REPUBLIC OF INDONESIA
MINISTRY OF PUBLIC WORKS
DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT

JENEBERANG RIVER FLOOD CONTROL PROJECT (PHASE II)

SUPPORTING REPORT-II

MAPPING AND SURVEYING
HYDROLOGY
GEOLOGY
WATER SUPPLY
IRRIGATION
HYDRO POWER
ATTACHMENT

MARCH 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

4. MAPPING AND SURVEYING

CONTENTS OF MAPPING AND SURVEYING

		Page
1.	GENERAL	4-1
2.	MAPPING WORKS	4-1
	2.1 Mapping Works in 1979	4-1
	2.2 Mapping Works in 1981	4-1
3.	GROUND SURVEYING WORKS	4-2
	3.1 Ground Surveying Works in 1979	4-2
	3.2 Ground Surveying Works in 1981	4-2
	Fig. 4-1 MAPPING AREA AND LOCATION OF SURVEYING POINTS	4-4

1. GENERAL

In the study period (1979) of the Lower Jeneberang River Flood Control Project, surveying and mapping works were carried out in a coverage of the Jeneberang lower reaches and the Ujung Pandang city in order to formulate an urgent flood control plan.

Additional surveying and mapping works have been required to formulate a flood control plan through construction of the Bili-Bili dam.

2. MAPPING WORKS

2.1 Mapping Works in 1979

The mapping works conducted in 1979 for a feasibility study of the Lower Jenberang Flood Control Project consist of aerophoto-taking and aerohoto mapping as described below.

1) Aerophoto-Taking

Aerophotos were taken in a total area of 330 km^2; covering 1) the inner basin and Ujung Pandang city in the lower reahces of Jeneberang river (150 km^2), 2) proposed dam site and reservoir area (110 km^2) and 3) sediment production area (70 km^2).

2) Aerophoto-Mapping

Based on the above-mentioned aerophotos, maps with a scale of 1/10,000 which covers the inner basdin and Ujung Pandang city (150 km^2 in a total area) have been prepared after surveying triangulation points.

2.2 Mapping Works in 1981

In addition to the maps preapred in 1979, maps covering the upper reaches of Sungguminasa (200 km^2 in a total area) have been prepared on the basis of aerophotos taken in 1979 as well as the terrestrial surveying results. The mapping works have been carried out in two kinds of scales; 1/5,000 and 1/10,000. The former scale mapping covers the proposed dam site and its regulating pondage site, while the latter covers the proposed reservoir area and the river course from Sungguminasa to Bili-Bili. (Refer to Fig. 4-1.)

3. GROUND SURVEYING WORKS

3.1 Ground Surveying Works in 1979

Ground surveying works have been conducted in 1979 to prepare fundamental data for hydraulic analysis and designing of the relevant structures, which are required for the formulation of the urgent flood control plan. The surveying works are described in details as follows:

Surveying of the Jeneberang River

1) Longitudinal and cross-sectional survey along the river channel in a stretch of 20 km from the estuary at 400 m interval

2) Location and height survey of the existing river structures along the river channel

3) Longitudinal survey of the roads in the upper reaches of the Sungguminasa bridge

4) Sounding survey in the estuary of Jeneberang in a area of 7 km^2

5) Cross-sectional survey at three alternative dam axes

Surveying of the Tallo River

1) Cross-sectional survey along the Tallo river at 25 sctions

Surveying of the Inner Basin

1) Longitudinal and cross-sectional survey for the existing drainage channels and cross-sectional survey for the newly proposed route

2) Topographical survey for proposed pumping station sites with a scale of 1/200

3) Cross-sectional survey for proposed gate sites

The location of longitudinal and cross-sectinal surveying points is presented in Fig. 4-1.

3.2 Ground Surveying Works in 1981

Longitudinal and cross-sectional surveying above Sungguminasa and palne table surveying has been additionally carried out in the upper stream of Sungguminasa during this study period, as described in details below.

Longitudinal and Cross-Sectional Surveying

Cross-sectional and longitudinal surveying has been carried out at the interval of 400 m along the Jeneberang river and the Jenelata river in order to identify the features of the river channel such as flow capacity and riverbed gradient. The surveying works cover the stretch from the Sungguminasa bridge to the Bili-Bili dam site along the Jeneberang river and also the stretch of 2 km along the Jenelata river above its confluence with the Jeneberang river. The axis of the proposed dam has also been surveyed cross-sectionally (2.8 km in length) and longitudinally.

The flow capacity of the main irrigation channel has also been checked by longitudinal and cross-sectional surveying.

Plane Table Skurveying

Plane table surveying has been conducted in and around the following three places;

1) the Sungguminasa bridge covering an area of 150,000 m^2,

2) the intake for the Gowa paper mill covering an area of 25,000 m^2, and

3) the intake for the Bili-Bili irrigation channel covering an area of 12,000 m^2.

Fig. 1-1 shows the location of longitudinal/cross-sectional and plane table surveying points mentioned above.

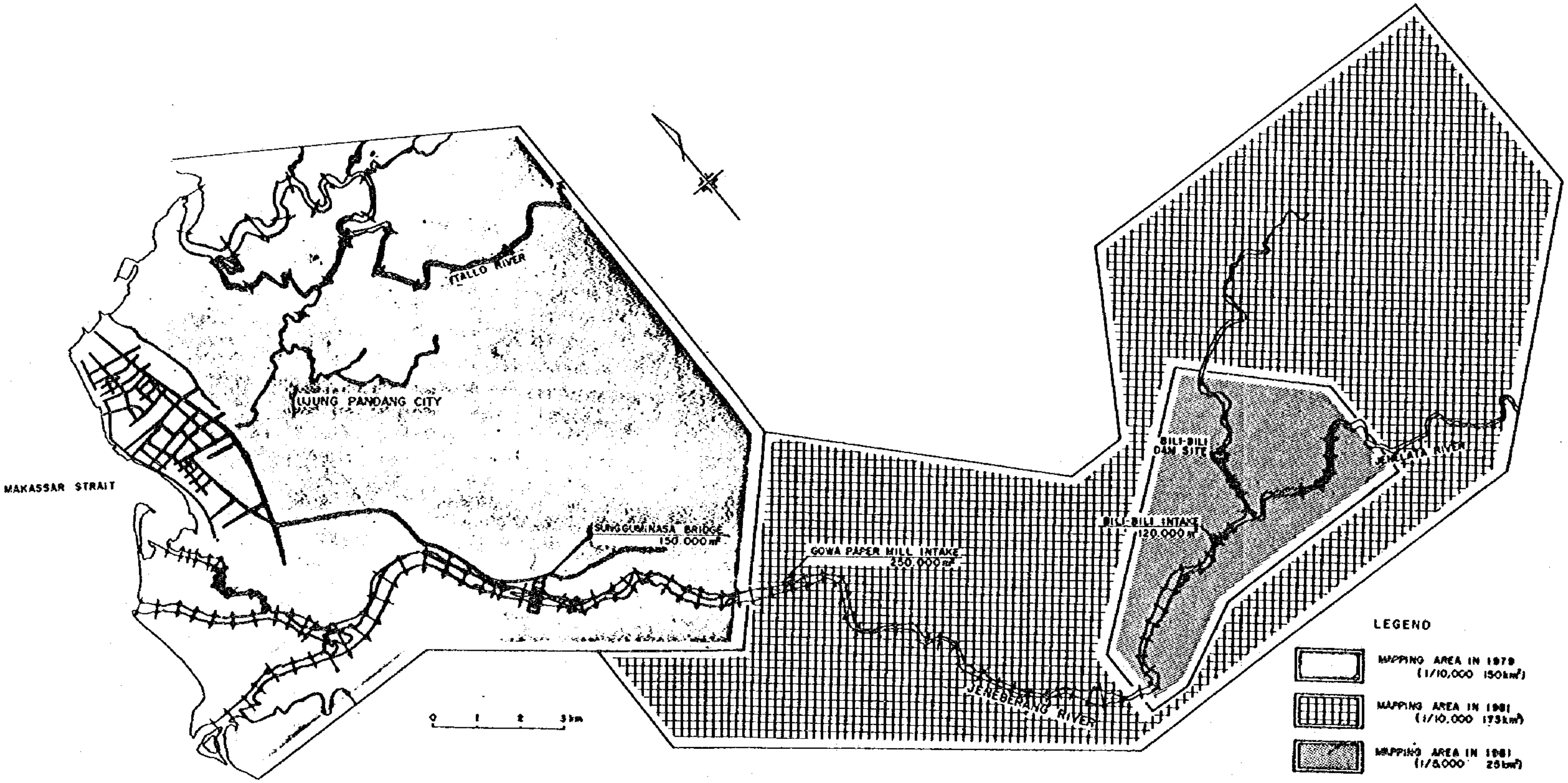


Fig. 4-1

MAPPING AREA AND LOCATION OF SURVEYING POINTS

5. HYDROLOGY

CONTENTS OF HYDROLOGY

Page

1. PURPOSE AND SCOPE 5-1

2. GENERAL INFORMATION 5-1

   2.1 Location of Study Area 5-1
   2.2 Basin Features 5-1

3. METERQROLOGY 5-2

   3.1 Stations and Available Date 5-2
   3.2 Characteristic of Meteorology 5-3
   3.3 Temperature 5-3
   3.4 Humidity 5-3
   3.5 Wind 5-3
   3.6 Sunshine 5-3
   3.7 Evaporation 5-4

4. RAINFALL 5-4

   4.1 Gauging Networks and Available Data 5-4
   4.2 Annual and Monthly Rainfall 5-4
   4.3 Daily Rainfall 5-5
   4.4 Storm Rainfall 5-5

5. RUNOFF 5-6

   5.1 Stream Gauging Network and Available 5-6
   5.2 Rating Curve 5-7
   5.3 Long-term Run-off 5-10

6. FLOOD 5-10

   6.1 Probable Discharge 5-11
   6.2 Flood Hydrograph 5-12

7. SEDIMENT 5-14

   7.1 River Bed Material 5-14
   7.2 Sediment Yield 5-14

ANNEX: SITES PROPOSED FOR RAINFALL GAUGE 5-16

LIST OF TABLES

		Page
Table 5-1	METERORОLOGICAL STATIONS AND OBSERVATION ITEMS	5-18
5-2	MONTHLY MEAN TEMPERATURE	5-18
5-3	MONTHLY MEAN HUMIDITY	5-19
5-4	MONTHLY MEAN WIND VELOCITY	5-19
5-5	MONTHLY MEAN SUN-SHINE HOUR	5-20
5-6	MONTHLY MEAN EVAPORATION	5-20
5-7	MONTHLY MEAN RAINFALL IN AND AROUND STUDY AREA	5-21
5-8	BASIN MEAN MONTHLY RAINFALL (1), (2)	5-22
5-9	ANNUAL MAXIMUM RAINFALL	5-24
5-10	PROBABLE RAINFALL	5-24
5-11	WATER STAGE RECORDING PERIOD	5-25
5-12	COEFFICIENT OF OVERFLOW DISCHARGE	5-26
5-13	MONTHLY AVERAGE DISCHARGE OF JENEBERANG RIVER AT BILI-BILI AND KAMPILI SITES	5-27
5-14	ANNUAL MAXIMUM DISCHARGE AT KAMPILI WEIR	5-28
5-15	PROBABLE DISCHARGE	5-29
5-16	PEAK DISCHARGE RATIO	5-30
5-17	BASE FLOW DISCHARGE AT BILI-BILI	5-30

LIST OF FIGURES

		Page
Fig. 5-1	RIVER SYSTEMS AROUND JENEBERANG RIVER	5-31
5-2	SCHEMATIC DIAGRAM OF JENEBERANG RIVER	5-32
5-3	LOCATION MAP OF METERОROLOGY STATION	5-33
5-4	LOCATION OF RAINFALL STATION AND ISOHYETAL OF MEAN ANNUAL RAINFALL	5-34
5-5	MONTHLY RAINFALL DISTRIBUTIONS	5-35
5-6	DAILY RAINFALL (1), (2), (3), (4)	5-36
5-7	GAUGE CORRELATION OF THE DAILY RAINFALL (1), (2)	5-40
5-8	PROBABLE RAINFALL	5-42
5-9	LOCATION MAP OF WATER STAGE STATION	5-43
5-10	PROBABLE DISCHARGE AT KAMPILI WEIR	5-44
5-11	FLOOD PEAK STAGE CORRELATION BETWEEN KAMPILI AND BILI-BILI SITE	5-45
5-12	MODEL HYDROGRAPH FOR BILI-BILI AND JENELATA	5-46
5-13	MODEL HYDROGRAPH FOR KAMPILI	5-47
5-14	FLOOD HYDROGRAPH OF 1000, 50 AND 20 YEARS	5-48
5-15	GRAIN-SIZE ACCUMULATION CURVE ALONG JENEBERANG RIVER	5-49
5-16	SEDIMENT DEPOSIT AT ESTUARY	5-50

ANNEX

5-1 (AN) SITES PROPOSED FOR RAINFALL GAUGE 5-51

1. PURPOSE AND SCOPE

The hydrological study on the Jeneberang river basin was once carried out by the JICA survey team in 1980 in connection with the study on the Lower Jeneberang River Flood Control Project. Its results are compiled in a report entitled "Republic of Indonesia, Ministry of Public Works, Directorate-General of Water Resources development: LOWER JENEBERANG RVIER FLOOD CONTROL PROJECT, Japan Internatinal Cooperation Agency, 1980."

The present hydrological study, also on the Jeneberang river basin, has been conducted through review of the data already prepared as the results of the previous study and collection-assimilation of additional data required. While the previous hydrological study was primarily meant for flood control, this study has a wider purpose of not only confirming the accuracy of the available data, but also collecting new data, on hydrology in order to establish the basic criteria for planning flood control, irrigation, municipal water supply and hydropower generation projects in the Jeneberang river basin.

Thus, the scope of the study covers meteorology, rainfall, runoff, flood analysis and sediment in retard to the Jeneberang river and its basin.

2. GENERAL INFORMATION

2.1 Location of Study Area

The Jeneberang river basin, the study area covered by this survey, is located in the southern part of the Sulawesi Island, the Republic of Indonesia, and is included in the South Sulawesi Province. The basin is located in the range from Lat. 5° 10' S to Lat. 5° 25' S, and from Long. 119° 20' E to Long. 119° 55' E, and the whole catchment area is 727.0 km^2.

2.2 Basin Features

The Jeneberang river basin is surrounded by the Maros and the Tallo river basins, on its northern boundary, and by the Pappa and the Gomanti river basins, on its southern boundary. Their alignment is shown in Fig. 5.1.

The Jeneberang river basin lies along the Jeneberang river with the total length of approx. 75 km and spreads in eastwest direction. The maximum width of the basin, north to southwards, is approx. 21 km. The river mouth opening in the western end of the basin faces to the Makassar Straight.

The Jeneberang river has its basin head in the eastern end of the mountainous area where are standing such high mountains as Mt. Bawakataeng (2,833 m above M.S.L.), Mt. Lemballawe (2,692 m above M.S.L.), Mt. Panrungan (2,565 m above M.S.L.) and Mt. Mandakko (1,556 m above M.S.L.).

From its basin head, the river runs westwards through deep valley in the mountainous region and joins its major tributary, the Jenelata river, with the catchment area of 226,3 km^2, at Bili-Bili site. The catchment area of the Jeneberang river before its confluencing with the Jenelata is 384.4 km^2.

The banks of the Jeneberang river upstream of the junction with the Jenelata is utilized as paddy field. The river then passes through a narrow gorge between Bili-Bili and Kampili intake. 623.3 km^2 is the catchment area of the Jeneberang river at the Kampili site.

After passing the Kampili intake, the river runs into an open flat plain, flowing under the Sungguminasa bridge where its catchment area extends over 673.0 km^2. Then the river diverts into two channels, the northern and the southern; the remaining courses of these two channels until they reach the sea is 4.4 km with the northern channel (hereinafter referred to as 'right course') and 3.2 km with the southern ('left course'). Between the Kampili intake and the said diversion point, there are such structures as Gowa Paper Mill's intake, Sungguminasa bridge and municipal water intake towers for the cities of Sungguminasa and Ujunpandang.

In the lowest reaches of the Jeneberang river, the urbanized area of Ujungpandang city, the capital of the South Sulawesi Province, expands on the right bank of the river course. At the river mouth of the left course, a small tributary, the Garassi river, joins at its left bank. The Garassi river's catchment area is 54 km^2. The schematic diagram of the Jeneberang river basin is shown in Fig. 5-2.

3. METEOROLOGY

3.1 Observation Stations and Available Data

Meteorological observation has been carried on at two stations in the Jeneberang river basin and at three stations around the basin. With almost all the stations, however, their observation records cover only short periods, the oldest being retraceable up to 1971 at the two stations of Makassar and Panakukkang which are located outside the basin. The station at Bonto Sunggu in the lower area of the river basin started its observation only in 1977.

Fig. 5-3 shows the location of these stations and Table 5.1 shows their meteorological observation items. The monthly mean values of their meteorological records are compiled in Tables 5-2 to 5-6.

3.2 Meteorological Characteristics

The South-East Asia, wherein the subject area is located, is dominated by two monsoons: the one is the North-East monsoon which blows from north to eastwards between November and March, and the other is the South-West monsoon blowing from eastwards on the Sulawesi Island between May and August.

As far as the Jeneberang river basin is concerned, the North-East monsoon brings much rainfall during its dominant season hence this period is defined as rainy season. The Southwest monsoon, on the other hand, brings lesser rainfall than the North-East monsoon and the corresponding period consists of dry season.

3.3. Temperature

Temperature is measured at five stations, and their monthly mean figures are compiled in Table 5-2. The monthly mean figures range between 25°C and 28°C, and the annual mean temperature is about 26°C. The temperature has a minimal fluctuation in the month-to-month distribution, while the maximum and minimum daily temperatures are 30°C and 22°C, respectively.

3.4 Humidity

Relative humidity is observed at five stations, and their mean montly figures are shown in Table 5-3.

The monthly mean relative humidity is about 85% in the rainy season and 70% in the dry season, with the minimal seasonal change.

3.5 Wind

Wind velocity is measured at three stations of Makassar, Bonto Sunggu and Bonto Bili, as shown in Table 5-4. The former two are on the coastal lowland, while Bonto Bili is located just downstream of the proposed Bili-Bili dam, being surrounded by hills in all directions.

From the records available from these three stations, it is known that both Makasar and Bonto Sunggu stations receive stronger wind than Bonto Bili station. This might be attributable to the difference of the situation of the stations concerned, the former two being exposed to the sea and land winds, while Bonto Bili station is protected from the wind in all directions.

3.6 Sunshine

Sunshine hour is measured at four stations, and their monthly mean records are shown in Table 5-5.

The Table shows the longest sunshine hour of approx. ten hours in September and the shortest of approx. four hours in December and January. The annual mean sunshine hour is approx. seven hours.

The rate of sunshine per month is between 40% and 50% in the rainy season, and about 80% in the dry season.

3.7 Evaporation

Evaporation is measured at two stations in and around the basin, as shown in Table 5-6. The measurement is done by class-A pan evaporimeter at all the stations. The annual evaporation ranges from 1,600 mm/year to 1,800 mm/year.

The highest monthly evaporation of approx. 6 mm/day occurs in September to October, and the lowest of approx. 3mm/day in December to January.

Evapotranspiration record is so far unavailable in the Jeneberang river basin.

4. RAINFALL

4.1 Gauging Networks and Available Data

24 rainfall gauging stations in and around the Jeneberang river basin are listed in Table 5-7, and their location is shown in Fig. 5-4. Most of these gauges started operation rather recently; 19 gauges out of the 24 started operation in and after 1975.

Out of the above 24 gauging stations, only 5 gauges; namely, Sungguminasa, Kampili, Bili-Bili intake, Bonto Bili and Malino are located in the Jeneberang river basin.

Among the five, only 3 (Sungguminasa, Kampili and Malino) have rainfall records for more than 10 years, though not exactly consistent in their recording because they contain much missing data.

4.2 Annual and Monthly Rainfall

The isohyetal map of annual mean rainfall in and around the Jeneberang river based on the rocords maintained at the 24 gauges is shown in Fig. 5-4.

The annual mean rainfall in the Jeneberang river basin ranges from 2,500 m in the coastal area to 4,000 mm at the basin head. The mountainous area in the Jeneberang river basin receives more rainfall than the coastal basin even in the dry season lasting from May to October.

Fig. 5-5 shows the monthly rainfall distributions at the four gauges at Malino, Bili-Bili intake, Sungguminasa and Ujungpandang where relatively long-term records are available. They show that rain concentrates in the rainy season between November and April. The ratio of rainfall between the rainy and dry seasons is approx. 80% vs. 20%.

4.3 Daily Rainfall

Daily mean rainfall in the Jeneberang river basin is estimated in two parts: one is the basin upstream from Bili-Bili site including the Jenelata river basin, and the other is the basin upstream from Sungguminasa site.

The daily mean basin rainfall is estimated by arithmetical mean method of the daily rainfall data recorded at the gauging stations which are located in respective basins: Malino and Bili-Bili gauges for the upstream area of Bili-Bili, and Malino, Bili-Bili and Sungguminasa gauges for the upstream area of Sungguminasa.

These estimated daily mean rainfalls cover ten years' period in total, four years from 1957 to 1960 and six years from 1975 to 1980. The rainfall data concerning the 14 intermittent years from 1961 to 1974 do not have enough consistence to be used for the purpose because of too much absence of the required figures.

The estimated daily mean rainfall over the two basins in those ten years is compiled in Table 5-8 in a form of monthly total rainfall. The mean annual rainfall during the said period is estimated at 3,856 mm in the upper Bili-Bili basin and at 3,488 mm in the upper Sungguminasa basin.

4.4 Storm Rainfall

Hyetal Area and Rainfall Correlation

Fig. 5-6 shows the daily rainfall distributions over the Jeneberang basin on the occasion of four major floods in the past. They show the daily rainfall distribution in the whole basin as a single hyetal region, though the correlation of the storm rainfall lacks uniformity among Malino, Bonto Bili, Sungguminasa and Ujungpandang.

The maximum one-day rainfall recorded is 235 mm at Malino, 222 mm at Bonto Bili, 259 mm at sungguminasa and 200 mm at Ujungpandang. And the maximum two-days rainfall is 351 mm at Malino, 313 mm at Bonto Bili, 300 mm at Sungguminasa and 353 mm at Ujungpandang.

Frequency Analysis

The duration of storm rainfall is estimated to be within two days on the basis of flood duration recorded at the stream gauges along the Jeneborang river.

Based on this fact, the magnitude of storm rainfall is analyzed by using one-day rainfall as well as two-days rainfall with regard to the upstream from Bili-Bili indluding the Jenelata river basin. The annual extremal series of rainfall is shown in Table 5-9.

The frequency analysis is made on the assumption that the annual extremal rainfall follows the log-normal distribution under the Thomas plotting formula. The annual extremal rainfall figures have been extracted from the estimated daily mean rainfall series over the basin area which are shown in Table 5-9. Fig. 5-10 presents the alignment plotted on the log-normal distribution paper.

The estimation results of the probable rainfall corresponding to different return periods of N-year are compiled in Table 5-10. It shows the two-day rainfalls corresponding to 200 years, 100 year and 50 year respectively at 465 mm, 440 mm and 400 mm.

5. RUNOFF

5.1 Stream Gauging Network and Available Records

Six manual gauges and three automatic gauges have been installed along the Jeneberang river in the downstream reaches from Bili-Bili site. The location of these gauges are shown in Fig. 5-9, and their recording periods are given in Table 5-11.

Stream stage records available at the three gauges; namely, Bili-Bili and Jenelata automatic gauges as well as Kampili manual gauge, are reliable but those at Sungguminasa automatic gauge are unreliable due to very poor operation and maintenance at this specific gauge.

The stream stage records maintained by the other manual gauges appear to be reliable except those at Cowa Paper Mill where measurement is made with the depth of water on the movable sand river bed. However, as shown in Table 5-11, records of manual gauges cover so short a period that they have not been analyzed in this study.

Discharge measurement at the three automatic gauges at Bili-Bili, Jenelata and Sungguminasa has been carried out rather poorly: Sungguminasa gauge has only three records of discharge measurement as of 1981, and the discharge measurement has been conducted at a rate of once a month at Bili-Bili and Jenelata, in the low water condition of the river alone.

At Kampili, stream stage is measured by reading twice a day the staff gauge which is installed at an immediate upstream of the Kampili irrigation weir which has a total span of 100 m. As the reading was started in 1965, its records cover the longest period among all the gauges existing along the Jeneberang river. However, records at the Kampili weir give essential information only of flood discharge and are incomplete to be used for estimation of discharge in low water condition, due to the following reason:

The reading of the staff gauge gives the depth of the water overflowing the said irrigation weir so that the overflowing discharge may be estimated by applying an overflow discharge formula suitable to the weir. This will be discussed in more detail under 5.2: Rating Curve.

In the low water condition, almost all the discharge from the upper stream is diverted into the Kampili irrigation system through the sluice gates which are equipped at an immediate upstream of left side of the weir. The diverted water then flows into a sand trapping pond at whose downstream are provided an overflow type weir to introduce the water into the Kampili main irrigation canal and the sluice gates which are meant for returning an excess water back to the Jeneberang river.

The discharge at the Kampili weir from the upstream is, therefore, given by the sum of the discharge overflowing the weir and flowing into the irrigation canal and the excess water returned to the Jeneberang river.

A staff gauge is installed at the downstream-end of the sand trapping pond and its gauge zero is set at the crest height of the said overflow weir. When the water stage in the sand trapping pond drops lower than the gauge zero, the staff gauge cannot be read because no graduations are notched below zero on the staff gauge. Such situation occurs frequently to make the discharge record at Kampili weir incomplete except at the time of flood.

5.2 Rating Curve

<u>Bili-Bili Gauge</u>

The river cross section at Bili-Bili gauge has a wide rectangular shape with a V-shaped pool at the left portion of the cross section. The discharge measurement has been carried out at Bili-Bili 39 times since 1976. However, such gauging has been done only of the discharge below the V-shaped pool crest. Therefore, there must exist a considerable difference in stage vs. discharge relationship between the said rectangular shaped section and the V-shaped pool section.

To reflect the difference in the river cross section (between the wide rectangular shaped portion and the limited V-shaped pool portion) at the low and high stages into the estimation of the rating curve, the high stage portion is estimated form the stage vs. discharge relationship which has been derived from the non-uniform flow calculation, and the lowstage portion has been estimated on the basis of the gauged stage vs. discharge relationship. The non-uniform calculation has been carried out under 400 m interval of the river cross sections.

The rating curve thus studied may be given by two parabolic equations as indicated below. One stands for the rating curve applicable to a period between 1976 and 1979 and the other to a period between 1979 and 1981.

$$Q = 118.8\ (H + 0.33)^2 \ \ldots\ 1976 - 1979$$
$$Q = 118.8\ (H - 0.27)^2 \ \ldots\ 1979 \text{ to date} \qquad \cdots\cdots(5.1)$$

where

Q: Discharge at Bili-Bili in m^3/s

H: Gauge reading above gauge zero reset in Sept. 1979*

Note: *Gauge zero was dropped by 0.6 m in Sept. 1979 due to bank scoreing at the site.

Jenelata Gauge

The discharge measurement at Jenelata site has been conducted 23 times since 1979. The results show that the river-bed is stable, and the gauging range has also been limited to the low stage of the river water. The estimated rating curve is shown in Equation (5.2); however, it should be noted that the rating curve has low accuracy for estimating the discharge at high stream stage.

$$Q = 20.58\ (H - 0.38)^2 \quad H < 1.53 \text{ m} \quad \text{Jan. 1977 to date}$$
$$Q = 56.25\ (H - 0.83)^2 \quad H \geq 1.53 \text{ m} \quad \ldots\ldots\ (5.2)$$

Kampili Gauge

The discharge overflowing the Kampili weir may be given in Equation (5.3). The coefficient in the equation is confirmed to be 2.0, based on the field observation at Kampili and Sungguminasa. The field observation consisted of staff gauge reading at Kampili weir, and simultaneous discharge measurement at Sungguminasa site. Six discharge measurements were carried out between March 2 and March 7, 1981 by using current meter and floating rod methods to attain accurate measuring.

There was no rainfall over the area between Kampili and Sungguminasa, not only during the measuring period but also for several days prior to the measurement. This fact was affirmed by the survey team's hydrologist who visited these two sites frequently for preparation as well as checking of the observation. It appears that the measured flood was generated by rainfall in a further upstream of the Kampili site.

The continuous fair days made the lateral inflow from the area (49.3 km^2) extending between the two sites negligibly small. Thus, the discharge observed at Sungguminasa site is assumed to be almost equal to that at Kampili site.

Based on such a reasonable assumption, gauged discharge at Sungguminasa and simultaneously measured overflow depth at Kampili weir are substituted into those of Equation (5.3) to estimate the coefficient in the equation. The results are compiled in Table 5-12 and the estimated C value is 2.0 on an average.

$$Q = C \cdot BH^{1.5} \quad \text{.........................} \quad (5.3)$$

where

Q: Overflow discharge from Kampili weir in m^3/s

C: Coefficient of overflow discharge; C = 2.0

B: Width of Kampili weir; B = 100 m

H: Overflow depth above the crest in meters

Sungguminasa Gauge

At Sungguminasa gauge, three discharge measurements were made since 1979. The survey team conducted six discharge measurements at Sungguminasa site in view of supplementing and checking the coefficient of overflow discharge from the Kampili weir.

The rating curve at this site is estimated on the basis of the discharge measurement results and the stage vs. discharge relationship has been estimated by non-uniform calculation around the site.

The result is given in flowing equation.

$$Q = 30.67 (H + 0.16)^2 \; ..... \text{ May 1980 to date} \quad (5.4)$$

where

Q: Discharge in m^3/s

H: Gauge reading above gauge zero in m. Gauge zero is 3.539 m above M.S.L.

5.3 Long-Term Runoff

Although water resources development planning usually requires the continuous runoff records of minimum ten years, the restrictions from the length of the recorded water stages and non-availability of rating curve cannot satisfy such requirement. To solve this problem, therefore, a runoff simulation model on the basis of so-called "Tank Model Method" has been applied to generate ten years' runoff series. The number of tank stages for the tank model method was three. The size and location of the holes on the tanks have been calibrated to generate an estimated runoff series which best fits to the observed runoff series.

The calibration was made at Bili-Bili site. Two kinds of observed data have been provided for calibration:

1) The basin mean rainfall covering 10 years between 1957-1960 and 1975-1980 (refer to 4.3).

2) The daily mean discharge at Bili-Bili which has been estimated from the rating curves between 1974 and 1980.

After several trials, the size and location of holes on the tanks were determined.

The daily mean discharge series at Bili-Bili has been obtained for the said ten years by use of the runoff simulation model mentioned in the above paragraph, and its results are tabulated in the form of montly mean discharge in Table 5-13.

6. FLOOD

The flood analysis has been done to construct a model hydrograph of potential floods at the Bili-Bili site. For constructing such a model hydrograph, the flood records at Bili-Bili and Kampili sites were utilized as follows:

The records at the Bili-Bili gauge, where the actual flood hydrographs are available, have been used to estimate the distribution of discharge in the model hydrograph.

The flood records at the Kampili gauge were used to estimate the probable peak discharge on the model hydrograph on the ground that they cover a longer period than those at Bili-Bili.

Although actual flood records were also obtainable from the Jenelata automatic gauge, they were not used for estimation because of insufficient record volume.

6.1 Probable Discharge

Kampili Site

The annual maximum water stages have been selected from the daily data which were converted to the annual maximum discharges based on the rating curve specified in the former section. The result is shown in Table 5-14.

The probable discharges have been determined from the frequency curve which was set by plotting the annual maximum discharges on the log-normal distribution paper.

Frequency curve of the flood discharge and probable discharge at Kampili are shown in Fig. 5-10 and Table 5-15, respectively.

The above-mentioned table also shows the probable discharge after flood controlling by proposed Bili-Bili dam, description of which is given in the following Chapter on "DAM AND RESERVOIR."

Bili-Bili Site

As the length of the annual maximum water stage recording at Bili-Bili site is shorter than that at Kampili site, the data at Bili-Bili site above been judged insufficient to carry out the frequency analysis for the probable discharge.

To conqure the problem encountered, the flood peak water stages at Bili-Bili have been estimated through the correlation of the water stages between Bili-Bili and Kampili sites. Such relationship was constructed on the basis of the major flood peak records at high water stage above one meter during 1977 and 1980. The correlation is expressed in the following formula (refer to Fig. 5-11):

$$HB = 0.57\ HK - 0.32 \quad \text{.................. (6.1)}$$

Where:

HB = Water stage at Bili-Bili above gauge zero in meter

HK = Water stage at Kampili above the crest height in meter

The equation is applied to estimate flood peak stage at Bili-Bili site prior to 1977, based on the recorded major flood peak stages at Kampili which had more than three meters in overflowing depth.

The estimated flood peak water stages at Bili-Bili are then converted into the discharges based on the rating curve at Bili-Bili site. The results are shown in Table 5-16. The ratio of the peak discharge of the simultaneous flood is 0.65 for Bili-Bili against 1.0 for Kampili, on an average. Therefore, the probable discharge at Bili-Bili may be estimated by multiplying 0.65 on the Kampili probable discharge, as shown in Table 5-12.

This multiplier of 0.65 is different from 0.75 specified in the previous hydrological study carried out in 1979. This is due to the modification made to the estimated water stage at Bili-Bili, based on the non-uniform calculation during the present survey.

6.2 Flood Hydrograph

Various runoff models may be applicable for constructing design hydrograph of any particular river basin. They need information on hourly rainfall behaviour over the basin which is hard to obtain in case of the Jeneberang river basin due to very limited rainfall gauges there.

Another approach to construct design hydrograph is to estimate, on the basis of the observed flood information, a model hydrograph of flood in which the peak discharge, the flood volume and the base flow should be properly evaluated.

Thus, flood analysis of the Jeneberang river is carried out through construction of model hydrograph, not based on runoff model.

Model Hydrograph

The shape of the model phdrograph at Bili-Bili, Jenelata and Kampili is estimated by actual hydrograph observed at Bili-Bili site.

The observed flood hydrographs of the five major floods are expressed in non-dimensional form in which discharge at arbitrary time in the flood hydrograph is divided by the flood peak discharge.

By taking the averages of both rising and falling limbs of the non-dimensional hydrographs, and by neglecting exceptional cases, the distribution of a model flood hydrograph has been decided as shown in Fig. 5-12.

Base flow of the model hydrograph corresponding to the 50-year flood at Bili-Bili is given a rather modest figure of 300 m^3/s, by taking the average of discharges which occur at the beginning of the flood rising limbs of the major floods (refer to Table 5-17).

The model hydrographs of Jenelata and Kampili have been compounded from the hydrographs at Bili-Bili on the following assumptions;

a. The hydrograph of Jenelata is assumed to flow out one hour earlier than that of Bili-Bili, which was calculated in the previous report (refer to "Lower Jeneberang River Flood control Project, Supporting Report, Chapter HYDROLOGY");

b. The peak discharge at Bili-Bili is assumed at 65% or that at Kampili. This ratio is specified in the former seciton;

c. The peak discharge at Jenelata is assumed at 59% of that at Bili-Bili, correspondingly to the areawise percentages of Jenelata catchment (226.3 km^2) and Bili-Bili catchment (384.4 km^2) and

The estimated model hydrographs of Bili-Bili, Jenelata and Kampili in non-dimensional form of discharge are shown in Fig. 5-13.

<u>Flood Hydrograph Corresponding to Different Return Periods</u>

Based on the model flood hydrograph, the flood hydrograph corresponding to particular return period may be estimated by multiplying the distribution ratio obtained in the model hydrograph on the probable flood peak discharge corresponding to each return period.

The flood hydrographs thus constructed at Bili-Bili and Kampili for the return periods of 20, 50 and 100 year are shown in Fig. 5-14.

<u>Verification of Estimated Flood Hydrographs</u>

Since the foregoing flood hydrographs are obtained from the peak discharge of the flood and the non-dimensional hydrograph figure, the appropriateness of such hydrographs may need to be further verified from the flood volume.

The direct runoff flood volume at Bili-Bili, from which the basic flow volume has been deducted, is calculated for different return periods.

The direct runoff depth of flood which lasts for 2 days is compared with the corresponding rainfall depth for 2 days, as shown below:

Probable Year	(1) Rainfall Volume mm	(2) Flood Volume mm	Ratio (2)/(1)
1000	660	494	0.75
50	400	276	0.69
20	325	218	0.67

Consequently, the flood volume is about 70% of the probable 2 days' rainfall volume.

Since this is near equivalent of the discharge ratio (f=0.7) obtained during the previous survey, the appropriateness of the model hydrograph is verified.

7. SEDIMENT

7.1 River Bed Material

Bed material of the Jeneberang river varries from fine sand in the estuary to cobble around Bili Bili site. The cumulative grain size curve of the bed material sampled at eight different places from the estuary to the Bili-Bili sites are shown in Fig.5-15. It shows that mean grain size of the bed material is smaller than 1.0 mm in the downstream of the Kampili weir, while larger than 50.0 mm in its upstream At Bili-Bili site, the mean grain size is approx. 100 mm.

7.2 Sediment Yield

According to the field investigation, it is observed that the majority of the sediments may originate at the upper reaches of the Jeneberang river which is dotted with the collapse area.

The quantity of sediments has already been studied under the "Lower Jeneberang Flood Control Project". The said study was based on the observation of sediments deposited at the Jeneberang river estuary and the exmerimental fromulae, which is judged to be effective to estimate the average annual sediment yield. The sediment discharge measurement on suspended and bed loads in the river is also enumerated as the method to grasp the sediment yield, however, it is virtually difficult to comprehend the average annual sediment yield on a long term, through the continuous measurement for a short period.

There are two survey sea charts of the Jeneberang river estuary; one was surveyed in 1,900 and another in 1979. (The later survey was conducted by the JICA Survey Team.)

The transition of the shore lines and the depth contour lines are shown in Fig.5-16. According to Fig.5-16, the depth of seabed is recognized to have been made shallow by sediments transported by the Jeneberang river during 79 years from 1,900 to 1,979 and the total volume of sediments is calculated to be around 60 x 10^6 m^3, which may correspond to 0.76 x 10^6 m^3/year in average annual sediment yield (= 60,000,000m^3/79years).

As for the spcific sediment yield, the annual average of the whole catchment area (727 km^2) is calculated at 1,049 m^3/km^2/year (= 0.79 x $10^6 m^3/727km^2$). The annual specific sediment yield in the upper reaches of the propose Bili-Bili dam (384km^2) may be bigger than that of the whole catchment area, because the majority of sediments originate at the upper reaches of the Jeneberang river as described above. That is to say, the annual specific sediment yeild of the Bili-Bili dam site will be within the limits or from 1,094 m^3/km^2/year to 1,978 m^3/km^2/year (that is calculated assuming all sediment deposit of 60 x 10^6 m^3 originates on the upper reaches of the Bili-Bili dam site).

The said specific yeild ranging from 1,094 m^3/year/km^2 to 1,078 m^3/year/km^2 is verified by the experimental formula. According to the study of the "Lower Jeneberang River Flood Control Project", the figure of 1,429 m^3/km^2/year is recommended as the annual specific yeild in the upper reaches by the Ezaki's formula (refer to the supporting report of "SABO AND SOIL CONSERVATION" under "Lower Jeneberang River Flood Control Project").

Consequently, the annual specific sediment yield of the upper reaches of the Bili-Bili dam may be set up at around 1,500 m^3/year/km^2 which is said in a round figure of 1,429 m^3/km^2/year, and also be within the limits from 1,094 m^3/km^2/year to 1,978 m^3/year/km^2. This volume of 1,500 m^3/year/km^2 is also compared with the sediment in other reservoirs of Indonesia and judged to be applicable.

Karankates dam (the Brantas R.):	980-1,460 m^3/km^2/year
Selorejo dam (the Kalikonto R.):	850-1,700 m^3/km^2/year
Wonogiri dam (the Sala R.) :	1,170 m^3/km^2/year

- ANNEX -

PROPOSED SITES FOR RAINFALL GAUGING

As described in Chapter 4.1, there are existing 24 (twenty four) rainfall gauging stations in and around the Jeneberang river basin. Most of them, however, are located on the coastal lowland except the one at Malino in the upper reaches of the Jeneberang river, and none is found in the Jenelata river basin.

Under the circumstances, a big difference in the rainfall amount can be observed between those recorded at the station which is situated at higher altitude and those on the lowland. While the said Malino station which stands at an altitude of about 1,500 m above. M.S.L. records 4,000 mm annual mean rainfall, the gauges located on the lowland show the annal rainfall ranging from 2,000 to 3,000 mm only.

The above-mentioned fact suggests that several additional rainfall gauging stations need to be installed in the upper reaches of the Jeneberang river as well as in the Jenelata river basin, to raise the accuracy of rainfall estimation over the area.

In this connection, a study on the necessary number and the desirable location of additional rainfall gauging stations has been made with the following results:

As for their density, it would be necessary that each station should be given at least 100 km^2 to 200 km^2 as its coverage to adequately comprehend the monthly and yearly rainfall in the subject area.

As for their location, an easy accesibility to each one of them is essential to ensure proper maintenance of the gauge, and then it is important not to concentrate stations on a similar altitude nor in the regions closely resembling among each other in their topographic conditions.

In consideration of the above, the following new rainfall gauging stations are recommended (their location is shown in Fig. 5-1 (AN)):

Two stations in the upper reaches of the Jeneberang river, the one at the point 26 km and the other at the point 44 km, away from the Bili-Bili dam-site, at respective altitude of approx. 260 m and 300 m above M.S.L.

Another two stations in the Jenelata river basin, the one at the point of 28 km and the other at the point of 16 km, from the Bili-Bili dam-site, at respective altitude of approx. 260 m and 300 m above M.S.L.

All the stations recommended in the above are located in the villages already existing along the Jalan Malino or its branch roads (the names of the new stations in Fig. 5-1 (AN) are from the names of respective villages involving these stations).

In this way, three rainfall gauging stations including the existing Malino station will cover the area of 384 km^2 in the upper reaches of the proposed Bili-Bili dam site, and two stations which will be newly established in the Jenelata river basin will cover an area of 226 km^2.

Consequently, each station will cover an average extent of around 100 km^2; 128 km^2 in the upper reaches of the proposed Bili-Bili dam site, and 113 km^2 in the Jenelata river basin. This-much average covering area per station will have to be maintained in order to adequately comprehend the monthly and yearly basin mean rainfall, and it is deemed sufficient in comparison with rainfall station's covering area in other districts of Indonesia.

Table 5-1 METEOROLOGICAL STATIONS AND OBSERVATION ITEMS

Station	Operation start	Temperature	Rainfall	Sunshine	Humidity	Wind	Evaporation	Location
Maros	1975	o	o	o	o	-	o	Outside of basin
Makassar	1971	o	o	o	o	o		"
Panakukkang	1971	o	o	o	o	-	-	"
Bonto Sunggu	1977	o	o	o	o	o	o	Inside of basin
Bonto Bili	1980					o		"
Malino	1975	-	o	-	-	-	-	"

Note: o Records available
- Records inavailable

Table 5-2 MONTHLY MEAN TEMPERATURE

(Unit: °C)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Maros	26	26	27	27	28	27	27	27	28	28	27	27	27.1
Makassar	26	26	26	26	26	26	26	26	27	27	27	26	26.3
Panakukkang	25	25	26	26	26	26	25	26	26	27	27	26	26.0
Bonto Sunggu	27	26	26	27	27	27	26	26	27	27	28	27	26.7

Table 5-3 MONTHLY MEAN HUMIDITY

(Unit: %)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Maros	87	87	87	84	83	81	78	69	77	79	83	83	81.5
Makassar	85	85	84	81	82	77	75	70	70	74	80	84	78.9
Panakukkang	87	87	86	83	82	80	77	71	71	71	77	86	80.0
Bonto Sunggu	93	94	94	93	93	92	90	91	89	88	89	93	91.7
Bonto Bili	93	95	94	92	93	92	90	92	88	87	89	93	91.3

Table 5-4 MONTHLY MEAN WIND VELOCITY

(Unit: m/s)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Makassar	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4
Bonto Sunggu	1.3	0.9	0.7	0.6	0.7	0.8	0.7	0.8	1.0	1.2	1.1	1.1	0.9
Bonto Bili	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1

Table 5-5 MONTHLY MEAN SUN-SHINE HOUR

(Unit: hour)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Panakukkang	4.5	3.7	4.2	7.5	7.3	7.4	8.4	9.7	8.5	8.6	8.2	3.5	6.6
Makassar	5.3	5.6	6.1	8.5	8.9	9.3	9.6	10.5	9.8	9.5	8.1	5.8	8.0
Bonto Sunggu	4.2	4.4	5.6	7.0	7.5	5.9	7.7	9.2	10.0	8.9	5.8	4.2	6.7
Bonto Bili	3.6	3.8	5.0	6.5	7.0	7.0	7.2	8.9	9.7	8.5	5.4	3.6	6.4

Table 5-6 MONTHLY MEAN EVAPORATION

(Unit: mm/day)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Maros	3.9	3.5	3.7	4.2	3.9	4.1	4.7	3.9	4.7	4.4	3.5	2.8	3.9
Bonto Sunggu	4.3	3.6	4.2	4.6	3.8	3.6	3.6	4.1	5.5	6.0	5.9	4.4	4.5

Table 5-7 MONTHLY MEAN RAINFALL IN AND AROUND STUDY AREA

(mm)

REF. NO.	STATION	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1	Salojirang	858	702	586	241	170	117	78	31	87	189	352	682	4093
2	Batu Bassi	642	388	629	259	215	119	67	24	81	73	403	577	3477
4	Ujung Pandang	688	513	384	109	67	61	0	2	0	5	37	640	2506
5	Senre	747	730	394	274	146	87	29	21	56	141	328	561	3514
6	Sungguminasa	679	596	464	151	113	55	43	11	39	76	242	614	3083
7	Borongloe	789	720	333	215	136	74	14	23	31	118	183	563	3201
8	Kampili	675	467	298	138	82	79	42	22	43	95	202	421	2564
9	Intake Bili-Bili	835	798	405	255	139	77	77	30	32	65	340	623	3676
11	Malino	895	724	532	332	210	164	91	38	40	113	286	577	4002
12	Julu Bori	634	677	433	179	106	44	22	9	36	43	178	441	2802
14	Mandalle	789	713	311	94	119	66	30	12	21	52	165	696	3068
15	Bontokassi	539	578	355	117	65	37	21	6	15	62	157	499	2451
16	Campagaya	974	608	388	131	186	54	32	11	25	56	149	656	3270
17	Maccini Baji	771	674	417	176	108	48	27	16	55	64	208	436	3002
18	Kalabajeng	779	658	387	191	157	87	21	12	41	56	179	611	3179
19	Tamalayang	848	439	387	175	115	62	23	12	42	56	174	465	2798
20	Bonto Salang	799	803	439	128	58	51	21	6	28	59	178	566	3136
21	Bonto Langkasa	819	609	332	133	79	61	14	3	9	16	125	509	2707
22	Sanro Bone	531	438	196	138	65	54	14	5	13	21	65	304	1844
23	Tetebatu Cambaya	1089	964	521	227	145	101	24	15	27	93	241	831	4278
24	Palleko	869	541	247	196	83	41	26	14	22	15	175	443	2672
25	Bajeng	775	522	307	167	107	42	13	3	37	8	213	459	2653
26	Jenemarung	887	793	1114	234	71	78	26	24	24	243	225	396	4115
27	Lengkese	718	574	177	106	112	44	32	4	4	21	142	376	2310

Table 5-8 BASIN MEAN MONTHLY RAINFALL (1)

(Upstream Area from Bili-Bili Site)

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1957	537	918	575	221	200	102	88	126	0	10	241	659	3677
1958	487	571	449	306	344	220	65	66	47	137	279	689	3660
1959	925	364	729	311	429	185	101	0	42	11	227	740	4064
1960	779	868	303	285	386	72	64	44	42	0	406	376	3625
1975	527	501	467	562	245	143	82	51	90	123	544	604	3939
1976	828	642	627	137	137	46	24	1	0	155	258	255	3110
1977	1063	1470	501	474	124	214	0	21	0	1	250	617	4735
1978	605	575	373	211	270	182	290	71	108	129	298	777	3889
1979	814	612	506	265	204	132	14	0	7	37	181	698	3470
1980	721	941	648	496	209	50	8	12	0	128	319	856	4388
Mean	729	746	518	327	255	135	74	39	33	73	300	627	3856

Table 5-8 BASIN MEAN MONTHLY RAINFALL (2)

(Upstream Area from Sungguminasa Site)

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1957	508	851	455	155	144	68	64	94	0	15	212	627	3193
1958	434	491	376	204	229	146	47	44	39	113	246	651	3020
1959	836	290	700	274	305	202	110	0	28	10	193	694	3642
1960	759	781	291	239	362	62	52	32	45	0	431	320	3375
1975	522	436	445	430	187	105	80	44	92	166	490	575	3572
1976	830	602	545	93	106	45	16	1	0	132	281	319	2970
1977	1128	1408	393	405	90	174	0	15	0	1	193	511	4313
1978	585	556	353	214	296	177	225	58	122	105	250	737	3678
1979	746	553	457	239	184	120	13	0	6	33	164	631	3146
1980	652	851	586	448	189	45	7	11	0	115	288	774	3966
Mean	700	683	460	270	209	114	61	30	33	69	275	584	3488

Table 5-9 ANNUAL MAXIMUM RAINFALL
(Upstream Basin from Jeneberang
and Jenelata Confluence)

Rank	1 - day Rainfall		2 - day Rainfall	
	Date	Rainfall volume mm	Data	Rainfall volume mm
1	1960 - 2 - 25	202	1953 - 2 - 5, 6	295
2	59 - 1 - 8	174	77 - 1 -23,24	234
3	53 - 2 - 6	163	60 - 2 -25,26	227
4	77 - 1 - 24	146	59 - 1 - 8, 9	214
5	76 - 1 - 12	125	76 - 1 -12,13	196
6	56 - 1 - 16	123	78 - 1 -11,12	190
7	73 - 1 - 22	102	79 - 1 - 9,10	189
8	78 - 1 - 11	98	56 - 1 -15,16	182
9	79 - 1 - 9	94	73 -11 -23,24	129
10	58 - 1 - 4	92	58 - 1 - 3, 4	104
11	54 - 1 - 27	69	54 - 1 -26,27	91
12	75 - 1 - 13	60	75 - 1 -14,15	83

Table 5-10 PROBABLE RAINFALL
(Upstream Basin from Jeneberang
Jenelata Confluence)

Return Period (year)	1-day Rainfall (mm)	2-day Rainfall (mm)
200	321	465
100	302	440
50	271	400
20	229	325
10	197	280
5	146	230
2	113	115

Table 5-11 WATER STAGE RECORDING PERIOD

Ref. No.	Station	Guage	Years in 1900															
			65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	Tompo Bulu	R													I	C	C	C
2	Tamalate	M															I	C
3	Sungguminasa	R															I	I
4	Sungguminasa	M															I	I
5	Gowa Paper Mill	M													C	C	C	C
6	Kampili	M	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
7	Bili-Bili Intake	M															I	I
8	Bili-Bili	R										I	C	I	C	C	C	C
9	Jenelata	R															I	C
10	Jenelata	M													I	C	C	C

Note: Gauge: R = Recording M = Staff gauge read manually

Record: C = Complete I = Incomplete

Table 5-12 COEFFICIENT OF OVERFLOW DISCHARGE

Date in 1981	Staff gauge reading (m)	Overflow depth (m)	Measured discharge (m^3/s)	Coefficient (C)
Mar. 2	2.75	1.85	509.8	2.01
Mar. 3	2.86	0.96	184.8	1.95
Mar. 4	1.48	0.58	88.1	2.00
Mar. 5	1.47	0.57	87.7	2.05
Mar. 6	1.37	0.47	66.7	2.06
Mar. 7	1.29	0.39	51.6	2.08

Table 5-13 MONTHLY AVERAGE DISCHARGE OF JENEVERANG AT BILI-BILI AND KAMPILI SITES

(1) Bili-Bili site (Unit: $m^3/sec.$)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1957	58.7	100.0	64.6	32.9	14.5	9.8	4.3	8.2	2.3	2.1	7.3	64.3
1958	57.5	65.3	44.5	30.7	37.2	8.9	14.0	2.7	2.9	8.1	17.0	58.8
1959	116.3	40.1	76.0	37.6	32.1	28.0	7.6	2.6	3.1	2.3	11.4	76.5
1960	71.8	112.6	34.9	25.8	38.8	8.5	5.1	3.4	2.6	2.3	24.7	41.8
1975	54.1	57.5	51.2	53.6	28.8	10.8	4.7	3.6	2.6	4.0	41.8	68.2
1976	94.8	69.4	68.8	16.6	13.8	2.9	2.8	2.6	2.3	7.7	17.5	24.1
1977	112.6	176.4	60.0	53.1	11.7	20.3	2.7	2.6	2.4	2.2	17.1	64.1
1978	67.5	64.7	35.3	21.1	22.3	16.1	27.5	6.7	4.3	4.4	20.6	76.1
1979	98.7	58.4	61.2	25.6	22.3	10.7	2.7	2.5	2.4	2.4	7.1	70.8
1980	85.7	106.3	73.6	49.3	20.8	5.3	2.6	2.4	2.3	6.8	21.5	85.8
Ave.	81.8	85.1	57.0	34.6	24.2	12.1	7.4	3.7	2.7	4.2	18.6	63.1

(2) Kampili site (Unit: $m^3/sec.$)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1957	95.2	162.2	104.8	53.4	23.5	15.9	7.0	13.3	3.7	3.4	11.8	104.3
1958	93.3	105.9	72.2	49.8	60.3	14.4	22.7	4.4	4.7	13.1	27.6	95.4
1959	188.6	65.0	123.3	60.9	52.1	45.4	12.3	4.2	5.0	3.7	18.5	124.1
1960	116.4	182.6	56.6	41.8	62.9	13.8	8.3	5.5	4.2	3.7	40.1	67.8
1975	87.7	93.3	83.0	86.9	46.7	17.5	7.6	5.8	4.2	6.5	67.8	110.6
1976	153.7	112.6	111.6	26.9	22.4	4.7	4.5	4.2	3.7	12.5	28.4	39.1
1977	182.6	286.2	97.3	86.1	18.9	32.9	4.4	4.2	3.8	3.6	27.7	104.0
1978	109.5	104.9	57.3	34.2	36.2	26.1	44.6	10.9	7.0	7.1	33.4	123.4
1979	160.1	94.7	99.3	41.5	36.2	17.4	4.4	4.1	3.9	3.9	11.5	114.8
1980	138.9	172.4	119.4	79.9	33.7	8.6	4.2	3.9	3.7	11.0	34.9	139.2
Ave.	132.7	138.0	92.4	56.1	39.2	19.6	12.0	6.0	4.4	6.8	30.2	102.3

Table 5-14 ANNUAL MAXIMUM DISCHARGE AT KAMPILI WEIR

Year	Annual maximum overflow depth gauge Zero	Annual maximum discharge
1966	3.69 m	1,409 m^3/s
1967	6.55	3,352
1968	3.63	1,378
1969	2.86	964
1970	2.42	750
1971	2.09	602
1972	2.70	881
1973	1.60	401
1974	3.74	1,441
1975	2.70	881
1976	2.75	909
1977	4.84	2,121
1978	3.30	1,194
1979	2.80	937
1980	3.30	1,199

Table 5-15 PROBABLE DISCHARGE

Return period (year)	Bili-Bili (384.4 Km^2)		Kampili (623.9 Km^2)	
1,000	4,300 m^3/s	(2,650) m^3/s	6,600 m^3/s	(4,250) m^3/s
200	3,250	(1,950)	5,000	(3,150)
100	2,800	(1,700)	4,200	(2,600)
50	2,400	(1,400)	3,700	(2,300)
20	1,850	(1,000)	2,850	(1,750)
10	1,650	(950)	2,500	(1,550)
5	1,200	(700)	1,850	(1,250)
2	750	(550)	1,150	(1,000)

Note: Figures in parenthese present the dicharge with dam regulation

Table 5-16 PEAK DISCHARGE RATIO

Year	Kampili Point		Bili-Bili Point		Ratio
	Water Stage	Discharge (1)	Water Stage	Discharge (2)	(2)/(1)
		m^3/s		m^3/s	
1966	3.69	1,409	2.42	900	0.64
1967	6.55	3,352	4.05	2,180	0.65
1968	3.63	1,378	2.39	860	0.62
1974	3.74	1,441	2.45	900	0.63
1977	4.84	2,121	3.02	1,300	0.62
1978	3.52	1,320	2.43	920	0.69
1979	2.80	937	1.92	610	0.69
1980	3.30	1,199	2.70	680	0.57
Mean	-	-	-	-	0.65

Table 5-17 BASE FLOW DISCHARGE AT BILI-BILI

Flood	Water Stage	Discharge	Remarks
1975	1.36 m	339 m^3/s	
1976	1.14	256	
1977	1.67	457	January flood
1977	1.30	315	February flood
1978	0.75	139	
1980	1.76	263	
Mean	-	295 ≑ 300	

Note; Stage and discharge is figures in the beginning of flood rising limb of the major floods.

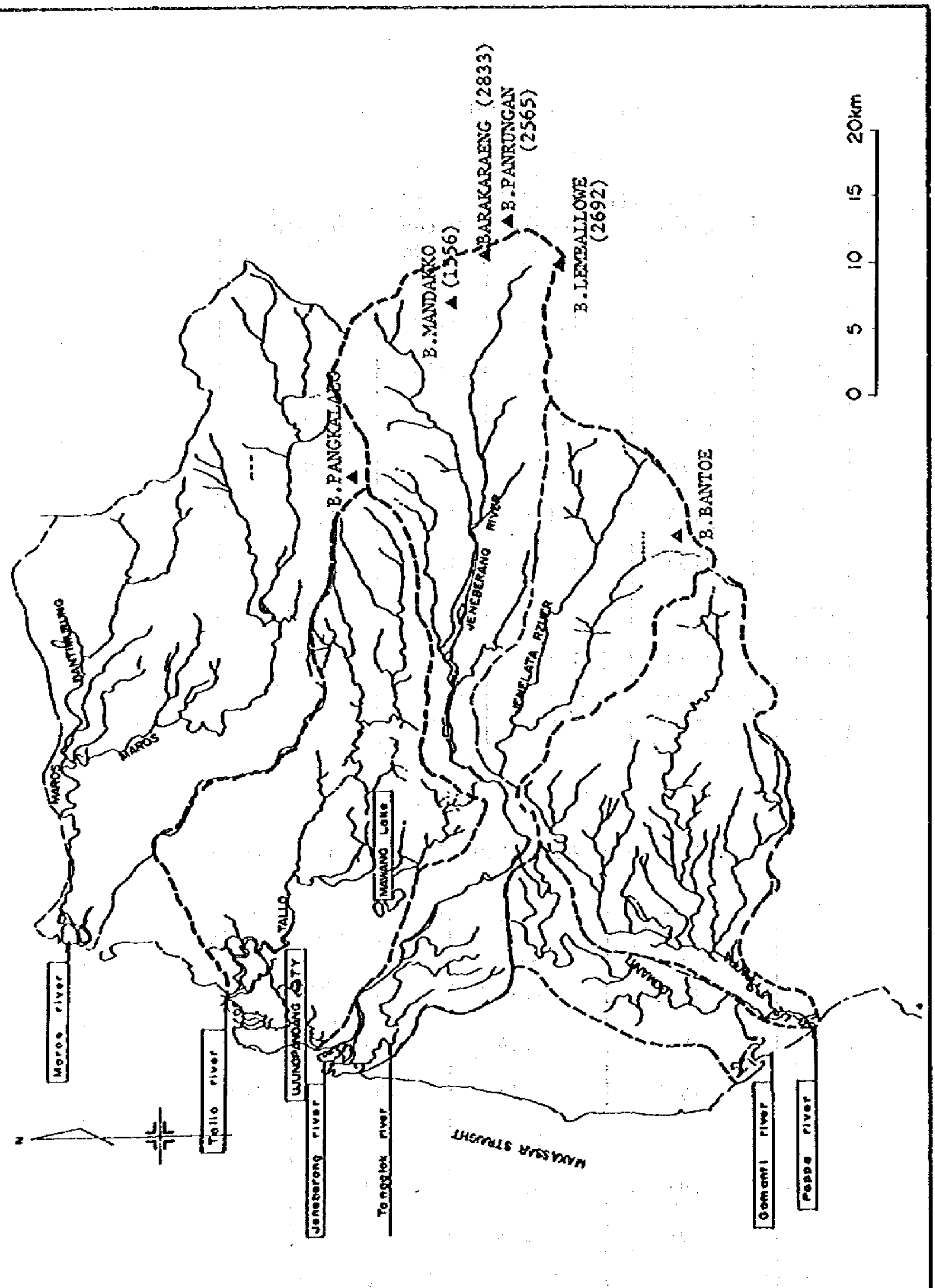


Fig. 5-1

RIVER SYSTEMS AROUND
JENEBERANG RIVER

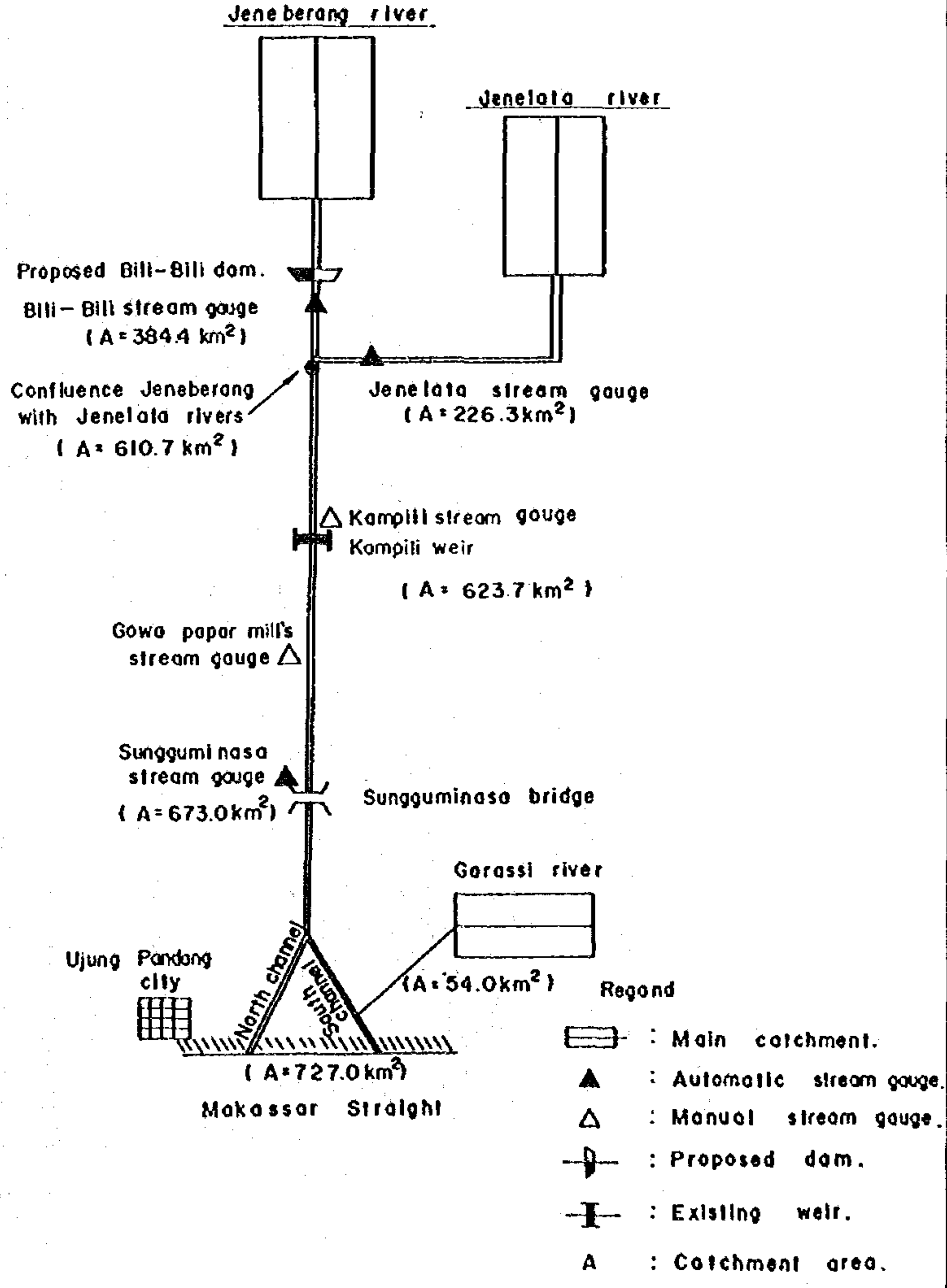


Fig. 5-2

SCHEMATIC DIAGRAM OF
JENEBERANG RIVER

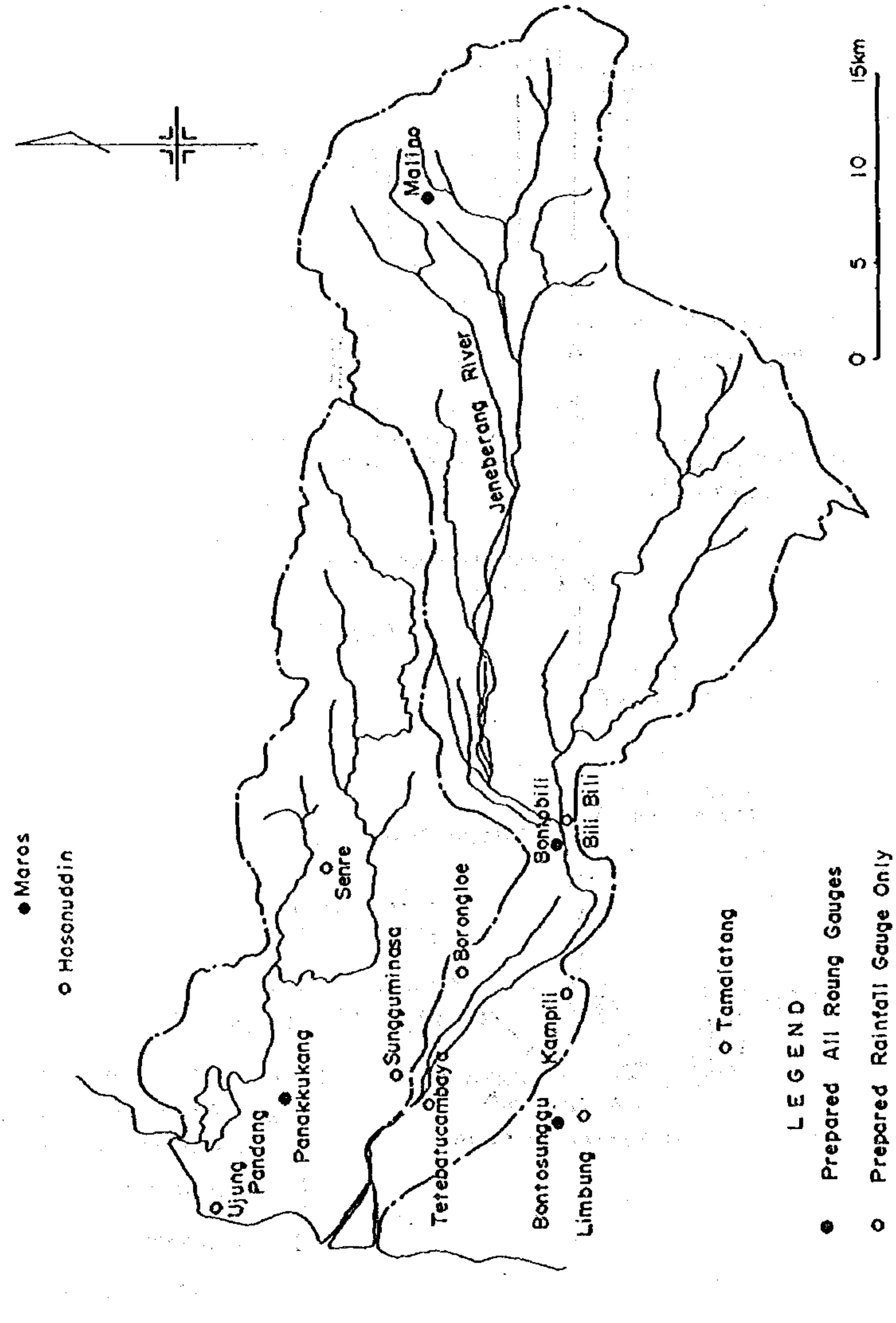


Fig. 5-3

LOCATION MAP OF METEOROLOGY STATION

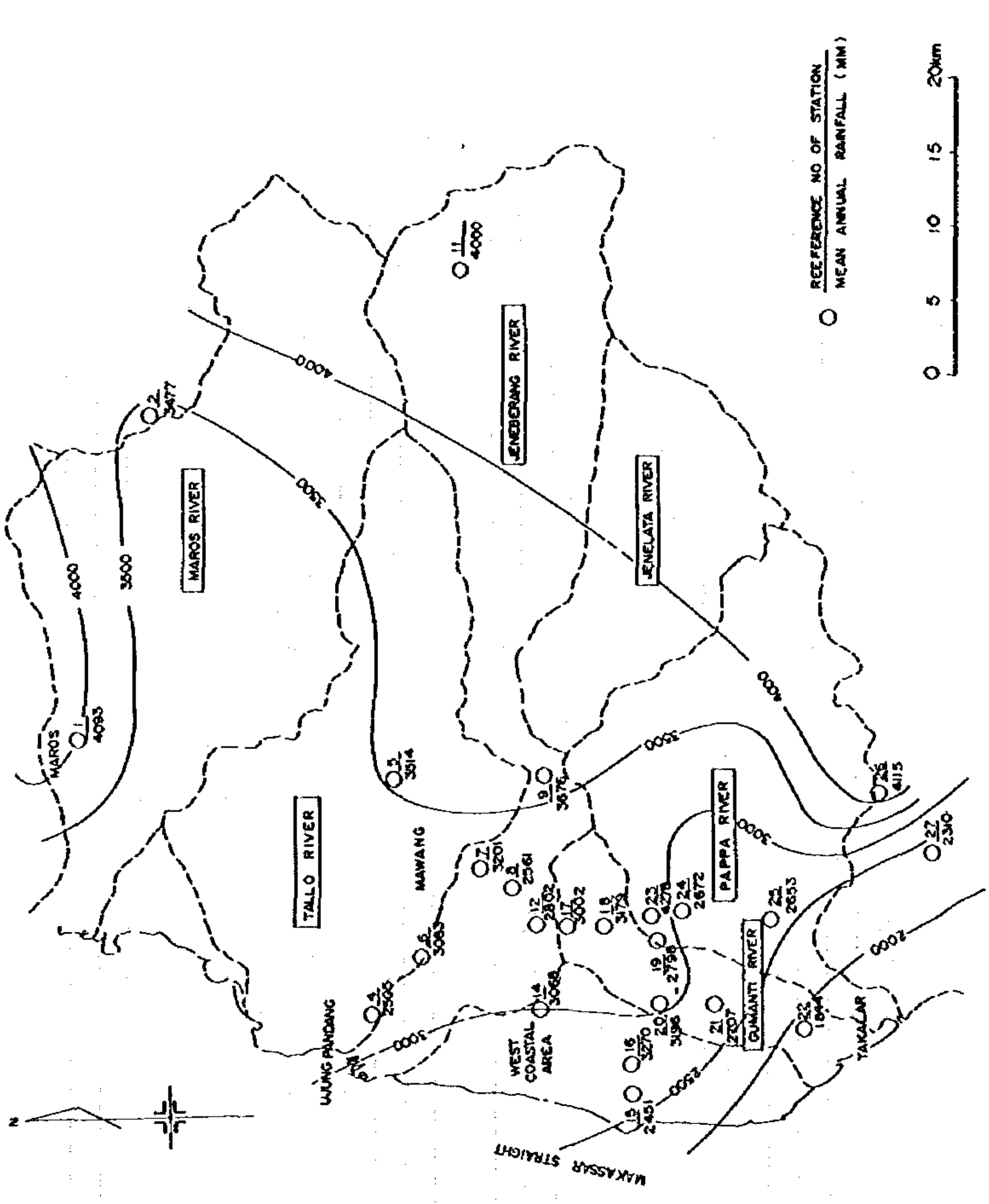


Fig. 5-4

LOCATION OF RAINFALL STATION AND ISOHYTAL OF MEAN ANNUAL RAINFALL

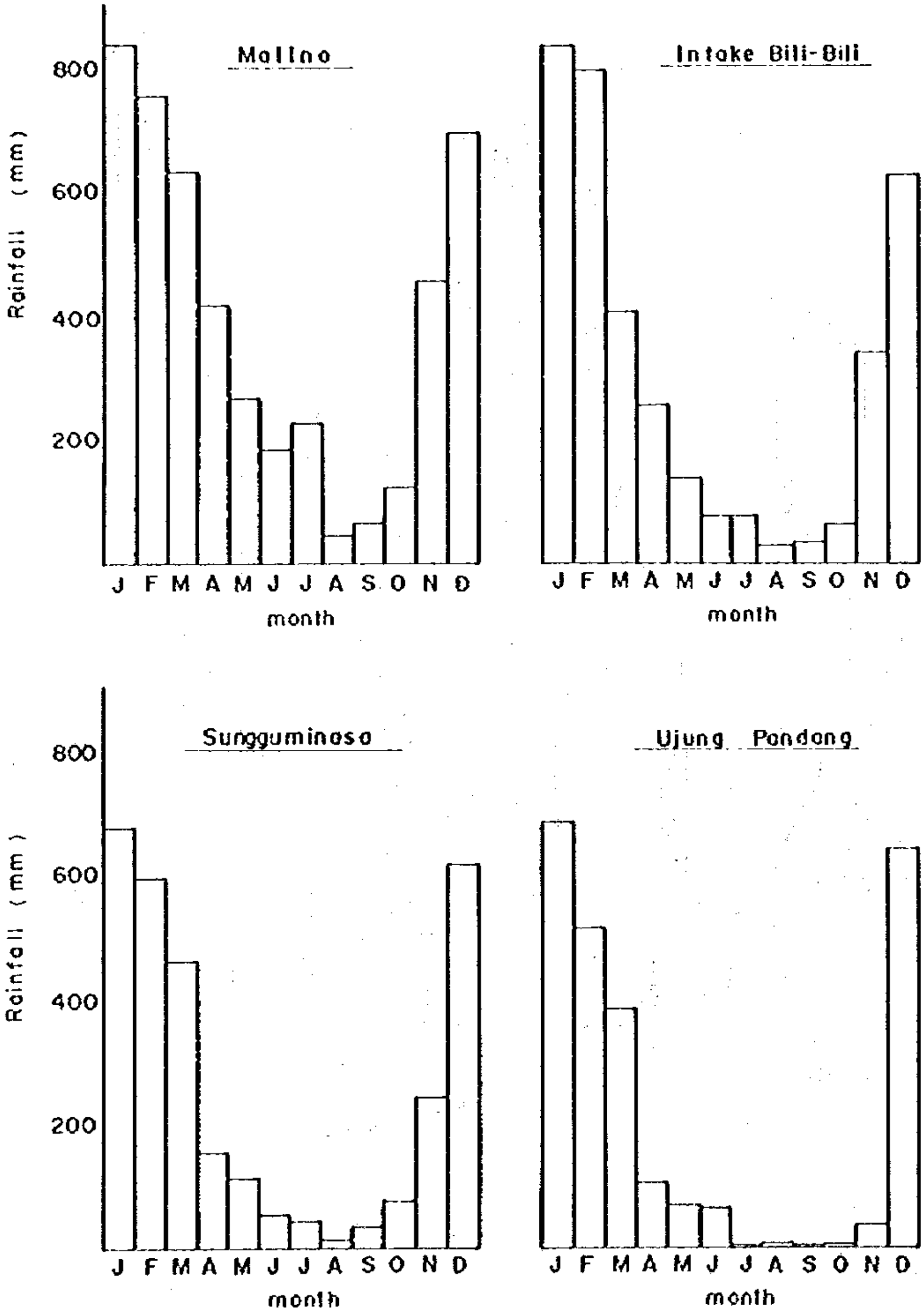


Fig. 5-5

MONTHLY RAINFALL DISTRIBUTIONS

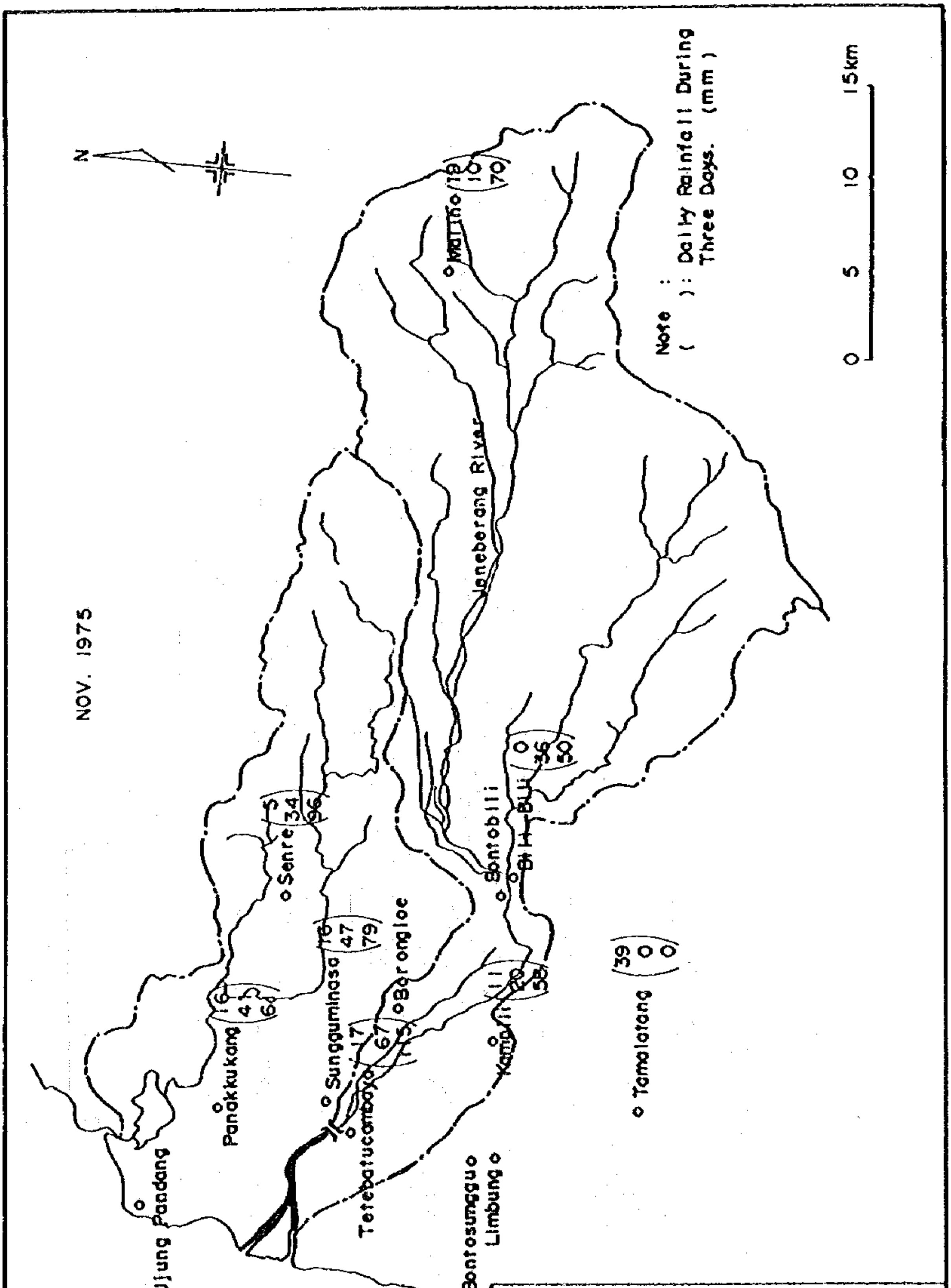


Fig. 5-6

DAILY RAINFALL (1)
NOV. 1975 FLOOD

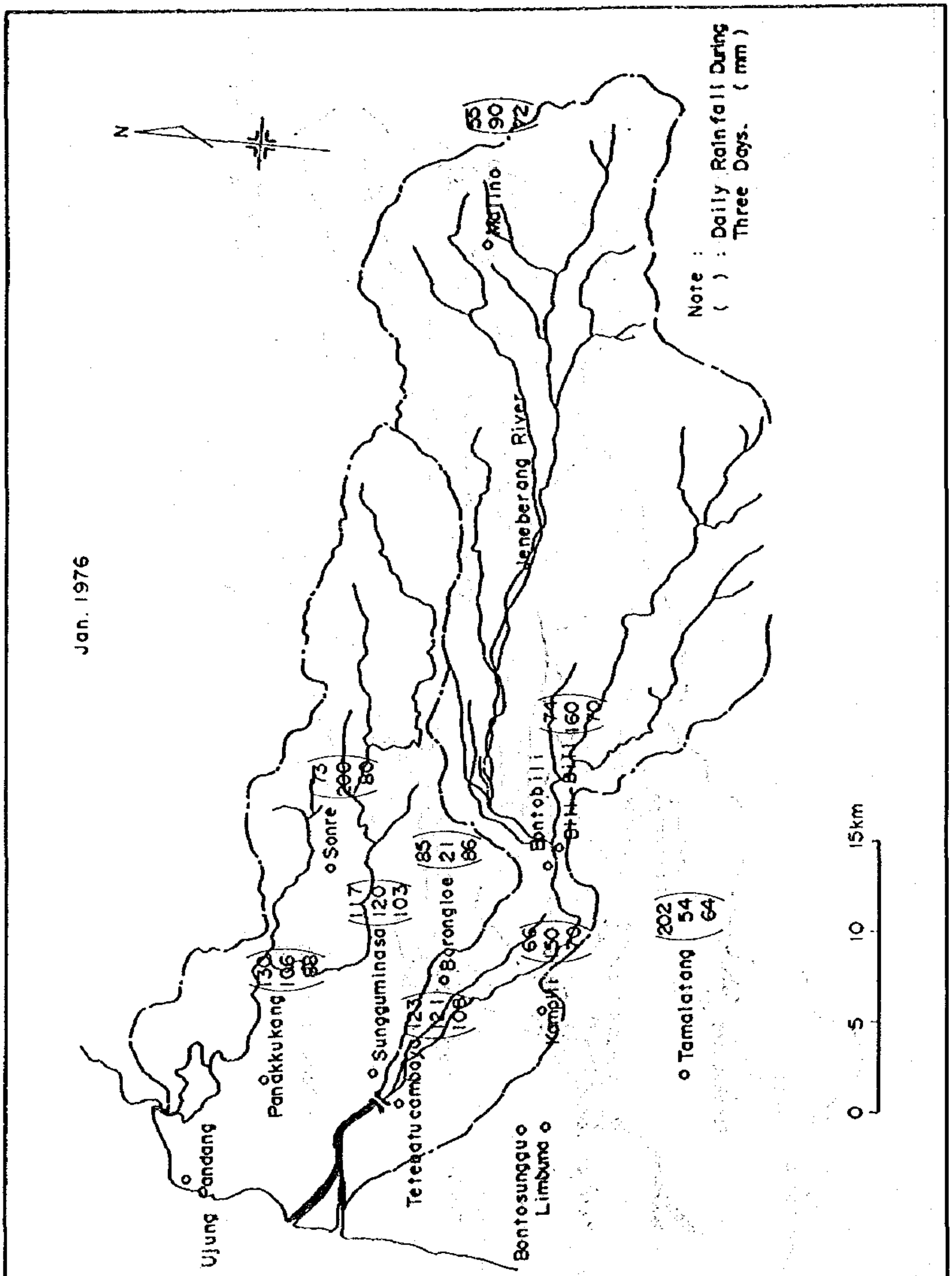


Fig. 5-6

DAILY RAINFALL (2)
JAN. 1976 FLOOD

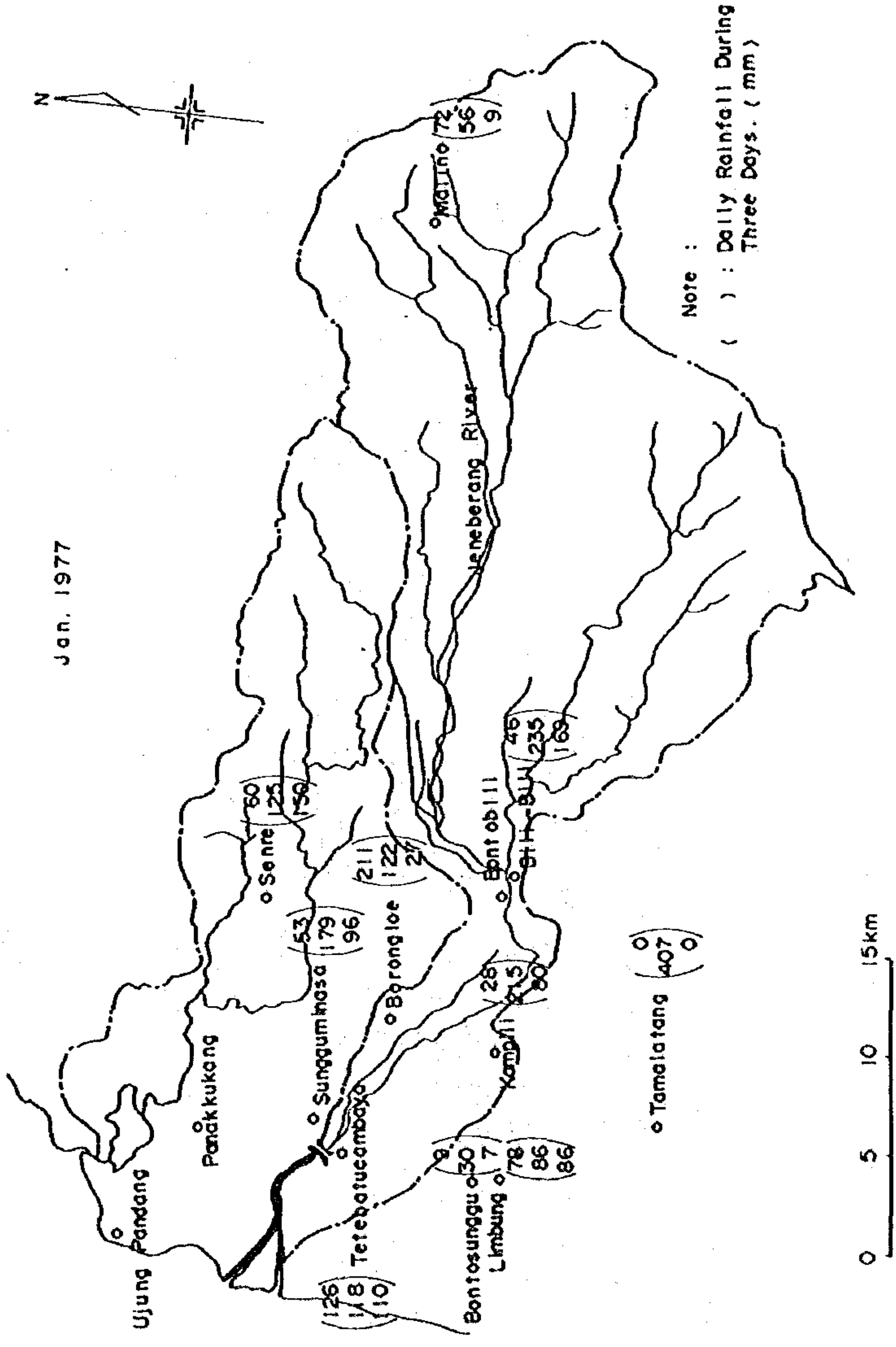


Fig. 5-6

DAILY RAINFALL (3)
JAN. 1977 FLOOD

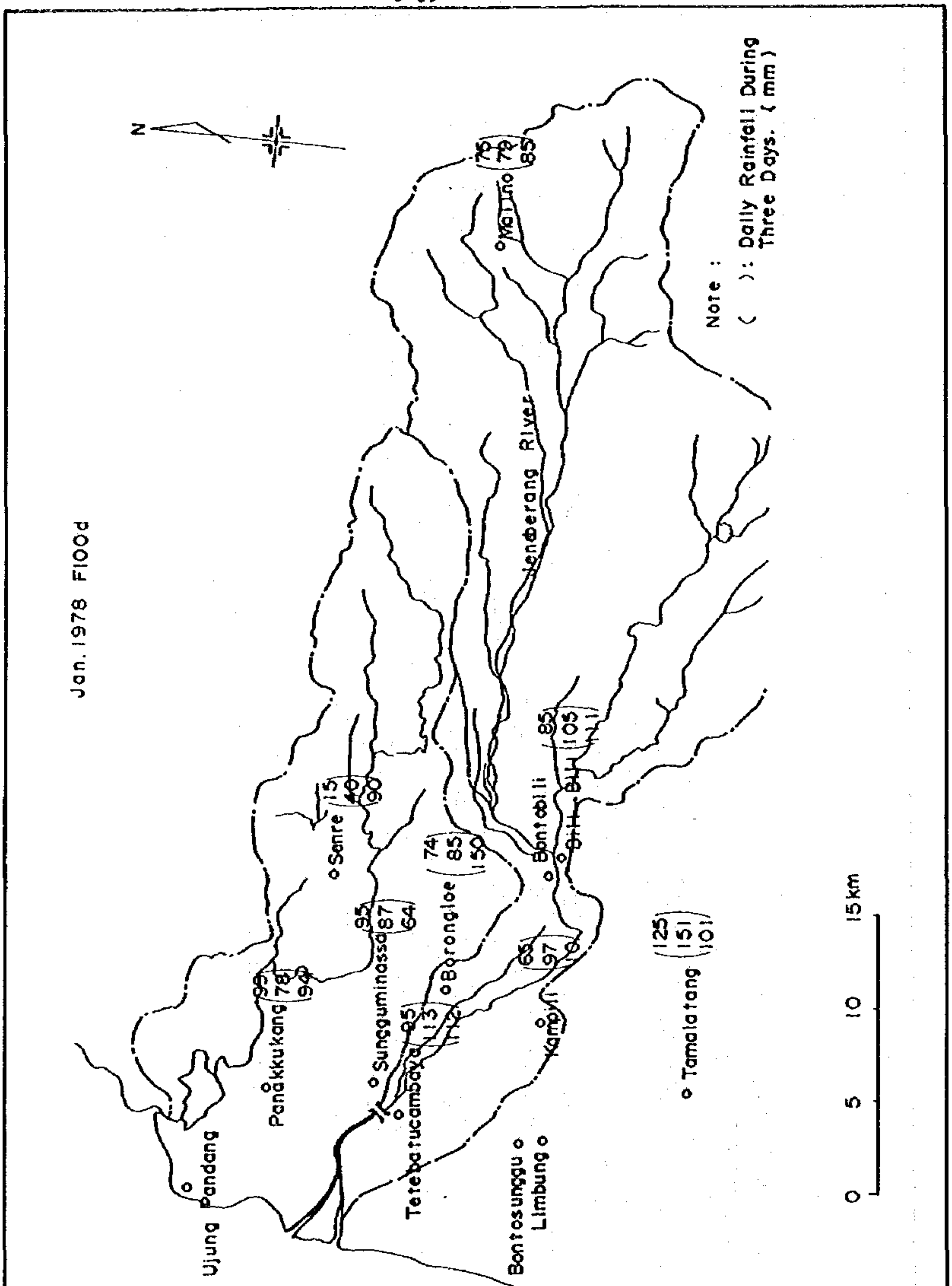
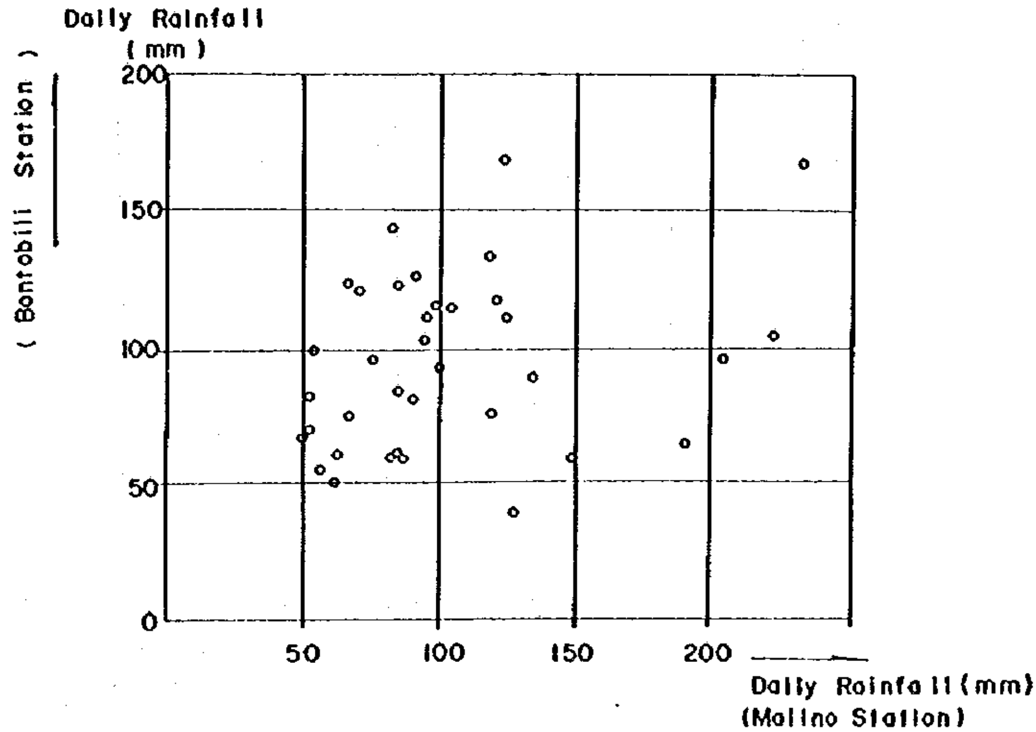


Fig. 5-6

DAILY RAINFALL (4)
JAN. 1978 FLOOD



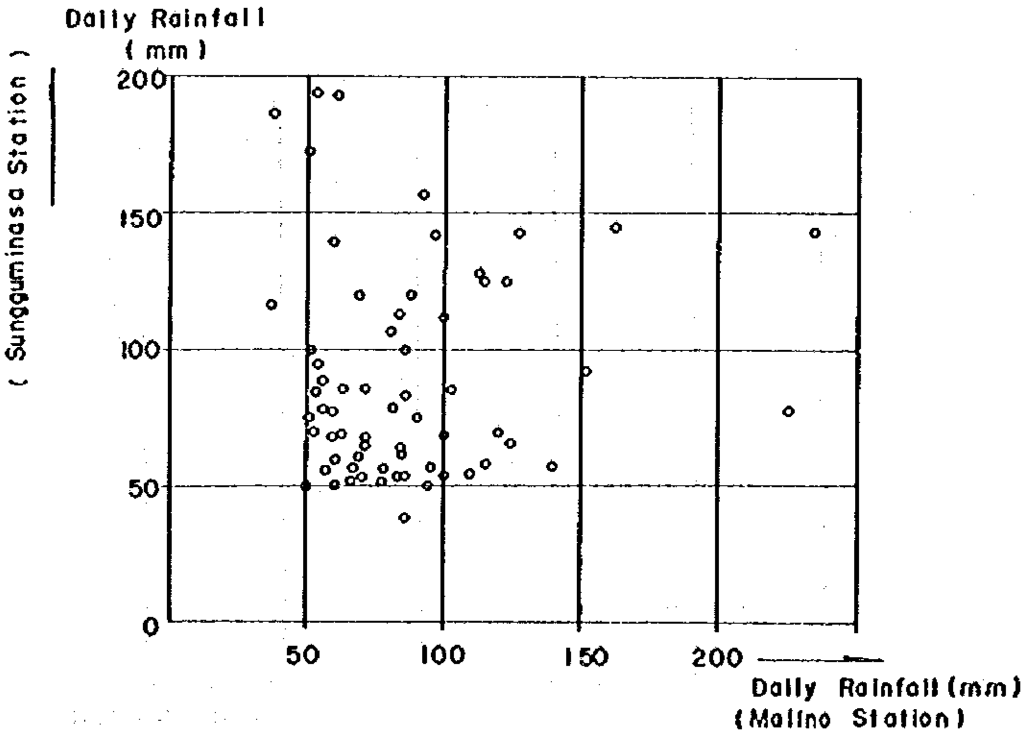
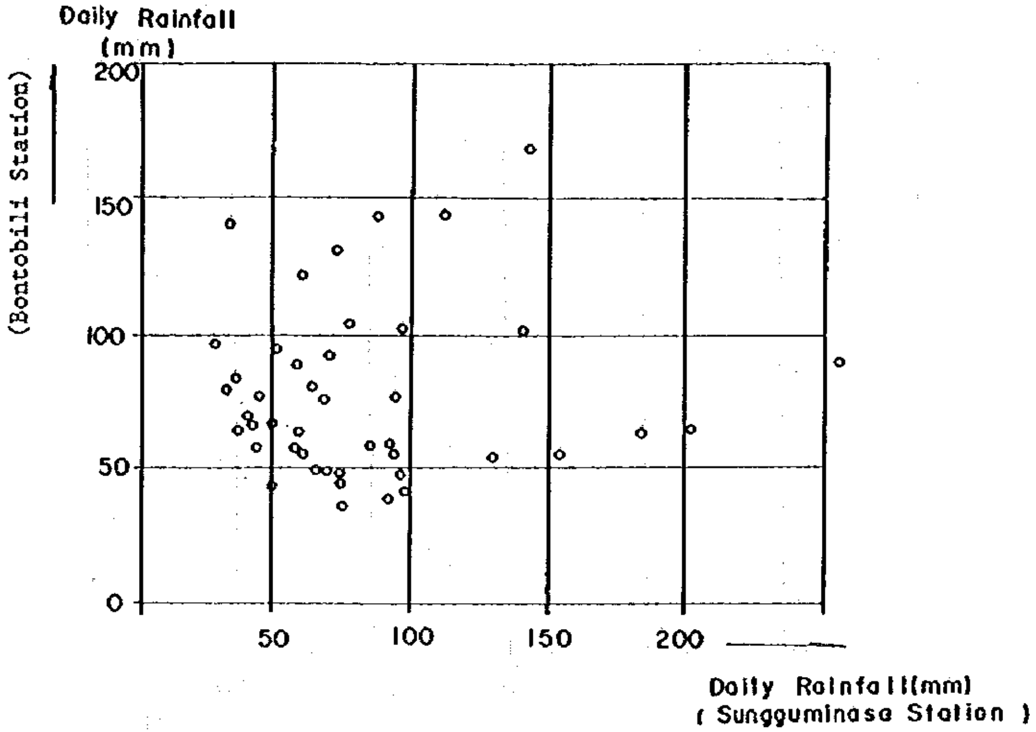


Fig. 5-7

GAUGE CORRELATION OF THE DAILY RAINFALL (1)



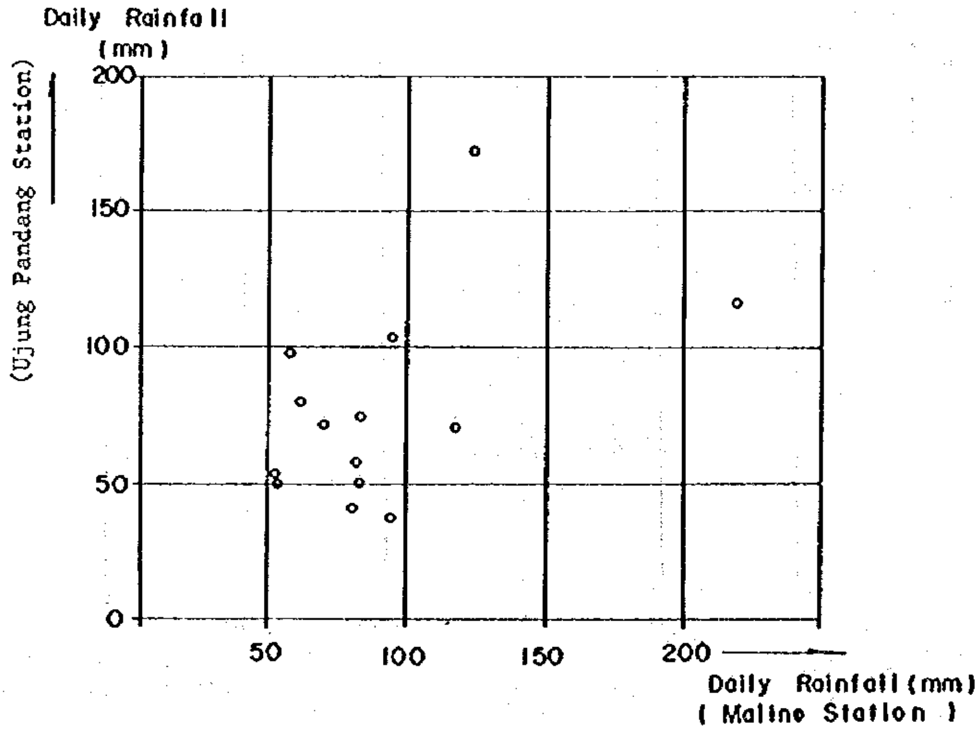


Fig. 5-7

GAUGE CORRELATION OF
THE DAILY RAINFALL (2)

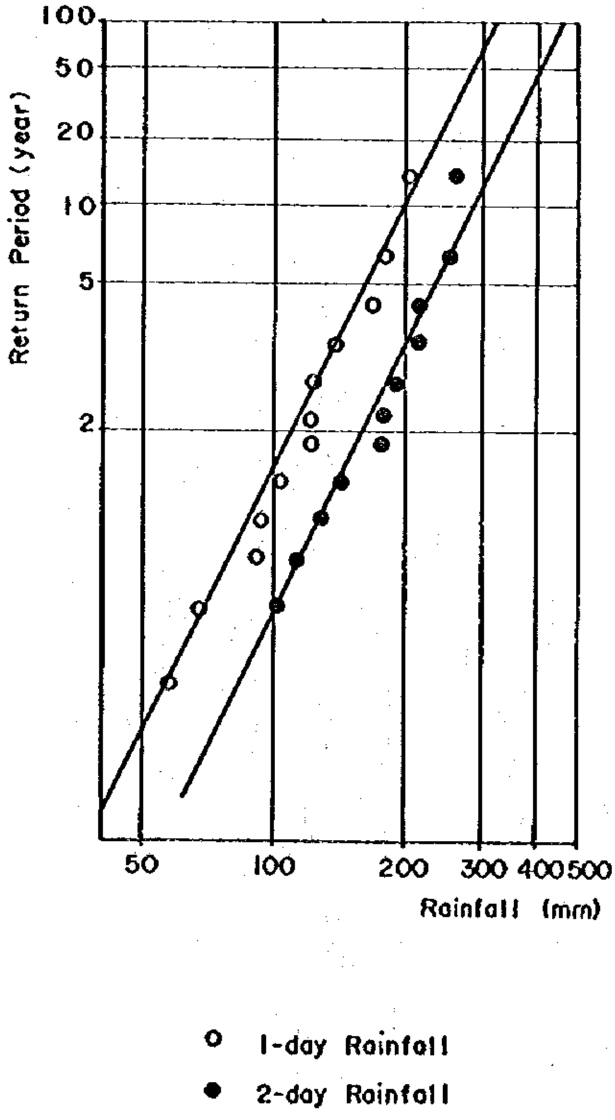


Fig. 5-8

PROBABLE RAINFALL

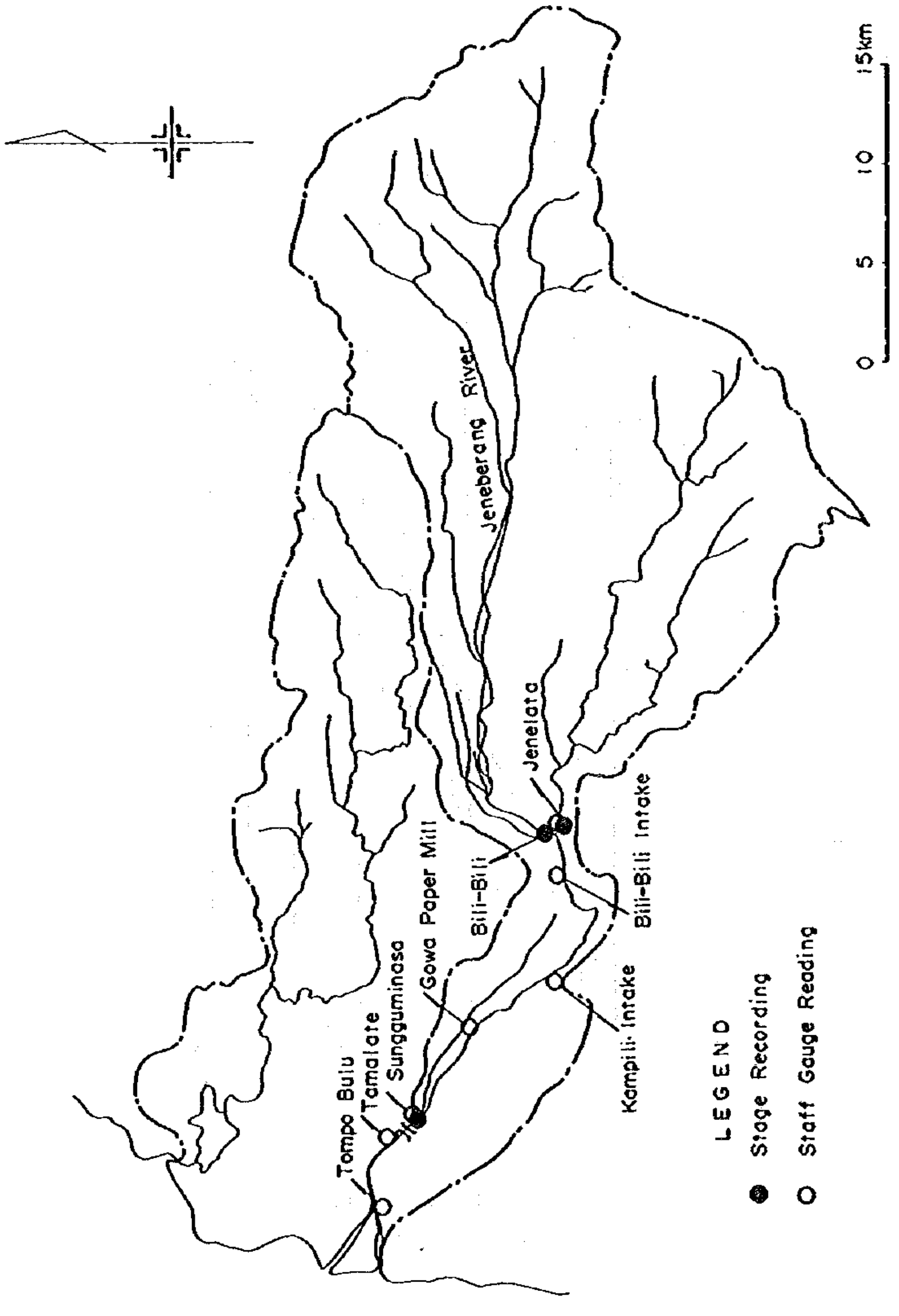


Fig. 5-9

LOCATION MAP OF WATER STAGE STATION

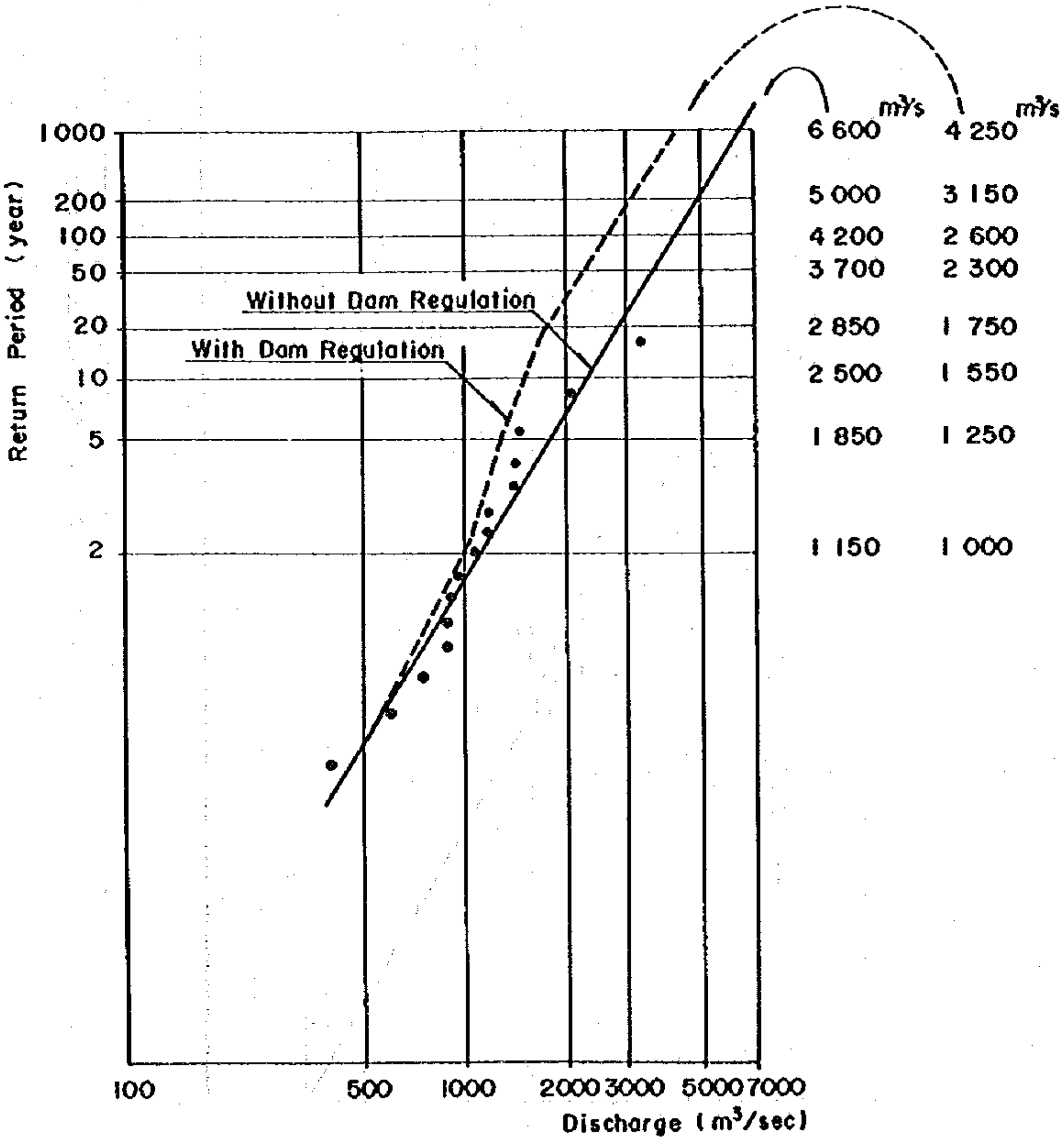


Fig. 5-10

PROBABLE DISCHARGE AT KAMPILI WEIR

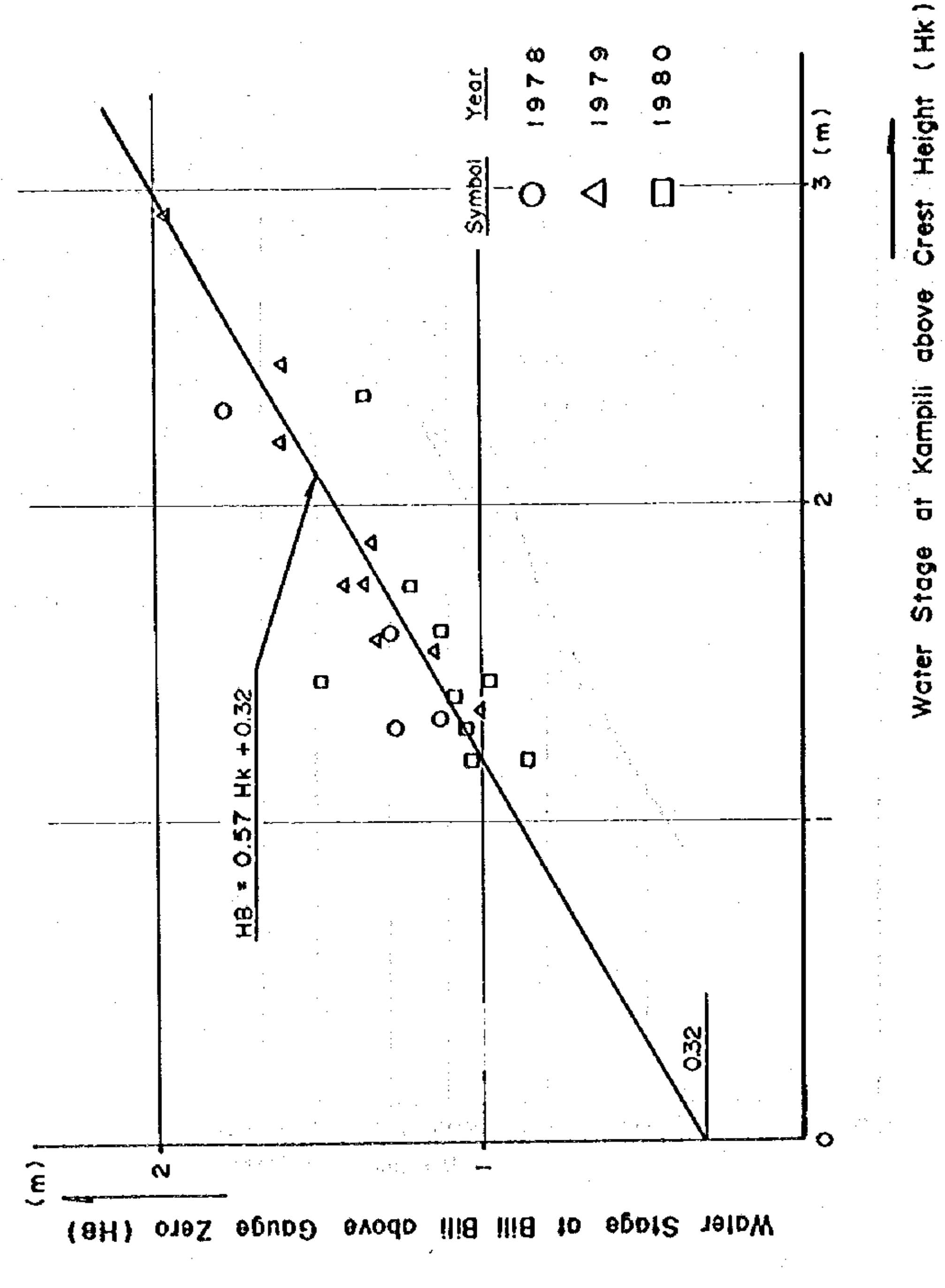


Fig. 5-11

FLOOD PEAK STAGE CORRELATION BETWEEN KAMPILI AND BILI-BILI SITE

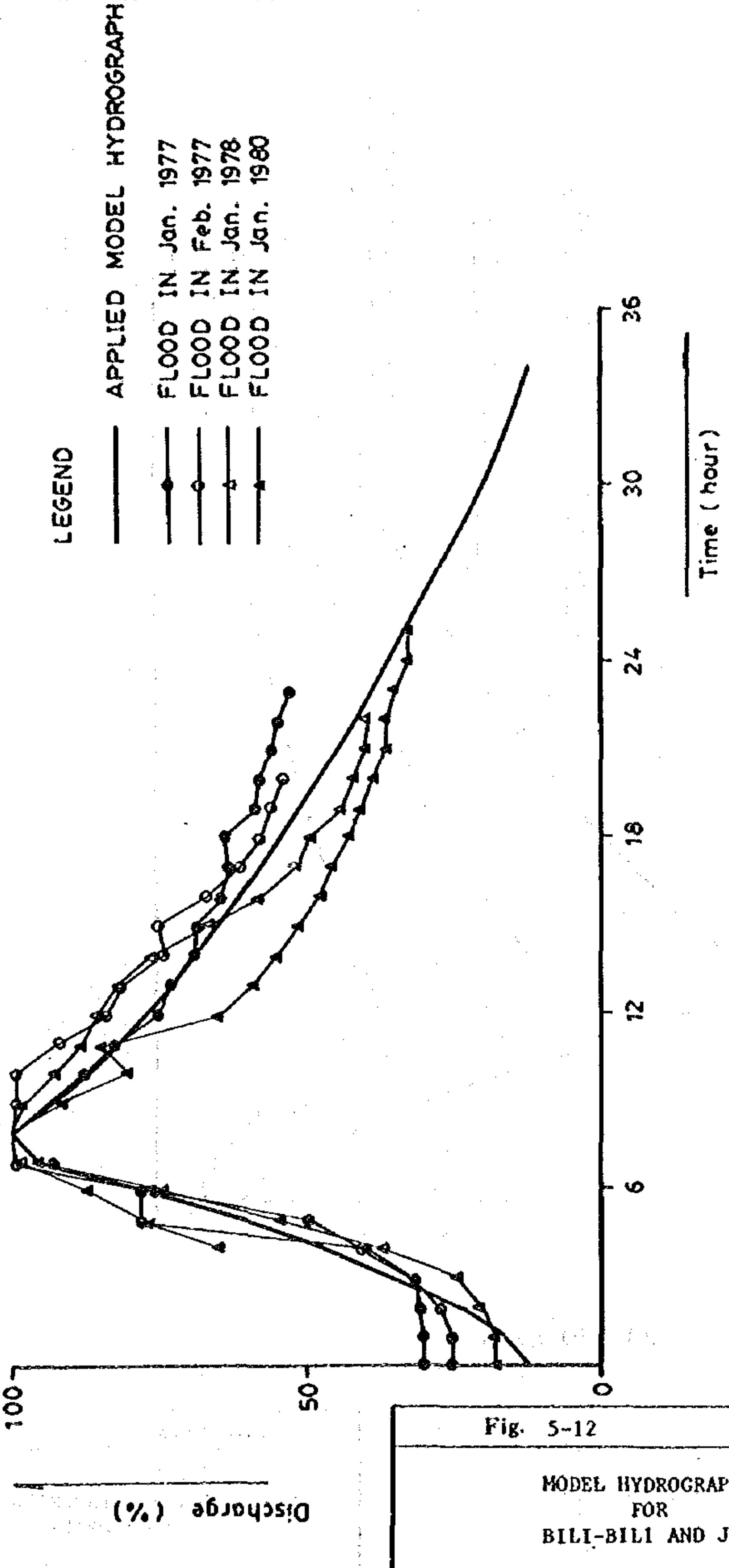


Fig. 5-12

MODEL HYDROGRAPH
FOR
BILI-BILI AND JENELATA

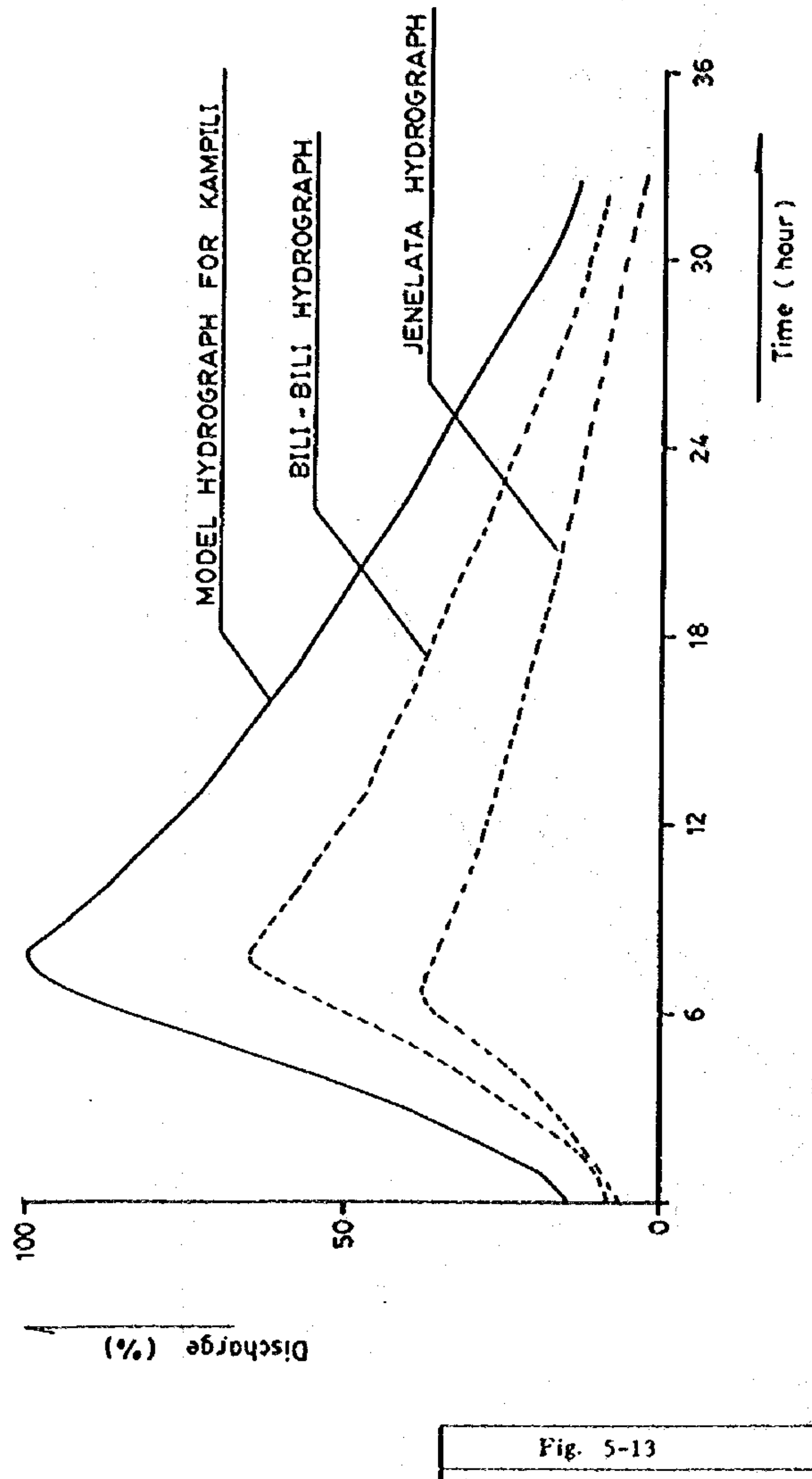


Fig. 5-13

MODEL HYDROGRAPH
FOR KAMPILI

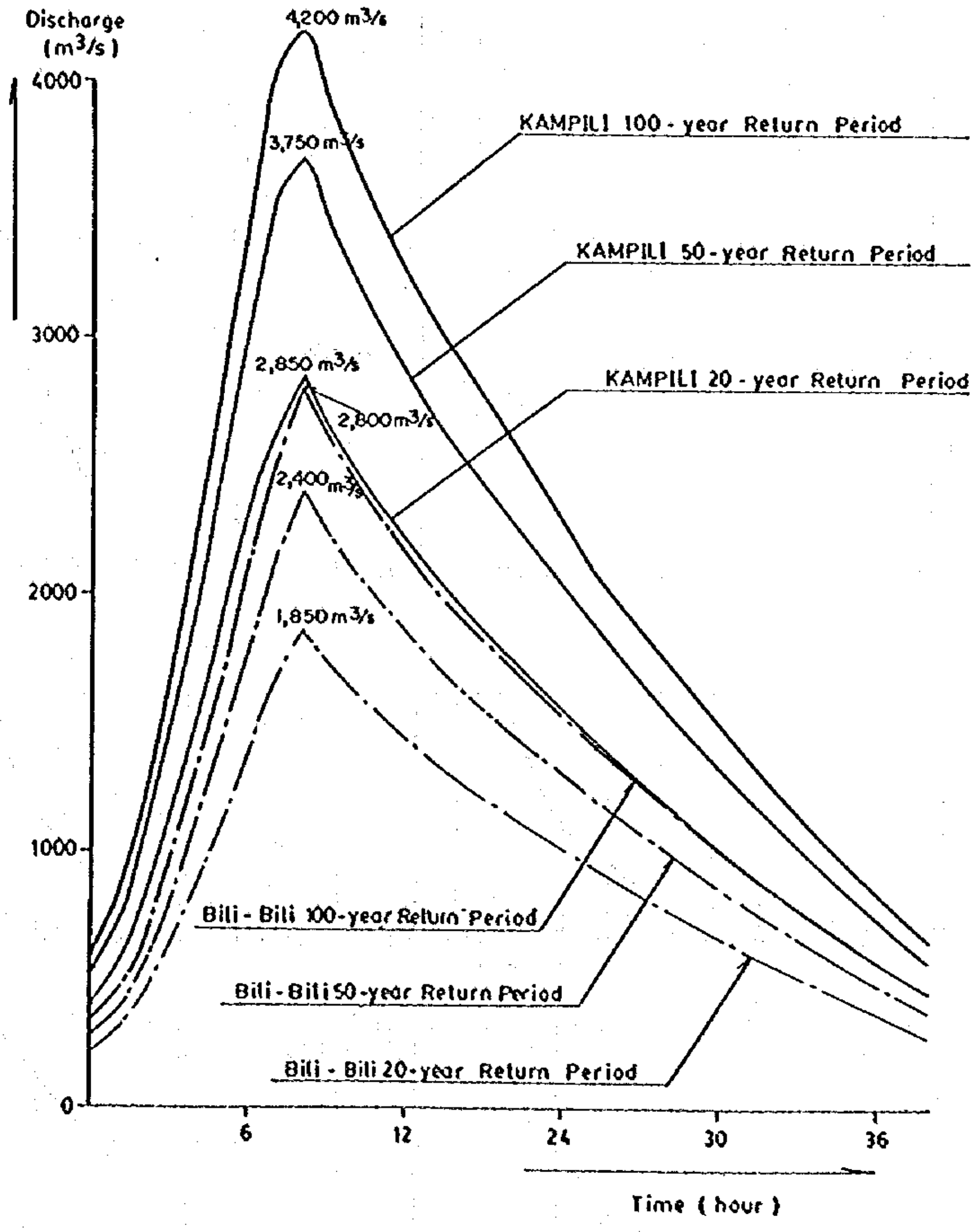


Fig. 5-14

FLOOD HYDROGRAPH
OF
1000, 50 AND 20 YEARS

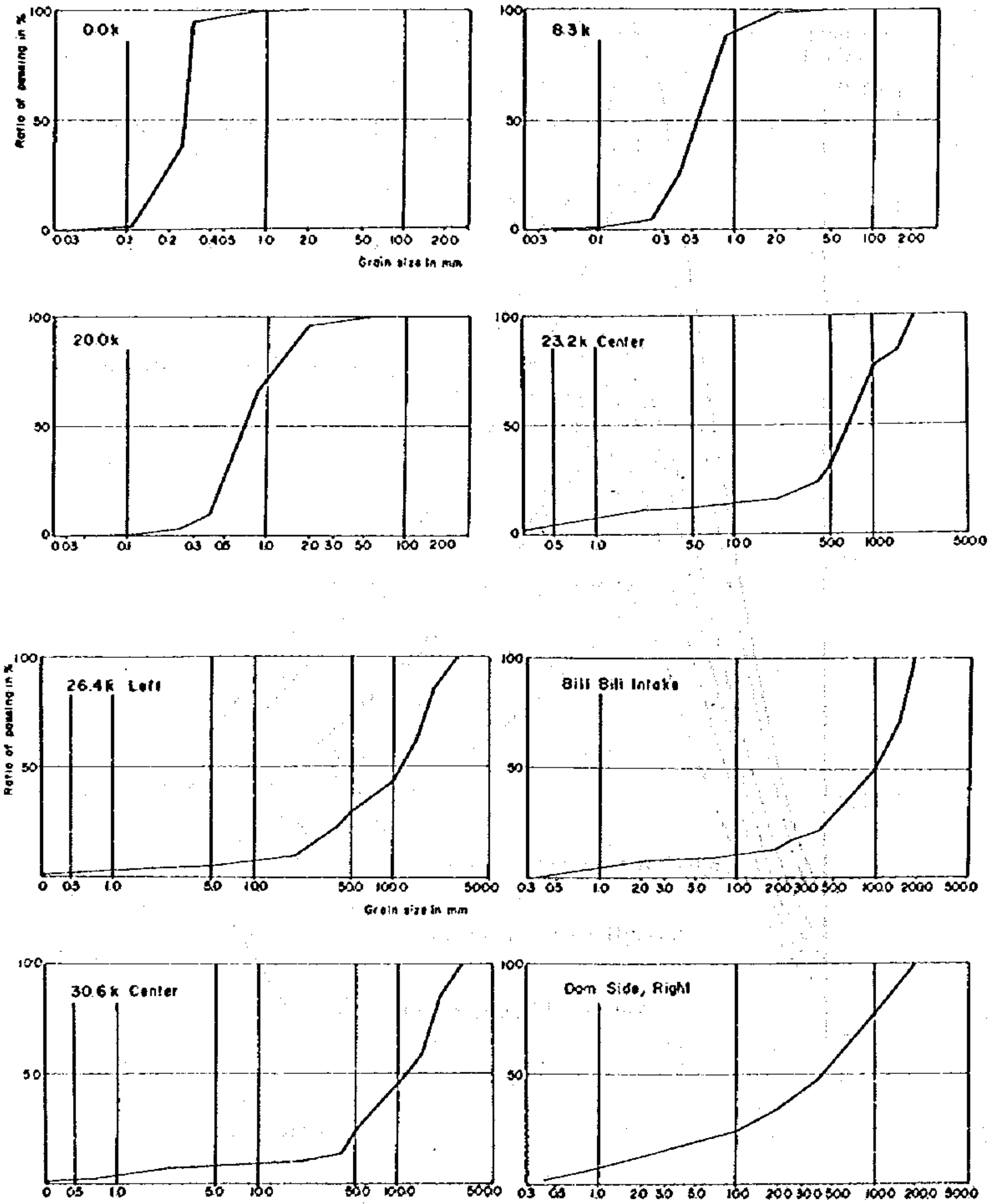


Fig. 5-15

GRAIN-SIZE ACCUMULATION CURVE
ALONG JENEBERANG RIVER

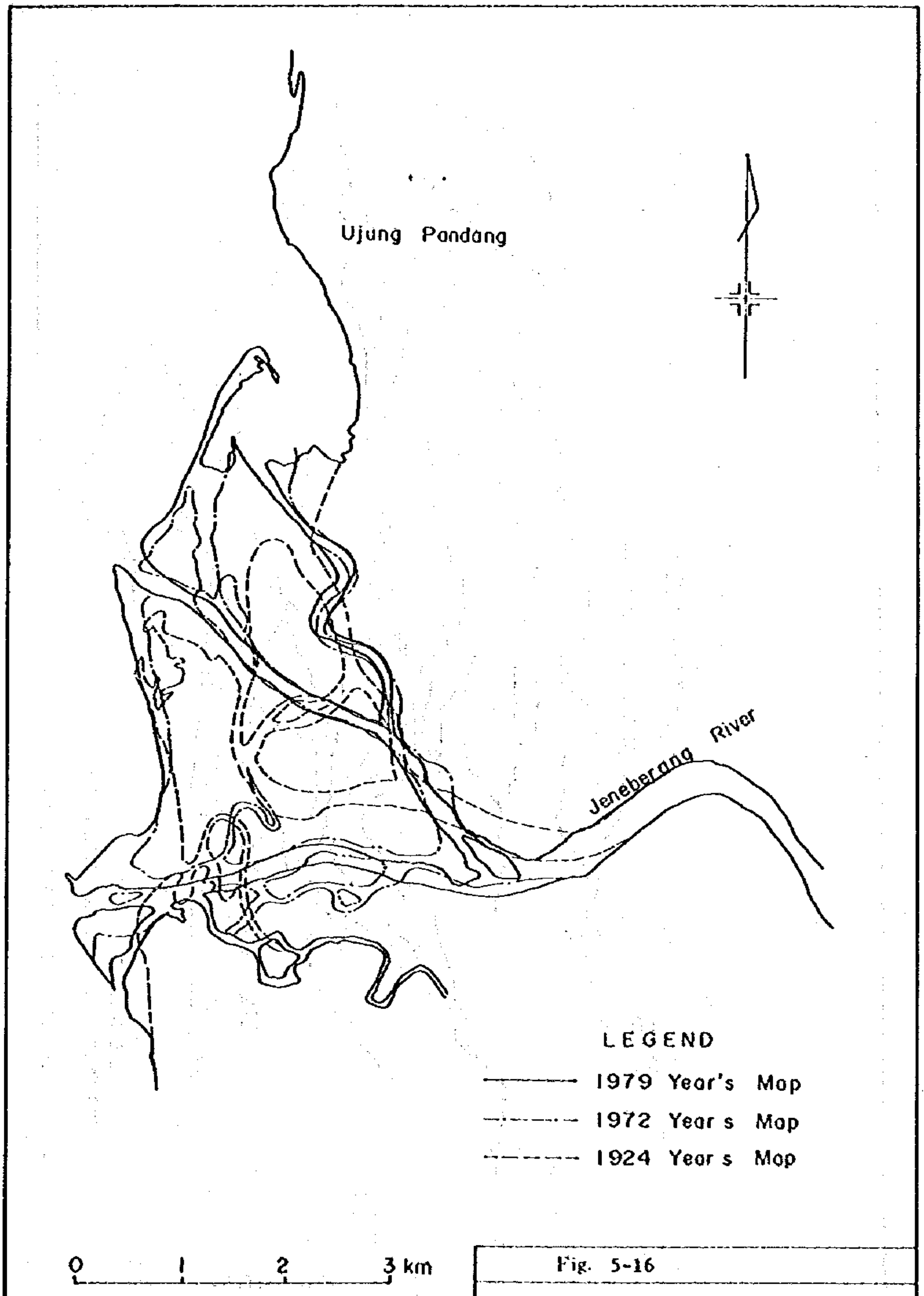


Fig. 5-16

SEDIMENT DEPOSIT
AT ESTUARY

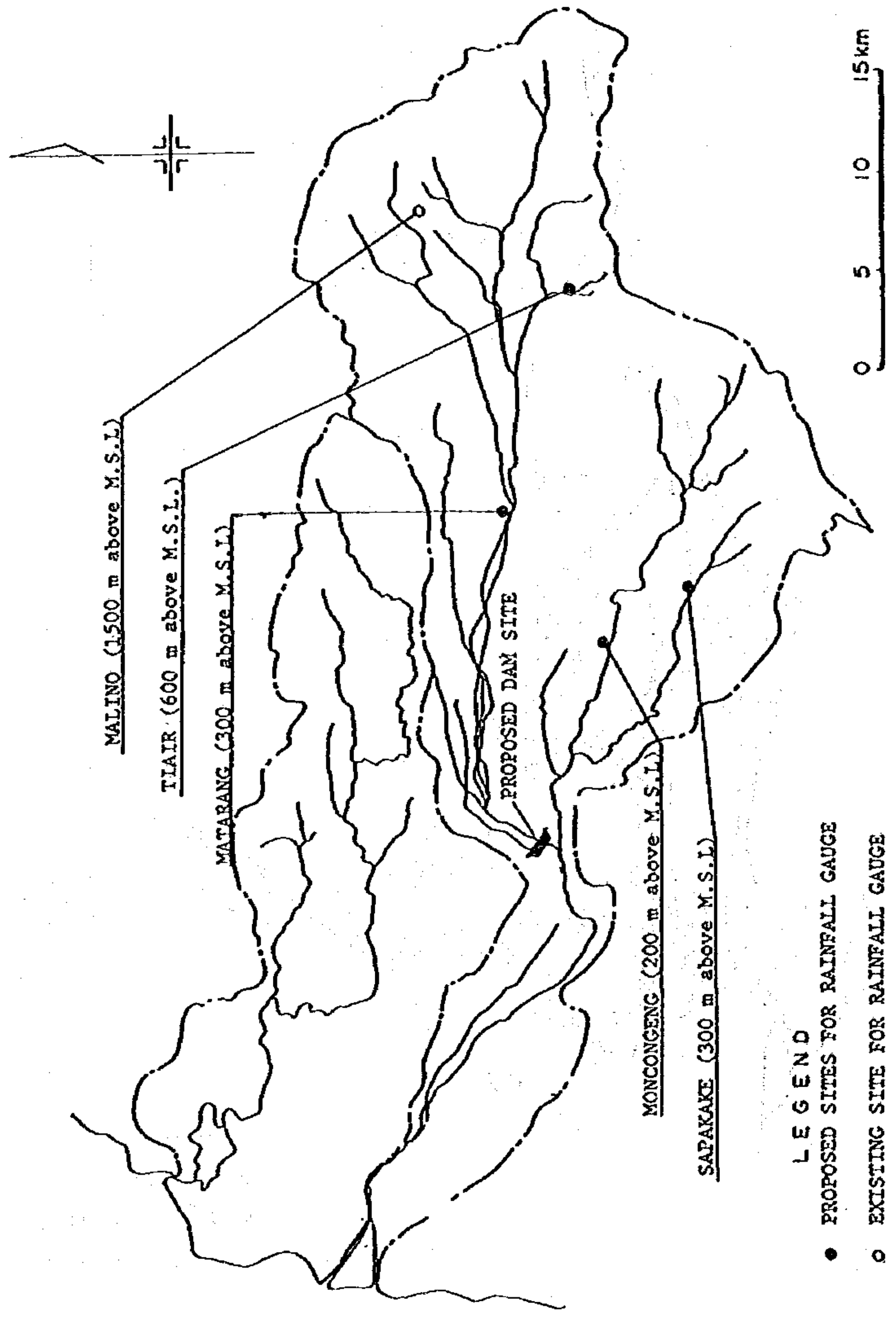


Fig. 5-1(AN)

SITES PROPOSED FOR RAINFALL GAUGE

6. GEOLOGY

CONTENTS OF GEOLOGY

		Page
1.	GENERAL	6-1
2.	GEOLOGY OF THE PROPOSED AREA	6-1
3.	TEST BORINGS AND WATER PRESSURE TESTS	6-4
4.	SEISMIC PROSPECTING	6-8
5.	MATERIALS SURVEY AND LAVORATORY TESTS	6-12
6.	ENGINEERING-GEOLOGICAL ANALYSIS	6-13

LIST OF FIGURES

			Page
Fig.	6-1	GEOLOGICAL MAP OF DAM SITE AND RESERVOIR AREA	6-18
	6-2	GEOLOGICAL MAP OF DAM SITE	6-19
	6-3	RESULTS OF BORINGS INCLUDING WATER PRESSURE TESTS	6-20
	6-4	GEOLOGY, ROCK MASS CLASSIFICATION AND LUGEON MAP (1)	6-21
	6-5	GEOLOGY, ROCK MASS CLASSIFICATION AND LUGEON MAP (2)	6-22

ANNEX:

LIST OF TABLES

			Page
Table 6-1	(AN)	CONDUCTED QUANTITIES OF BORING WORKS	6-23
6-2	(AN)	RESULTS OF WATER PRESSURE TEST (1)	6-24
6-3	(AN)	RESULTS OF WATER PRESSURE TEST (2)	6-25
6-4	(AN)	RESULTS OF WATER PRESSURE TEST (3)	6-26
6-5	(AN)	MEASURING OF GROUND WATER TABLE	6-27
6-6	(AN)	CONDUCTED QUANTITIES OF SEISMIC PROSPECTING	6-28
6-7	(AN)	CORRELATION BETWEEN VELOCITY LAYER AND GEOLOGICAL CONDITION	6-29
6-8	(AN)	FORMATIO OF VELOCITY LAYERS OF MAIN DAM (C-LINE)	6-30
6-9	(AN)	FORMATION OF VELOCITY LAYERS OF LEFT WING DAM (A-LINE)	6-31
6-10	(AN)	FORMATION OF VELOCITY LAYERS OF RIGHT WING DAM (C & D-LINE)	6-32
6-11	(AN)	FORMATION OF VELOCITY LAYERS AROUND SPILLWAY (B-LINE)	6-33
6-12	(AN)	RESULTS OF LOW VELOCITY ZONE	6-34
6-13	(AN)	RESULTS OF LABORATORY TEST (CORE MATERIALS - 1)	6-35
6-14	(AN)	RESULTS OF LABORATORY TEST (CORE MATERIALS - 2)	6-36
6-15	(AN)	RESULTS OF LABORATORY TEST (CORE MATERIALS - 3)	6-37
6-16	(AN)	RESULTS OF LABORATORY TEST (RIVER GRAVEL)	6-38
6-17	(AN)	RESULTS OF LABORATORY TEST (BORING CORE)	6-39
6-18	(AN)	CLASSIFICATION CRITERIA OF ROCK MASS FOR DAM FOUNDATION (HARD ROCK)	6-40
6-19	(AN)	CLASSIFICATION CRITERIA OF ROCK MASS FOR DAM FOUNDATION (SOFT ROCK)	6-41

ANNEX:

LIST OF FIGURES

Page

Fig. 6-1 (AN) SCHMIDT NET 6-42
6-2 (AN) GROUND WATER TABLE ALONG THE DAM AXIS ... 6-43
6-3 (AN) RESULTS OF GRAIN SIZE ANALYSIS 6-44
6-4 (AN) RESULTS OF SOIL TESTS (CORE MATERIALS) 6-45
6-5 (AN) TIME DISTANCE CURVE AND ANALYSED CROSS SECTION OF A, B, C & D LINE 6-46
6-6 (AN) TIM DISTANCE CURVE AND ANALYSED CROSS SECTION OF E, F, G, G_1, G_2, H & I LINE 6-47
6-7 (AN) LEGEND OF BORING LOG 6-48
6-8 (AN) BORING LOG .... 6-49∿59
6-9 (AN) RESULTS OF WATER PRESSURE TESTS (1-24).... 6-60∿83
6-10 (AN) COLUMN SECTIONS OF TEST PITS (1-4) ...... 6-84∿87

1. GENERAL

Geological survey were carried out to get the basic data required for designing a dam. The three important purposes of dam geology are as follows; 1) dam foundation 2) construction materials and 3) geological condition of the proposed reservior area.

To make them clear, in this feasibility study, geological surveys such as geological mapping, test borings, water pressure tests, seismic prospecting, materials survey and their laboratory tests were carried out.

2. GEOLOGY OF THE PROPOSED AREA

Bedrock around the proposed area is, as shown in Figs. 6-1 and 6-2 composed mainly of: 1) pyroclastic rocks such as tuff, lapilli tuff and tuff breccia, 2) dike rocks such as diabase and diorite, and 3) less marine sedimentary rocks such as mudstone, calcareous mudstone and sandstone, and partly limestone, all of which were formed in the geological age of Neogene Tertiary. Concerning geological structure of bedrock, pyroclastic rocks and marine sedimentary rocks first deposited and thereafter dike rocks intruded into them. Then some faults are found, while a few bedding plane is found by dipping gently or horizontally. Covering these bedrock, Alluvial deposits such as river gravel and sand including terrace deposits along the recent river, and detritus deposits containing large angular hard gravels on the slope and foot of mountain are found.

Pyroclastic Rocks

Most of the proposed area are almost occupied by pyroclastic rocks which consist of lapilli tuff, tuff, muddy tuff, tuff breccia and volcanic breccia, interbedded by some thin layers of mudstone. These are inferred to be formed in Miocene of Neogene Tertiary. Most of these rocks have the unconfined compression strength less than 200 kg/cm^2 and belong to soft rocks in engineering geological field.

1) Lapilli tuff

Lapilli tuff is massive and relatively harder in soft rocks, showing grey, greenish grey, reddish brown and brown in color. Lapilli is composed of tuff, andesite, mudstone and siltstone with angular and subangular shape. Diameter of lapilli is mostly less than 10mm and maximum diameter is often found by 20mm and sometimes more than that. Lapilli content is approximately between 30% and 70%, and matrix is composed of tuff.

2) Tuff

Tuff is composed of fine, medium, coarse tuff and muddy tuff, and sometimes includes lapilli, some minerals, pisolite and pumice. These tuff are relatively massive and soft, showing grey, bluish grey, white, pale green, reddish brown and bown in color. Bedding plane and crack are rarely found, but a few cracks in a reddish brown colored tuff are found to be altered by white color. Some of tuff have the properties of slaking, if they are subjected by the repeat of dry and wet action.

3) Tuff breccia and volcanic breccia

Tuff breccia and volcanic breccia are massive and relatively harder in soft rock, showing dark grey and grey in color. Breccia is almost between 5cm and 20cm in diameter, and has angular and subangular shape of andesite and tuff. maximum diameter is rarely found by 40cm. And sometimes subrounded gravels, instead of breccia, are found, showing tuffous conglomeretes.

Marine Sedimentary Rocks

Marine sedimentary rocks, which consist of limestone, calcareous mudstone and sandstone, siltstone and mudstone, are found in a small area around the proposed dam site. These are inferred to be formed in Miocene of Neogene Tertiary and belong to soft rocks in engineering geological field.

1) Limestone

Small distribution of limestone is found at the next lower part of the proposed dam site. Limestone is somehow massive, soft and muddy in some parts.

2) Calcareous mudstone and sandstone

The distribution of these rocks is found, specially by boring No. BM-4, under the river gravel around the proposed dam axis of main dam. These rocks are massive and soft. Many fossils such as foraminifera and some kind of shells are found. Some parts of them at the contact with dike rocks have only recrystallization of calcite caused by the intrusion of dike rocks, but no other alternation is found. Limestone and these calcareous sandstone and mudstone are inferred to be the same stratigraphic facies and both of these seem to be lifted up by the intrusion of dike rocks because of the distribution of these rocks surrounded by the dike rocks.

3) Mudstone and silstone

These rocks are sometimes found to be interbedded in pyroclastic rocks. They are massive and soft, but sometimes found by few bedding planes. Mudstone is black or dark grey and siltstone is white or grey in color.

Dike Rocks

Dike rocks consist of diabase and diorite, and are characterized by their distribution along the ridge surrounding the reservoir area. Lithologic character of diabase has melanocratic and holocrystalline porphyritic texture. Mineral assemblage is composed mainly of 0.5mm to 3mm large pyroxene, hornblende and olivine as phenocryst and matrix is also crystallized by the very small crystal less than 0.5mm in diameter. Lithologic character of diorite has leucocratic and holocrystalline granular texture sometimes including holocrystalline porphyritic texture. Mineral assemblage is composed mainly of 1mm to 4mm large feldspar, including little pinkish feldspar, 1mm to 2mm large hornblende and pyroxene. Dike rocks are very hard and belong to hard rocks in engineering geological field, as their unconfined compression strength of fresh samples are inferred to be more than 800 kg/m^2. Joints moderately develop, but stick together in fresh rock mass.

Alluvial Deposits

Alluvial deposits distributed in the proposed area consist of river, terrace and detritus deposits. River deposits, including terrace deposits, distributed along the river course are composed mostly of gravels in the range from 2mm to 600mm in diameter and coarse sand. Gravels are fresh and hard, composed of diabase, andesite, etc., and have rounded and subrounded shape. Thickness of river deposits is nearly 9 m at BH-3 around the proposed dam axis of main dam. Detritus deposits have large distribution on the surface of slope and foot of mountain all over the proposed area. These deposits are composed mainly of gravels and clayey soils. Diameter of gravels composed mainly of diabase are mostly between 30cm and 50cm with maximum diameter of 100cm. Most of these gravels are fresh, hard and angular. Thickness of detritus deposits is mostly between 1m and 5m.

Geological Structure

Pyroclastic rocks and marine sedimentarty rocks formed in the age of Miocene in Tertiary have a few bedding plane dipping gently or horizontally though they rarely have the bedding plane. These are cut by the intrusion of dike rocks in Miocene, Tertiary. Joints system of dike rocks distributed around the proposed damsite, shown in ANNEX, has a dominant direction of NE-SW and NW-SE on the Schmidt Net, while trends of the dike rocks found in their distribution show NE-SW, NW-SE, E-W and N-S. Faults are found and their trends almost coincide with the trends of dike rocks.

Covering these basement rocks, fluvial river deposits and detritus deposits are formed in Quaternary.

3. TEST BORINGS AND WATER PRESSURE TESTS

Eleven boreholes having total drilling depth of 700m with water pressure tests were carried out along the three proposed dam axes. The detailed quantities conducted and their locations are shown in Table 6-1 and Fig 6-2 respectively. Summary of test borings and water pressure tests are shown in Fig 6-3. Followings are briefly explained by test borings and water pressure tests. For further details of them, boring logs and the results of water pressure tests shown in ANNEX can be available. The grade of rock mass classification expressed in boring logs depends on ANNEX of the classification criteria after SAITO & KIKUCHI. The results of water pressure tests are given by Lugeon Value.

Test Borings and Water Pressure Tests

- BL-1 (Drilling depth: 50m, left side of Left Wing dam

  Top sandy clay of 1.2m in thickness is found without humus soil. Below the depth of 1.2m, massive soft rocks such as tuff, lapilli tuff mudstone and muddy tuff, are distributed.

  Weathering of rock is found down to the depth of 8.05m. Cracks due to weathering and their discoloration are found down to 11.35m from 1.2m in depth. Below 11.35m in depth, soft rock almost show massive except for the apparent cracks happening to peal off along the boundary of diffent rocks or unclear bedding plane. In depth between 22.40m and 23.60m, clayey soils are found within slightly weathered soft rocks. Lugeon value obtained by water pressure tests is more than 20 Lu down to 15m in depth, 6.6 Lu to 18.3 Lu between 15m and 35m in depth, 1.4 Lu between 35m and 40m in depth and 0 Lu below 40m in depth. Ground water table is measured by 15.75m in depth from the ground surface.

- BL-2 (Drilling depth: 70m, Center base of Left Wing Dam)

  Top sandy clay is found down to 1.4m in depth. Below its depth, massive soft rocks such as tuff, lapilli tuff, mudy tuff and mudstone are distributed. Bedrock is, though soft, fresh and massive without the alternation by weathering below the depth of 1.4m, down to which surface deposits are found.

  Lugeon value obtained by water pressure tests is less than 1 Lu from 2m down to 70m in depth, except 16.6 lu between 45m and 50m in depth. Ground water table is measured by 7.20m in depth from the ground surface.

- BL-3 (Drilling depth: 50m, Right side of Left Wing Dam)

  Top clayey soil with some gravels is found down to 2.5m in depth. And below its depth down to 50m in depth, diabase is recovered. However, diabase distributed between 2.5m and 5.5m in depth shows weathered soil due to extremely high weathering, and between 5.5m and 15.3m shows highly to moderately weathered rock which is recovered by the fresh core and highly weathered clayey and sandy soil existing along the joint plane. Below the depth of 15.3m, fresh and hard diabase is obtained. Lugeon value obtained by water pressure tests is less than 1 Lu from 15m down to 50m in depth. Ground water table is measured by 6.3m in depth from the ground surface.

- BG-1 (Drilling depth: 60m, summit of the ridge between Main and Left Wing Dam)

  Top clayey soil mixed with some gravels is found down to 1.3m in depth. And below its depth down to 60m in depth, diorite is recovered. Down to 5.0m, rock condition is highly weathered, and moderately or slightly weathered between 5.0m and 16.6m in depth. Below the depth of 16.6m, fresh and hard rocks are recovered. Lugeon value obtained by water pressure tests is between 5.7 Lu and 18.7 Lu from 16.0m to 25m in depth. Below the depth of 25m, Lugeon value is almost less than 1.0 Lu, except 1.8 Lu between 30m and 35m, and 1.2 Lu between 45.0m and 50.0m in depth. Ground water table is measured by 19.66m in depth from the ground surface.

- BM-1 (Drilling depth: 70m, left side abutment of Main Dam)

  Top clayey soil mixed with some gravels is found down to 2.9m in depth. Below the depth of 2.9m down to 70m in depth, diorite is recovered. However, diorite recovered between 2.9m and 5.20m in depth, shows weathered soil mixed with some gravels due to extremely high weathering, and from 5.2m down to 15.6m, diorite is highly or moderately weathered. Below the depth of 15.6m, fresh and hard rocks are recovered.
  Lugeon value obtained by water pressure tests is almost less than 1.0 Lu, though 1.5 Lu between 10 m and 15m, and 1.2 Lu between 30m and 35m in depth are obtained. Ground water table is measured by 9.75m in depth from the ground surface.

- BM-2 (Drilling depth: 70m, left side of river bed of Main Dam)

  River gravel is found down to 1.5m in depth. Below the depth of 1.5m down to 70m, diabase is recovered.

  Diabase between 1.5m and 4.5m in depth is moderately or slightly weathered. Below the depth of 4.5m fresh and hard rocks are recovered.

  Lugeon value obtained by water pressure tests is less than 1.0 Lu. Ground water table is measured by 0.15m in depth from the ground surface.

- BM-3 (Drilling depth: 100m, center of river bed of Main Dam)

  River gravel is recovered down to 8.9m in depth. From 8.9m to 15.75m in depth, calcareous sandstone and calcareous mudstone containing marine fossils are found. Below the depth of 15.75 down to 100m, diabase is recovered by almost fresh and hard rock. At the boundary between calcareous sedimentary rocks and dike rock of diabase, no clay, no brecciated zone and no thermal alternation except for some recrystallization of calcite and spots of few pyrite caused by intrusion of dike are found. However, a few developing of cracks and discoloration around the boundary of them are found.

  Lugeon value obtained by water pressure tests is less than 1.0 Lu below the depth of 10.0m down to the bottom. Ground water table is measured by 0.15m above the ground surface.

- BM-4 (Drilling depth: 70m, Right side of river bed of Main Dam)

River sand and gravel are recovered down to 8.50m in depth. From 8.5m to 31.35m, and from 51.65m to 70m in depth diabase is found. Between 31.35m and 51.65m in depth, tuff including a little calcareous sandstone and mudstone are found, though few diabase between 32.6m and 33.15m in depth is recovered. Fault is found between 33.85m and 36.0m in depth, and small fault is also found around 51.25m in depth. Tuff between 37.70m and 51.25m is not affected by fault and intrusion of diabase, but the other part of tuff is somehow affected by them. Diabase around the boundary between diabase and tuff is altered by discoloration, developing of cracks, sometimes filled with calcite veins and somehow softening. The other part of diabase are fresh and hard.

Lugeon value between 1.7 Lu and 5.7 Lu is obtained from 10m to 40m in depth and below the depth of 40m, Lugeon value is less than 1 Lu.

Ground water table is measured by 2.5m in depth from the ground surface.

- BR-1 (Drilling depth: 60m, Left side abutment of Right Wing Dam)

Top clayey soil is recovered down to 4.30m in depth. Below the depth of 4.30m to the bottom, diorite is obtained. Diorite recovered between 4.30m and 13.25m in depth, by extremely high weathering, becomes clayey sandy soil mixed with weathered and fresh gravels. Below the depth of 13.25m, hard and fresh diorite is obtained, and completely fresh rock is found below 21.00m in depth.
Lugeon value below the depth of 20m is almost less than 1 Lu, except 4.5 Lu from 15m to 20m in depth.

Ground water table is measured by 26.70m in depth from the ground surface.

- BR-2 (Drilling depth: 50m, Center base of Right Wing Dam)

Top clayey soil mixed with gravels is recovered down to 0.8m in depth. Below the depth of 0.8m to the bottom, lapilli tuff, tuff, muddy tuff and mudstone are recovered.

Lapilli tuff and tuff distributed between 0.8m and 9.60m are highly weathered to become weathered soil in which standard penetration tests were carried out. From 9.6m to 19.0m, weathering along the bedding boundary and a few cracks of tuff is, though most of them show massive, easily found by existing of clayey materials and being more softened. Below 19.0m in depth, few affection due to weathering is found and most of rock are massive but soft. Lugeon value between 10.25m and 20m in depth is obtained by 8.2 Lu and 20.7 Lu.

Below the depth of 20m, Lugeon value is almost less than 1 Lu, except 1.4 Lu between 30m and 35m in depth. Ground water table is measured by 3.70m in depth from the ground surface.

- BR-3 (Drilling depth: 50m, right side abutment of Right Wing Dam)

Top sandy clayey soil mixed with hard gravels is recovered down to 1.70m in depth. Below the depth of 1.7m, lupilli tuff, tuff and muddy tuff are recovered. Lapilli tuff distributed down to 8.9m in depth, is highly weathered to be hard soil in which standard penetration tests were carried out. And Lapilli tuff down to 11.60m in depth is also highly weathered, though standard penetration test could not be carried out. Below its depth, the bedding boundary and a few cracks of lapilli tuff and tuff are somehow weathered to be clayey materials and softened.

Lugeon value between 11m and 25m in depth is more than 30 Lu, and that between 25m and 35m in depth is 1.1 Lu and 2.0 Lu. Below the depth of 35m in depth, Lugeon value is less than 1.0 Lu.

Ground water table is measured by 19.4m in depth from the ground surface.

4. SEISMIC PROSPECTING

The observation and analysis of eleven profile lines having total length of 5,145 m were carried out along the three proposed dam axes and perpendicular to them. Followings are briefly explained, while their locations, analysed cross sections and further detailed results are shown in ANNEX.

The analysis of the results of seismic prospecting gives the three following area divided by the obtained fastest velocity layer; namely, 1) 5.0 km/sec, 2) 3.3 km/sec and 3) 1.9 - 2.8 km/sec.

The area showing 5.0 km/sec of the fastest velocity layer is found around the Jeneberang river bed and both side abuntments of the proposed Main dam, right side of Left Wing Dam, left side of Right Wing Dam and ridge of spillway. Formation of velocity layers of this area is as next page.

Velocity layer	Velocity (km/sec)	Approximate thickness of velocity layer (m)	Approximate depth from ground surface to the upper boundary of velocity layer(m)
First Velocity layer	0.2-0.3	1-2.5	-
Second Velocity layer	0.5-0.7	4-8	1-2
Third Velocity layer	1.7-2.3	5-10	5-10
Fourth(Fastest) Velocity layer	5.0-5.4	-	(5) 10-20

The area showing 3.3 km/sec of the fastest velocity layer is distributed around the part of the Jeneberang river bed of Main Dam and the terrace of proposed stilling basin of spillway.

Formation of velocity layers of this area is as follows.

Velocity layer	Velocity (km/sec)	Approximate thickness of velocity layer (m)	Approximate depth from ground surface to the upper boundary of velocity layer(m)
First Velocity layer	(0.1)	(1.0)	-
Second Velocity layer	0.4-0.8	1.0	0-1
Third Velocity layer	1.4-1.9	10-11	1-2
Fouth(Fastest) Velocity Layer	3.3	-	(6) 10-12

The area showing 1.9 - 2.8 km/sec of the fastest velocity layer is distributed around the center base and left side of Left Wing Dam and the center base and right side of Right Wing Dam.

Formation of velocity layers of this area is as follows.

Velocity layer	Velocity (km/sec)	Approximate thickness of velocity layer (m)	Approximate depth from ground surface to the upper boundary of velocity layer(m)
First Velocity layer	0.2-0.4	1-2.5	-
Second Velocity layer	0.5-1.2	1.5-12	1-2.5
Third(Fastest) Velocity layer	1.9-2.8	-	3.0-14.0

As range of the velocity of the fastest velocity layer of this formation is somehow large, it is farther divided by the two fastest velocity of 1.9 km/sec to 2.3 km/sec and 2.7 km/sec to 2.8 km/sec. The area showing 1.9 km/sec to 2.3 km/sec of the fastest velocity layer is found around left side of Left Wing Dam, and center base and right side of Right Wing Dam. The area showing 2.7 km/sec to 2.8 km/sec of the fastest velocity layer is found around center base of Left Wing Dam.

The low velocity zone, which has a velocity remarkably lower than its surroundings in the velocity layer, is obtained by 16 points shown in ANNEX.

Formation of velocity layers obtained around the proposed three axes are as follows.

- Main Dam

Formation of velocity layers of Main Dam obtained along C-Line is shown in ANNEX and as follows. It is divided into four velocity layers and the velocity of fastest velocity layer (Fourth velocity layer) is mostly obtained by 5.0 km/sec except for 3.3 km/sec in partly center and right side of the Jeneberang river bed.

The first velocity layer of 0.2 km/sec to 0.3 km/sec is obtained all over the profile lines of Main Dam except for no existing in river bed. Its thickness is mostly between 0.5 m and 2.5 m, but 4 m in right side abutment.

The second velocity layer of 0.4 km/sec to 0.8 km/sec has its thickness of 2.0 m to 7.0 m in left side, 0.5 m to 2.5 m in river bed and 3.0 m to 14.0 m in right side.

The third velocity layer of 1.7 km/sec to 2.3 km/sec has its thickness of 2.5 m to 10.0 m in left side, 5.0 m to 10.0 m in river bed and 5.0 m to 9.5 m in right side. Also the depth of the upper boundary of the third velocity layer is obtained by 4.0 m to 12.0 m in left side, 0.5 m to 3.5 m in river bed and 5.0 m to 14.0 m in right side.

The fourth velocity layer of 5.0 km/sec to 5.4 km/sec gives the depth of this upper boundary of 9.0 m to 17.0 m in left side, 5.0 m to 8.5 m in river bed and 10.0 m to 22.5 m in right side. On the other hand, the fourth velocity layer of 3.3 km/sec gives the boundary depth of 9.0 m to 11.5 m between the velocity layer of 1.8 km/sec and 3.3 km/sec.

- Left Wing Dam

Formation of velocity layers of Left Wing Dam obtained along A Line is shown in ANNEX and as follows. It is divided into four velocity layers of the fastest velocity of 5.3 km/sec in right side and three velocity layers of the fastest velocity of 2.0 km/sec to 2.3 km/sec in left side and of the fastest velocity of 2.7 km/sec to 2.8 km/sec in center base.

Velocity and thickness of the first velocity layer are 0.2 km/sec to 0.4 km/sec and 0.5 m to 4.0 m in left side, 0.2 km/sec to 0.25 km/sec and 0.5 m to 1.0 m in center base, and 0.15 km/sec to 0.2 km/sec and 0.5 m to 1.0 m in right side respectively.

Second velocity layer has velocity of 1.1 km/sec to 1.2 km/sec with its thickness of 2.5 m to 11.5 m in left side, 0.7 km/sec velocity with its thickness of 0.5 m to 2.0 m in center base and 0.4 km/sec to 0.5 km/sec velocity with its thickness of 2.0 m to 8.0 m in right side.

Third velocity layer is the same as the fastest velocity in left side and center base. Its velocity of 2.0 km/sec to 2.3 km/sec in left side has boundary depth of 6.0 m to 14.5 m between second and third velocity layer, and velocity in center base is 2.7 km/sec to 2.8 km/sec with the boundary depth of 2.0 m to 3.0 m between second and third velocity layer. Third velocity layer in right side has velocity of 2.0 km/sec with its thickness of 2.5 m to 11.0 m and the boundary depth between second and third velocity layer is 2.5 m to 10.0 m in depth from the ground surface.

The velocity of fourth velocity layer found only in right side is 5.3 km/sec and its upper boundary depth is found by 4.0 m to 18.0 m in depth from the ground surface.

- Right Wing Dam

Formation of velocity layer of Right Wing Dam obtained along C and D Lines is shown in ANNEX and as follows. It is divided into four velocity layers of the fastest velocity of 5.4 km/sec in left side and three velocity layers of the fastest velocity of 1.9 km/sec to 2.2 km/sec in center base and right side.

In four velocity layers obtained in left side, first velocity layer has velocity of 0.2 km/sec with its thickness of 0.5 m to 1.0 m. Second velocity layer has velocity of 0.5 km/sec to 0.6 km/sec with its thickness of 7.0 m to 13.5 m. Third velocity layer has velocity of 2.0 km/sec with its thickness of 4.0 m to 6.5 m. Fourth velocity layer as same as the fastest velocity layer has velocity of 5.4 km/sec and its upper boundary depth is found by 13.5 m to 19.0 m in depth from the ground surface.

In three velocity layers obtained in center base and right side, first velocity layer has velocity of 0.25 km/sec to 0.3 km/sec with its thickness of 0.5 m to 2.5 m. Second velocity layer has velocity of 0.5 km/sec to 1.1 km/sec with its thickness of 2.0 m to 12.5 m. Third velocity layer of the fastest velocity layer has velocity of 1.9 km/sec to 2.2 km/sec and its upper boundary depth is found by 3.0 m to 14.0 m in depth from the ground surface.

Formation of velocity layers of spillway obtained along B Line is shown in ANNEX and as follows. It is divided into four velocity layers with its fastest velocity of 5.0 to 5.3 km/sec.

First velocity layer of 0.2 km/sec to 0.3 km/sec with its thickness of 0.5 m to 2.0 m, second velocity layer of 0.4 km/sec to 0.6 km/sec with one of 2.0 m to 8.0 m and third velocity layer of 1.8 km/sec to 2.0 km/sec with one of 10.0 m to

14.0 m are obtained. Fourth velocity layer of 5.0 km/sec to 5.3 km/sec has this upper boundary depth of 12.0 m to 20.0 m in depth from the ground surface.

Correlation between respective velocity layer obtained by seismic prospecting and geological condition is shown in ANNEX.

5. MATERIALS SURVEY AND LABORATORY TESTS

Materials survey and laboratory tests were carried out to get the availability of construction materials about their location, properties in soil mechanics and quantities. Embankment materials such as impervious core, filter and rock materials, and concrete aggregates were examined.

Impervious Core Materials

Twelve test pits, as their locations are shown in Fig. 6-1 were carried out to be digged for examination around the proposed dam site. The depth of test pits carried out is mostly in range from 2.7 m to 3.3 m, and their column sections examined are shown in ANNEX, including the depth of sampling which were examined by laboratory soil tests. Test items examined are as next page.

1) Specific gravity, 2) Natural moisture content, 3) Grain size analysis, 4) Liquid limit, 5) Plastic limit, 6) Compaction, and 7) Tri-axial compression.

The results are tabulated in ANNEX.

Filter Materials and Fine Aggregates

River sand is expected to apply to filter materials and fine aggregates, and already has examined at the same time as the last survey (1980) of river coarse condition. Those data are again applied to them and shown in ANNEX.

Rock Materials and Coarse Aggregates

Dike rocks distributed around the dam site are, according to the geological survey, expected to apply to them. The boring cores of dike rocks recovered by test borings conducted along the proposed dam axes were examined by the laboratory test, and at the same time soft rocks are also examined. The test items examined by laboratory rock tests are 1) Unconfined compression test, 2) Measuring the velocity of seismic wave, 3) Specific gravity, 4) Apparent specific gravity (unit weight) and, 5) Porosity including void index.

On the other hand, river gravel distributed in the proposed reservoir area were, as expected to apply to them, examined by laboratory test of 1) Grain size analysis, 2) Specific gravity, 3) Apparent specific gravity and 4) Porosity including void index.

The results of them are shown in ANNEX.

6. ENGINEERING-GEOLOGICAL ANALYSIS

The engineering-geological analysis of the data obtained by the geological survey is examined by 1) dam foundation, 2) construction materials and 3) geological condition of the proposed reservoir area. It gives no problem which makes difficulty to build a fill type dam in the proposed site.

Dam Foundation

Dam foundation is examined on the main two points -- mechanical condition of bedrock and its permeability. As for mechanical condition of bedrock, hard rocks of dikes are appropriate for the base of a concrete dam with its proposed height, but soft rocks such as tuff, lapilli tuff, calcareous sandstone and mudstone with the existing of fault under river bed are not appropriate for it. The geological conditions of bedrock at the proposed dam site are, however, able to safely support a filltype dam. The results obtained are shown in Figs. 6-4 and 6-5.

1) Main Dam (height: approximately 66m)

Bedrock of Main Dam consists mainly of dike rocks and slightly of calcareous mudstone and sandstone, and tuff, covered by river gravel which has approximately 9 m in thickness and 225 m in width along the Jeneberang river. Fault having nearly 1.0 m-thick fault breccia and clay is found under the river bed, and another few fault is also inferred under the river bed and in the left side abutment.
Dike rocks are very fresh and hard except the weathered zone distributed on right and left side slope. Completely fresh bedrock of dike rocks is, in depth, obtained by 9 m in the center of river bed, 15.6 m in the left side and 21.0 m in the right side abutments. The boundary between weathered soil including surface deposits and weathered dike rocks having the range from 1.7 km/sec to 2.3 km/sec of primary seismic wave is, in depth, obtained by 5.2 m in the left side, 13.25 m in the right side abutment, and no weathered zone under the river bed. Calcareous mudstone and sandstone, and tuff are, as partly distributed under the river bed, fresh and soft, and have 3.3 km/sec velocity of seismic wave.

Mechanical condition of bredrock is rather favourable, though the boundary location of soft rocks and faults found in the bedrock under the river bed should be cleared in future.

Permeability condition is relatively, favourable as same as bedrock condition, showing that the boundary depth below which lugeon value is less than 1 Lu is obtained by 10 m in the center of river bed, 15 m in the left side and 20 m in the right side abutments.

2) Left Wing Dam (height: approximately 40 m)

Bedrock of Left Wing Dam consists mainly of lapilli tuff, and tuff interbedded by the thin layers of mudstone and slightly of dike rocks on the right side abutments. Massive lapilli tuff showing 2.7 km/sec velocity of seismic wave, forms the bedrock on the center base of the proposed dam and there are little or no distribution of surface deposits. In the left side abutments, fresh but soft rock mass of tuff showing 2.3 km/sec velocity of seismic wave is obtained below the depth of 11.35 m, but somehow weathered softer rock mass including the clay is found below the depth of 14.9 m, while weathered surface soil of its thickness of 1.2 m and weathered rock mass is obtained down to 11.35 m in depth. In the right side abutments, very fresh and hard rock mass of dike rocks is obtained below the depth of 15.3 m, and the boundary between weathered soil and weathered surface rock mass is found at the depth of 5.5 m, The above mentioned shows that mechanical condition of bedrock in the center base and right side abutments is favourable, while not so good in the left side abutments.

Permeability condition is the same as the mechanical condition of bedrock, showing high permeability on the left side and small permeability on the center base and right side. The boundary depth below which Lugeon value is less than 1 Lu is obtained by 2 m in the center base, 40 m in the left side and 15 m in the right side abutments.

3) Right Wing Dam (height: approximately 50 m)

Bedrock of Right Wing Dam consists mainly of lapilli tuff and tuff interbedded by the thin layers of mudstone and slightly of dike rocks on the left side abutments. Tuff and lapilli tuff, compared with bedrock condition of Left Wing Dam, have somehow thicker weathered zone and smaller velocity of seismic wave of 2.1 km/sec in the fresh bedrock.

Soft rock mass, though sometimes weathered, is found below the depth of 9.60 m in the center base and of 11.6 m in the right side abutments, the depth of which are also the boundary between weathered soil and weathered bedrock. Weathered soil is examined by standard penetration tests obtained by the number of blows in range from 7 to 110. On the left side abutments, hard rock mass of dike rock is obtained by 13.25 m in depth, being covered by weathered soil and surface deposits.

Mechanical condition of bedrock is, compared with the other two dams of Main and Left Wing Dam, relatively poor.

Permeability condition is also not so favourable as same as the mechanical condition of bedrock.

The boundary depth below which lugeon value is less than 1 Lu is obtained by 20 m in the center base, 35 m in right side and 20 m in left side abutments.

Construction Materials

Embankment materials such as impervious core, filter and rock materials, and concrete aggregates are examined. The results are shown in ANNEX.

1) Impervious core materials

The weathered soil and rock derived from tuff, lapilli tuff, siltstone and some surface deposits like detritus around the proposed dam site were sampled and examined for them. Their properties in soil mechanics are classified by Unified Soil Classification System into the symbol of SC, CL, CH and MH, showing more fine materials and higher natural moisture content.

Passing percentage of silt and clay is between 31% and 87%, and natural moisture content is measured between 21% and 64%. Maximum dry density obtained by compaction test shows the range from 1.1g/cm^3 to 1.5g/cm^3 and optimum moisture content, most of which are smaller than natural moisture content, is obtained by the range from 26.0% to 47.1%.

These results show that materials obtained here, especially more fine ones, are not so favourable for impervious core materials. But some of them and others derived from slightly weathered soft rocks and highly weathered hard rocks are available for them.

2) Filter materials and fine aggregates

River sand distributed between river mouth and 17.6 km distance from river mouth is available for them, while its nearest location is approximately 10 km far from the proposed dam site. Their properties are classified by Unified Soil Classification System into the symbol of SP.

3) Rock materials and coarse aggregates

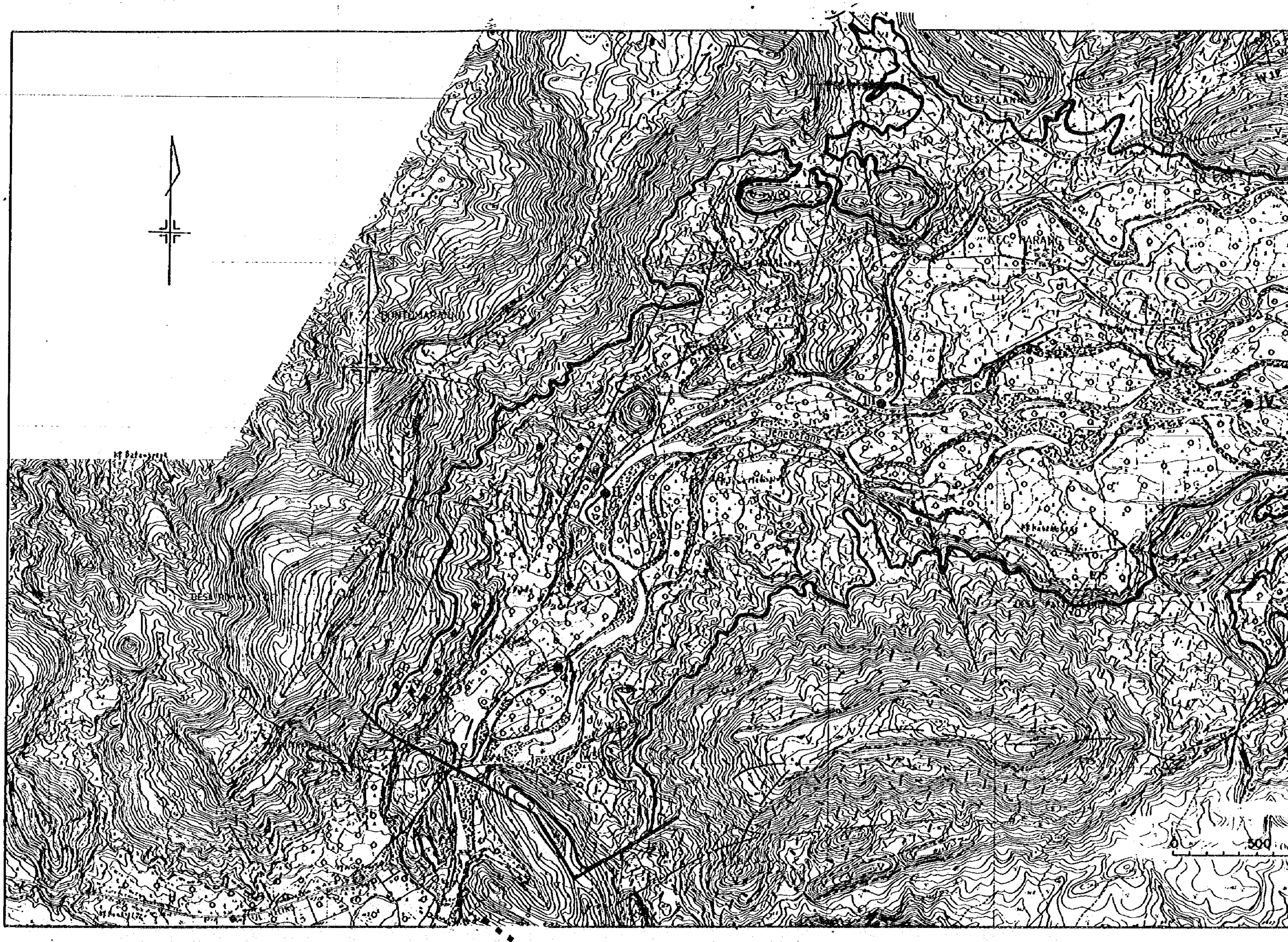
Fresh and hard dike rocks such as diabase and diorite distributed around the next lower reach of the dam site are available for them. And also river gravel distributed in the proposed reservoir area is available. The properties of these materials are, according to the results of laboratory test, available for concrete aggregates. Boulder hard gravel included in detritus deposits is also available for rock materials.

Geological Condition of the Proposed Reservoir Area

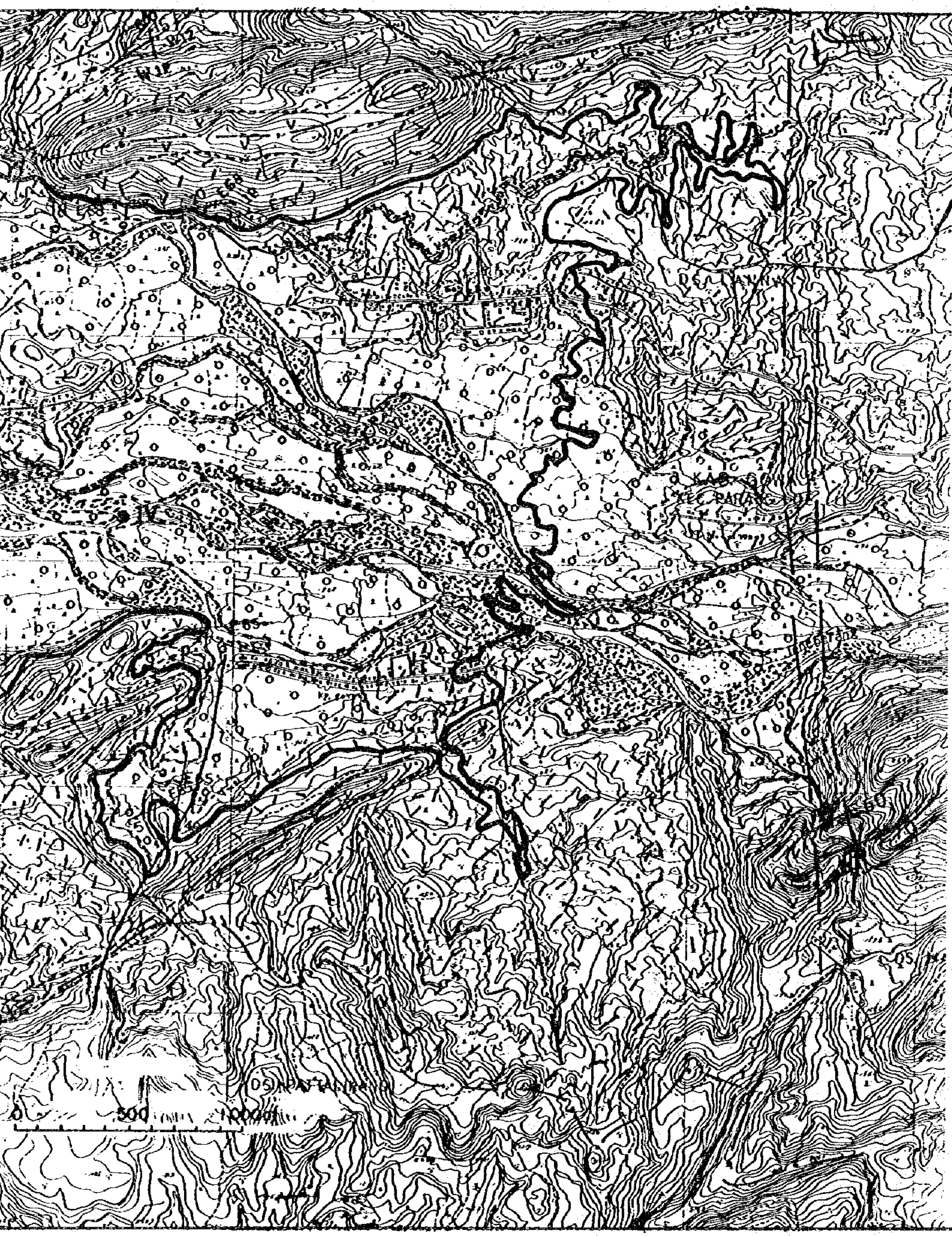
As for geological condition of the proposed reservoir area, landslide in it and water leakage out of it are examined.

A few traces of landslide are found, but too small to affect the concerned structure of dam, even if it would happen to slide after ponding.

Leakage of water due to insufficient height against the proposed high water level at a few topographical saddle points in the surroundings of the reservoir may seem to happen. The treatment against leakage is not so difficult, as the bedrock, though weathered, is found in the height more than the proposed high water level.



KEC. PARANG LOE
S. Jeneberang
500



LEGEND

Quaternary (Alluvium)
- Recent River Deposits (Gravel)
- Terrace Deposits (Gravel and Sand)

Tertiary
- Dyke Rocks
- Pyroclactic Rocks (Tuff, Lapilli Tuff, Tuff Breccia including some Mudstone)
- Marine Sedimentary Rock (Calcareous Mudstone and Sand stone partly Lime stone)

Note: The area around the distribution of dyke rocks and their foot are almost covered by detritus.

- Boundary of the geological division
- Fault
- Dominant lineation
- Boundary ridge of the catchment area
- 100m countour line expected as reservior area
- E50 / 10 — Dip and strike of the bedding plane.
- E55 / 80 — Dip and strike of the joint plane.
- ■ D — Location of test pit for core materials
- ● II — Location of sampling river gravel

Fig. 6-1

GEOLOGICAL MAP OF DAM SITE AND RESERVOIR AREA