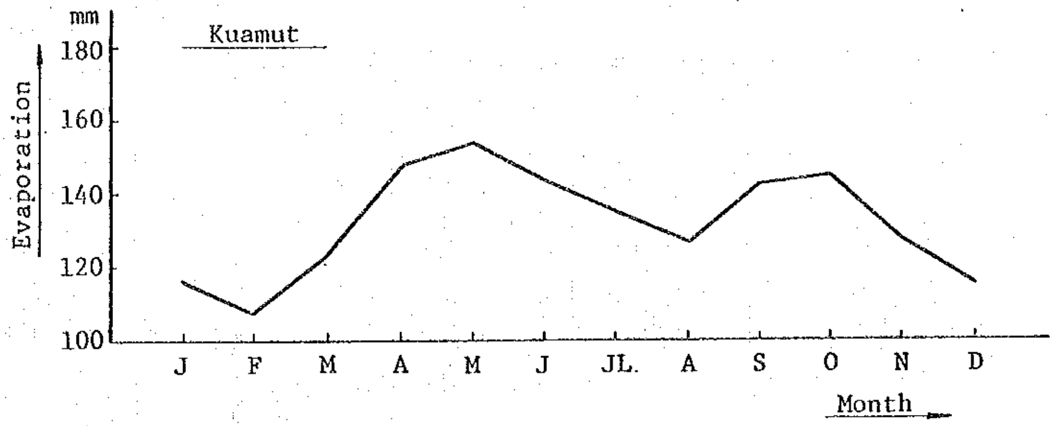
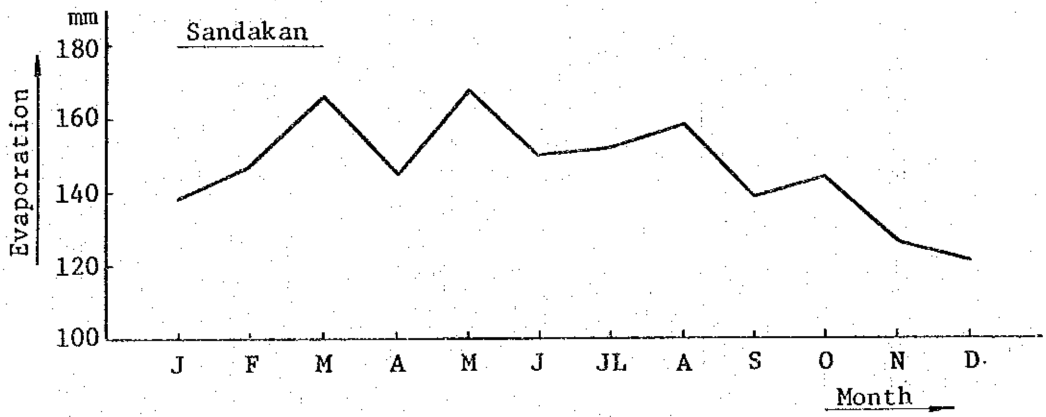
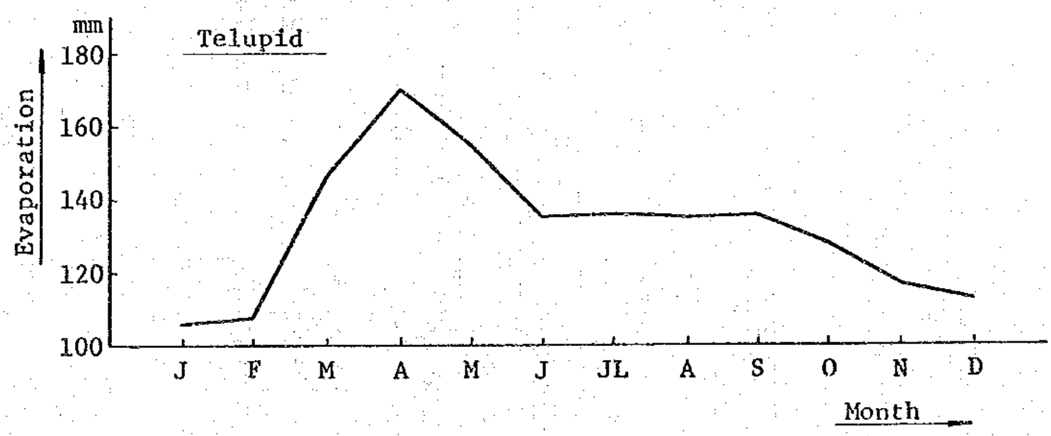


Fig. I-7 MONTHLY MEAN EVAPORATION







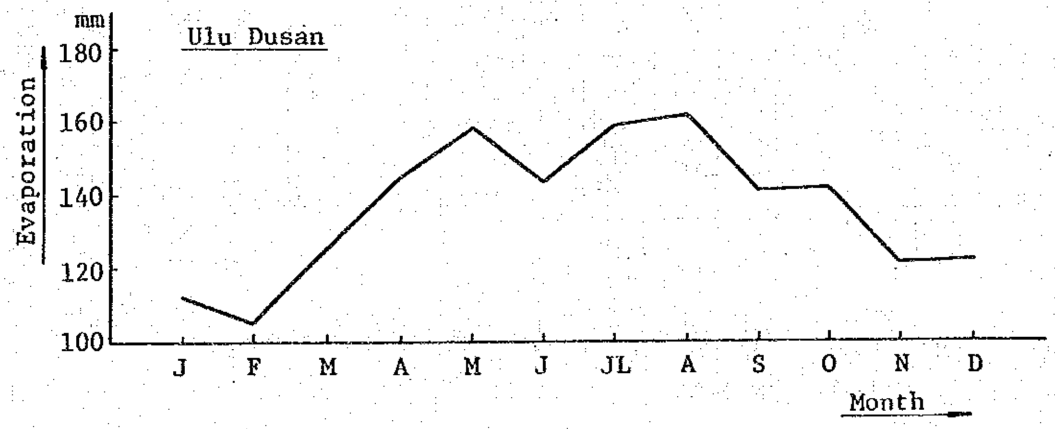
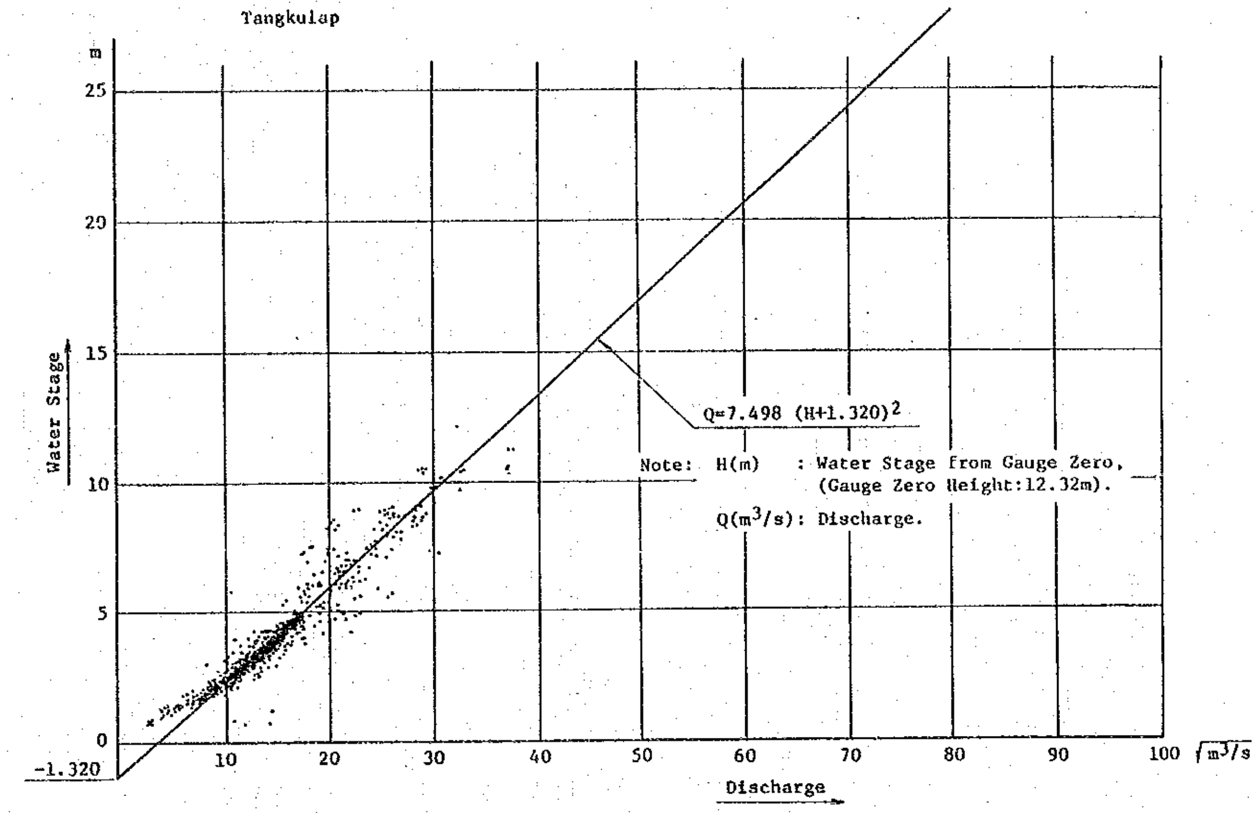


Fig. I-8 EXISTING WATER STAGE DATA

Station No.	Station Name	Data Existing Condition											
		1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
5074401	Ulu Kuamut	o	o	o	o	o	o	o	o	o	o	o	*
5373401	Tangkulap	o	o	o	o	o	o	o	o	o	o	o	*
5375401	Balat	/	/	/	/	/	/	/	/	/	*	*	*
5478401	Barik Manis	/	/	/	/	/	/	/	/	/	/	*	*

Note: o : Water Stage data is already read from record-chart and arranged for use.
* : Water Stage data is not read from record-chart and arranged for use yet.

Fig. I-9 DISCHARGE RATING CURVE



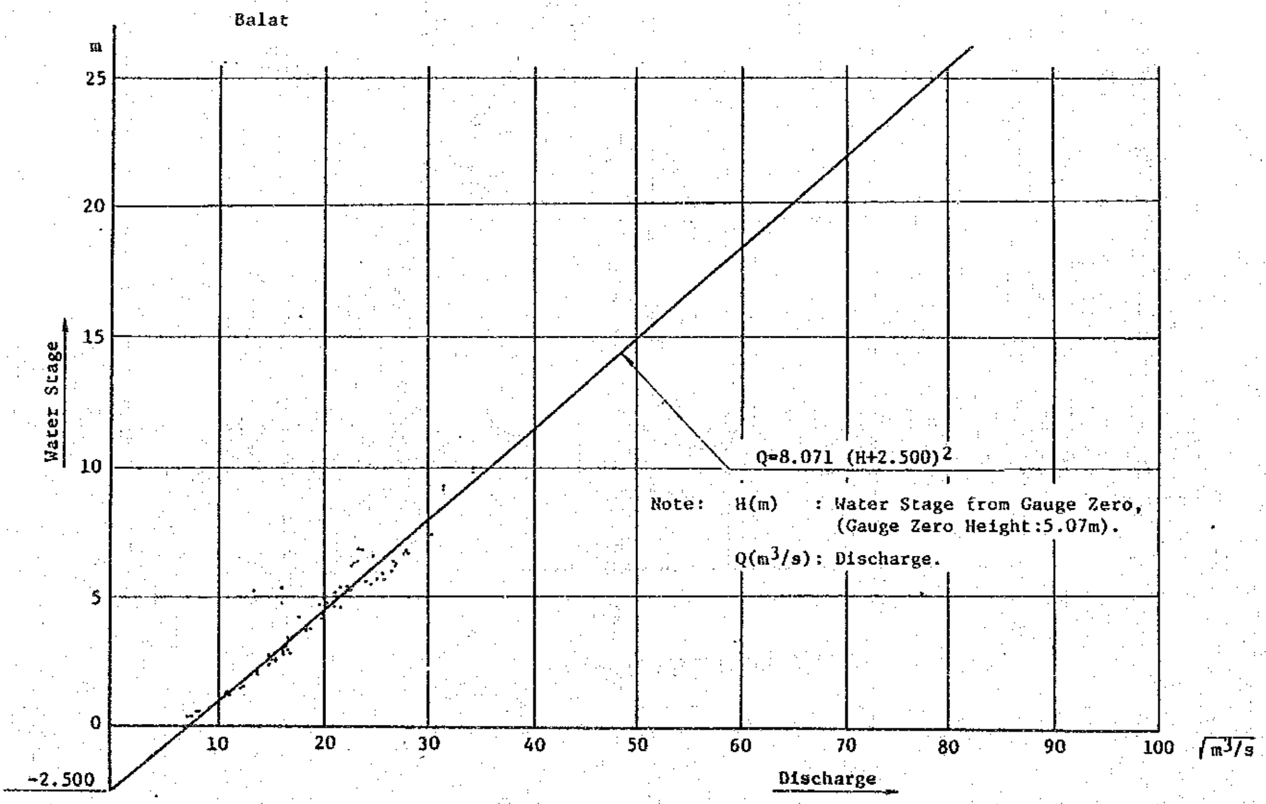


Fig. I-10 RELATION BETWEEN DISCHARGE AND SEDIMENT

Tangkulap

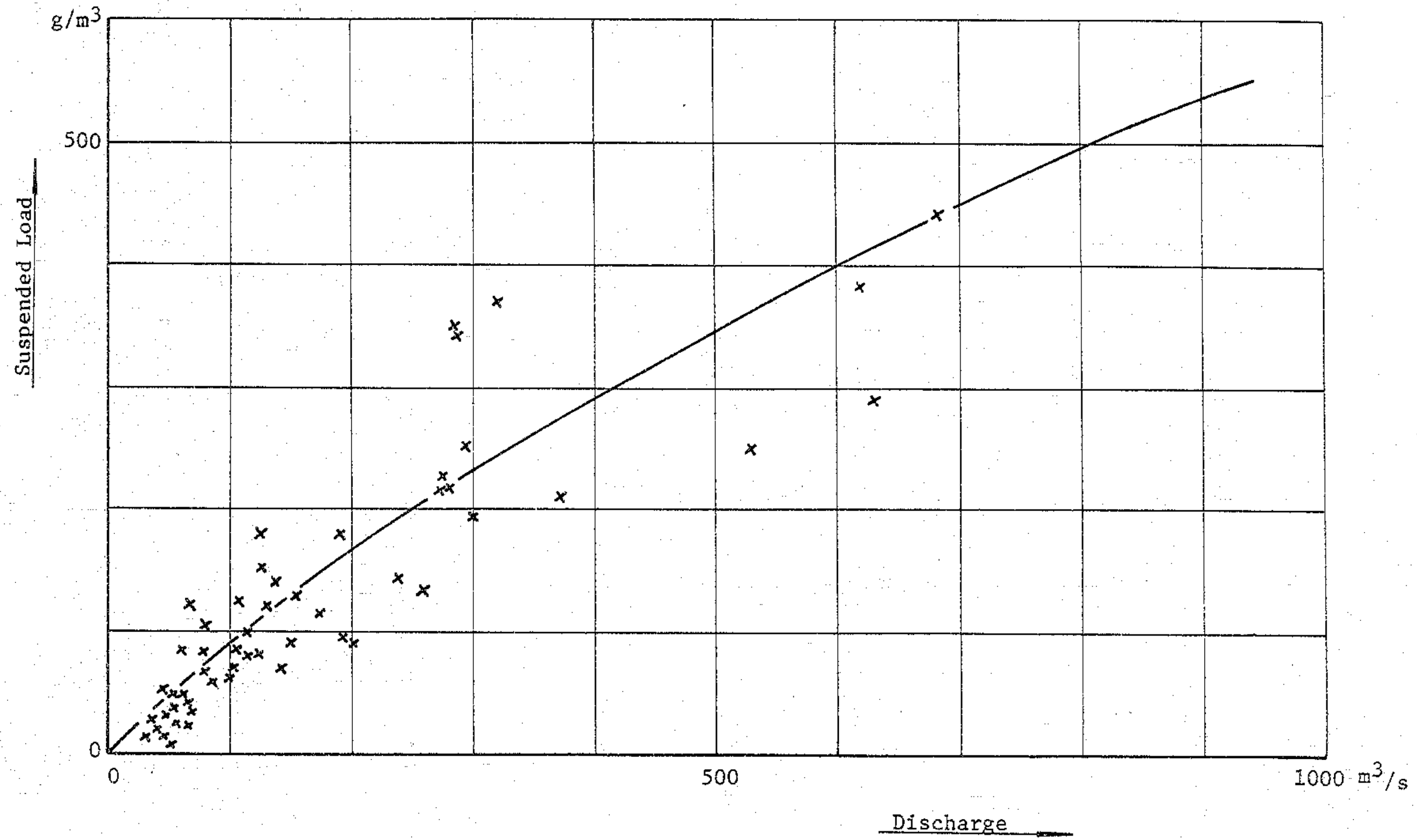
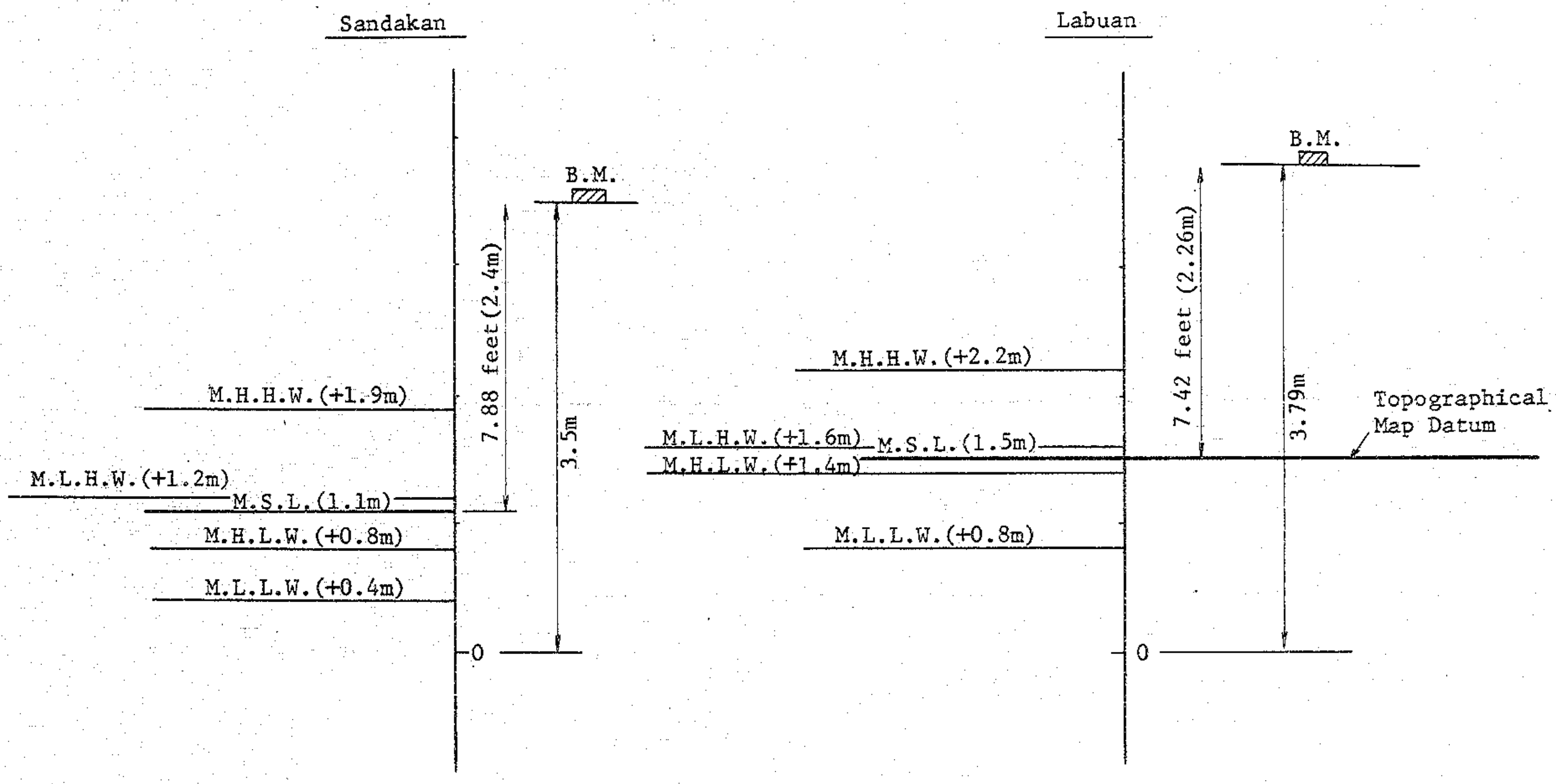
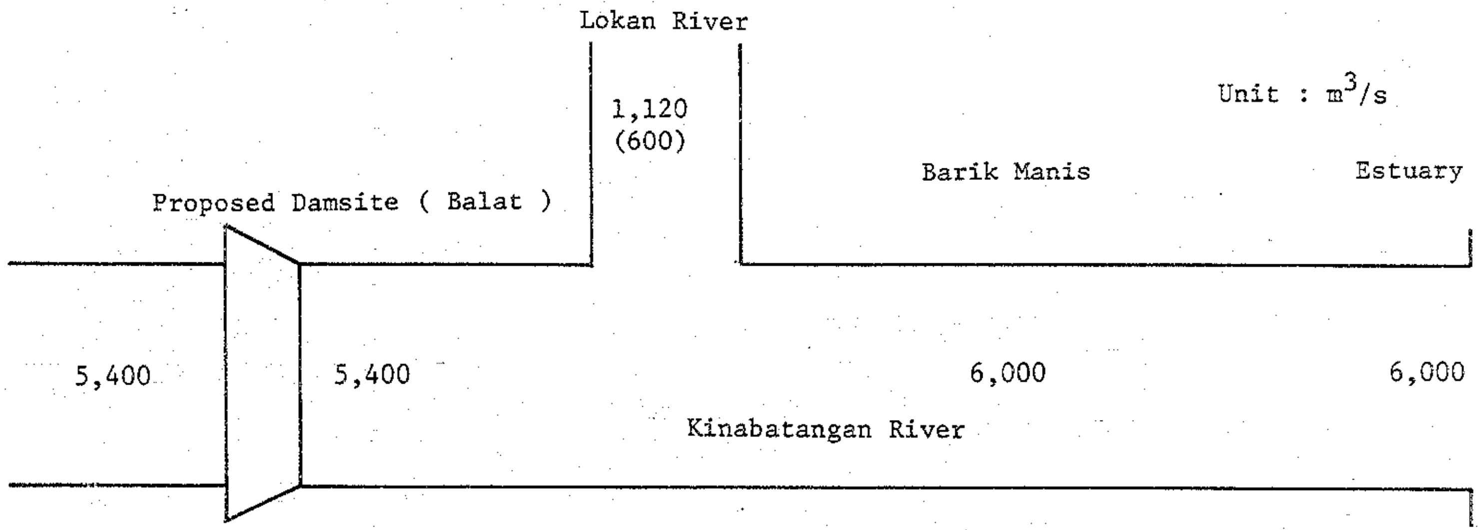


Fig. I-11 TIDE STAGE AT SANDAKAN AND LABUAN



Note : M.H.H.W. ; Mean Higher High Water, M.L.H.W. ; Mean Lower High Water,
M.S.L. ; Mean Sea Level, M.H.L.W. ; Mean Higher Low Water,
M.L.L.W. ; Mean Lower Low Water, B.M. ; Bench Mark

Fig. I-12 DISTRIBUTION OF STANDARD PROJECT FLOOD



Note : Figure in parenthesis represent discharge joining the main stream.

Fig. I-13 HYDROGRAPH OF STANDARD PROJECT FLOOD

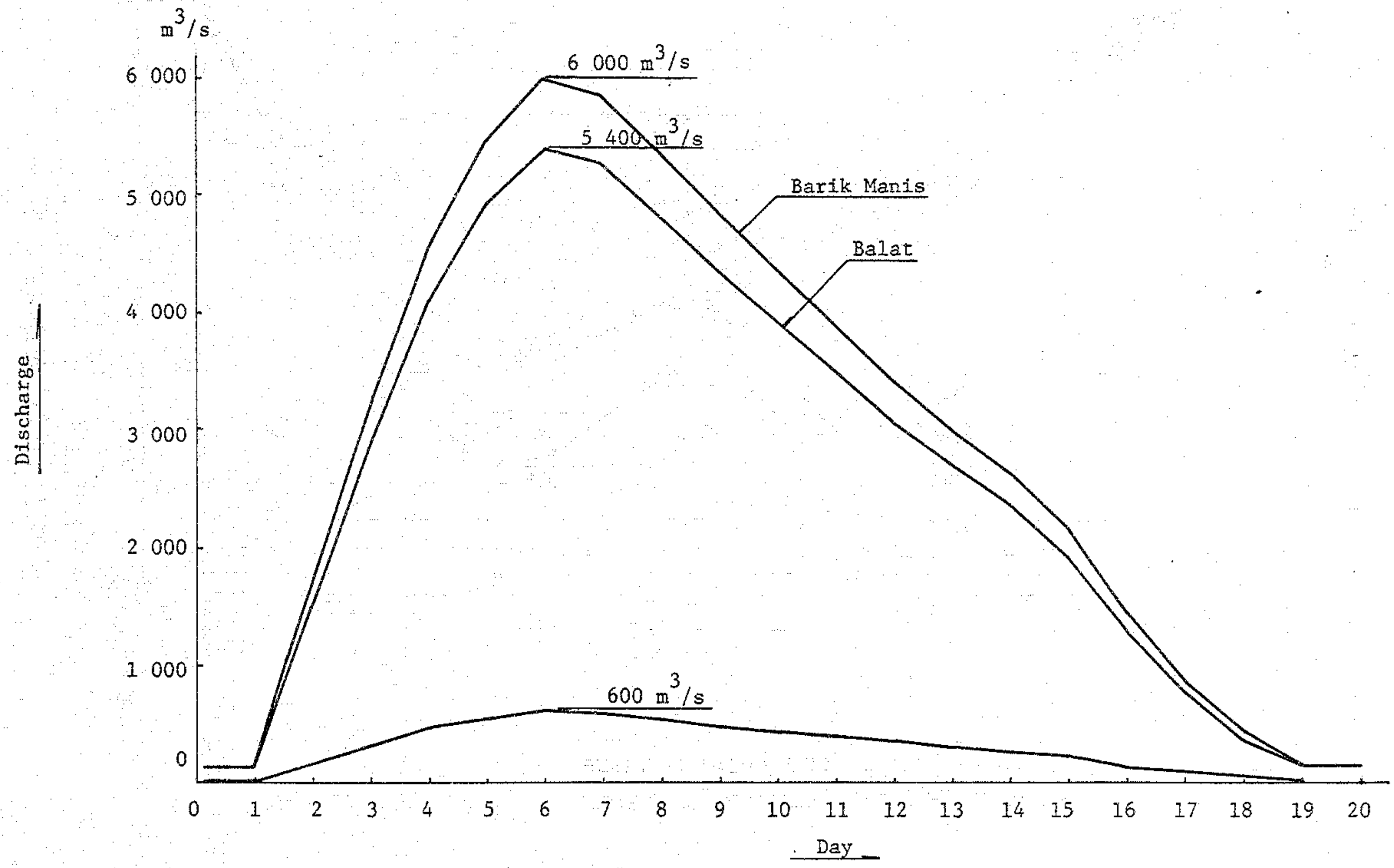


Fig. I-14 FLOOD HYDROGRAPH IN DRAINAGE AREA BETWEEN BALAT AND BARIK MANIS

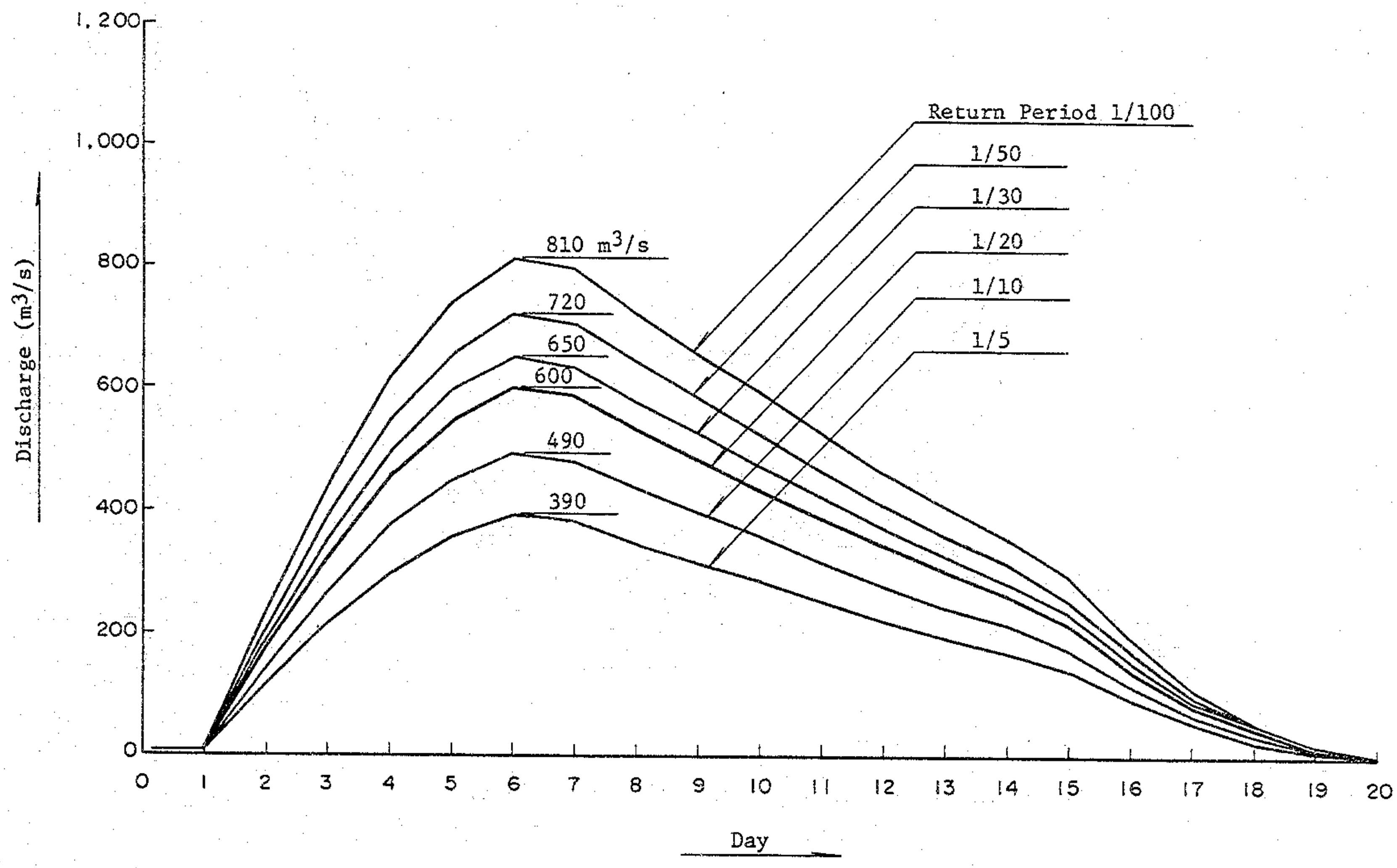


Fig. I-15 PROBABLE DISCHARGE at Tangkulap

(1970 - 1980)

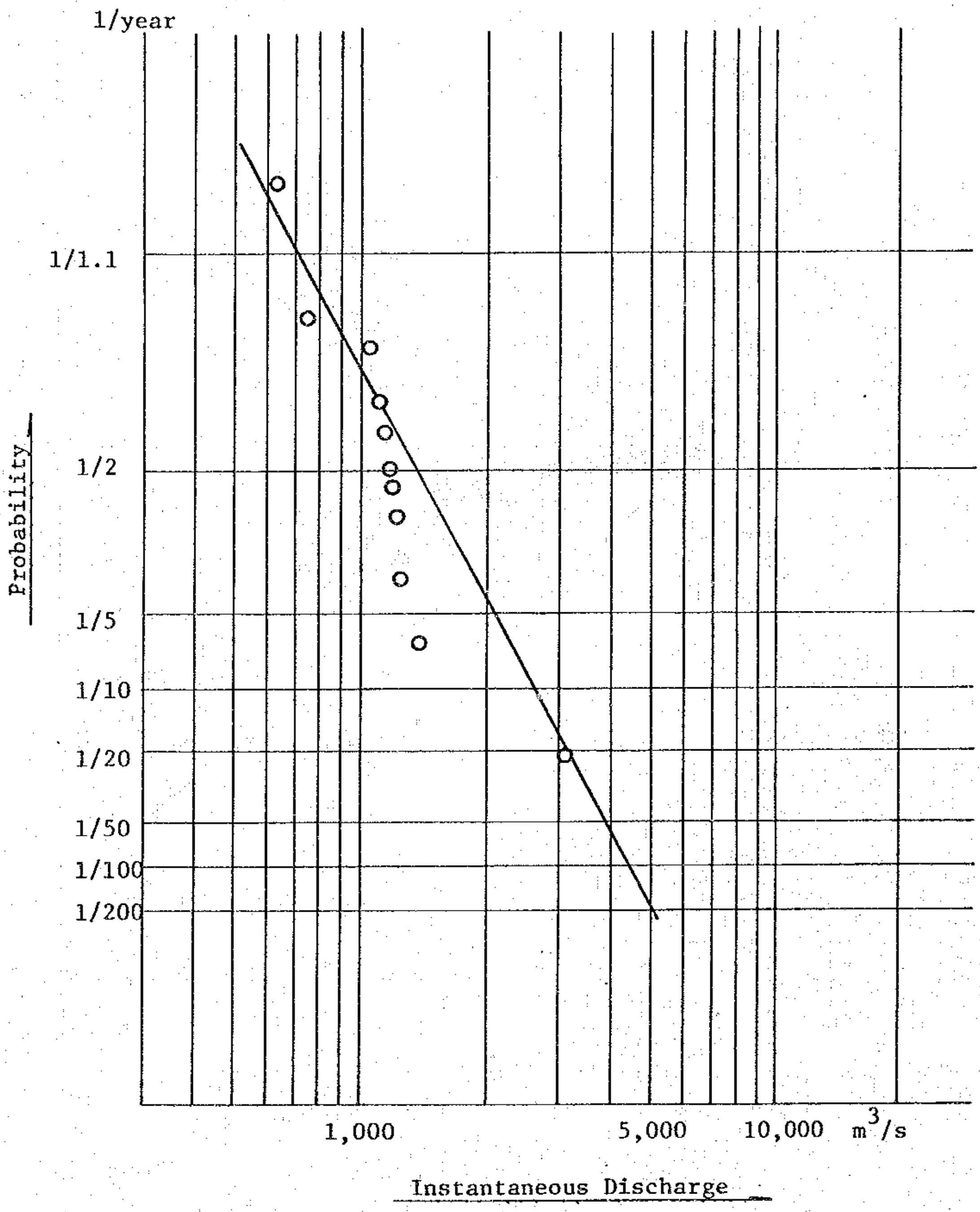


Fig. I-16 COMPARISON OF FLOOD HYDROGRAPHS (Peak Discharge ≧ 1000 m^3/s)

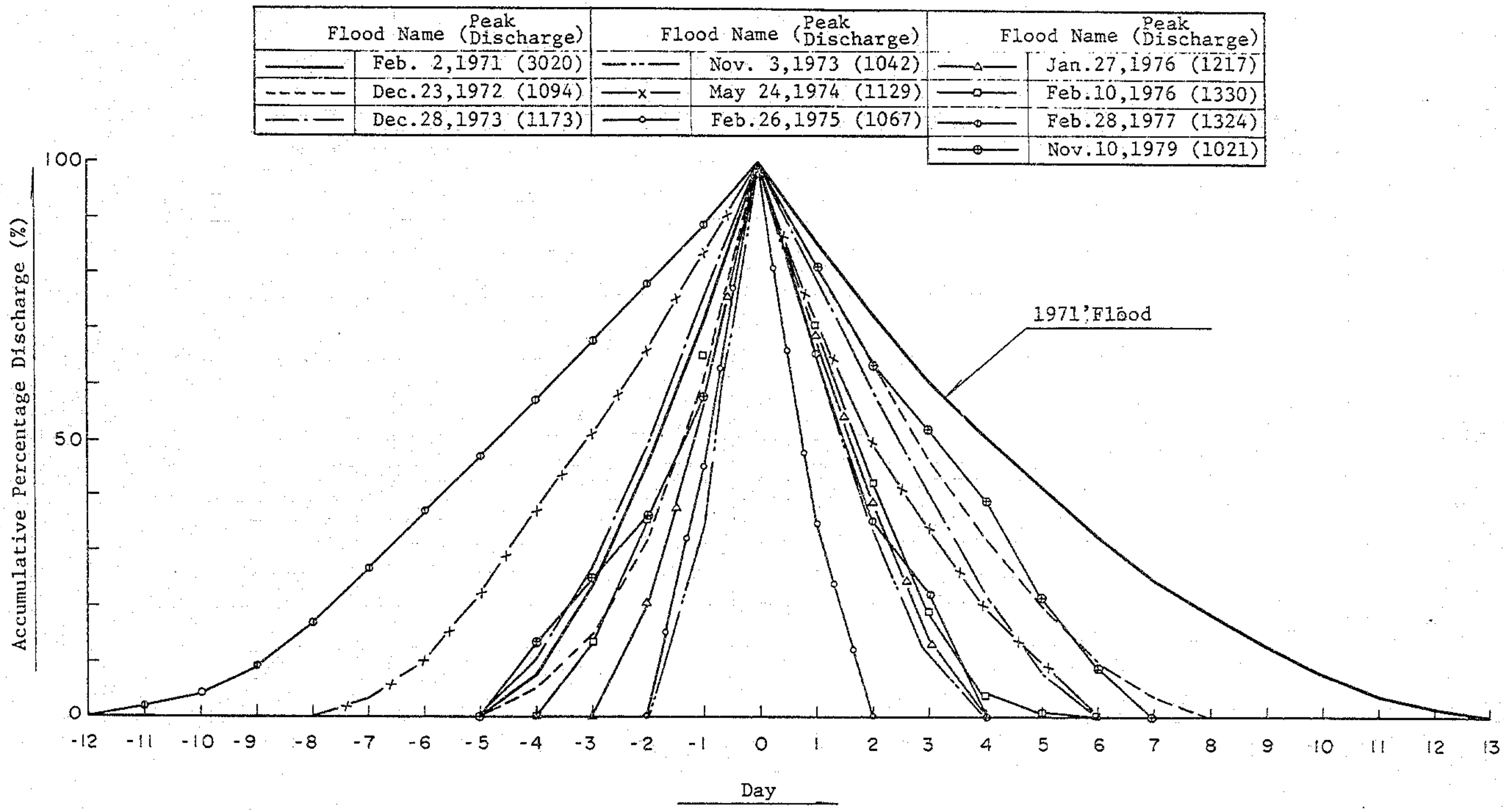


Fig. I-17 HYDROGRAPH DURING THE FLOOD IN FEB.1971

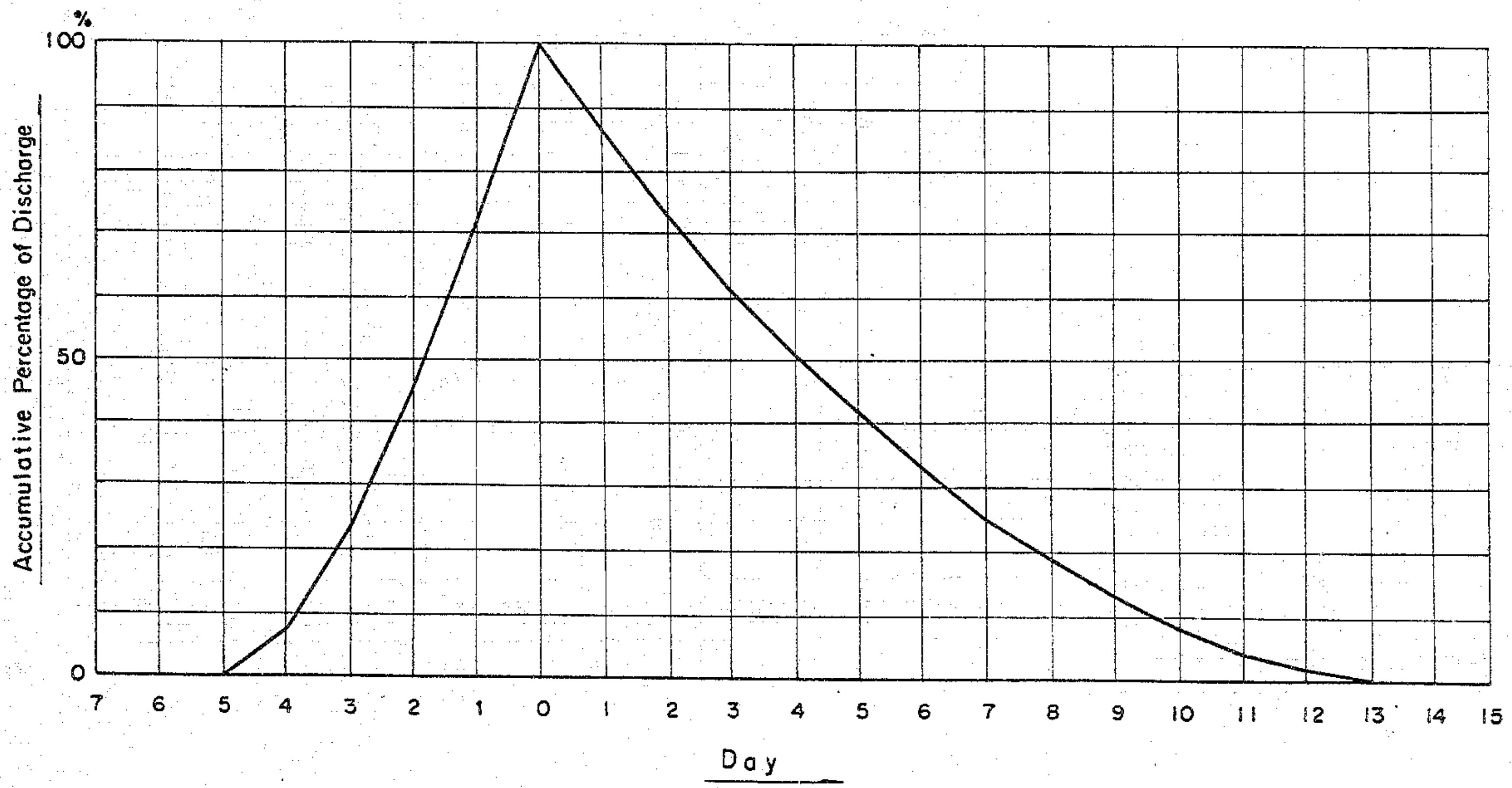
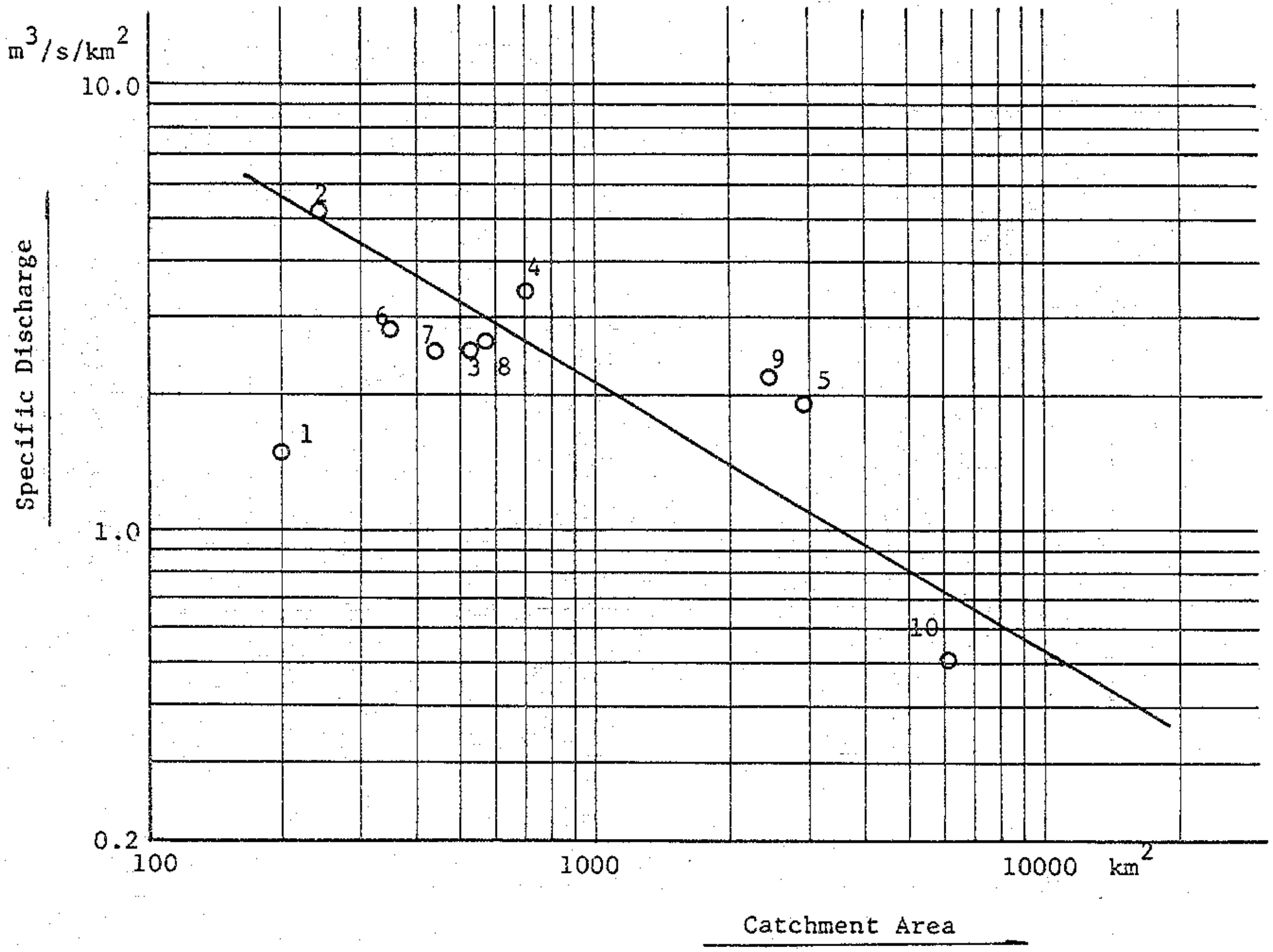
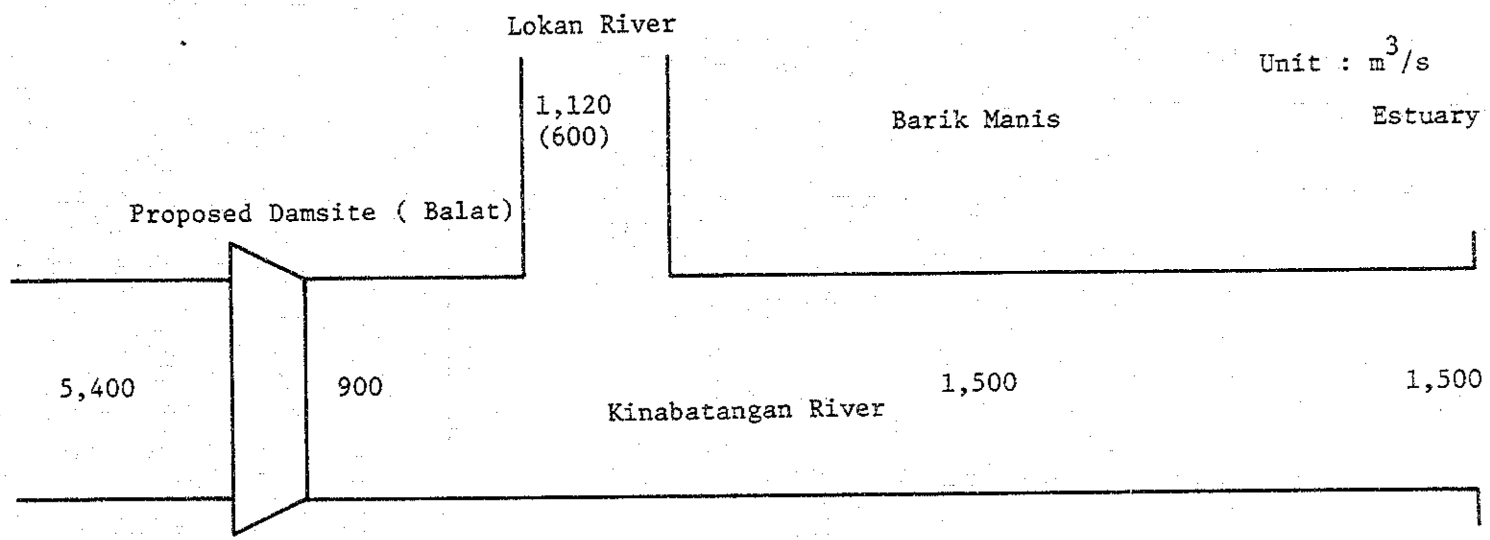


Fig. I-18 RELATION CURVE BETWEEN CATCHMENT AREA AND SPECIFIC DISCHARGE



	Name of Place	Name of River
1	Penanpang	S. Paper
2	Bridge No.2	S. Wariu
3	Kagopon	S. Paper
4	Basai	S. Tungud
5	Ulu Kuamut	S. Kuamut
6	Kaiduan	S. Paper
7	Bedukan	S. Liwagu
8	Kobon	S. Bengkoka
9	Tomboloi	S. Labuk
10	Tangkulap	S. Milian

Fig. I-19 DISTRIBUTION OF DESIGN FLOOD



Note : Figure in parenthesis represent discharge joining the main stream.

Fig. I-20 HYDROGRAPH OF DESIGN FLOOD

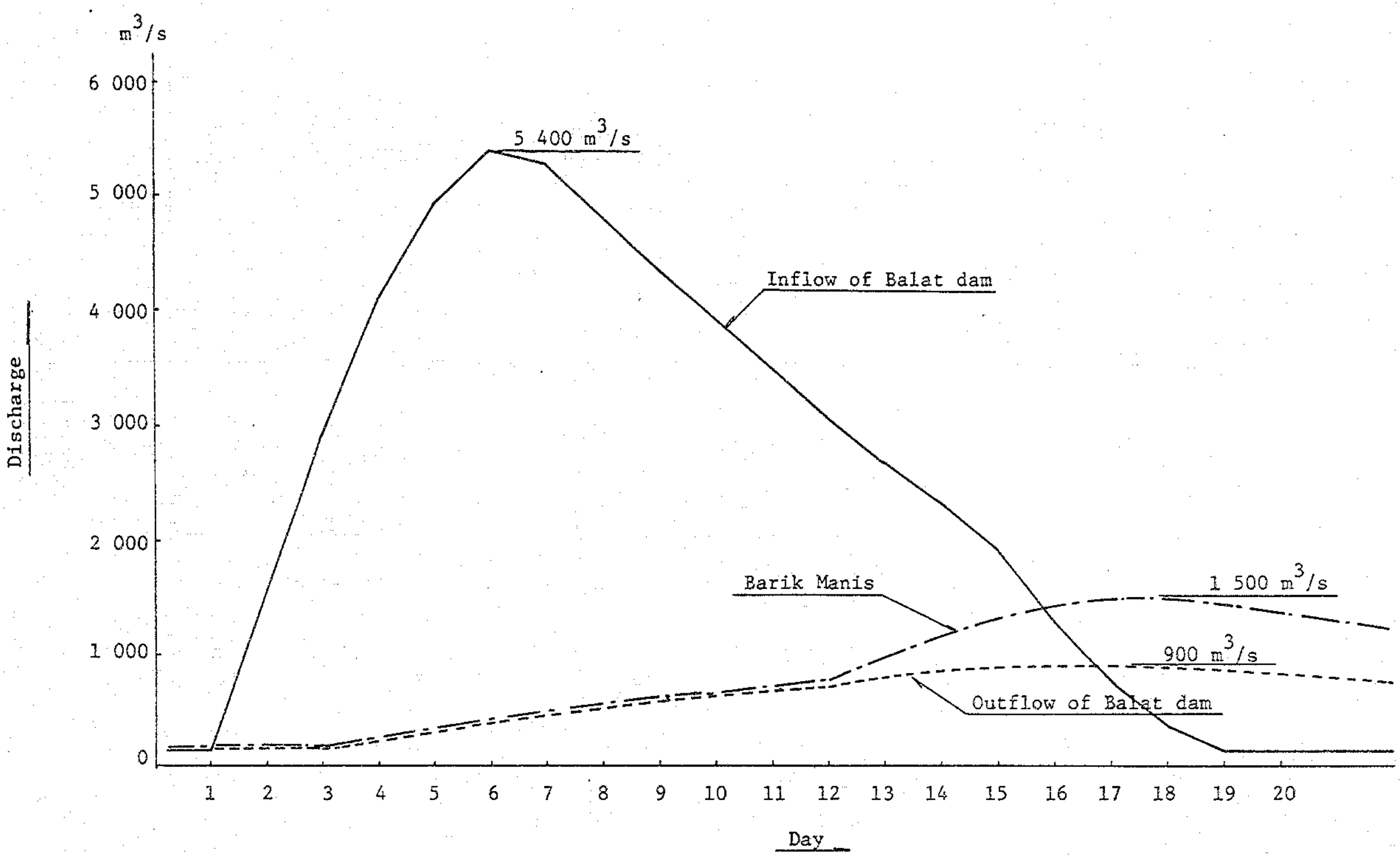
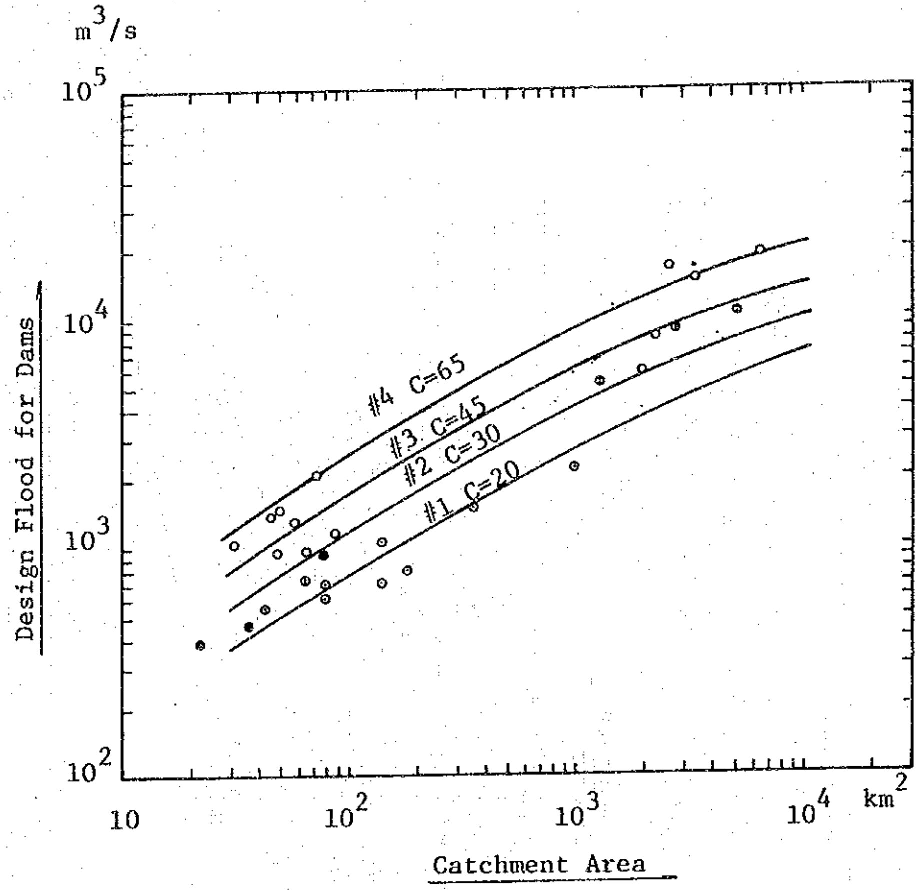


Fig. I-21 DESIGN FLOOD ENVELOP CURVE



LEGEND :

#1 ⊙ ; West Cast

#2 ● ; Johor & Pahang-West

#3 ⊕ ; Pahang-East

#4 ○ ; Kelantan, Trengganu, Perak-North

C ; Creager's value

Fig. I-22 INFLOW HYDROGRAPHS OF BALAT DAM

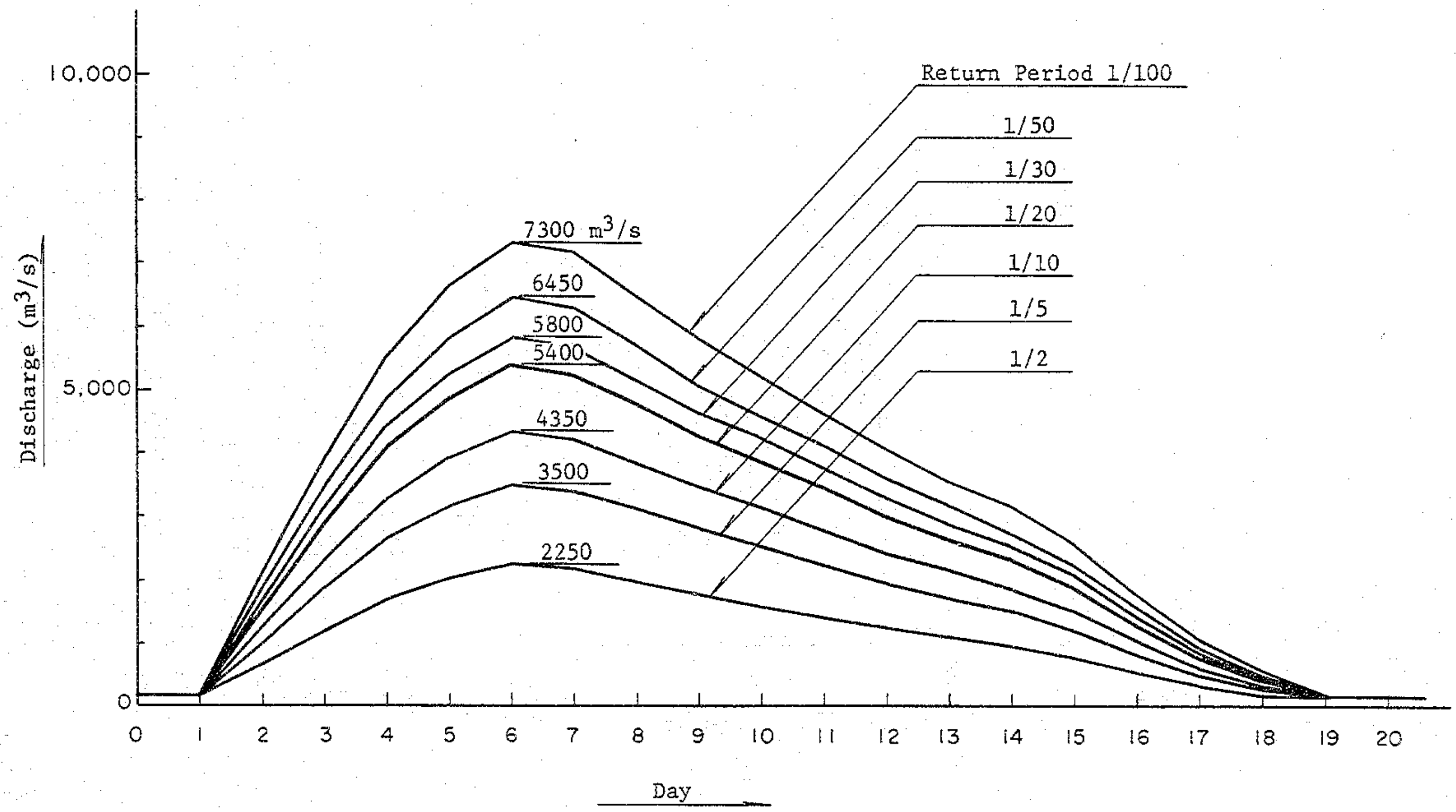


Fig. I-23(1) COMPARISON OF HYDROGRAPH AFTER AND BEFORE THE REGULATION OF DAM

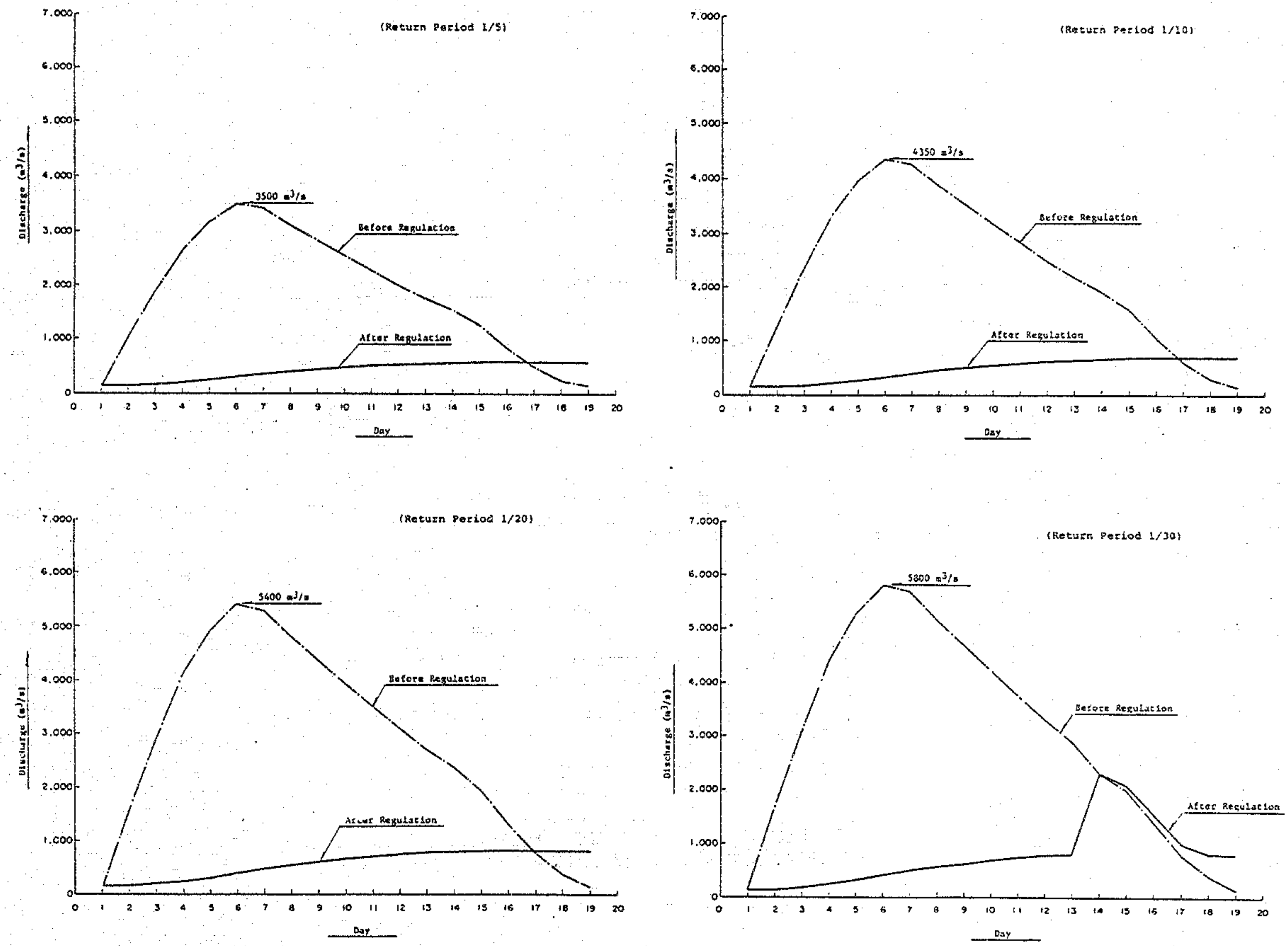


Fig.I-23(2) COMPARISON OF HYDROGRAPH AFTER AND BEFORE THE REGULATION OF DAM

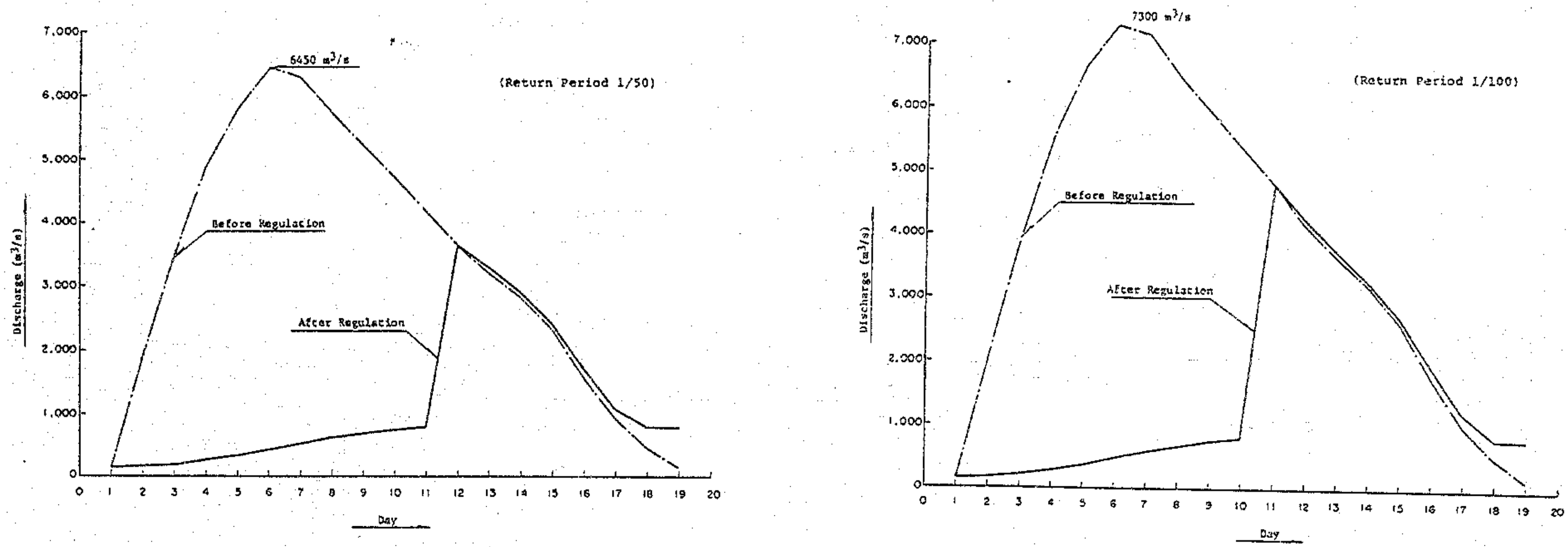


Fig. I-24 DESIGN FLOW REGIME, 1970

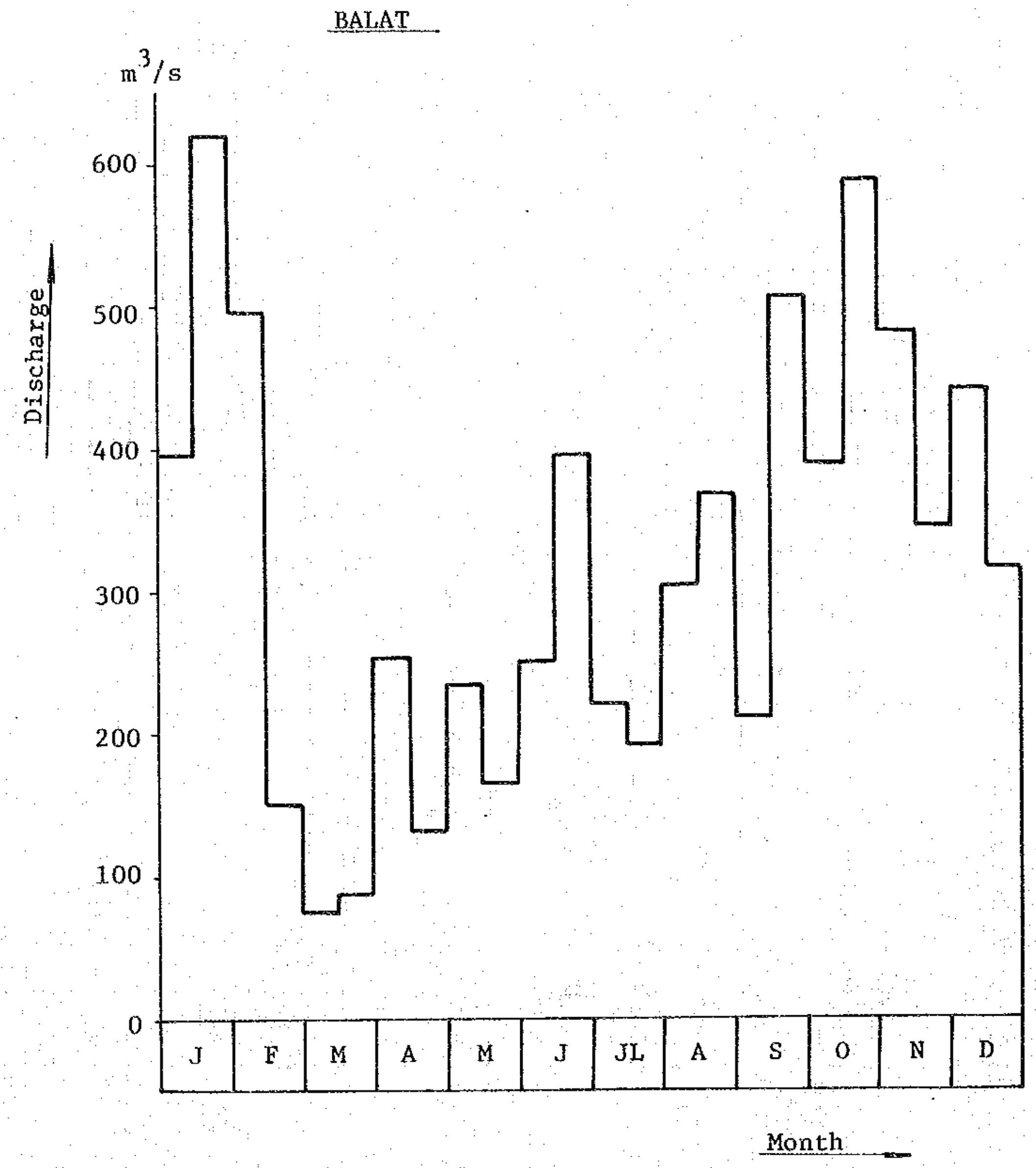


Fig. I-25 DESIGN FLOW REGIME, 1975

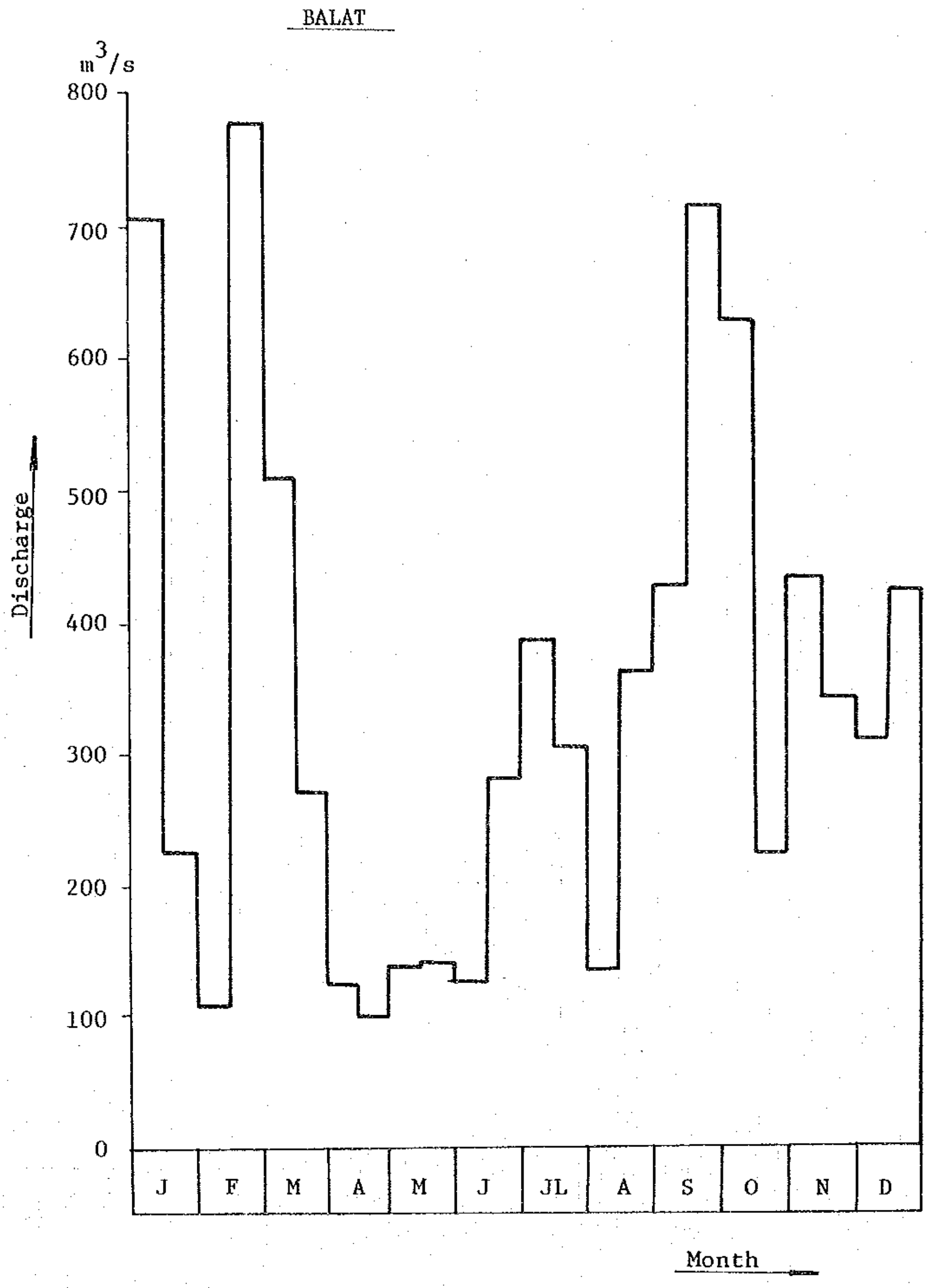
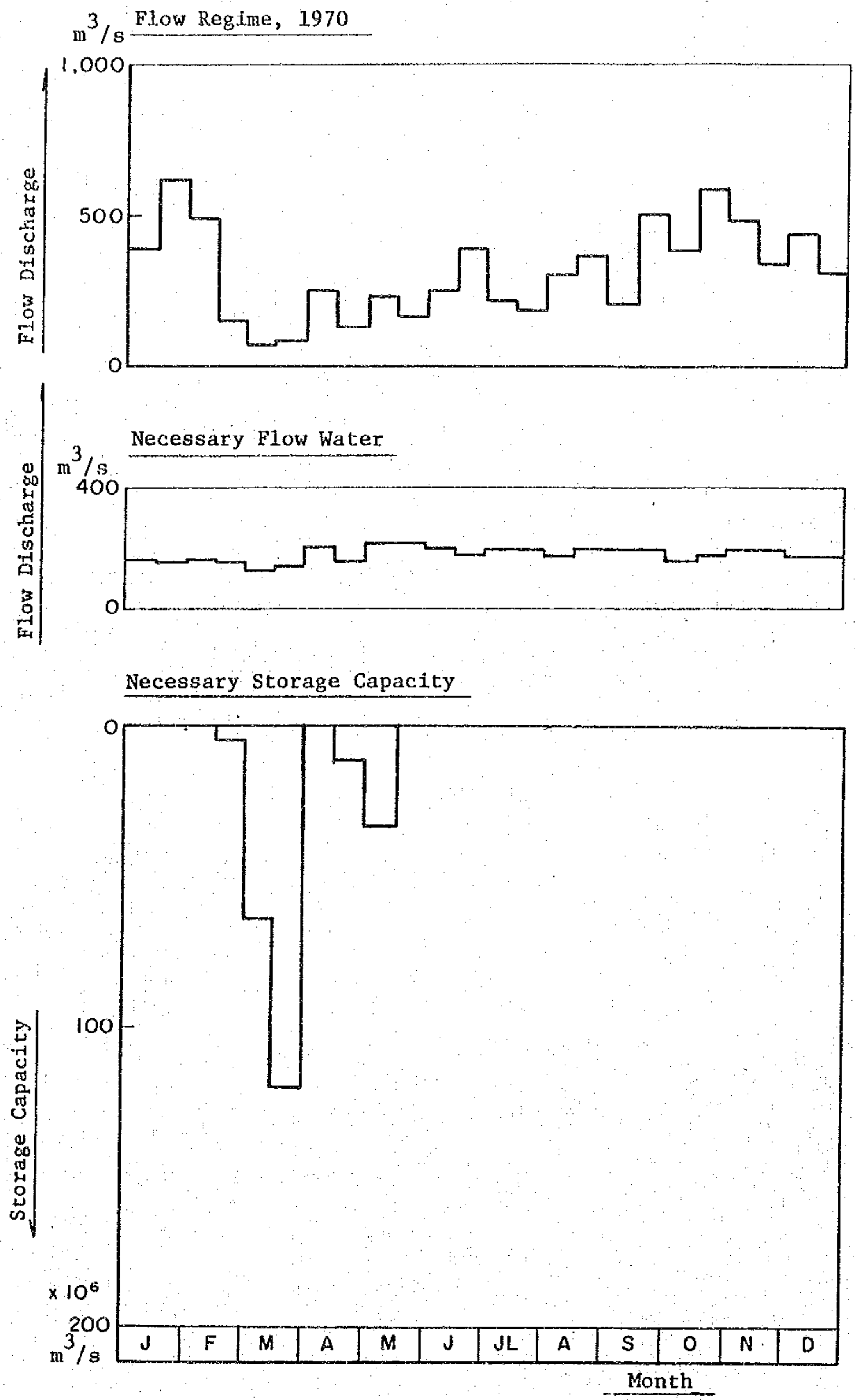


Fig. I-26 RESERVOIR OPERATION FOR WATER UTILIZATION



II. GEOLOGY

II. CONTENTS OF GEOLOGY

LIST OF TABLES

LIST OF FIGURES

1 GENERAL

The three proposed damsites, Balat, Deramakot and Milian-Kuamut damsite taken into consideration to be compared among them and selected by better one by the first state survey and additional test borings at Balat damsite were consequently carried out.

The proposed Balat and Deramakot damsites are, as shown in Fig. II-1(1), located in 10 km to 15 km lower reaches in north-eastern direction from kampung Kuamut where the Milian and Kuamut rivers join together to become the Kinabatangan River. They are also located in the place of approximately 80 km far from Sandakan in the south-eastern direction.

The proposed Milian and Kuamut damsites are respectively located in the place of approximately 10 km upper reaches in western and southern direction from Kuamut confluence of the Milian and Kuamut rivers.

Topographic condition in the Kinabatangan River Basin has almost three regions of mountains, dissected peneplains and alluvial plains, shown in Fig. II-1(2). The proposed damsites are nearly located around the boundary between the topographic regions of mountains and dissected peneplains.

Bedrock around the proposed damsites is mainly composed of soft sandstone, mudstone, shale and their alternating beds from Eocene to Miocene in Tertiary geologic age, and has more or less many folds and faults.

Alluvial deposits in Quaternary geologic age cover these bedrocks mainly along the present river.

2. GEOLOGY OF THE PROPOSED AREA

2.1 STRATIGRAPHY

The stratigraphy of the proposed area is summarized in Table II-1 and its distribution is shown in Fig. II-1(3). According to this Figure, bedrock around the proposed damsites consists of mainly Tanjong Formation and less Kuamut, Labang and Kulopis Formation, being covered by the Alluvium along the River.

The followings are briefly described by respective Formation.

1) Alluvium

This is the fluvial deposits distributed along the river and around the river mouth, and consists of gravel, sand, silt, clay and peat.

2) Tanjong Formation

This formation is composed mainly of mudstone and shale with prominant bed of commonly scarp-formation sandstone and rare conglomerate, including minor coal seams. The sandstone-shale strata form synclinal basins which are well marked by the drainage pattern as in the Bangan Basin and Malua Basin. The sandstone beds stand out prominently as curving strike ridges and the shale beds are usually indicated by the main river valleys.

3) Kuamut Formation

This formation consists mainly of slump breccia and sequences of sandstone and shale including mudstone, comglomerate, minor chert and interlayered sequencers of tuff and tuffous sediments. The slump breccias of this formation comprise fragments and blocks of various type of older formations randomly embedded in argillaceous matrix. The fragments range from less than 15 cm to large blocks over 1 m across.

4) Labang Formation

This formation comprises sandstone, mudstone, shale and more rearely lenses of fossiliferous limestone and calcarenite. The sandstone and shale sequences form prominent strike ridges of sandstone in the area between the Malubuk and Malua valleys.

5) Kulapis Formation

This formation is characterized by fine-grained gritty, chocolate brown and violet massive sandstone and hard, reddish-brown or red, locally sandy, non-calcareous shale.

6) Coker Formation

This formation comprises hard, grey sandstone, generally massive, with apparently rare beds of grey or red shale. In some places the sandstone encloses spherical concretions. This formation is cut by plugs and dykes of dolerite around hills located in upper reaches of the Milian river.

7) Sapulut Formation

This formation comprises more mudstone, shale and less sandstone, conglomerate and limstone. The alternating beds of thin shale and siltstone and of shale and silty sandstone are sometimes repeated.

8) Chert-Spilite Formation

This formation comprises sedimentary and volucanic rocks. The sedimentary rocks consist mainly of sandstone, immature volucanic arenite, chert, conglomerate, shale, siltstone, limestone, marl and porcellanite. The associated volucanic rocks include spilite and basalt with tuff and agglomerate.

9) Igneous Rocks and Crystalline Basement Rocks

Igneous rocks consist of gabbro, diorite, dolerite as mafic rocks and peridotite, normally serpentinized, less dunite and pyroxenite as ultramafic rocks. Crystalline basement rocks have one of the oldest rocks in age of Lower Triassic and/or earlier underlying Late Mesozoic and Tertiary rocks in Sabah. Rock types consist of hornblend-plagioclase gneiss, amphibolite and some other kinds of gneiss and schist.

2.2 STRUCTURE

The Geologic structure of the proposed area has faults, folds and unconformities, and the general trends of beds are roughly divided by the Kuamut Fault which is located along the Kuamut river with the north-north eastern trend. Most of the bedding trends in the eastern part of Kuamut Fault show north-east direction except Malua basin structure. This basin structure is shown by the curving strike ridge and valleys, in which sandstone beds stand out as ridges and shale beds have been eroded to be valley. The respective geologic relations among Tanjong, Kuamut, Labang, Kulapis and Chert-Spilite Formation are unconformities except the conformity between Tanjong and Kuamut Formation. Each Formation is strongly folded and some faults with the trends of northeast, east-northeast and northwest are found.

On the other hand, bedding trends in western part of Kuamut Fault show north-noetheast, northeast and northwest direction except Bangan basin structure. The respective geologic relations among existing Formations are the same as described before. Beds are strongly folded and some faults with the trends of north-northeast and northwest are found.

Igneous intrusive rocks accompanied near by crystalline basement rocks are distributed in the southern and western parts far from the proposed damsites.

Alluvial surface deposits, which are mostly fluvial deposits along the present river, cover these bedrocks.

3. GEOLOGIC CONDITIONS OF THE PROPOSED DAMSITES

The limited geologic investigation of the proposed damsites gave their geologic maps of 1:50,000 scale, shown in Figs. II-2 -3, -4 and -5. And the bedrocks of their geologic maps are described by the rock facies, such a sandstone-rich beds, shale-rich beds and sandstone and shale beds, though they are included in Tanjong, Kuamut, Labang and Kulapis Formations.

3.1 ROCK FACIES

3.1.1 Sandstone-rich Beds

These beds are included in Tanjong, Kuamut, Labang and Kulapis Formation. It is difficult to get the differences among them, unless a detail geologic mapping will be carried out, but ones of Kupais Formation are distinguished by the others.

Sandstone of Tanjong, Kuamut and Labang formation is commonly grey to brownish-grey and less commonly buff in colour. The grain size of sandstone has the range from very fine to coarse, sometimes to granule or conglomerate, but most of them are fine to medium sandstone. The prominant fragment of the sandstone is, in most of cases, quartz with 50 to 70 percentage in amount, and the fragments of chert and feldsper are also found. These beds are somehow massive without showing the bedding plane and have sometimes lenticular-shaped and shperical-shaped hard concretion.

These beds are not hard except concretion and rare hard parts. Of course, some layers of shale and alternating beds of thin sandstone and shale are included in these beds and thin red shale beds are rarely found.

Sandstone of Labang Formation is sometimes fractured or jointed and some jointed planes are filled by criss-crossed calcite veins.

Sandstone of Kulapis Formation is characterized by red, purple and grey in colour, and also includes red, purple and buff siltstone and shale of thin layer and sometimes chert in the basal beds.

Grain size of this sandstone is also fine to coarse and has a largely calcareous matrix enclosing distinctly angular grains of quartz and a few of plagioclase. This sandstone is massive and soft rocks, but sometimes hard parts and concretions are found.

3.1.2 Shale-rich Beds

These beds are included in mainly Tanjong and Kuamut Formation and rare Labang Formation, though it is somehow difficult to find differences between them. These beds comprise shale, mudstone and alternating beds of shale and sandstone with some thin layers of sandstone.

Herewith, shale has much fissility parallel to the bedding plane and mudstone has no fissility showing massive rock, though both of them are argillaceous rocks. Shale and mudstone are commonly dark grey, partly reddish brown, soft rocks and sometimes contain carbonaceous partings, leaf and plant fragments.

They are easily weathered to show yellowish grey, pale yellow in color and easily break conchoidally. These beds of Tanjong Formation may have lenticular-shaped quartzose nodules. These beds of Kuamut Formation have slump breccias of various rock types. Huge block of gabbro is in this Formation, reported to be found by the result of additional field survey.

3.1.3 Sandstone and Shale Beds

These beds are included in Kuamut Formation, and consist mainly of shale, mudstone, alternating beds of shale and sandsotne, and less conglomerate. The character of these beds has slump breccias of various rock types such as sandstone, limstone, chert, conglomerate, basalt, gneiss and serpentine in the range of their diameter of 15 cm to 1 m. These slump breccias are randomly enbedded in sheared argillaceous matrix. The sandstone, shale, mudstone of these beds are not so different from those of Tanjong Formation.

3.2 BALAT DAMSITE

3.2.1 Topography

This proposed damsite is in upper reaches, located at 1.5 km south-western part of Kampung Balat. Macro topographic condition around it shows the character of hill belt, the summit of which is in the range of approximately 100 m to 300 m in height above the mean sea level, and the elongations of ridge and valley show nearly northeast direction. The Kinabatangan river flows through these topographic conditions and has 100 m to 150 m in river width and roughly 360 m including terrace plain. Both of right and left slopes of river are very gentle. Due to the topographic zonal arrangement of ridge and valley, four more sub dams have to be built for keeping the water in the proposed reservior area.

3.2.2 Geology

Bedrocks around the proposed damsite, shown Fig. II-2, consists of more sandstone-rich beds and less shale-rich beds of Tanjong, Kuamut and Labang Formation in age of Oligocene to Miocene in Tertiary. And Alluvium in Quarternary covers these bedrocks along the present river and the other valleys. These bedrocks belong to relatively soft rocks. As for the weathering condition of bedrock, weathered soils are found by about a few meters in depth from the ground surface and below its depth weathered rock is found down to a few more meters. At the place where the weathered depth is the shallowest, fresh bedrock is covered by 1 m-thick weathered soils. The constituents formed by weathering are red-brown, brown, grey clayey soils and sandy soils sometimes mixed with weathered soft gravels. Small out crop of highly weathered gabbro is reported to be found by the additional survey. In geologic structure of bedrocks, the strike of beds has commonly northeast direction in the range of 30° to 80°, and mostly dipping to north, sometimes south, as these beds are often strongly folded. These bedrocks' structure controls topographic conditions, in which the elongations of ridges are almost the same as the strike of sandstone-rich beds. And the elongations of valleys are distributed by shale-rich beds. Also, the faults are developed and inferred by the northeast, northwest and eastwest direction. One unconformity or fault is inferred, according to existing geologic map, but this limited geologic investigation did not confirm it to be sure. The Alluvium is included by the present river deposits and fluvial deposits forming flood plains and/or terrace along the present river. And their constituents are expected by sand, gravel and clay. The boundary depth of the Alluvium from the bedrock is not sure, but may be infereed by a few ten meters based on the results of drilling carried out at nearly 30 km lower reaches far from this location. The additonal drilling result shows that the thickness of river deposits is more than 35 m.

3.3 DERAMAKOT DAMSITE

3.3.1 Topography

The proposed damsite is, in upper reahces, located at 5 km south-western part of the proposed Balat damsite. Topographic condition is about the same as Balat damsite, except its condition at the right side of the proposed dam has very gentle slopes with some valleys and seems to have no mountains. According to unclear topographic map of 1:50,000 scale, one proposed dam may be considered at this location and have approximately 1,240 m width of river including terrace plain, while a few right wing sub dams might be necessary after the clear topographic condition will be obtained.

3.3.2 Geology

Geologic condition including its structure around the proposed damsite is, shown in Fig. II-3, about the same as Balat damsite, except shale-rich beds have prominant distribution around the damsite and the trends of inferred faults show northeast direction.

3.4 MILIAN-KUAMUT DAMSITE

3.4.1 Topography

Milian damsite is, in upper reaches, located at 10 km western part of Kampung Kuamut and Kuamut damsite at 6 km southern part of Kampung Kuamut. Both sites of Milian and Kuamut have relatively good abutments at right and left sides of dam, compared with Balat and Deramakot damsites. But the widths of river and neighbouring terrace along the dam axis are so wide, such as roughly 2,100 m at Milian and 1,300 m at Kuamut damsite. Sub dam of Milian damsite has good topographic condition in addition to good geologic condition, even if concrete gravity type dam with the height less than 40 m may be considered to be built.

3.4.2 Geology

Bedrocks around the proposed Milian damsite, shown in Fig. II-4, consist of snadstone-rich beds and shale-rich beds of Tanjong and Kulapis Formations. General properties of these rocks such as weathered depth and engineering geologic condition are not so different from those of Balat damsite. In geologic structure of bedrocks, the strike of bed has northwest direction and dipping to south with 20° to 50° at the right side of the dam and the strike of northeast direction and dipping to north with 30° to 80° at the left side of the dam are measured. These beds are folded and unconformity or inferred fault might exist along the river, though it is not clear. The boundary depth of Alluvium may be a little shallower than the proposed damsites of lower reaches.

The bedrocks of the proposed Kuamut damsite, shown in Fig. II-5, consist of sandstone-rich beds, shale-rich beds and sandstone and shale beds of Tangjong and Kuamut Formations. General properties of those rock are considered not to be so different from Balat damsite, but bedrocks are somehow sheared more than ones of the other damsites, because of the existing of Kuamut fault. In geologic structure of bedrocks, the strike of beds has north-northeast direction parallel to the trend of Kuamut fault and dipping to west and east with commonly 35° to 90°. Those beds are sometimes strongly folded, and Kuamut fault with north-northeast trend exists along the river and the other faults with northeast and eastwest trends are found. The boundary depth of the Alluvium covering the bedrocks may be shallower than the other proposed damsites.

4. CONSTRUCTION MATERIALS

The proposed dam type is supposed to be built by fill dam or partly concrete dam. Accordingly availability of construction materials such as concrete aggregates, core, transition, filter, rock, and lip lap materials must be taken into consideration.

4.1 CONCRETE AGGREGATES, ROCK AND LIP LAP MATERIALS

These materials may be available by the future examination on the following geologic compositions distributed around the proposed area.

1) River Gravel and Sand

Along the river bed of the Kuamut and Mulbuka rivers, gravels are found and used for timber gravel road. The kinds of gravels consist mainly of igneous mafic rocks, hard sandstone and chert, and their diameter of 1 cm to 30 cm are found as hard and subrounded gravels. As the period of field survey was carried out at rainy season having high river water level, the detail constituents of river deposits along the Kinabatangan river was not cleared.

2) Mountain Gravel (Quartz Gravel)

The quartz gravels are found in many places of peneplains as shown in Fig. II-1(2), and they are considered to have been formed in age of Pliocene to Pleistocene. These gravels almost consist of hard rounded quartz with maximum diameter of 10 cm and commonly less than 5 cm. The matrix among gravels is formed by sandy clay soils and thin layers of fine soils may be sometimes found among them. These quartz gravels have been used for concrete aggregates around the Sandakan area. Few and rare distribution of these gravels are found around the proposed damsites area.

3) Hard Sandstone

The hard sandstone of Tanjong, Labang and Kulapis Formations in Tertiary, the uniaxial compression strength value of which may be inferred less than 500 kg/cm^2, may be used for concrete aggregates, though they are not so good to be used. Crushed stones of this hard sandstone were used for timber gravel road at Balat timber camp. As this hard sandstone beds are distributed thinly in thickness and always accompanied with soft sandstone and shale, big quantity required is not available.

4) Chert

Chert is found in Chert-Spilits Formation, which distributes at about more than 10 km to 20 km in southern parts far from the proposed damsite area. Crushed stones of this rock are available for gravel road and concrete aggregates, but not so good because of easiness of flat and small fragment after crushing them.

5) Limestone

Few limestone is found around the proposed damsites area. One of limestone is reported to have been used for gravel road and concrete aggregates. But its small distribution is not available for big quantity required.

6) Igneous Mafic Rocks and Crystalline Basement Rocks

These rocks are found at about more than 10 km to 20 km in southern parts far from the proposed damsites area. They are available for concrete aggregates and gravel road. But some of mafic rocks are altered by serpentization and some of crystalline basement rocks have schistosities. Therefore, rock type will be investigated to be sure in future study and then may be considered to be used for these construction materials.

According to the explanation stated just above, river gravel and sand, hard sandstone and limestone might be, in this study stage, available for concrete aggregates and hard sandstone might be also available for small quantity of rock and lip lap materials, because they might be obtained near the proposed damsites area. But these concerns must be considered by future investigation. The other hand, quartz gravel, chert, igneous mafic rocks and crystalline basement rocks have the distributions somehow far from the proposed damsites area, and are not so available for construction materials.

4.2 CORE, TRANSITION AND FILTER MATERIALS

The core materials are available, by using the weathered soils of bedrocks, weathered soft sandstone around the proposed damsites area, though using weathered shale is not so available.

The transition materials are also available by using the soft sandstone rather than shale around the proposed damsites area.

The filter materials may be available by using river sand near the proposed area, but future investigation will give the details about their distribution, grain size and so on.

5. GEOLOGIC COMPARISON AMONG THE PROPOSED DAMSITES

The very important viewpoints of dam geology to make comparison among the proposed some damsites are divided by the three of dam foundation, construction materials and geologic condition of the proposed reservoir area.

5.1 DAM FOUNDATION

Bedrocks of the proposed three damsites consist mainly of soft sandstone-rich beds, shale-rich beds and sandstone and shale beds, while the portions of their distribution are somehow different at the respective site. The proposed Deramakot damsite has many distribution of shale-rich beds, which is not so good for foundation. As the weathered bedrocks are generally covered by the weathered soils of few meters in thickness at the slopes of right and left side abutments, it is not so big problems foundation for fill dam including the concerns of spillway foundation. Concerning faults, medium fault is inferred along the Kuamut river at the proposed Kuamut damsite, and small faults are inferred with the same conditions in the proposed damsites. The proposed dam is considered to be built by fill dam, and its foundation around the river and terrace may be, though depends on the conditions of Alluvium, founded on the river and terrace deposits, as is called soil foundation. Their thickness, constituents and width affect to the foundation treatment so much that the big difference of construction cost may be obtained. Concerning their thickness and constituents, the details are not clear yet, but the total width of river bed and terrace plain along the proposed dam axis is roughly shown as follows:

Proposed damsite:	Approximate width of river and terrace obtained by topographical map of 1:10,000 magnified from 1:50,000 scale
Balat :	810 m
Deramakot :	1,240 m
Milian-Kuamut :	3,440 m

Therefore, concerning the foundation treatment of soil foundation, the construction cost is the cheapest at the proposed Balat damsite.

5.2 CONSTRUCTION MATERIAL

Concerning the embankment materials available around the proposed damsites, there is no difference except Milian sub-dam, and no big quantity of rock materials is available. Therefore, it may be better to consider to build dam by earth fill type with some zoning. And it may be better to use most of fill materials by sandstone-rich beds rather than shale-rich beds.

concerning the concrete aggregates, it may be easier for damsite located at upper reaches to obtain them, as river gravel and sand will be, in this stage, expected to be used. But it might not be so much difference between damsites of upper and lower reaches, if gravel investigation will be carried out along the tributary river near the proposed damsites.

5.3 GEOLOGIC CONDITION OF THE PROPOSED RESERVOIR AREA

The limited geologic investigation did not confirm the existing of big landslide which affects much to the dam, but many small landslides which affect very little to dam are found. Concerning this matter, there is no difference among the proposed damsites.

Conclusion in the study of first stage survey gives the followings. On the comparison among the three proposed damsites, the proposed Balat damsite firstly becomes better on the viewpoints of topographic conditions and also the following two points from the geologic viewpoints recommend the Balat damsite to be chosen among them.

- The width of Alluvial river and terrace deposits at Balat damsite, which may be required by foundation treatment to build the dam on, is the shortest.

- Bedrock condition at Balat damsite, the construction capability and availability of core and transition materials obtained from the bedrocks, is better than the proposed Deramakot dam and is about the same or little bit better than the proposed Milian-Kuamut damsite.

6. RESULTS OF ADDITIONAL TEST BORINGS AT BALAT DAMSITE

Additional test borings including water pressure tests (Lugeon test) and some laboratory tests, and geologic mapping were carried out by Malaysia side, based on the study results of the first stage survey which decided that the proposed Balat damsite was better among the nominated damsites. The results of geologic mapping are added in the previous paragraph, but results of test borings are, here, explained and shown by the summary of boring log. (Refer to Tables II-2 to -6 and Fig. II-6)

Conducted quantity of test borings and their concerns are shown as follows.

Borehole No.	Drilling Depth	Nos. of Lugeon Test	Nos. of Standard Penetration Test	Nos. of Soil Test
B-1	35 m*	0	35	24
B-2	30	3	7	3
B-3	20	1	12	9
B-4	40	1	6	4
B-5	20	1	10	7
Total (5 holes)	145 m	6	70	47

*This hole was at first expected to be drilled down to 50 m in depth.

6.1 TEST BORING

<u>Borehole No. 1</u> (Main dam, River side on the terrace, Drilling depth 35 m)

River deposits including clay, sand and gravel are obtained. Clay is found down to 15.4 m in depth from ground surface. Clayey sand between 15.4 m and 16.8 m, clay between 16.8 m and 18.1 m, fine to medium sand between 18.1 m and 24.5 m, clay or loose sand between 24.5 m and 26.9 m, and below its depth to 35.0 m in depth coarse sand and gravel are obtained. Clay or loose sand between 24.5 m and 26.9 m in depth is so soft or loose, showing 3 to 4 numbers of blow of Standard Penetration Test (S.P.T.). The other number of blows of S.P.T. is obtained by 4 to 17 in clay, 13 to 22 in sand and 33 to 43 in coarse sand and gravel. The boundary between river deposits and bedrock was not found, because of the stop of drilling at 35 m in depth due to the difficulty of drilling. It is clear that the thickness of river deposits is more than 35 m. (Refer to Table II-2.)

Borehole No. 2 (Main dam, Right side slope, Drilling depth 30 m)

Clay of weathered soils and surface soils is obtained down to 2.5 m in depth from ground surface, of which number of blows of S.P.T. is between 5 and 10. Weathered shale and clay with 15 to 31 numbers of blows of S.P.T. are obtained between 2.5 m and 6.9 m in depth. Below 6.9 m in depth, number of blows of S.P.T. is more than 50. Hard sandstone is obtained between 6.9 m and 8.2 m in depth. From 8.2 m to 30.0 m shale is obtained. (Refer to Table II-3.)

Borehole No. 3 (Sub dam No. 1, Centerbase, Drilling depth 20 m)

Weathered shale and sandstone showing clay due to the weathering are obtained down to 12.9 m in depth from ground surface, of which number of blows of S.P.T. is between 8 and 25. Below 12.9 m down to 20 m in depth, shale with number of blows of S.P.T. more than 50 is obtained. (Refer to Table II-4.)

Borehole No. 4 (Sub dam No. 2, Right side of center base, Drilling depth 40 m)

Clay and clayey sand are obtained down to 5.0 m in depth, of which number of blows of S.P.T. is less than 5. Below 5.0 m down to 6.4 m in depth, shale with 38 to 50 numbers of blow of S.P.T. is obtained. Below 6.4 m in depth down to bottom, S.P.T. could not be carried out. Below 6.4 m down to 13.7 m in depth, sandstone with thin layer of shale is obtained. Below 13.7 m down to 40.0 m in depth, shale with thin layer of sandstone is obtained. (Refer to Table II-5.)

Borehole No. 5 (Sub dam No. 4, Center base, Drilling depth 20 m)

Soft clay of surface deposits is obtained from top down to 5.7 m in depth and number of blows of S.P.T. is between 0 and 5. Weathered shale with 20 to 45 numbers of blows of S.P.T. is obtained below 5.7 m down to 9.9 m in depth. Below 9.9 m down to bottom, shale is obtained and S.P.T. could not be carried out. (Refer to Table II-6.)

6.2 WATER PRESSURE TEST (LUGEON TEST)

Six water pressure tests were carried out to obtain data on permeability condition of bedrock, by using just drilled borehole. Only two of them were, however, completed to get the data shown as follows, but the others were unsuccessful to get them.

Borehole No.	Depth of test section (m)	Lugeon value (Lu)	Maximum Pressure (kg/cm^2)
B-2	23.0 - 28.1	0.7	3
B-4	15.9 - 20.5	2.0	5
The other points	Unsuccessful due to serious leakage or bad condition of wall rock inside the borehole		

6.3 SOIL TEST

Fourty-seven samples obtained by S.P.T. were carried out to be examined by laboratory soil test such as natural moisture content, grain size analysis, liquid and plastic limit to classify them by unified soil classification system. Results are summarized in Table II-7. Clay of river deposits, surface soils and weathered soils derived from shale are mainly devided into symbol of CL and rare CH, ML and CL-ML by unified soil classificaiton system. The other hand, sand and gravel of river deposits are mainly devided into symbol of SW, SP, SC and SW-SC.

6.4 EXAMINATION ON THE ADDITIONAL DATA OF TEST BORINGS

The data so far obtained by additional test borings are examined on the dam fundation and embankment materials.

6.4.1 Dam Foundation

River deposits such as clay, sand and gravel have the thickness more than 35 m and the boundary between river deposits and bedrock was not found at main damsite. The proposed fill dam of main dam will be put its foundation on these river deposits as soil foundation, which requires considerable foundation treatment.

Dam foundation must be examined on mechanical condition and permeability condition.

As for mechanical condition, soil foundation can bear the proposed burden of fill dam. But clay soils are included in soil foundation, and therefore consolidation settlement of clay due to the proposed weight and examination against shear sliding of embankment through soil foundation must be examined, unless all clayey soils will be excavated. And another problem is the existing of soft clay or very loose sand layer which is distributed between 24.5 m and 26.9 m in depth and has 3 to 4 numbers of blows of S.P.T. Its thickness is only 2.4 m, but if it is sand, liquefaction due to the shock derived from earthquick might happen and if it is clay, consolidation settlement will happen.

Bedrocks of main and sub dam, though soft rock and weathered soft rock, are sufficiently applied to the proposed dam foundation, but fault and sheared zone found in bedrocks will be carefully examined on their conditions.

As for permeability condition, sand and gravel included in river deposits as soil foundation of Main dam are very permeable. Therefore, foundation treatment against high permeability must be examined. Permeability condition of bedrocks is, in this stage, not clear, though two Lugeon values resulted by water pressure test are obtained by 0.7 Lu. and 2.0 Lu. showing small permeability. Bedrocks are, however, sheared so much and serious leakage on water pressure test were reported. Therefore, high permeabitlity of bedrock down to certain depth from ground surface will be inferred.

6.4.2 Embankment Materials

Most of weathered soils derived from shale and some surface soils have symbol of CL by unified soil classificaiton system. Silt and clay contents of them are mostly more than 73% and their natural moisture contents are between 10% and 49%. (Refer to Fig. II-7)

These results show that weathered soils derived from shale are not favouragle for embankment materials. Weathered soils derived from sandstone will be available for them.