AG:DP/INS/69/518
Technical Report 1

# LAND AND WATER RESOURCES DEVELOPMENT IN SOUTHEAST SUMATRA

# INDONESIA

## LAND, WATER AND FORESTRY RESOURCES

UNITED NATIONS DEVELOPMENT PROGRAMME

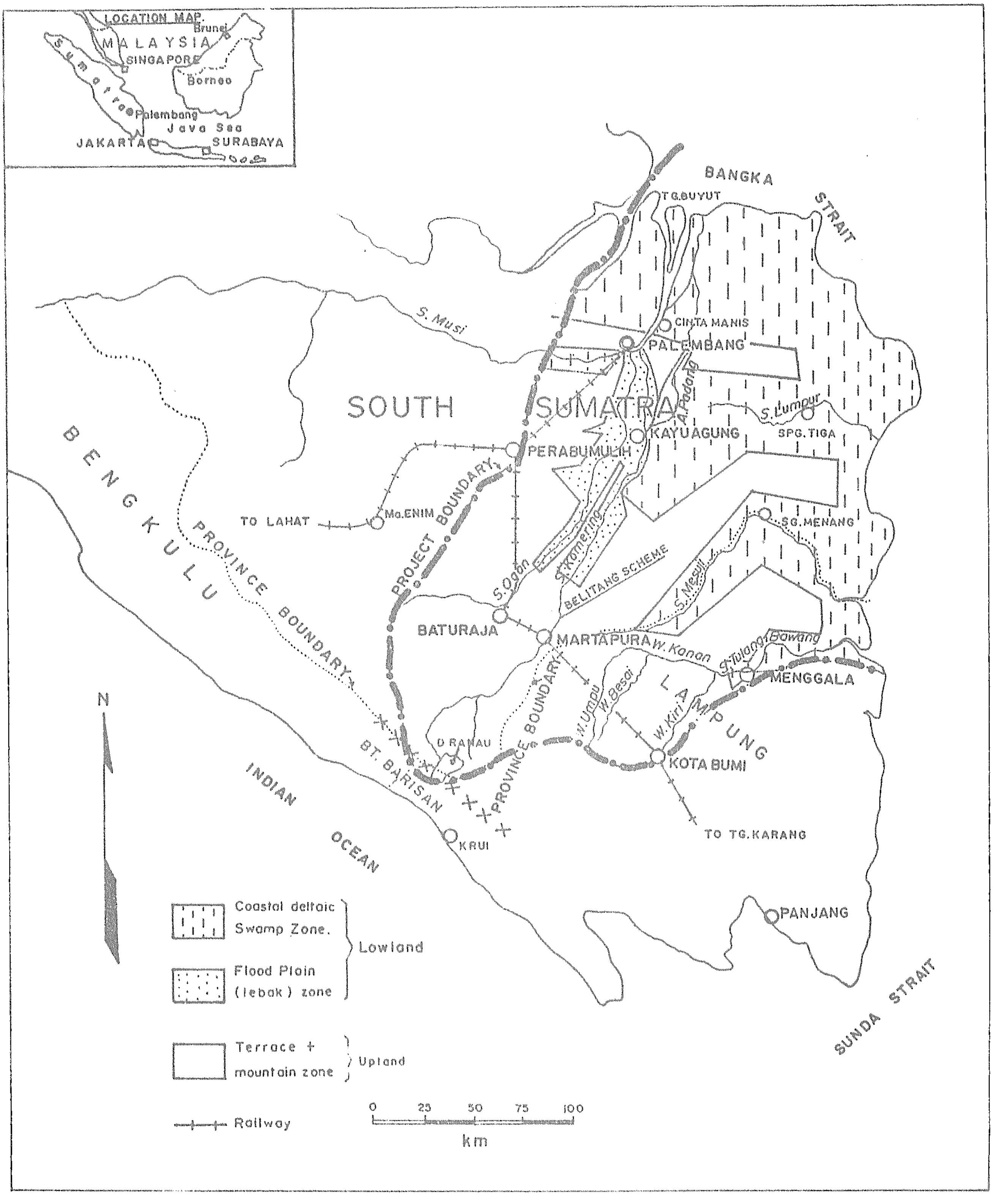
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS ROME, 1976

# LAND AND WATER RESOURCES DEVELOPMENT IN SOUTHEAST SUMATRA

I N D O N E S I A

FRONTISPIECE

# LOCATION OF PROJECT AREA



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# LAND AND WATER RESOURCES DEVELOPMENT IN SOUTHEAST SUMATRA

## I N D O N E S I A

## LAND, WATER AND FORESTRY RESOURCES

Report prepared for
the Government of the Republic of Indonesia
by
the Food and Agriculture Organization of the United Nations
acting as executing agency for
the United Nations Development Programme

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1976

FAO. Land and Water Resources Development in Southeast Sumatra, Indonesia. Land, water and forestry resources. Rome, 1976. 164 p., 49 figs, 10 maps. AG:DP/INS/69/518, Technical Report 1.

## ABSTRACT

The Government of Indonesia together with the United Nations Development Programme and the Food and Agriculture Organization of the United Nations carried out a project in Southeast Sumatra during 1970-75. Objectives included making a basic technical inventory covering the water resources (hydrometeorologic aspects, water quality and groundwater), land suitability, and forests and forest production, of an area of 4.5 million ha.

Problems in the planning of water resources concern uneven distribution of rainfall in time, indicating the need for supplementary irrigation, and constant annual flooding making intensive cropping during rainy months hazardous. The high watertable presents a difficulty in water management. Except in areas where tidal waters intrude, the water in the project area is of good quality and can be used to irrigate any type of plant or soil group. The most favourable areas for potential groundwater development are the anticlinal structures near Palembang, Perabumulih and Muara Enim and in the vicinity of Baturaja. Other possible sites are where the Muara Enim coal, the Air Benakat sand and clay, and the Baturaja limestone or the Talang Akar shale outcrop or lie at relatively shallow depths. A systematic investigation is required to determine the quantities of groundwater available. The potential for utilizing groundwater for dry-season irrigation is sufficiently favourable to warrant further investigation into hydrogeologic conditions.

A land suitability classification was developed for unimproved shifting cultivation and, under improved practices, for upland crops, pasture, tree crops and paddy (wetland) rice.

In the forestry sector, the basic requirements have been pinpointed as regional rural fire control; control of shifting cultivation; erosion control on steep lands; species trials; the establishment of plantations of fast-growing general purpose timbers in selected inland areas; forestry-inventory and timber-utilization studies in the Palembang swamp-forest complex and the establishment of an integrated forest industry.

The Food and Agriculture Organization is greatly indebted to all those who assisted in the implementation of the project by providing information, advice and facilities.

# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF MAPS

# GLOSSARY

| | | |
|---|---|---|
| adat | - | custom, tradition |
| air | - | river |
| alang-alang (or lalang) | - | *Imperata cylindrica*, a coarse grass |
| belukar | - | secondary forest |
| danau | - | lake |
| Dinas Peternakan Daerah, Propinsi Sumatra Selatan | - | South Sumatra Animal Husbandry Department |
| DITTOP | - | Direktorat Topografi |
| Direktorat Gizi Dinas Penelitian | - | Directorate for Nutrition, Subdivision of Research |
| Direktorat Jendral Kehutanan | - | Directorate General of Forestry |
| DPU | - | Dinas Pekerjaan Umum - Public Works Department |
| hutan | - | forest |
| hutan marga | - | forest pertaining to the marga |
| ITB | - | Institut Tekhnologi Bandung |
| kabupaten | - | district or country |
| kuala | - | mouth of river |
| kecamatan | - | subdistrict |
| lebak | - | back swamp behind river levee |
| marga | - | a sub-subdistrict usually centred in a large village |
| muara | - | mouth of tributary river |
| penghijauan | - | a system of afforesting grassland, using strip planting |
| PUSRI | - | Palembang fertilizer factory |
| sawah | - | wet rice fields |
| seru | - | *Schima bancana*, a species of tree |
| sungai | - | river |
| sumba | - | a scheme for cattle multiplication by smallholders |
| taungya | - | a type of cropping, tree crops interspersed with food crops |
| USDA | - | United States Department of Agriculture |
| way | - | river |

Chapter 1

# INTRODUCTION

## 1.1 DESCRIPTION OF PROJECT

This report describes activities undertaken by the UNDP/FAO project 'Land and Water Resources Development in Southeast Sumatra', from December 1970 to December 1975. The area under investigation, covering some 4.5 million ha, included the catchments of the Rivers Ogan, Komering, lower Musi, Mesuji and Tulang Bawang.

The urgent need to relieve, by transmigration, the population stress on land in Java and to meet the increasing demand for more food and agricultural products has focused the Government's attention on sparsely populated and agriculturally underdeveloped areas. Southeast Sumatra is one such area and in particular the coastal deltaic lowland, still largely under virgin swamp forest, offers an opportunity to grow rice, utilizing irrigation by tidal inundation. The vast but comparatively empty hinterland, which had been subjected to shifting cultivation for many years, also has a potential for agricultural expansion.

This analysis of the agricultural and water resources of the area is based on the work of A.G. Pike, Hydrologist, M. Molina G., Consultant (Hydrology and Agrometeorology), L.W. Hyde, Consultant (Groundwater), D.R. Harris, Soil Surveyor, F.J. Dent, Land Capability expert, R.G. Menon, Soil Scientist and R.G. Dixon, Consultant (Forestry). Together with the second report in this series, it was subsequently used to prepare an overall development plan for the area 1/.

## 1.2 PROJECT AREA BACKGROUND

### 1.2.1 Topography

The project area lies within latitude 2°15' and 4°40' south and longitude 102°57' and 106°05' east. In the west is the Bukit Barisan range which forms the mountain spine along the whole length of Sumatra. The highest point is Gunung Pugung at 1 964 m, a zone which is still volcanically active. A large lake, Danau Ranau, with a surface area of 121 $km^2$ and depth about 400 m, fills one crater. Forests still cover a large area of this hilly broken country; clearing of this natural forest cover has resulted in very heavy erosion and deposition of the eroded material in the lower courses of the main rivers, particularly the Ogan and Komering.

East of the main range, there is a vast area of some 2 million ha of a rolling, undulating old terrace formation into which the main rivers and their tributaries have incised and broadened their valleys. The altitude of this formation varies from 200 m above mean sea level (m.s.l.) at Sungsang in the west, to about 6 m in the east. Islands of this old terrace, above the coastal and deltaic lowlands, occur further east.

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1/ FAO. Land and Water Resources Development in Southeast Sumatra, Indonesia. Socio-economics, land tenure and agricultural and fisheries production. AG:DP/INS/69/518, Technical Report 2. Rome, 1976.
FAO. Land and Water Resources Development in Southeast Sumatra, Indonesia. Plan of development. AG:DP/INS/69/518, Technical Report 3. Rome, 1976.

Filling the enlarged and broadened river valleys are some 500 000 ha of floodplain. This area, here referred to as the Lebak, contains extensive old river courses, ox-bow lakes, braided river channels and shallow lakes and depressions which become flood storage reservoirs in the wet season. The northern limit of this area is immediately upstream of Palembang in the east, the right bank of the Komering river. The Lebak or back swamp is usually inundated for some six months of the year. Narrow ridges within the area and the natural level along the river bank provide the village and orchard sites.

Downstream of Palembang over the Sungai Musi delta and coastal lowlands and in the lower reaches of the Mesuji and Tulang Bawang Rivers there are over 1 million ha of practically dead flat and waterlogged land. Internal drainage is very poor, almost non-existent, and tidal movement affects the whole area.

### 1.2.2 Map coverage and levelling

The project area is covered by government-issued and other externally printed topographical maps of scale 1: 100 000. The information recorded is basically that plotted by the Netherlands East Indies survey department, amended by subsequent observations from aerial photography carried out by Allied airforces during the second world war, and after. The UNDP/FAO Aerial Photography project INS/69/522 completed from aerial photos a set of 1:50 000 semi-controlled mosaics. Three sets of the photos were in use during the present project's operation. In addition, 1:10 000 scale aerial photography of two specific areas - the Belitang irrigation area and Cintamanis agricultural development area - were utilized. To overcome deficiency in level information, particularly for the micro-levelling needed in the practically flat lower Musi area, the project completed a second-order levelling programme with assistance of the Public Works Department (DPU), the Institute of Technology, Bandung (ITB) and the Direktorat Topografi (DITTOP) to establish a grid of bench marks based on m.s.l. at Sungsang, Kuala Musi - the exact location being at Tanjung Jerat some 5 km downstream of Sungsang village. Sungsang m.s.l. datum is 4.96 m below m.s.l. datum at Panjang (Lampung pale) - this difference being found within the Belitang Scheme where the two levellings overlapped.

### 1.2.3 Climate, meteorology and river flow measurement

The area has a tropical monsoon climate, hot and humid throughout the year. Heavy rains occur during the northeast monsoon, which blows from the South China Sea between December and April. From late April to June and again from September to November, the southeast trade winds prevail but since the project area is so close to the equator, their influence is slight. From June to September a very weak southwest monsoon, from the Indian Ocean, at its eastern limits, causes some rainfall along the coastal strip between the Bukit Barisan range and the Indian Ocean, but little falls in the project area, so that this period is the driest of the year. Average annual rainfall in the project area ranges from 1 500 mm at the coast to about 3 200 mm in the mountainous zone. Most of the rain falls between December and April, and river flows are at their lowest during August and September. However, it has become apparent that in South Sumatra, the dry season can frequently be quite wet with a fairly even distribution of rainfall throughout the period, and the start of the rainy season can also be delayed with dry periods occurring during the wet season.

Temperatures range from $19.5^{\circ}$ to $36.5^{\circ}C$. Humidity is also high all the year round and varies between 60 and 99 percent.

To extend data collection, the project established or further equipped agro-meteorological stations at Raksajiwa, Cintamanis, Belitang, Menggala and Banding Agung and sited rain gauges at six other places. Water level gauges, some automatic, were installed at 14 places on the main rivers and at these sites, river flows were measured and flow rating curves established.

### 1.2.4 Groundwater

In the low-lying zones of coastal swamps and the Lebak, the ground is completely saturated and agricultural improvement depends very largely on an ability to lower groundwater level. In the higher zones, notably on the old terrace formation, there is some evidence of a fluctuating groundwater source. No quantitative measurements were made of this resource, which is considered to be of minor importance.

### 1.2.5 Soils and land use

In general, the uplands are fertile, soils being of volcanic origin. Extensive areas are devoted to tree and bush crops such as coffee and pepper, and there are some small flattish areas where irrigated rice and vegetables are or could be developed.

The old terrace lands have been subject to shifting cultivation for centuries and now carry tree crop plantations such as rubber, a vast area of alang-alang grass (Imperata cylindrica), remains of dryland forests and large expanses of secondary forest (belukar). The soil over many parts of this formation has become highly degraded and exhausted of plant nutrients.

In the lebak area, agriculture, principally rice cultivation, is undertaken only in the receding flood water during the dry season April to October - a timing which is extremely risky as rapid and excessive drying-out can occur and early floods can damage the ripening crop. Only some 80 000 ha are cultivated in this area, the rest being under swamp forest or grass and reed growth. The people, mostly indigenous Sumatrans, are continually trying to expand the area by further clearing at the forest and swamp edges. Freshwater fishing is an important occupation in the Lebak with its extensive, permanent water.

Apart from some man-made clearings, the deltaic and coastal lowlands are covered by a dense swamp forest, which is shallow rooted in a few centimetres of humus material overlying, in most locations, potentially acid sulphate soils.

Some agriculture, mostly rice growing, facilitated by tidal inundation, is practised on areas contiguous to the lower reaches of the water courses. A feature of this land use is that the extensive formerly cropped areas, now abandoned, do not revert to their original forested condition. These areas have developed highly acid soil conditions, particularly unsuitable for most crops.

### 1.2.6 Forests

It is estimated that productive forest resources and other scattered forests hold 156 000 ha of exploitable forest, carrying about 7.2 million $m^3$. In addition, a large compact swamp forest complex of over 1.1 million ha, adjacent to Palembang and round the coast holds an estimated 500 000 ha of exploitable forest, carrying some 30 million $m^3$ of commercial timber.

Dryland forest is rapidly disappearing under the onslaught of shifting cultivation and associated burning. The largest block of dryland forest, about 70 000 ha in extent, is in the headwater region of the Mesuji river. This piece of forest is reported to hold a herd of 70 elephants - a very strong reason for conservation of this resource. In the higher and steeper areas, destruction of forest has created a serious erosion problem which has contributed to the annual flooding in the lebak area.

1.2.7 Communications

Three large rivers, the Ogan, Komering and Tulang Bawang, cross the project area from the Bukit Barisan uplands and discharge into the Bangka Strait. The Ogan and Komering join the Musi River at Palembang, at approximately 90 km from the sea. Tidal influence extends at some times of the year to some 100 km inland, measured along the rivers' tortuous courses. The Mesuji and Lumpur, along with innumerable creeks and streams, also drain the lowlands to the Bangka Strait and are subjected to tidal movement over their entire courses.

Up to 40 years ago it was possible on the Sungai Ogan to move goods and passengers by rivercraft as far as Baturaja at all times. Heavy siltation in the middle reaches of this river now prevents the use of this transport route.

A railway, whose passenger and goods capacity is steadily being improved, runs from Palembang via Perabumulih, Baturaja and Martapura to Lampung province and finally to Panjang in the south. A branch line takes off at Perabumulih to Muara Enim, Lahat and Lubuk Linggau in the north of South Sumatra province. This rail route has remained open all the time, even during the late sixties when road communications were practically severed throughout the project area.

A main road which is still, in parts, not all-weather, roughly follows the railway route and a subsidiary network of fair-weather roads lies along the Ogan and Komering river courses. One route along Sungai Komering is rapidly being sealed. One track leads eastward from Palembang for some 100 km toward Simpang Tiga on the Sungai Lumpur. The Sungai Mesuji basin is only connected to the rest of the area by poor tracks which are not always jeepable because of lack of culverts and stream crossings. A good, surfaced road connects the village of Menggala with the Kotabumi-Tanjung Karang road. From both Martapura and Maturaja, roads lead into the mountains at Lake Ranau and connect to northwest Lampung and Krui on the Indian Ocean.

There are landing strips near Martapura and Tanjung Raja, and Palembang has an important airfield. There is a military airfield at Astra Ksetra near Menggala. Helicopters were used for difficult project transport throughout the area.

1.2.8 Minerals

Since the twenties the whole area has been prospected for petroleum and the western section, particularly in the neighbourhood of Perabumulih, is a producing field, pumping the crude to the two refineries at Palembang. Natural gas is also pumped to Palembang for use in the oil refineries and the PUSRI fertilizer plants.

Investigations are now under way to determine the extent of the near-to-surface coal deposits which lie north and east of a line joining Tanjung Enim, Baturaja, and Martapura.

There is an extensive limestone formation near Baturaja which is little exploited. This asset will certainly be needed for agriculture and for a cement factory to be sited near Baturaja.

# Chapter 2

# WATER RESOURCES

## 2.1 HYDROMETEOROLOGIC INVESTIGATIONS

Hydrometeorologic data on the project area were determined through various mathematical and statistical analyses. While data collected by the project were mainly used, that provided by the Agriculture Office and the Lampung Hydrological Project also proved valuable. Except for monthly rainfall, however, the available records are of rather short duration and therefore whenever possible, synthetic data have been generated to complete the information and thereby acquire a better idea of the potential of the resource.

Local counterpart personnel were instructed in the techniques of mathematical and statistical analysis that apply to hydrological studies. They will therefore be able to interpret the findings reported here and use the methods for further studies and analyses.

Findings are presented mostly in graphic form. The necessary tabulations and step-by-step calculation papers are available in the office of the successor organization to the project - the Public Works Department, Hydrological Section. The information presented gives a complete picture of the potential of the atmospheric and superficial waters in the project area, and can be used in the planning of these resources. However, some findings should be interpreted with care, particularly those based on short-term records.

It is concluded that the atmospheric and surface waters in the project area constitute a reliable resource for irrigation, water supply, energy, or any other form of water use for the benefit of the community, if the necessary steps are taken to control flooding and properly manage the water-table.

### 2.1.1 Materials and methods

#### 2.1.1.1 Data and records

Except for the total monthly rainfall records, available hydrometeorologic data cover no more than three years. The installation of the hydrometeorologic network and the collection of data began only in late 1971. Some observations since then have been discontinued while some data are discontinuous owing to instrument failure not promptly repaired. Figure 1 shows the length of the monthly rainfall records. Tables 1 and 2 give the available climatologic and hydrologic information collected by the project. Figure 2 shows the hydrometeorologic network installed and maintained by the project.

Samples of water to determine salinity were taken in many rivers (see Map 1) between October 1971 and June 1973, and 88 samplings for sediment discharge in the main river were taken between December 1971 and April 1973 1/.

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1/ In addition to the data collected by the project, pertinent information was provided by the Agricultural Office and the Lampung Hydrological Project, a British Bilateral Aid project directed by Messrs Howard Humphreys & Sons, Consulting Engineers, which was also helpful in analyses and studies.

Table 1

AVAILABLE CLIMATOLOGIC DATA

(beginning on: and continuing, unless otherwise stated)

| Available data | Location of climatologic station | | | | | |
|---|---|---|---|---|---|---|
| | Cintamanis | Belitang | Raksajiwa | Menggala | Banding Agung | Simpang Tiga |
| Rainfall intensity | Dec. 71 | Jan. 71 | Dec. 71 | Dec. 71 | Mar. 72 | Apr. 72 |
| Pan-evaporation | Dec. 71 | Dec. 71 | Dec. 71 | Dec. 71 | Mar. 72 | none |
| Relative humidity | Dec. 71 | none | Feb. 72 | Mar. 72 | June 72 | none |
| Air temperature | Dec. 71 | Jan. 71 | Dec. 71 | Dec. 71 | Mar. 72 | none |
| Sunshine duration | Dec. 71 | Dec. 71 | Dec. 71 | Dec. 71 | none | none |
| Solar radiation (Gunn Bellani) | Dec. 71 | Dec. 71 | Dec. 71 | Dec. 71 | none | none |
| Solar radiation (actinograph) | none | Aug. 72 to Apr. 74 | none | Apr. 74 | Mar. 72 | none |
| Wind velocity | Dec. 71 | Dec. 71 | Dec. 71 | Dec. 71 | Mar. 72 | none |

Table 2

AVAILABLE HYDROMETRIC RECORDS

| Watershed | River | at | Rating curve | Measurement beginning on: AWLR 1/ | Staff gauge | |
|---|---|---|---|---|---|---|
| OGAN | Lengkayap | Batu Putih | yes | none | May 72 – | |
| | Ogan | Baturaja – Kota | yes | none | Nov. 70 – | |
| | Ogan | Baturaja-Terusan | no | Aug. 71 | Aug. 71-Feb. 74 | 2/ |
| | Rambang | Tanjung Rambang | yes | Oct. 72 | Apr. 72-Feb. 74 | 2/ |
| | Rambang | Tambangan Rambang | no | none | Apr. 72 | |
| | Ogan | Tanjung Raja | yes | Aug. 71 | Nov. 70-Feb. 74 | 2/ |
| | Simpang | Muara Simpang | no | none | Aug. 71 – | |
| KOMERING | Selabung | Banding Agung | yes | Mar. 72 | Feb. 72-Feb. 74 | 2/ |
| | Komering | Martapura | yes | July 71 | Nov. 70-Feb. 74 | 2/ |
| | Komering | Menanga | no | Aug. 71 | Nov. 70-Feb. 74 | 2/ |
| | Lempuing | Cahaya Bumi | yes | none | Sept. 71 – | |
| | Lempuing | Pedamaran | no | none | Nov. 71 – | |
| | Komering | Sirah Pulau Padang | yes | Aug. 71 | Dec. 70-Feb. 74 | 2/ |
| LEMATANG | Lematang | Sungai Rotan | no | Apr. 73 | May 72-Dec. 73 | 2/ |
| MUSI | Musi | Tebing Abang | no | Oct. 72 | May 72-Jan. 74 | 2/ |
| | Musi | Palembang – Bom Baru | no | Sept.71 | Sept.71 – | |
| | Musi | Selat Jaran | no | none | July 71-July 72 | 2/ |
| | Musi | Upang | no | Oct. 73 | June 71-Feb. 74 | 2/ |
| | Musi | Teluk Sindon | no | none | July 71-July 72 | |
| | Musi | Tanjung Buyut | no | Aug. 71 | Aug. 71 – | |
| LUMPUR | Lumpur | Simpang Tiga | no | none | Oct. 70 – | |
| MESUJI | Mesuji | Pematang Panggang | no | none | Oct. 71 – | |
| | Mesuji | Sungai Menang | no | none | Sept.71 – | |
| TULANG BAWANG | Giham | Rantau Jangkung | yes | none | June 72 – | |
| | Tahmi | Tanjung Agung | yes | none | June 72 – | |
| | Umpu | Negeri Batin Baru | yes | none | June 72 – | |
| | Besay | Banjar Masin | yes | none | Apr. 71 – | |
| | Umpu Kanan | Pakuan Ratu | yes | Mar. 73 | June 72-Feb. 74 | 2/ |
| | Tulangbawang | Menggala | no | Oct. 71 | Jan. 71-Feb. 74 | 2/ |

1/ Automatic Water Level Recorder.

2/ Discontinued on this date.

### 2.1.1.2 Data consolidation

Careful observation and revision of all the data were undertaken to establish the accuracy, reliability and consistency of the information collected. Double mass analyses were carried out to check the consistency of the monthly rainfall records shown in Figure 1 and corrections were made when necessary. Missing data were estimated, when applicable, by correlation analysis and lineal regression equations.

Of the variables or hydrometeorologic factors observed anomalies were found in streamflow, pan-evaporation and solar radiation recording.

In streamflow recording, the mean daily discharge should be obtained by reading the respective rating curve of the discharge corresponding to each of the three staff gauge readings and recording average of these three discharges. Calculating the average of the three staff gauge readings and recording its corresponding discharge should not be done. The corrections were needed most particularly during the rainy months when the use of the latter method introduced errors as high as 10 or 15 percent which, for rivers that carry hundreds of cubic metres per second, implied a big underestimation of the potential. However, during the dry months, when low and almost constant discharges are observed, either method is equally accurate.

Records of the daily total pan-evaporation showed gross and obvious errors when values of 100 mm or more of evaporation had been recorded, particularly during the rainy days. On the other hand, zero daily evaporation had also been recorded even though during the same day many hours of sunshine, high radiation, low humidity and high wind velocity had been recorded. When either one of these situations was found in the records, the value recorded was deleted and replaced by the daily mean, calculated using the number of days with reliable data. It is strongly recommended that the method of measuring daily pan-evaporation be improved.

Solar radiation is measured by means of two different instruments (see Table 1), to find a rating curve for the radiation measured by the Gunn Bellani as a function of the radiation measured by the actinograph. In this report, the calibration performed by the Lampung Project is used to calculate the solar radiation measured by the Gunn Bellani.

No significant anomalies were noted in the records of the other meteorologic variables - temperature, relative humidity, wind velocity, hours of sunshine.

### 2.1.1.3 Methods of analysis

The methods used in the analysis of the records are those generally adopted in hydrologic studies and water resource evaluations. The methods most frequently used in the present study are noted below.

Simple and multiple correlation analysis was used to find the relationship between two or more hydrometeorologic variables. The least square method was used to calculate the coefficients of the corresponding equations.

In order to generate synthetic data, simple stochastic models were developed. They include a random component which is a function of the standard error of the deviates and a random number normally distributed, both obtained from tables.

The following probability distributions were found to fit one or more of the hydrologic data: normal, geometric, Gumbel, Weibull, Log-Pearson Type III. Their parameters were determined following standard procedures described in any book on statistics or probability.

The procedure followed in processing the data is shown in a flow chart (Figure 3).

### 2.1.2 Rainfall analysis

A complete analysis of the rainfall records was carried out to evaluate the potential and variation in time and space of the water that falls from the atmosphere to the ground. The analysis included annual, monthly and instantaneous rainfall as related to distribution in time and space.

(a) Annual rainfall : areal variation

The map of isohyets (Figure 4) shows the variation of the mean annual rainfall over the project area, whose value varies between 1 500 mm and 3 200 mm. The average annual rainfall over the project area has been computed using the isohyets and amounts to 2 359 mm.

(b) Annual rainfall : frequency distribution

Assuming normality, the frequency distribution of annual rainfall at several stations was estimated (Figure 5). As an example, the areal (geographical) variation of the 5-year and 50-year return period annual rainfall has been plotted (Figures 6 and 7).

(c) Monthly rainfall : frequency distribution

The rainiest months are November to April and the less rainy months June to September; May and October appear as transition months in Figure 8 (a) through (i), showing the 5, 10, 25 and 50 percent relative frequency of monthly rainfall at nine different stations. The cumulative monthly rainfall at four stations (Figure 9) shows that the annual rainfall concentrates in a few months, 80 percent occurring between October and May.

(d) Storm analysis

A storm is defined by its intensity, duration and frequency. To determine the frequency, the long, monthly rainfall records were used to generate long records of rainfall intensities at 14 stations. Mathematical relationships were found between monthly rainfall, maximum daily rainfall of the month, maximum hourly rainfall and maximum intensities of rainfall for different storm durations. The following equations were derived:

$$I_{60} = 0.461 \; R_d^{\;1.08}$$

$$I_M = 3.9 \; I_{60} \; D^{-0.33} \quad \text{for } D \leq 60 \text{ min.}$$

$$I_M = 31 \; I_{60} \; D^{-0.84} \quad \text{for } D > 60 \text{ min.}$$

In these expressions:

$I_{60}$ – rainfall amount in one hour (mm)

$R_d$ – total maximum daily rainfall of the month (mm)

$I_M$ – maximum rainfall intensity (mm/h)

D – duration of storm (min).

The derivation of these equations can be seen in Figures 10 and 11. These generated data were used to carry a frequency analysis and to draw the storm duration-frequency-intensity curves that can be seen in Figure 12 (a) through (n). As examples, Figures 13 and 14 are maps of the geographic variation of the two year-15 minute and the five year-30 minute storms, respectively.

(e) Rainfall duration distribution

A well-fitting Weibull distribution was used to define the frequency distribution of rainfall duration. The cumulative distribution of rainfall duration and the parameters of the distribution for six stations in the project area are presented in Figure 15.

(f) Rainfall depth - duration - frequency curves

As a first approximation, the information of the six climatologic stations was assembled and the curves of rainfall depth - duration - frequency determined (Figure 16).

### 2.1.3 Streamflow

Because of the shortness of existing streamflow records (see Table 2), several schemes were devised to produce synthetic streamflow records. Mainly, monthly and peak discharges are generated by use of very simple mathematical models. These data are then used to carry the statistical analysis to give some idea of the characteristics of this variable.

(a) Daily discharge

The daily discharge is better visualized by means of the duration curves of the rivers Ogan, Komering, and Lempuing (Figure 17). These curves provide information on the number of days per year that one can count on a certain discharge.

(b) Synthesis of monthly streamflow

Existing discharge records are too short for any second statistical analysis. It was necessary to devise a scheme to generate long records of monthly discharge based on the long rainfall records at nearby stations. The few months of available discharge records were used to find the parameters of the mathematical model which is:

$$Q_i = a + b_1 P_i + b_2 P_{i-1} + e n_i$$

where:

| | | |
|---|---|---|
| $Q_i$ | - | discharge, mean daily of the month ($m^3/sec$); |
| $P_i$, $P_{i-1}$ | - | precipitation, monthly total at nearby station during months i and i-1, respectively (mm); |
| a, $b_1$, $b_2$ | - | constants computed using multiple regression analysis; |
| e | - | standard error of the deviates; |
| $n_i$ | - | random number normally distributed with mean equal to zero and standard deviation equal to one (N (0,1)). |

The following parameters were found:

| Discharge river/station | Rainfall station | coefficients a | $b_1$ | $b_2$ | e |
|---|---|---|---|---|---|
| Ogan/Baturaja | Baturaja | 27.7 | 0.31 | 0.31 | 62 |
| Komering/Martapura | Muaradua | 71.6 | 0.26 | 0.35 | 74 |
| Umpukanan/ Pakuan Ratu | Blambangan Umpu | 20.6 | 0.34 | 0.21 | 67 |

Using these relationships, monthly discharges for the above rivers were computed, the information then being used to find some statistical characteristics of the streamflows.

(c) Relative frequency of monthly discharge

The relative frequency curves for the rivers Ogan, Komering, and Umpukanan at Baturaja, Martapura and Pakuanratu, respectively, are given in Figure 18. These curves show the discharge that can be expected each month with a given frequency. The corresponding return periods are also indicated.

(d) Flood analysis

Long records of peak discharges were generated using the relationships of monthly mean, and mean daily and maximum (or peak) daily discharges. This was done using the existing short records of discharge in the main streams. The equations have the general form:

$$Q_D = a \; Q_M^{\;b}$$

and

$$Q_I = c \; Q_D^{\;d}$$

where :

$Q_M$ , $Q_D$, $Q_I$ are the monthly mean, daily mean and peak (maximum instantaneous) daily discharge, respectively,

a, b, c, d are the coefficients calculated by the least square method.

The $Q_M$'s are found using the expression in 2.1.3 (b) above.

Figures 19, 20 and 21 show binary relationships for the three main rivers mentioned above.

Once the peak discharges for each year have been estimated, the corresponding flood analysis is done assuming the Gumbel distribution. Figures 22 (a), 22 (b) and 22 (c) show the results for the same three rivers.

(e) Design discharge and risk analysis

The dimensions of any engineering project related to water use or control are linked to the expected life, cost and risk of failure of the project. Figures 23 (a), 23 (b) and 23 (c) show the results of the risk analysis carried out for the Ogan, Komering and Umpukanan Rivers. The curves provide information about the discharge that should be considered, for a given risk and expected life, in the design of any project on these rivers at, or nearby, Baturaja, Martapura or Pakuanratu, respectively.

### 2.1.4 Evapotranspiration

(a) Potential evapotranspiration

Potential evapotranspiration is estimated using the Thornthwaite method. Even though there are only two complete years of any climatologic records available, the results found can be useful to assess the characteristics of this variable, as temperature is a relatively stable factor in the area.

(b) Monthly variation

The accumulated monthly potential evapotranspiration of four stations is shown in Figure 24; the variability between months is relatively small.

Hydrologic balances using Thornthwaite's method were also carried out to estimate the interaction between precipitation and evapotranspiration. As Figures 25 and 26 show, 1972 was an exceptionally dry year.

(c) Areal variation of annual potential evapotranspiration

Potential evapotranspiration values are useful for agricultural planning. Figures 27 and 28 show the variation of this factor on the project area and can be used as a first approximation to estimate the water needs of plants in a given place. The maximum difference of water consumption between any two places in the project area appears to be about 2 mm/day.

(d) Areal variation of water deficiency

The results of the hydrologic balance, were used to draw the maps of water deficiency shown in Figures 29 and 30. The two-year records on which these maps are based are however insufficient to draw any valid conclusion on the behaviour of this variable.

### 2.1.5 Climatology

The most important climatologic factors covered by existing records are temperature, evaporation, solar radiation, relative humidity, wind velocity and hours of sunshine. The stations that have instruments recording all or most of these variables are listed in Table 1. In general, the variability of these factors in time is not too large and it is possible to draw some valid conclusions from the results of the analysis made.

(a) Temperature

The monthly and areal variation of temperature can be seen in Figures 31 and 32. The lowest mean daily temperature is at Banding Agung (23.8°C, March) and the highest at Menggala (28.4°C, November). Considering maximum and minimum temperatures, the greatest difference between any two months is around 10°C.

(b) Solar radiation

The radiation measured by the Gunn Bellani instrument has to be transformed and the following equation was used :

$$R = 27 \quad q + 50$$

where:

R – net incident solar radiation as measured on a Kipp and Zonen solarimeter (g-cal/cm$^2$/day)

q – volume of distilled water collected in the Gunn Bellani for the day under consideration (ml).

The results are shown in Figures 33 and 34, which give the areal and monthly variation of the radiation in the project area.

(c) Evaporation

The corrected data of pan-evaporation has been used to draw Figures 35 and 36 which show the geographical variation of the total annual evaporation and the monthly variation at the five stations, respectively. Lake evaporation can be estimated by multiplying the pan-evaporation by 0.7.

(d) Other factors

Other factors studied were number of hours of sunshine, the wind velocity and relative humidity. The mean values of these variables have been calculated and plotted (Figure 37). As with previous factors, the variability throughout the year is relatively slight; this would prove that the weather (apart from rainfall) in the project area is relatively stable.

### 2.1.6 Related studies

#### 2.1.6.1 Sediment discharge

The results of the 88 measurements of sediment discharge in the main rivers of the project area are plotted in Figure 38. A single equation was derived as the few data for each river, taken individually, are not extensive enough and because all the points plotted are fairly well distributed around a line. The equation is :

$$Q_s = 0.65 \ Q^{1.5}$$

where : $Q_s$ - sediment discharge of the river (t/day)

$Q$ - water discharge of the river during the same period of time ($m^3/sec$)

The equation can be used to estimate sediment discharge for any river located in the project area whose watershed has physical and climatic conditions similar to those for which the equation was derived.

#### 2.1.6.2 Drought

A "dry day" is defined as a day when the amount of rainfall collected or recorded is less than 6 mm. The cumulative distribution of this variable was determined (Figure 39) assuming geometric distribution for the length of the sequences of a dry day. Meanwhile Figure 40 shows the number of dry days in each month at six different stations as well as the average number of dry days per month in the whole project area.

A special probability analysis was carried out to find the frequency distribution of dry days during July, the most critical month for agriculture in the area. A total of 18 months from six different stations was used and assuming, as before, geometric distribution the frequency values were computed (Table 3).

Table 3

FREQUENCY DISTRIBUTION OF DRY DAYS, DURING JULY

| k (number of days when rain is less than 6 mm per day) | Probability of having more than k dry-days consecutively % |
|---|---|
| 1 | 86 |
| 2 | 74 |
| 3 | 64 |
| 4 | 56 |
| 5 | 48 |
| 6 | 41 |
| 7 | 36 |
| 8 | 31 |
| 9 | 27 |
| 10 | 23 |
| 11 | 20 |
| 12 | 17 |
| 13 | 15 |
| 14 | 13 |
| 15 | 11 |

### 2.1.6.3 Salinity content of the streams

Figures 41-44 show the salinity variation of the main rivers based on distance from the ocean, at different dates. A large variability of the salinity content for the same location can be noted because the salinity is probably influenced by one or more of the following factors: the tidal movement, rainfall rate and its frequency, evaporation rate and its frequency, and salt content and solubility of the soils upstream from the sampling point. The higher and lower limits in the graphs have been drawn by eye, to give an idea of the amplitude of salinity content at any point in the river. The standards of salinity for irrigation waters are shown in Table 4.

Table 4

STANDARD FOR IRRIGATION WATERS

| Water class | Electrical conductivity EC x $10^6$ µmho/cm | Qualitative aspect |
|---|---|---|
| 1 | 0 - 1 000 | excellent to good, suitable for most plants under most conditions |
| 2 | 1 000 - 3 000 | good to injurious, probably harmful to the more sensitive crops |
| 3 | over 3 000 | injurious to unsatisfactory, probably harmful to most crops. Unsuitable under most conditions |

### 2.1.6.4 Lake Ranau water potential

Lake Ranau, in the southeast of the project area, is the only large water body that could serve as a natural reservoir for regulation purposes. The free-water surface covers approximately 124.6 $km^2$. The Komering River, known as the Selabung River, originates from this lake. Since February 1972 the water levels at the outlet of the lake have been recorded. Twenty-eight discharge measurements, were carried out between 1972 and 1974 and the following rating curve has been found:

$$Q = 39.26 H - 12.09$$

where : Q – discharge at the outlet of the lake ($m^3$/sec)

H – water level, above a local datum (m)

The mean daily water level at this point was calculated as being 0.76 m. With a standard deviation of 0.12 m, and assuming normal distribution, the annual volumes that Lake Ranau releases to the Komering River are as shown in Table 5.

Table 5

ANNUAL VOLUMES OF WATER RELEASED BY LAKE RANAU TO KOMERING RIVER

| | Water level above datum (m) | Annual volume (million $m^3$) | Equivalent constant discharge ($m^3$/sec) | Confidence limits (%) |
|---|---|---|---|---|
| mean : | 0.76 | 559.45 | 17.74 | - |
| | 0.64 | 411.23 | 13.04 | 68 |
| | 0.88 | 708.30 | 22.46 | |
| | 0.52 | 269.69 | 8.33 | 95 |
| | 1.00 | 856.83 | 27.17 | |

Should the annual water volume be used for regulating purposes the curves in Figure 45 can be used to determine the availability of water, during any number of continuous weeks.

### 2.1.6.5 Runoff/rainfall relationship

Runoff/rainfall relationship (RO/RF) is an important variable that can be used to estimate the amount of water yield of a given watershed, knowing only the area of the watershed and the average rainfall over it. The records of nine watersheds in the project area which have monthly rainfall and discharge records for the same period of time were used to compute monthly RO/RF relationships for December 1971 through October 1974. The average rainfall over the different watersheds was estimated using Thiessen polygons. Figure 46 shows the areas of the watersheds, and the monthly mean of the relationship (Figure 2 shows the catchment boundaries.)

From December to May the variability of the RO/RF relationship is relatively small and for this reason the mean values of these six months were used in the map of the RO/RF geographic variation (Figure 47). During June to November the values of the relationship are too erratic and should not be used to estimate the watershed yield.

### 2.1.6.6 Rainfall 1972

Records and the observations of the local people indicate 1972 as a particularly dry year. A statistical analysis of the recorded rainfall in Palembang shows that the 1972 rainfall has a 33-year return period (Figure 48).

### 2.1.6.7 Water level of Tulangbawang River at Menggala

The maximum yearly water level of the Tulangbawang River at Menggala is plotted in Figure 49. A theoretical Log-Pearson Type-III distribution has been fitted and can be used to estimate the frequency and return periods of maximum water levels at this point.

## 2.2 WATER QUALITY

When assessing the suitability of water for irrigation, several factors must be taken into consideration. The total concentration of the suspended and dissolved materials in the water and the relative concentrations of the individual ions are the main factors pertaining to water quality. In the soil, important features are the nature and properties of the soil including the physical and chemical characteristics and the changes that could possibly occur due to irrigation with a particular type of water. The plant factors are mainly the tolerance of plants to salts as well as to specific ions.

A study of the chemical characteristics of water from the various rivers and their tributaries in the project area shows that except in areas where tidal saline water intrudes, the water is of good quality and can be used to irrigate any type of plant on any soil group without harmful effects.

A comparison of the amounts of ions in the water from various rivers with the permissible levels of these ions in drinking water indicates that water from these rivers is safe from the chemical point of view for drinking. However, the water will have to be filtered to remove all suspended materials and boiled thoroughly to destroy all micro-organisms.

The location of the water sampling points is shown on Map 1.

### 2.2.1 Salinity and sodium content

Salinity - the amount of solid materials dissolved in water - can be estimated from the electrical conductivity (EC) of the sample, as well as gravimetrically. Water salinity can be classified into four groups, according to the EC (Table 6a).

An estimation of the EC of water samples from the different river locations in the project area is contained in Table 7. The conductivity given for each sampling point is the average conductivity of all the samples collected over a two-year period. The seasonal fluctuations in conductivity can be seen from the maximum and minimum conductivities.

Table 7 indicates that apart from the locations in Upang and Musi where salt water intrusion takes place during high tides (data not given), all rivers have low salinity ($C_1$) water. The Komering River and its tributaries show an EC of 30 to 130 µmho. The maximum EC of 150 µmho was found in the sample collected from Way Selabung at Muaradua during September; and the minimum, 18 µmho, in the sample from the Komering at Sirah Pulau Pedang collected in January. Samples from the Ogan and its feeders show an EC of 50 to 120 µmho with a maximum 330 and minimum 30 µmho.

Table 6

CLASSIFICATION OF WATERS ACCORDING TO SALINITY AND SODIUM CONTENT 1/

(a) Salinity

| Class | µmho/cm$^2$ | Use of irrigation water |
|---|---|---|
| $C_1$ - low salinity | 250 | irrigation of any type of soil or crop without danger of salt accumulation |
| $C_2$ - medium salinity | 250 - 750 | for all crops other than highly salt-sensitive plants, if the soil has adequate to moderately good drainage to prevent salt accumulation in the soil |
| $C_3$ - high salinity | 750 - 2 250 | cannot be used for irrigation unless the soils have good drainage and only salt-tolerant plants are grown |
| $C_4$ - very high salinity | over 2 250 | cannot be used for irrigation |

(b) Sodium

| Class | SAR 2/ | Use of irrigation water |
|---|---|---|
| $S_1$ - low sodium | 0-10 | can be used for any type of soil with no danger of sodium accumulation in the soil. For all plants, except those which are sodium-sensitive |
| $S_2$ - medium sodium | 10-18 | unsuitable for heavy-textured soil unless accompanied by good leaching. Can be used for coarse-textured soils and organic soils with good permeability |
| $S_3$ - high sodium | 18-26 | not normally suitable for irrigation. Very good drainage should be provided and salts should be leached out often. Chemical amendments will be required to replace sodium |
| $S_4$ - very high sodium | over 26 | not suitable for irrigation |

1/ USDA. Saline and alkali soils. Agriculture Handbook No. 60. United States Department of Agriculture, Washington D.C. 1954.

2/ Sodium adsorption ratio - the ratio of sodium to the square root of half the sum of calcium and magnesium, the concentration of all the ions being expressed in milliequivalents per litre (mEq/l).

Table 7

MAXIMUM AND MINIMUM pH, AVERAGE, MAXIMUM AND MINIMUM CONDUCTIVITY AND SODIUM CONCENTRATIONS IN WATER SAMPLES FROM RIVERS IN SOUTHEAST SUMATRA

| River | Sampling location | pH | | Electrical conductivity (µmho) | | | Sodium | | | | Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Average | | max | min | |
| | | max | min | average | max | min | mEq/l 1/ | ppm 2/ | mEq/l | mEq/l | |
| Air Saka | Muaradua | 7.4 | 6.4 | 70 | 110 | 54 | 0.17 | 3.9 | 0.42 | 0.08 | $S_1$ |
| Way Selabung | Muaradua | 7.7 | 6.5 | 131 | 150 | 110 | 0.39 | 8.9 | 0.51 | 0.26 | $S_1$ |
| Air Komering | Martapura | 7.1 | 6.3 | 92 | 120 | 70 | 0.29 | 6.7 | 0.97 | 0.16 | $S_1$ |
| Air Tobong | Menanga Tengah | 7.8 | 6.4 | 82 | 130 | 58 | 0.27 | 6.2 | 0.42 | 0.14 | |
| Air Komering | Menanga Tengah | 7.7 | 6.2 | 79 | 136 | 40 | 0.27 | 6.2 | 0.49 | 0.07 | |
| S. Lempuing | Pedamaran | 7.1 | 5.7 | 33 | 77 | 18 | 0.13 | 3.0 | 0.42 | 0.03 | |
| Air Komering | S.P. Padang | 7.6 | 5.7 | 50 | 105 | 18 | 0.18 | 4.1 | 0.42 | 0.04 | |
| Air Komering | S. Gerong | 7.0 | 5.7 | 50 | 130 | 21 | 0.15 | 3.4 | 0.28 | 0.04 | |
| Air Ogan | Raksajiwa | 7.4 | 6.2 | 120 | 330 | 63 | 0.49 | 11.3 | 1.36 | 0.13 | |
| S. Lengkayap | Baturaja | 7.5 | 6.2 | 65 | 110 | 39 | 0.15 | 3.4 | 0.21 | 0.08 | |
| Air Laya | Baturaja | 7.4 | 6.1 | 62 | 90 | 23 | 0.15 | 3.4 | 0.29 | 0.03 | |
| Air Ogan | Peninjawan | 7.5 | 6.1 | 79 | 190 | 34 | 0.29 | 6.7 | 0.91 | 0.07 | |
| Air Ogan | Tanjung Raja | 7.5 | 6.1 | 70 | 136 | 33 | 0.21 | 4.8 | 0.50 | 0.08 | |
| Air Ogan | Pelabuhan Dalam | 7.0 | 6.0 | 56 | 95 | 35 | 0.18 | 4.2 | 0.32 | 0.05 | |
| Air Riamun | S. Tiga | 6.0 | 4.4 | 27 | 45 | 19 | 0.06 | 1.4 | 0.10 | 0.03 | |
| S. Talang Rimba | S. Tiga | 6.1 | 4.2 | 26 | 75 | 11 | 0.10 | 2.3 | 0.26 | 0.01 | |
| W. Tulangbawang | Menggala | 7.0 | 5.8 | 36 | 70 | 18 | 0.15 | 3.4 | 0.40 | 0.04 | |
| W. Kanan | Pagardewa | 6.9 | 6.0 | 36 | 55 | 18 | 0.14 | 3.2 | 0.33 | 0.05 | |
| W. Kiri | Pagardewa | 6.8 | 5.9 | 31 | 70 | 21 | 0.11 | 2.6 | 0.39 | 0.05 | |
| Air Mesuji | Pagardewa | 6.8 | 4.8 | 17 | 35 | 9 | 0.04 | 0.9 | 0.08 | 0.01 | |
| Air Keramasan | Pedadabungkuk | | | 39 | 72 | 21 | 0.09 | 2.0 | 0.11 | 0.04 | |

1/ Milliequivalents per litre.

2/ Parts per million.

Riamun and Talang Rimba, the two feeders of S. Lumpur, have a conductivity of less than 30 µmho with a variation in EC during the two-year period from 10 µmho minimum to 75 µmho maximum. The average conductivity of samples from Tulangbawang and its tributaries is under 40 µmho, the maximum and minimum conductivities measured being 70 and 18 respectively. The Mesuji has water with conductivity 35 to 10 µmho.

The salinity of water from the Musi and its branches, the Upang, Saleh and Tolang, depends on the distance of the location from the sea. The sample taken from the Musi at a point 42 km from the sea shows that the water here is of low salinity and the change in conductivity with change in season is not appreciable. The salinity surveys of the Musi and distributaries, up to a distance of 40 km from the sea, indicated that the Musi has water with an EC of under 100 µmho 1/. A little downstream from the point of bifurcation of the Musi, the conductivity of water rises a little, however still within the $C_1$ level. This continues up to a point about 35 km from the sea. From here for about 5 km downstream, the water can be classified as $C_2$, increasing to $C_3$ and reaching $C_4$ as the river approaches the sea. (Samples taken 6.3 km from the sea show sodium concentrations ranging from 50 to 4 000 ppm and those near the sea 2 000 to 7 000 ppm sodium.) Similarly, in the Upang River, up to 30 km from the sea, the water has low salinity, about 25 km from the sea medium salinity and further down very high salinity.

In $C_1$ waters where the total concentration of dissolved materials is low, the concentration of individual ions will also be low. Of the major cations, sodium is the most harmful in irrigation water, not only because of the injury it may cause to the plants as a result of sodium accumulation in the plant tissues, but also due to its effect on the physical and chemical properties of soil. Sodium disperses the soil colloids resulting in very poor tilth and low permeability. Water with a high ratio of sodium to calcium plus magnesium, is harmful to the structure of the soil. The sodium adsorption ratio (SAR) is a useful index in assessing the hazards due to sodium. Irrigation water can be classified into four categories depending on the sodium hazard (Table 6b).

Most of the rivers from the project area have water belonging to the $S_1$ group, with an average sodium concentration in the samples of under 10 ppm. The exceptions are the salt waters from the Musi and Ugang Rivers.

### 2.2.2 Concentration of other ions

The analysis of the water from the rivers of southeast Sumatra indicates that almost all the samples contain less than 2 ppm potassium. Potassium is one of the major elements needed in large quantities by plants and therefore the irrigation water will contribute practically nothing to the potassium needs of plants.

A high ratio of calcium and magnesium to sodium is desirable in irrigation water. These cations counteract the effect of sodium in the soil, improve its physical condition, and supply needs in plant nutrition.

Although calcium and magnesium constitute 70 to 80 percent of the cations in many of the waters from the area, the data given in Table 8 show that total concentration is very low. Many of the samples contained no calcium, and the average of most samples is less than 8 ppm. Magnesium is found in very small concentrations in all the river waters. The average magnesium concentration is less than 5 pp. In the highly saline waters from Musi and Upang from locations near the sea, however, the magnesium concentrations are high.

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1/ A.G. Pike. Interim summary of hydrological and meteorological data. Working Paper, INS/69/518.

The irrigation of any soil which is already deficient in calcium and magnesium, with these waters cannot therefore be expected to improve its calcium and magnesium status.

The concentration of boron in some of the water samples is given in Table 8. Even though some of the samples contain up to 0.4 ppm boron, which is far below the toxic limit of 1 ppm, in most samples there is no boron present.

Iron in irrigation water is not of any practical significance for plant growth or soil improvement. The water from almost all the rivers contains little or no iron; in the strongly to very strongly acidic hydromorphic soils, part of the iron is present in soluble forms. In an exceptionally dry year the soil dries out and the iron which is present in the reduced form will be oxidized. During the rainy season, part of this will be washed out into the rivers and canals. This was seen in a sample of water collected from Cintamanis. The water was yellow in colour. The water was filtered and it was found that the filtered water contained 0.06 ppm Fe. Without filtering, the water showed 0.78 ppm iron. The sediment obtained by filtering the sample had an iron concentration of 18 229 ppm.

Carbonates, bicarbonates, chlorides, and sulphates and at times, nitrates, are the anions present in irrigation water. Of these, carbonates are not found in waters from the rivers in southeast Sumatra. This is to be expected as all the waters studied are neutral to slightly acidic in reaction. However, bicarbonates are found in almost all the samples. The effect of bicarbonate ions depends on the species of plant. Some plants are very sensitive to bicarbonates while others are more tolerant. If the bicarbonate concentration in irrigation water is high, there is the danger of precipitation of calcium and magnesium and the resulting increase in the proportion of sodium in the soil.

However, in the waters from the various rivers in southeast Sumatra this danger does not exist. Even though the bicarbonate ion constitutes the bulk of the anions in most of the low conductivity waters, the concentration of the ion is low enough not to cause any harmful effects. Almost all the samples studied had less than 40 ppm bicarbonate ions (Table 8). The residual sodium carbonate (difference between carbonates and bicarbonates and the sum of calcium and magnesium) is well below the harmful level.

The amount of chloride ions present in the low conductivity waters of the rivers is very low (Table 8). Almost all samples showed less than 20 ppm chloride, which is well under the 75 ppm danger limit.

Sulphates are generally less toxic than chlorides. In most of the waters under study, the samples did not contain any sulphates or showed only traces. The highly saline waters, however, contain significant amounts of this anion.

Phosphates although beneficial for crops stimulate the growth of algae and this may give a strong smell to the water and also hamper the growth of paddy. Table 8 indicates that many of the water samples analysed showed no phosphates or only traces.

Nitrates are the most common form of nitrogen found in water. River water generally contains less than 10 ppm nitrates, but when contaminated especially with human wastes it may contain several hundred parts per million nitrates. For irrigation use, nitrates in water are beneficial. As Table 8 shows, the river waters in the project area contain less than 1 ppm nitrate nitrogen.

### 2.2.3 Reaction

The pH of all the samples from the main rivers is generally in the range 6.0 to 7.0, and remains more or less constant throughout the year.

Table 8

AVERAGE CONCENTRATIONS OF EIGHT IONS IN WATER SAMPLES FROM RIVERS IN SOUTHEAST SUMATRA (ppm)

| River | Sampling location | Ca | Mg | B | Fe | $PO_4$ | $NO_3 - N$ | $HCO_3$ | Cl |
|---|---|---|---|---|---|---|---|---|---|
| Air Saka | Muaradua | 5.6 | 3.8 | 0 | 0 | 0 | 0.06 | 38.4 | 6.0 |
| Way Selabung | Muaradua | 11.2 | 4.6 | 0 | 0 | 0 | 0 | 65.8 | 9.5 |
| Air Komering | Martapura | 6.6 | 4.0 | 0 | 0 | 0.03 | 0.44 | 37.8 | 10.6 |
| Air Tobong | Menanga Tengah | 8.8 | 1.8 | 0 | 0 | 0.13 | 0.04 | 39.0 | 6.3 |
| Air K. Mati | Menanga Tengah | 8.2 | 2.1 | 0 | 0 | 0.19 | 0.04 | 35.3 | 6.0 |
| S. Lempuing | Pedamaran | 2.2 | 1.5 | 0 | 0 | 0 | 0.68 | 15.8 | 5.6 |
| Air Komering | S.P. Padang | 9.6 | 1.0 | 0.4 | - | - | - | 20.1 | 5.6 |
| Air Komering | S. Gerong | 2.8 | 2.7 | - | - | - | - | 16.5 | 9.2 |
| Air Ogan | Raksajiwa | 5.6 | 2.7 | 0.4 | 0 | 0 | 0.12 | 26.8 | 22.6 |
| S. Lengkayap | Baturaja | 7.8 | 1.7 | - | - | - | - | 34.7 | 5.3 |
| Air Laya | Baturaja | 5.8 | 2.9 | 0 | 0 | 0 | 0.08 | 32.3 | 5.6 |
| Air Ogan | Peninjawan | 5.0 | 2.7 | 0 | - | - | - | 27.4 | 14.1 |
| Air Ogan | Tanjung Raja | 7.4 | 1.9 | 0.2 | - | - | - | 32.3 | 8.1 |
| Air Ogan | Pelabuhan Dalam | 2.6 | 3.3 | - | - | - | - | 24.4 | 7.8 |
| Air Riamun | S. Tiga | 1.8 | 1.4 | 0.2 | 0 | 0.05 | 0.12 | 5.5 | 6.7 |
| S. Talang Rimba | S. Tiga | 1.2 | 1.4 | 0 | 0.02 | 0 | 0.18 | 10.4 | 7.4 |
| S. Tulangbawang | Menggala | 1.8 | 2.1 | 0.3 | 0 | 0.02 | 0.06 | 15.8 | 6.0 |
| W. Kanan | Pagardewa | 2.4 | 1.9 | 0.4 | 0 | 0 | 0 | 16.5 | 5.6 |
| W. Kiri | Pagardewa | 2.0 | 1.6 | 0.3 | 0 | 0.01 | 0 | 14.6 | 4.9 |
| Air Mesuji | Pagardewa | 0.2 | 1.4 | 0 | 0.1 | 0.05 | 0.08 | 2.4 | 5.3 |
| Air Keremasan | Pedadabungkuk | 2.0 | 2.4 | - | - | - | - | 6.7 | 6.7 |
| Air Musi | 40 km upstream from mouth | 4.4 | 2.0 | - | - | - | - | 24.4 | 6.7 |

## 2.3 GROUNDWATER

### 2.3.1 Geology

The basement rocks beneath the South Sumatra Basin are igneous and pre-Tertiary metamorphic rocks which were extensively folded during an Upper Cretaceous tectonic stage. These older structural trends do not coincide with the younger northwest-southwest structural trends in the younger sediments of the basin.

In early Tertiary times, the pre-Tertiary basement rocks were covered by volcanic andesitic material. Gradual sinking of the basin floor followed, resulting in fresh to brackish-water basins in the eastern part and marine basins in the western part. A transgression of the sea from the south transformed these small basins into a shallow, extensive sea. During the initial transgression, the area had rugged topography and was subject to considerable volcanic activity which deposited thick layers of extrusive material, mainly in the southern part of the basin. On the slopes of basement platforms and ridges, conglomerates, breccias, sands and carbonaceous remains were deposited. In the depressions, the basement floor continued to subside resulting in the deposition of thick sections of dark shales. As the basin became more shallow due to infilling, the shales were succeeded by coarser materials. Coral and foraminiferal limestones were deposited on or around the ridges and basement highs and coral reefs grew into the sea.

The infilling changed the basin floor into a generally flat plain without deep troughs or steep basement highs. Thereafter, seaward regression began and brown clays, brown coal beds and sands were deposited. The tertiary sedimentation sequence was terminated by a relatively recent orogenic period which resulted in well-developed northwest-southeast trending folds in the Tertiary sediments.

The sedimentary basin probably attains a maximum thickness of more than 6 000 m. The complex sedimentary history, in combination with volcanic activity, is significant from a hydrogeologic standpoint because it caused rapid facies changes which markedly affected the lithologic characteristics of potential aquifers. Such changes make it impossible to trace water-bearing zones for long distances without detailed geologic studies and test drilling.

The surface geology in the project area is shown on Map 2 and the stratigraphic sequence is summarized in Appendix 1. The stratigraphic sequence within the South Sumatra Basin is well known from records of oil exploration programmes. The geologic formations which occur in the project area are described below in ascending geologic order.

The geologic structure of the older pre-Tertiary Basement Complex rocks is masked by the younger sediments. However, deep oil-test holes have shown the Basement Complex to consist of pre-Tertiary igneous and metamorphic rocks which were extensively folded prior to deposition of the Tertiary sediments. The older structural trends do not coincide with the younger northwest-southeast trends of the shallower sediments.

The Tertiary formations have been folded and faulted by relatively recent activity. The result of the structural deformation is a series of broad anticlines and synclines trending northwest-southeast across the South Sumatra Basin. These structures are buried beneath a cover of younger volcanics on the southwest and by alluvial deposits on the east and north. The general structural configuration of the Tertiary sediments in the project area is shown on Map 2.

A large anticlinal structure trending almost east-west enters the project area west of Palembang and bends to a northwest-southeast trend in the vicinity of Palembang and continues on to become buried beneath the younger alluvial sediments. This broad outcrop of Tertiary sediments and the extensive outcrops of the Air Benakat and Muara Enim Formations southeast of Plaju and near the coast in the east-central part of the project area, indicate that the Tertiary formations probably occur at relatively shallow depths beneath much of the area mantled by alluvium.

Another broad northwest and southeast anticlinal structure enters the project area in the vicinity of Perabumulih and plunges into the subsurface in a southeasterly direction. The structure is cut by numerous transverse faults west of Perabumulih. A broad, apparently synclinal, structure trends from west of Muara Enim through Baturaja and plunges beneath younger sediments in a southeasterly direction. The structure is highly folded and cut by numerous faults, especially in the vicinity of Baturaja. Many small anticlinal features superimposed on the major structures occur between Muara Enim and Baturaja. Numerous outcrops of Tertiary sediments in the mountains reveal that the younger volcanic rocks have covered extensive Tertiary deposits. The parallel banding of the formations indicate that they are highly folded and faulted, probably along trends similar to those formations at lower altitudes.

The geologic structure within the project area is of great importance in the occurrence and development of groundwater. The folding and faulting make the location of specific well sites very difficult. On the other hand, the fracturing or rocks by folding and faulting and the exposure of permeable zones to the surface can be factors favourable for the occurrence and development of groundwater.

## 2.3.2 Groundwater

### 2.3.2.1 Recharge and discharge

Recharge to the aquifers underlying southern Sumatra occurs as infiltration of rain falling directly on the land surface and, to a much greater extent, from infiltration from extensive lakes and streams which originate in the high rainfall areas in the mountains. Very little recharge occurs in the mountains because of the steep slopes and rapid runoff, but as the stream velocity slows in the foothills and the streams cross the permeable zones within the folded Tertiary sediments significant amounts of water are lost into the ground. In the flat swampy lowlands, the flood waters and rainfall directly on the area recharge the alluvial sediments and maintain a very high water-table throughout the year. The average annual recharge to the groundwater reservoir beneath southern Sumatra is not known and cannot be reasonably estimated at present.

The natural discharge of groundwater in southern Sumatra takes place by evaporation and transpiration, by spring discharge, by groundwater underflow to the sea or out of the area, and to a very small extent through extraction from dug and drilled wells.

Evaporation from the groundwater reservoir occurs where the capillary fringe is at or near the land surface. This condition probably exists for at least nine months of the year in the area covered by alluvium and for a considerable length of time in some other areas. Therefore, evaporation from the groundwater reservoir is one of the major sources of discharge. Transpiration by the dense tropical vegetation probably accounts for an even larger amount of natural discharge of groundwater from the area.

### 2.3.2.2 Wells and springs

Prior to this study there were no tabulated records of wells or springs in southern Sumatra other than those recorded by Howard Humphreys and Sons in Lampung Province. Appendix 2 lists 70 wells and four springs within or near the project area. Location of wells and springs is also shown on Map 1. Of the 70 wells, 41 are drilled (including jetted or other mechanical construction techniques) and 29 are dug wells. This tabulation probably includes most of the drilled wells in the area but is only a very small percentage of the dug wells.

Most of the drilled wells are very shallow and of small diameter and many have ceased to be a source of water. The small diameter wells are generally installed by jetting a well point to depths ranging from 12 to 33 m. Soon after installation, several such wells were reported to be "dry". The problem is likely to be clogging of the sand points by fine-grained sand rather than a decline in the water-table. The shallower drilled wells may go dry during the more severe dry seasons.

Wells M-1 and M-2, drilled in 1906 and 1907 at Menggala, are still flowing but, based upon old reports, at a reduced pressure and volume of water. Undoubtedly the well casings have deteriorated and the holes have caved-in to some extent. Nevertheless, these wells still supply relatively good quality water after almost 70 years. These two flowing wells are indicative of conditions in a number of areas of the South Sumatra Basin where similar wells probably could be drilled.

Five large diameter wells ranging in depth from 54 to 155 m were located at Pertamina Oil Company pumping stations. Two of the wells were dry but three were cased with 20-cm-diameter steel casing and equipped with well screens. Pump installations were not complete at the time of the project visit and consequently only water-level data from the driller's reports were available and it was not possible to collect water samples for chemical analysis. Based on data from driller's reports, specific capacities of the wells were 9.6 l/m, 24.7 l/m and 14.1 l/m.

The dug wells observed in the project area were generally about 100 cm in diameter and had a concrete curbing to a depth of about 1 m or less below ground level. Below that, the wells were generally open. It was reported however that most wells were constructed with wooden curbing or no curbing at all. The dug wells observed ranged in depth from less than 2 m to more than 13 m. The depth of the dug wells generally depends upon the height of the land surface above the nearest stream or lake. Near a stream or lake, the wells are very shallow and higher on the hills the wells must be deeper to reach the water-table. Water is generally extracted from the dug wells by a bucket but some are equipped with hand or electric pumps. Most dug wells are reported to go dry in August, September and October. Dug wells are important sources of water supply for many villages in the project area.

Only four springs were located during the field inventory; however, there are undoubtedly numerous springs in the project area as geologic conditions are favourable for their occurrence over much of the area. Most springs, while generally not supplying large quantities of water, would provide adequate quantities of good quality water for village supplies. Scattered high-yielding springs may occur in the highly folded and faulted Tertiary sediments.

The largest spring, or series of springs, observed was at Pasir Puteh, west of Palembang.

### 2.3.2.3 Groundwater quality

During the field investigations water samples were collected from 11 wells and two springs. Water analyses from four wells were obtained from Howard Humphreys and Sons, and two analyses were obtained from the Directorate of Geology. Analyses of the water samples were also made by the Project laboratory. Other than those chemical analyses reported in Appendix 3 there are no groundwater quality data available for the project area.

Based upon the analyses of this very limited number of groundwater samples, it appears that water from the shallow, non-artesian aquifer is of good quality and could be used for irrigation with few limitations. This is to be expected as the source of the water is direct infiltration of rainfall or surface recharge into the shallow aquifer.

The water from the two artesian wells at Menggala is unsuitable for irrigation because of the very high SAR values. However, these samples represent only one relatively shallow artesian aquifer and are not representative of groundwater quality in general. The significance of the analyses from these two wells is to indicate that there might be groundwater quality problems in some areas of the project. Until considerably more data are available to give a representative picture of the water quality from the deeper aquifers, no definite statements can be made regarding limitations of water quality to irrigation.

### 2.3.3 Groundwater development potential

Historically there has been very little interest in groundwater development in southern Sumatra and consequently data on which to evaluate potential groundwater supplies are limited. Based on the sparse data available, the hydrogeologic conditions appear to be sufficiently favourable to warrant further investigations. The groundwater potential of the various geologic formations is summarized in Appendix 1 and the surface exposure of the formations is shown on Map 2.

Although the alluvial deposits are extensive, the sediments are mostly very fine-grained and do not appear to be a source of water for irrigation. Wells dug or drilled into sufficiently thick sections of the coarser-grained alluvium would provide adequate quantities of water for domestic use throughout the year. Water developed from properly constructed wells located above sources of potential pollution would provide much safer domestic water supplies than streams or dug wells adjacent to the streams.

The younger volcanic materials cover vast areas of the mountains in the southwest and central parts of the project. These materials are predominantly fine-grained ash deposits which are relatively impermeable and therefore not favourable for development of large quantities of groundwater. However, within the volcanic materials there are probably some zones of high permeability that might be the source of local water supplies. These zones, however, are of limited areal extent and therefore not important in terms of water supply for irrigation. The occurrence of such permeable zones may be indicated by springs flowing from the volcanic materials or from the contact zone between the volcanics and underlying impermeable rocks.

The Kasai tuff occurs over a broad belt across the centre of the project and is generally not a potential source of large quantities of groundwater. The Kasai probably is, however, a potential source of water for domestic or village water supplies from wells tapping permeable zones within the tuffaceous materials or the conglomerates. The Kasai tuff is an important unit in the regional hydrogeologic setting as the relatively impermeable Kasai beds serve to impart artesian pressure to more permeable zones in the underlying formations. The Kasai also contributes to recharge through the slow downward movement of water into the lower units.

The Muara Enim coal formation outcrops in broad anticlinal structures which have been deformed by folding and faulting. Based on lithologic data from oil test holes the lower sections of the Muara Enim consist of coarser sands which are a potential source of large quantities of groundwater, but no water wells have been drilled into these beds. The P.T. Sumbara Shell Company began coal investigations in June 1974 and drilled a number of core holes into the Muara Enim in the vicinity of Baturaja. The resulting data will indicate whether or not the Muara Enim justifies further investigations for groundwater. Water quality, however, might be a problem in wells tapping carbonaceous beds within this formation.

The Air Benakat sand and clay is a possible source of large quantities of groundwater. However, based upon lithologic descriptions, the sandy zones within the formation generally contain a high percentage of clay and therefore well yields might not be too great. The formation would probably supply adequate quantities of water for village supplies and domestic purposes.

The Gumai shale is not a potential source of groundwater for irrigation although the marly or limestone zones within the formation might yield adequate water for domestic or small village supplies. The Gumai shale is relatively impermeable and would act as a confining layer between the more permeable overlying and underlying formations.

The Baturaja limestone is a possible source of water although its subsurface thickness probably limits its potential. The major outcrop of the Baturaja is a long narrow northwest-southwest trending band southwest of Baturaja town. Wells drilled into the formation in that area or wells begun in the overlying Gumai shale and penetrating into the Baturaja could conceivably yield large quantities of water. Nothing is known about the surface exposures of the Baturaja. If it is fractured by folding and faulting, the formation might contain solutionally enlarged openings that would yield large quantities of water.

The Talang Akar shale and sand is a potential aquifer but the areas of outcrop in the project are very limited. The upper units of the formation are reported to be finegrained sands with shaly sands and coarse grit. The lower member consists of thick layers of coarse sand that are potentially the best aquifers within the project area, but it is questionable whether or not they occur at shallow enough depths or in thick enough sections to be of importance. The small areas of outcrop of the Talang Akar are factors which severely limit the recharge to potential aquifers within the formation.

The Lahat tuff-breccia and the pre-Tertiary rocks are not potential aquifers in the project area.

Based solely upon geologic data - lithology and structure - the most favourable areas for potential groundwater development appear to be the anticlinal structures near Palembang, Perabumulih and Muara Enim and the folded and faulted sediments in the vicinity of Baturaja. The long, narrow bands of the Air Benakat sand and clay and the Baturaja limestone southwest of Baturaja village are also potential areas for wells that might yield quantities of water sufficient for irrigation. Areas where the Muara Enim coal, Air Benakat sand and clay, Baturaja limestone, or the Talang Akar shale outcrop (Map 2), or where those units lie at relatively shallow depths are also potential well-development sites.

The alluvium and Kasai tuff deposits are not potential sources of irrigation supplies but are important sources of water for domestic or small village supplies. Village water supplies developed from properly constructed wells would have an important impact on public health in southern Sumatra.

# Chapter 3

## LAND SUITABILITY

Soil investigations were an integral part of the project. The investigations involved a general purpose reconnaissance soil survey of the project area, analysis of the soil samples and subsequently an interpretation of this information in terms of land suitability with a view to possibilities for development in agriculture 1/. The soil survey was at a very low intensity with an overall frequency of auger or pit examinations of about 1 per 12.5 $km^2$.

### 3.1 MAIN SOIL CHARACTERISTICS

Organic matter: the percentage of organic matter in the soil samples was distributed between lowland and upland soils as follows:

| Percentage organic matter | Percentage of samples | |
|---|---|---|
| | Lowland soils | Upland soils |
| 0 - 1.9 | 4.8 | 1.9 |
| 2 - 4.9 | 30.4 | 30.8 |
| 5 - 9.9 | 29.6 | 48.1 |
| 10 - 15.9 | 10.4 | 12.5 |
| 15 - 19.9 | 4.8 | 2.9 |
| 20 - 29.9 | 4.0 | 1.9 |
| over 30 | 16.0 | 1.9 |

The soils of the flood plains and the swamps contain a high percentage of organic matter. In the swamps, acid peats occur over the mineral soil or are found as an association or complex with hydromorphic alluvial or humic gley soils which also contain a high percentage of organic residues.

The upland soils contain much less organic matter. The swamp soils contain organic residues throughout the profile with peat layers alternating in some profiles; in the uplands, the organic matter is low and is confined to the surface soil. Since many of the nutrients in these acid soils derive from the decomposition of organic matter, the upland soils have low fertility. On the other hand, in spite of the high acidity, crops grow well initially in the swamp areas because of the high humus content of the soil. However, when these soils are drained and cultivated the organic matter will be depleted at a rapid rate by oxidation, increased bacterial activity, over-cropping, burning and erosion by wind and water. The depth of the organic horizon will thus be reduced due to shrinkage, and drainage problems may recur.

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1/ D. Harris and R.G. Menon. Reconnaissance and semi-detailed soil surveys. INS/69/518. January 1973.
F.J. Dent. Land capability. INS/69/518. February 1974.

Soil reaction: high acidity is a prominent characteristic of all soils in the project area, particularly in the lowland soils, as the following breakdown of an extensive series of samples shows:

| Class | pH range | Percentage of samples | |
|---|---|---|---|
| | | Lowland soils | Upland soils |
| Very strongly acid | 2.5 - 3.4 | 4.4 | 0 |
| Strongly acid | 3.5 - 4.4 | 33.1 | 12.4 |
| Moderately acid | 4.5 - 5.4 | 55.2 | 70.5 |
| Slightly acid | 5.5 - 6.4 | 7.3 | 15.2 |
| Neutral | 6.5 - 7.4 | 0 | 0 |
| Slightly alkaline | 7.5 - 8.4 | 0 | 1.9 |

In Upang and Cintamanis, the sub-soil is in a highly reduced condition. These sulphide-rich soils are slightly acidic or even neutral when water-logged, but when air-dried, they become highly acidic with the pH reduced to less than 3.

Very few plants, in any, can thrive under strongly acid conditions. Because of the high acidity, copper, zinc, manganese, iron and aluminium will be more soluble and may be present in toxic amounts, while molybdenum, calcium, magnesium, phosphorus and potassium will be deficient. Bacterial activity and consequently the mineral decomposition of organic matter will be lessened. On the other hand fungi can thrive at pH 3.5 to 5.5, and the incidence of fungus-induced diseases may therefore be high.

Aluminium toxicity is of special importance in strongly acid soils. As little as 1 ppm aluminium retards plant growth. The concentration of aluminium in some of the soils of the project area is several times this limit.

Lime status: as indicated above, the soils of the region are moderately to strongly acidic. Liming is necessary to make them more productive and suitable for a wide range of crops. Lime-requirement studies show that nearly 5% of the lowland samples and 23% of the upland samples would need 10 t lime/ha, 44% from lowland and 48% from upland 10 to 20 t/ha, and 32% from lowland and 23% from upland 20 to 30 t/ha.

Potential acidity: in some of the swampy area the soil is underlain by layers of pyrite-containing potential acid-sulphate soils. The acid-sulphate horizon generally occurs at a depth of 50 to 120 cm. The surface soil is moderately to strongly acidic. The acid-sulphate layer may be neutral to strongly acidic under water logged conditions, but becomes very strongly acidic (pH under 3) on air-drying. The surface soil is generally very rich in organic matter or consists of acid peat, and is nonsaline; the acid sulphate layers, however, are saline and contain large amounts of sulphur compounds.

When these areas are opened up, drained and cultivated several problems are liable to arise:

a. reduction in the thickness of the surface soil and decrease of distance between the root zone and the acid sulphate layer by shrinkage and less organic matter;

b. development of very strong acidity due to the oxidation of sulphides;

c. salinization and acidification of the surface soil due to capillary rise of saline, strongly acid groundwater;

d. toxicity due to aluminium;

e. micronutrient inbalance.

To prevent or overcome these problems, strict conservation and amelioration methods will have to be followed:

a. keeping the water-table above the acid-sulphate layer at all times;

b. leaching out of acid and toxic materials from the top soil;

c. application of lime to reduce acidity;

d. keeping organic matter at reasonably high level;

e. application of fertilizers.

Salinity: the upland soils are nonsaline with less than 0.2% salt in the surface and in the sub-soil. In the lowland areas, 77% of the surface samples showed less than 0.1% salt, 12% showed 0.1 to 0.2% and 11% showed 0.2 to 4.0%. The high salinity is found in the alluvial soils developed from marine deposits where the surface as well as the sub-soil is highly saline.

In places such as Upang where potential acid-sulphate soil occurs at certain depths, the surface soil is non-saline, but the acid-sulphate layers are highly saline.

Cation exchange capacity: the lowland soils have high cation exchange capacity (CEC) because of the high organic matter and clay content as the following data show.

| Unit values 1/ | Percentage of samples | | | | | |
|---|---|---|---|---|---|---|
| | Lowland soils | | | Upland soils | | |
| | CEC | EA | BS | CEC | EA | BS |
| 0 - 9 | 0.9 | 4.9 | 17.5 | 3.5 | 22.8 | 36.5 |
| 10 - 19 | 9.0 | 44.4 | 15.8 | 45.5 | 48.8 | 14.7 |
| 20 - 29 | 46.0 | 32.6 | 12.3 | 39.3 | 23.6 | 15.6 |
| 30 - 39 | 30.6 | 13.2 | 16.6 | 6.3 | 2.4 | 12.8 |
| 40 - 49 | 9.9 | 4.2 | 14.9 | 2.7 | 2.4 | 9.4 |
| 50 - 59 | 1.8 | 0.7 | 12.3 | 0.9 | - | 6.4 |
| 60 - 69 | 0.9 | - | 7.9 | 0.9 | - | 3.7 |
| 70 - 79 | 0.9 | - | 2.7 | 0.9 | - | 0.9 |

1/ Values refer to mEq/100g soil for CEC and EA, and to percentages for BS.

Over 75% of the lowland samples have a CEC of 20 to 40 mEq/100g soil. In contrast, nearly 50% of the upland samples have a CEC of less than 20mEq/100g soil.

Although the CEC is high, the percentage base saturation in the surface layers of most soils is very low, less than 20 in one third of the lowland and one half of the upland soils.

Exchange acidity (exchangeable hydrogen and aluminium) is high in all the soils, values up to 30mEq/100g soil being recorded in over 80% of the lowland and 95% of the upland soils.

Exchangeable sodium, potassium, calcium and magnesium are present in only very small amounts.

Nitrogen, phosphorus and potassium: the lowland soils have a high organic matter content and therefore a high percentage of total nitrogen while the upland soils contain much less nitrogen:

| N% | Percentage of samples | |
|---|---|---|
| | Lowland soils | Upland soils |
| > 1.0 | 10 | 8 |
| 0.5 - 1.0 | 22 | 27 |
| 0.2 - 0.3 | 20 | 25 |
| 0.1 - 0.2 | 24 | 39 |

At the time of sampling, the level of $NO_3$ - N in all the soils was very low; a third of the samples showed no $NO_3$ and nearly 30% only a trace.

Because of the high acidity and the resulting solubility of iron and aluminium, all the phosphorus in the soil is fixed in a form unavailable for plant use. This is conformed from the analysis of soil from the lowland as well as upland areas. Over 50% of the former samples had no water-soluble phosphorus, 27% a trace and 12% had 0.5 to 1 ppm P. Similarly, 10% of the lowland samples and 23% of the upland ones showed no acid-fluoride-soluble P (Bray).

Water-soluble potassium is found only in very small amounts in all the soils. The level of available potassium in 6% of the lowland soils and 16% of upland soils is low (less than 45 ppm K), and in 15% of soil from lowland and 28% from upland, medium (6C-100 ppm K). Nearly 60% of the lowland soils and 30% of the upland ones contain an adequate amount of potassium at present. However, continued use of nitrogen and phosphorus fertilizers will result in a potassium deficiency and potassium fertilizers will have to be applied.

Conclusions: the saline hydromorphic soils are not suitable for cultivation. The hydromorphic alluvial and recent alluvial soils are deep, well drained and have fair to average amount of organic matter and an exchange capacity of 15 to 30 mEq/100g soil. The hydromorphic alluvial soils are strongly acidic in reaction and have 19 to 40 percent base saturation. The recent alluvial soils are moderately acidic and have 50 to 60 percent base saturation.

Nearly half of the project area comes under the hydromorphic group which is an association of humic gleys, grey hydromorphic soils and organosols. These are strongly acidic with high exchange capacity, high exchange acidity and low base saturation. The surface soil is non-saline, but at times the sub-surface soil is underlain by saline, acid-sulphate layers.

The latosols are moderately acidic soils with low to average organic matter, low exchange capacity, low base saturation and low fertility.

The red/yellow podzolic soils are well drained acid clays and sandy clays which are moderately acidic, have low to average organic matter, an exchange capacity of 20 to 25 mEq/100g, and low base-saturation percentage. These soils are easily erodable when the surface vegetation is removed. They are not very fertile and have low moisture-holding capacity.

The factors that inhibit the optimum growth of plants in these soils are many and varied. Very low pH, high exchange acidity and low base-saturation, micro-nutrient imbalance, and low fertility are common to all the soils of the region. The riverine and coastal swamp areas have in addition, the problem of the possible presence of acid-sulphate soils.

## 3.2 SOIL MAPPING UNITS

The results of the general-purpose reconnaissance soil survey were prepared in the form of a reconnaissance soil map at a scale of 1:250 000 - reproduced here as Map 3. Thirty-eight soil mapping units were delineated, each unit comprising several kinds of soils plus small inclusions of other mapping units. The mapping units were established on the basis of parent material, land form, relief, and the morphological and chemical characteristics of the soil and are based upon combinations of one or more sub-groups or great groups following the soil classification system developed by the Soil Research Institute, Bogor. In addition, correlations were made with the FAO/Unesco Soil Map of the World legend 1/ and with the USDA Soil Taxonomy for purposes of international correlation.

The 38 soil mapping units and their computed areas are given in Table 9. They may be classified in seven major soil groups as follows:

| | Soil group | Occurrence | Area ('000 ha) |
|---|---|---|---|
| | Lowland soils | | |
| 1. | Saline hydromorphic soils | Coastal plains | 81.0 |
| 2. | Hydromorphic alluvial soils | River banks | 149.6 |
| 3. | Recent alluvial soils | River banks and flood-plains | 70.7 |
| 4. | Hydromorphic soils | Marshes, swamps and depressions | 1 945.1 |
| | Upland soils | | |
| 5. | Lithosols, regosols, andosols | Hills and mountain slopes | 63.9 |
| 6. | Latosols | Undulating to steep uplands | 230.7 |
| 7. | Red/yellow podzolic soils | Rolling to undulating areas areas | 1 747.1 |

## 3.3 LAND SUITABILITY CLASSIFICATION

Various interpretations can be made from soil surveys, but in accordance with project objectives, interpretations made in this study are directed towards regional development planning in agriculture. However, it should be understood that any interpretation can only be as accurate or as detailed as the data on which it is based. Low intensity, reconnaissance soil surveys only provide general information with regard to the variety, the characteristics and geographical distribution of the soils; consequently, any interpretations made will also tend to be of a general nature.

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1/ FAO. Definitions of soil units for the soil map of the world, by R. Dudal. World Soils Resources Report No. 33. 1968, supplement December 1973. Rome. (FAO/Unesco Soil Map of the World, 1974 edition, available from Unesco, Paris).

Table 9

SOIL MAPPING UNITS

(see also Appendix Table A4.1)

| | Mapping unit | Area (ha) |
|---|---|---|
| 1. | Hydromorphic alluvial soils of the coastal plains - marine clay deposits | 76 704 |
| 2. | Hydromorphic alluvial soils of the present river banks - recent alluvial | 143 067 |
| 3. | Brown alluvial soils of the present river banks-recent alluvium | 12 000 |
| 4. | Association of brown alluvial and hydromorphic alluvial soils - recent alluvium | 19 808 |
| 5. | Association of greyish brown alluvial and hydromorphic soils of the present river banks - recent alluvium | 37 308 |
| 6. | Association of yellowish brown alluvial soils of the present river banks and hydromorphic alluvial soils - recent alluvium | 10 586 |
| 7. | Hydromorphic alluvial soils, humic gley soils and organic soils developed from river alluvium | 1 226 620 |
| 8. | Complex of hydromorphic alluvial soils, humic gley soils and low humic gley soils - recent alluvium | 52 959 |
| 9. | Humic gley soils of the Lebak Dalam - recent alluvium | 49 298 |
| 10. | Humic gley and organic soils - recent alluvium | 491 026 |
| 11. | Grey hydromorphic soils - semi-recent alluvium | 10 135 |
| 12. | Deep, light grey regosols - Aeolian sand | 11 399 |
| 13. | Grey regosols, grey hydromorphic soils and low humic gley soils - semi-recent alluvium | 86 685 |
| 14. | Brown regosols and grey hydromorphic soils - residuum from sandy tuffs and semi-recent alluvium | 10 615 |
| 15. | Very shallow, rendzina soils of the rolling to hilly area - residuum from limestone | 7 040 |
| 16. | Dark brown andosols of mountains lands - unconsolidated volcanic material | 49 746 |
| 17. | Brown latosols developed from intermediate tuffs | 42 960 |
| 18. | Deep brown latosols and eroded phase of the same - igneous rocks | 61 120 |
| 19. | Reddish brown latosols developed from acid and intermediate tuffs and igneous rocks | 13 020 |
| 20. | Reddish brown latosols of variable depth from acid tuffs and igneous rocks | 7 906 |

| | Mapping unit | Area (ha) |
|---|---|---|
| 21. | Reddish brown latosols of variable depth from intermediate tuff | 3 120 |
| 22. | Reddish brown latosols developed from igneous rocks | 2 040 |
| 23. | Reddish brown latosols and yellowish red latosols of variable depth developed from intermediate tuffs | 77 960 |
| 24. | Yellowish red latosols and eroded phase of the same developed from igneous rocks | 11 200 |
| 25. | Moderately deep to deep, reddish brown latosols and yellowish brown podzolic soils | 16 520 |
| 26. | Moderately deep to deep, yellowish brown and brown podzolic soils developed from acid sandstone | 783 069 |
| 27. | Deep, yellowish brown podzolic soils developed from acid tuffs | 23 920 |
| 28. | Deep, yellowish brown podzolic and moderately deep yellowish red podzolic soils developed from acid tuffs | 46 720 |
| 29. | Yellowish brown podzolic soils and grey hydromorphic soils developed from acid sandstone and semi-recent alluvium | 172 990 |
| 30. | Moderately deep to deep, yellowish brown and yellowish red podzolic soils developed from sandy tuffs | 45 020 |
| 31. | Moderately deep to deep, yellowish brown and yellowish red podzolic soils developed from acid sandstone | 172 266 |
| 32. | Moderately deep, yellowish brown and yellowish red podzolic soils developed from acid sandstone | 182 253 |
| 33. | Moderately deep to deep, yellowish brown and yellowish red podzolic soils formed from acid claystone | 167 897 |
| 34. | Moderately deep, yellowish brown and yellowish red podzolic soils developed from acid sandstone | 51 160 |
| 35. | Deep, brown podzolic soils and brown regosols formed from acid tuffs | 32 160 |
| 36. | Brown regosols and eroded phase of the same developed from acid plutonic rocks | 13 640 |
| 37. | Moderately deep to deep, yellowish brown and yellowish red podzolic soils developed from clay sediments | 23 106 |
| 38. | Moderately deep to deep, yellowish brown and reddish brown podzolic soils developed from sandy tuffs | 27 053 |
| Lakes | | 16 026 |
| | Total area of the reconnaissance soil map ... | 4 288 125 |

To facilitate regional development planning in agriculture the land suitability classification should provide an evaluation of identified land units in relation to defined, foreseeable forms of rural land use. Identified land units in this study are the reconnaissance soil map units which comprise one or more kinds of soil. The relationship between the soil mapping units and the suitability classes is shown in Appendix 4, Table A4.1.

Five forms of rural land use or land utilization types were identified as possible development alternatives, and suitability evaluations were prepared:

- unimproved, upland shifting (swidden) cultivation (Appendix 5, Map 4)
- improved, upland crop cultivation (Appendix 6, Map 5)
- improved pasture (Appendix 7, Map 6)
- improved tree-crop cultivation (Appendix 8, Map 7)
- improved paddy (wetland) rice cultivation (Appendix 9, Map 8)

In each of the five suitability classifications the same structure of interpretative groupings is used with each class retaining its basic meaning of suitability in relative terms within the context of the different classifications and in relation to each land utilization type. Three categories of generalization are recognized in each of the suitability classifications. These categories in order of decreasing generalization are: Land Suitability Orders, Land Suitability Classes and Land Suitability Subclasses (see Appendix 4) 1/.

Land suitability evaluations were made for each land utilization type independently and without reference to the desirability of other relevant uses of the same land. However, the interpretative categories which comprise the land suitability classification are appropriate in their definition for application to each land utilization type so that it is feasible to show that individual land units (reconnaissance soil mapping units) are suitable, perhaps in varying degrees, for a wide range of uses. A parallel listing of suitabilities does not, of course, assist in establishing use priorities unless all the evaluations listed have at least a common quantitative basis for class distinction in economic terms.

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1/ Structure of the interpretative groupings, category nomenclature and definitions are based upon proposals for a standard framework for land evaluation made at "An Expert Consultation on Land Evaluation for Rural Purposes", International Institute for Land Reclamation and Improvement, Wageningen, Netherlands, October, 1972.

The land classification (ha) for specific uses is summarized 1/ below:

| | Land use type | Suitable 2/ land | Conditionally 3/ suitable land | Unsuitable 4/ land | Mixed 5/ suitability |
|---|---|---|---|---|---|
| 1. | Unimproved upland shifting cultivation | 1 257 614 (29.3 %) | – | 2 636 092 (61.5 %) | 394 416 (9.2 %) |
| 2. | Improved upland crop cultivation | 1 754 391 (40.9 %) | 1 973 105 (46.06 %) | 104 129 (2.4 %) | 456 497 (10.7 %) |
| 3. | Improved pasture | 2 173 050 (50.7 %) | 634 093 (14.8 %) | 104 129 (2.4 %) | 1 376 850 (32.1 %) |
| 4. | Improved tree crop cultivation | 1 775 896 (41.4 %) | 2 059 847 (48.0 %) | 104 129 (2.4 %) | 348 250 (8.2 %) |
| 5. | Improved paddy (wet land) cultivation | 335 161 (7.8 %) | 76 704 (1.8 %) | 1 888 321 (44.0 %) | 1 987 936 (46.4 %) |

Note: Percentages are additive horizontally, but owing to overlap of suitabilities, not vertically.

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1/ See Tables A5.1, A6.1, A7.1, A8.1 and A9.1.

2/ Land on which sustained use (for the defined land use type), is expected to yield benefits (ranging from high to low) that will justify required recurrent inputs.

3/ Land having characteristics which, at present, make it unsuitable for sustained use (for the defined land use type) but which, with various special management practices, could become suitable.

4/ Land having characteristics which preclude its sustained use (for the defined land use type) or which would create production, upkeep and/or conservation problems requiring a level of recurrent inputs unacceptable at the present time.

5/ Land with very mixed suitable, unsuitable and conditionally suitable areas.

# Chapter 4

# FOREST RESOURCES AND PRODUCTION

## 4.1 GENERAL FEATURES OF LAND USE

### 4.1.1 Present land use

A land-use inventory undertaken in December 1967 gives the following information for the mainland districts of South Sumatra Province.

Table 10

LAND USE - SOUTH SUMATRA PROVINCE (MAINLAND) 1967

| Category | Area ('000 ha) | Total area ('000 ha) | % |
|---|---|---|---|
| Wet rice | | 169 | 2.0 |
| Permanent agriculture: | | | |
| Rubber | 334 | | |
| Coffee | 45 | | |
| Coconuts | 8 | | |
| Tea, cloves, pepper | 9 | | |
| Horticulture | 24 | 420 | 5.1 |
| Fields | | 31 | 0.4 |
| Shifting cultivation | | 200 | 2.4 |
| Grassland (alang-alang) 1/ | | 2 001 | 24.5 |
| Forest reserve: | | | |
| Production | 386 | | |
| Protection | 591 | 977 | 12.0 |
| Other land: | | | |
| Urban land, rivers, lakes, mining, swamps, forest, fish-ponds | | 4 375 | 53.6 |
| | | 8 173 | 100.0 |

1/ *Imperata cylindrica* predominantly.

The 4.4 million ha in the "other land" category probably now include considerable additional areas of shifting cultivation, alang-alang and periodically-burnt savanna scrubland.

### 4.1.2 Shifting cultivation

In southern Sumatra, shifting cultivation in association with the uncontrolled and irresponsible use of fire has caused, and is still causing, havoc to the extent of creating a foreseeable ecological disaster. It is both a social and administrative problem, irresolvable by law enforcement alone. The main trouble is that shifting cultivation cycles seldom work out because of persistent fire damage to the area normally under bush fallow.

Under these circumstances, cultivators seek new and additional land every year, resulting in an accumulative sequence of site deterioration. Some village land resources appear to be becoming exhausted for dry rice cropping, causing a stronger tendency to invade forest reserves and the steep lands. Air photographs of steep lands in the north of the project area indicate a serious growing soil erosion problem and invasion of protection forest.

Every production forest reserve shows some degree of invasion and destruction, from partial to almost complete. This deterioration will continue at an increasing rate unless fire is controlled and shifting cultivators either:

- convert their lands to the production of permanent crops; or
- are encouraged (and possibly subsidized) to use fertilizers; or
- migrate to wet rice areas; or
- find employment in other industries.

The first may provide a workable solution. Such conversion is already being practised by some of the larger land holders, under what is generally termed in forestry a taungya 1/ system. The land is cleared, planted with dry rice, followed by interplanting with rubber. After two or three rice harvests the rubber is allowed to continue (with weed tendings) to produce a plantation. There are great virtues in the system. It is capable of making the individual a cash cropper within ten years, it requires no development capital, and no extra energy other than in planting the permanent crop and maintaining and protecting it after temporary food-cropping ceases. The system has been very successfully applied in forestry; in Asia, Africa (the shamba system) and the West Indies. It is regulated by the issue of special permits of a fixed duration of 18 to 24 months to individual farmers. The permits allow the holder to undertake seasonal crop cultivation within specifically demarcated small blocks not exceeding one hectare, on previously logged areas in forest reserves. Under conditions of the permit, the farmer must clear and plant his allocated block within a prescribed time, and simultaneously plant and maintain trees provided by the Forest Service, all in accordance with specifications. The system could probably be applied effectively in southern Sumatra to rehabilitate damaged forest reserves. Such an operation would make use of the shifting cultivators who have invaded the forest.

### 4.1.3 Fire

Fire in its association with shifting cultivation has been the major large-scale destroyer of land resources in the project area - and continues to destroy the land's population-supporting capacity at a rate much faster than it can be created through the efforts of development projects. Any rational approach to overall

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1/ Taungya - derived from two Burmese words meaning "hill farm", but now used to identify a special system of conversion from seasonal food crops to permanent tree crops by simultaneously interplanting trees with the food crops.

development must include fire control and prevention as a first priority item - otherwise little overall headway will be made. To achieve any effective results a comprehensive and intense campaign would be needed covering publicity and education, fire legislation, the organization of rural fire control bodies, training and law enforcement. Since the problem is one which is not only confined to southeast Sumatra 1/, it is suggested that central government sponsorship and support be requested for a national fire control campaign.

The main causes of fires in southeast Sumatra were reported to be:

(a) fires going out of control during the clearing of land for planting;

(b) deliberate burning of alang-alang to stimulate new growth which attracts game and feeds domestic animals;

(c) deliberate burning to clear access and reduce insect pests around villages;

(d) burning of road and railway edges by cleaning gangs;

(e) carelessness in throwing away lighted cigarette butts;

(f) irresponsible burning of grass for amusement.

Every so often, South Sumatra Province is subject to extreme fire years. This century, they occurred in 1914, 1961, 1963, 1972 and were the results of dry weather in July, followed by almost no rain during August, September and October. According to inhabitants, the whole countryside blazed, including some rain forest. During the 1972 fires Palembang airport was closed periodically because of poor visibility due to smoke. At the same time, all preceding reforestation work in the Province was wiped out.

A major attack needs to be concentrated on preventive measures; using every possible medium of publicity and education to highlight the patriotic, moral and practical justifications involved. Education should be directed at schools, public and government bodies, railways and the petroleum industry, and the public generally through press and radio announcements, road signs, notices in public transport facilities, slogans on vehicles, compulsory (if necessary) slogans on match-boxes and packets of cigarettes, the issue of special proclamations and warnings during extreme fire danger weather. Secondly, rural fire fighting units must be organized, equipped and trained; and legislation made to cover their status. It would be helpful if certain specified government officers and village heads were made ex-officio fire wardens so that both power and responsibility are extended. Thirdly, theoretical and practical training is needed on a larger scale, covering fire prevention and control measures, and the use and maintenance of fire control aids, facilities and equipment. To be really effective, fire fighting and control work requires precision, coordination, discipline and mobility.

Rural fire control covers a rather comprehensive and specialistic field and there is need to seek expert guidance and advice on the matter and, above all, advanced training for future regional fire control officers. Because of its own similar fire problems, Australia might be a suitable country to give advanced training and experience. At the same time, the Forest Service needs to strengthen and equip its own fire-fighting service. It is imprudent to carry out reforestation work unless there is some assurance that it will not be destroyed by fire, as has occurred in the past.

In particular consideration of its socio-economic side, one solution might be to organize a rotation of lands and allow the villagers to burn an area for a number of years, and then only go back to the same area after 10 to 15 years. If such a

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1/ It has been stated that up to 30 million ha of alang-alang exist in Indonesia.

rotation of fires could be established, public education, fire fighting organization and law enforcement can be organized and implemented more efficiently. If the cultivators can be contained in a zone where fire is rotated, then forest reserves (either for protection or production purposes) can be better safeguarded.

After examining the penghijauan schemes - a block system of afforesting grasslands by planting strips at regular intervals - it is considered that such schemes may be unjustified and unnecessary.

Penghijauan cannot cure the fire problem, nor are the plantings made under such a scheme immune from fire damage, or even, complete destruction. Under this system it would take over 100 years of treatment at the rate of 20 000 ha per year to rehabilitate the present estimated area of damage - even if there was no further fire damage.

If it is accepted that the basic problem is one of persistent fire damage rather than merely ecological rehabilitation, then it must be recognized that only rural fire control is capable of both preventing and curing the problem. Nature will repair the damage, if fire is prevented.

### 4.1.4 Soil conservation

A strong need exists to enforce soil conservation measures and to review legislation. The practical side of soil conservation largely hinges on control of shifting cultivation in steep land areas and fire control.

Certain legal aspects require review. It is believed that soil conservation control was previously based on a "height above sea level" criterion, i.e. no land above 500 m elevation to be cleared. If so, it hardly seems a suitable basis for achieving erosion control, nor a satisfactory basis for defining land-use suitabilities. The main factors deciding whether or not an area can be safely developed are slope and the type of land use that is to be employed; further specific considerations are rainfall and soil type.

It is felt that a system on the lines suggested below would form a reasonable and simple general basis for land-use determination and regulation:

(a) no land of above 25° inclination to be cleared for any purpose other than to provide access routes or specific works of public benefit;

(b) no land of above 10° inclination to be cleared other than for the planting of permanent tree crops;

(c) no land within 10 m of any stream to be cleared for any purpose other than to provide public access to recreation facilities.
For steep areas, however this 10-m strip will need to be increased.

## 4.2 EXTENT AND UTILIZATION OF FOREST RESOURCES

### 4.2.1 The forest estate

The formal forest estate of mainland South Sumatra Province contains 26 production forest reserves and 28 protection forest reserves. These have been formally constituted and their boundaries mapped in detail. In addition recent legislation places all other forest land (previously termed hutan marga or village forest) under state jurisdiction and control. However, it appears that the entire forest estate situation is now being reviewed from a land-use point of view and that the present area of production forest reserves in the Province is likely to be reduced by a very considerable amount.

At the present time, the only significant remaining timber resources, outside forest reserves, are those in the freshwater swamp forest where natural fire protection and exploitation difficulties have guarded them to some extent.

Map 9 shows the present extent of forest resources.

4.2.1.1 Production forests

The production forests in the project area cover 134 000 ha. An assessment of their present timber resources and condition is presented in Table 11.

Table 11 indicates that some 75 percent of the forest resources in production forest reserves have been exploited or destroyed. Moreover, in most cases, the remaining resources are scattered and isolated in the remotest portions of the reserves - making further exploitation difficult and expensive.

4.2.1.2 Protection forests

The upper watersheds contain protection forest reserves (Map 9). It is difficult to accurately locate reserve boundaries on air photographs, but it is clear that serious invasion has occurred, particularly southwest of Baturaja and in the upper Ogan and Komering watersheds. It is also obvious that the soil conservation problem is associated with the cultivation of steep slopes generally, whether inside or outside the forest reserve. Most of the present problem areas lie outside the protection forest boundaries.

4.2.1.3 Inland forests

In the more settled areas - there are no remaining natural forests outside forest reserves - forest now consists of scattered stands of seru (Schima bancana) which is a well-formed, fire-hardy species sometimes forming a savanna forest in association with alang-alang. It regenerates well and is capable of reshooting even after scorching by fire. The wood is milled at Baturaja and seems to be of very acceptable quality. It is capable of colonizing in alang-alang areas and, with reasonable fire protection could provide a valuable forest resource. A good example of seru savanna forest and its potential can be seen between Belitang and Betung.

The only significant remaining stands of natural forest lie in the more inaccessible and less settled areas - particularly the Mesuji river basin. They comprise six areas totalling about 60 000 ha - approximately 50 000 ha south of the Mesuji river, one partly-logged area of 3 000 ha north of Forest Reserve No. 10, and one partly-damaged area of 7 000 ha adjoining Forest Reserve No. 46.

4.2.1.4 Swamp forests

Between the Mesuji and Lumpur rivers there appear to be at least 63 000 ha of undisturbed swamp forest. There is possibly considerably more just south of the Lumpur river, but it is undetectable because of a gap in the air-photo coverage. The identifiable resources consist of seven separate stands, including one major area of about 45 000 ha adjacent to the coast and which shows some previous attempts at logging directly from the sea.

Table 11

PRODUCTION FORESTS IN THE PROJECT AREA

| Forest No. | Province | Total area ha | Virgin forest ha | Secondary forest including logging ha | Savanna ha | Shifting cultivation ha | Alang-alang ha | General appraisal |
|---|---|---|---|---|---|---|---|---|
| 10 | S. Sumatra | 8 000 | - | 7 600 | - | - | 400 | destroyed by shifting cultivation |
| 36 | S. Sumatra | 5 230 | 3 230 | - | - | 2 000 | - | only southern section included in project area, shifting cultivation up to 6 km inside |
| 45 | S. Sumatra | 30 500 | 11 500 | 18 000 | - | 1 000 | - | extensive areas have been selectively logged |
| 30 | S. Sumatra | 20 000 | 1 600 | - | 18 000 | 400 | - | logging followed by fire damage has led to the creation of a savanna-type forest |
| 13 | S. Sumatra | 9 416 | 750 | 3 100 | 2 666 | 1 000 | 1 900 | almost completely destroyed by shifting cultivation and fire. The reforestation scheme has not been successful |
| 44 | S. Sumatra | 11 600 | 1 350 | 10 050 | - | - | 200 | almost completely logged over |
| 33 | S. Sumatra | 6 590 | 2 490 | 2 860 | - | 310 | 930 | large area of secondary forest in southern end, probably due to severe fire |
| 34 | S. Sumatra | 13 300 | 4 700 | - | 7 100 | 300 | 1 200 | the savanna area is of low quality |
| 42 | Lampung | 12 700 | 3 800 | 6 900 | - | 2 000 | - | extensive logging and shifting cultivation |
| 46 | Lampung | 16 700 | 2 860 | 11 740 | - | 600 | 1 500 | much shifting cultivation edging Way Umpu |

### 4.2.1.5 Palembang coastal swamp complex

#### (a) The forest area

The broad coastal swamp area between the Lumpur and the Calik rivers, directly opposite Bangka Island, has considerable timber resources. This is part of an enormous freshwater swamp complex which appears to extend as far north as Medan.

An area of about 1.1 million ha has been indicated on Map 9 enclosing the resources within the project area. It is estimated that this area contains at least 600 000 ha of freshwater swamp forest of several types which are fairly easily distinguishable on 1:50 000 scale air photography.

The net 600 000-ha area appears to contain around 250 000 ha of a triple-storey, high forest type; around 250 000 ha of a double-storey, high forest type, and around 100 000 ha of a single-storey forest of smaller trees with compacted crowns. Most likely the last carries only one main species and is associated with deep flooded areas. In all, there appear to be no more than five significant forest types, excluding the mangrove complex on the coastal fringes.

#### (b) Volume and species distributions

Three large concession areas (A, B and C on Map 9) totalling 430 000 ha have been applied for within the main swamp forest. Well-conducted, low-intensity forest inventories have been carried out on these areas by field parties from the Forest Research Institute at Bogor. In all, the figures convey a rather hopeful situation, as they suggest that as few as nine broadly distributed species contribute a major percentage of a fairly attractive total volume (Table 12).

Table 12

SUMMARY OF INVENTORY RESULTS IN PALEMBANG SWAMP FOREST 1/

| SPECIES | AREA A 2/ | | AREA B | | AREA C | |
|---|---|---|---|---|---|---|
| | $m^3$/ha volume | % total volume | $m^3$/ha volume | % total volume | $m^3$/ha volume | % total volume |
| Shorea<br>Alstonia<br>Lophopetalum<br>Dyera | 36.1 | 62.5 | 52.4 | 62.0 | 54.4 | 43.7 |
| Campnosperma<br>Genua<br>Endospermum<br>Koompassia<br>Nauclea | 13.0 | 21.3 | 11.3 | 13.3 | 1.6 | 1.3 |
| Total, 9 species | 49.1 | 83.8 | 63.7 | 75.3 | 56.0 | 45.0 |
| Other commercial species | 5.3 | 10.4 | 7.5 | 8.9 | 37.4 | 30.0 |
| Total commercial species | 54.4 | 94.2 | 71.2 | 84.2 | 93.4 | 75.0 |
| Non-commercial species | 3.3 | 5.8 | 13.4 | 15.8 | 31.1 | 25.0 |
| TOTAL VOLUME | 57.7 | 100.0 | 84.6 | 100.0 | 124.5 | 100.0 |

1/ Trees over 35 cm diameter.

2/ See Map 9.

Since these figures were collected from a very extensive total area, and without any attempt at forest type stratification, it seems reasonable to assume that:

- the nine species noted in Table 12 are predominant and widely distributed throughout the total area;
- stratification of the forest, based on types distinguishable from air photography, would produce even more simple and regular species and volume associations.

Taking into account the large size of the resources, the apparent high concentration of volume in so few species, and the likelihood that two proven peeler species (Shorea and Alstonia) are able to provide yields of at least 25 $m^3$/ha in trees of over 50 cm diameter, there appears to be some possibility that the forest could support a large integrated forest industry. This is, of course, provided that a suitable logging technique could be designed to extract the timber.

(c) Timber utilization

As far as can be ascertained, only 22 species, or species groups, are likely to produce any significant contribution to volume. It is significant that all the important species (except Koompassia malaccensis, which is in low concentration) have specific gravities within a range of 0.3 and 0.7 - indicating pulping possibilities as well as veneer and sawnwood production.

(d) Industrial prospects

Whereas the Palembang swamp forest does not appear to be as potentially high-yielding in either quantity and quality of wood as an average lowland dipterocarp forest, it displays other natural advantages when considered from the point of view of integrated, export-orientated, forest industry development. It is compact; it is right beside a local market, though modest, it has internal accessibility by water; and its wood volume is favourably concentrated into a very limited number of species. On the other hand logging and extraction might be difficult. However, partly-mechanized logging has been carried out successfully elsewhere under the same conditions.

Present and future supply and demand prospects for the paper industry in Asia (particularly Japan) 1/ and recent developments in long-distance trade in wood chips 2/ places a new perspective on forest industries development prospects in a forest of this nature. They convey a very real prospect of wood-chip export, in combination with sawnwood and veneer production from the higher quality wood component of the forest - which can mean almost complete forest utilization and an enormously favourable change in forest economics. Australia, New Nealand, New Guinea, Sarawak, Sabah and West Malaysia have risen to this opportunity and some of them are already exporting hardwood wood chips to Japan. Apart from wood-chip export possibilities, Indonesia itself needs to consider its own internal demands for pulp and paper 3/.

The mere fact of a forest industry being large enough to support a veneer-slicing plant, fed from its selected quality log production, greatly enhances overall profitability, since it creates an end product approximately ten times more valuable than sawn timber, by volume.

(e) Site conditions

Freshwater swamp forests have general characteristics which appear to be much the same all over the world. From logging, ecological and silvicultural aspects, the following points are important:

- The level of the water-table within the swamp is usually 50 to 100 cm higher than the mean tidal level of adjacent rivers, the swamps being enclosed in a shallow basin formed by the natural levee banks of the river. If these levees are cut through at the river level into the swamp forest (which is usually 200 to 400 m from the river bank) it is found that the swamps drain outwards except during monthly peak tides and periods of river flooding. If a series of canals were

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1/ Market study for forest products from Asia and the Pacific Region. Report for FAO by Tuolumne Corporation, July 1971.

Outlook for pulp and paper consumption, production and trade to 1985. FAO Secretariat, March 1972.

2/ The implications for forestry of recent developments in long distance trade in wood chips. Committee on Forestry, FAO Secretariat Note, March 1972.

3/ The Chief of Chemical Bureau, Chemical Industries Department, states that Indonesia produces around 25 000 t of pulp each year from 6 small soda/sulphite, rice and bamboo mills and imports 1 000 t of long fibre pulp to mix with it. At the same time 70 000 t of paper (newsprint: 28 000 t; Kraft: 20 000 t; writing paper: 22 000 t) are imported each year.

cut into the swamp forest, and they are kept open, the general water-table level rapidly falls, producing dry surface conditions which completely alter the ecology. In Ecuador, for example, it has been found possible to grow coconuts, bananas, pineapples and beans on typical swamp-forest sites recently drained by logging canals.

- Swamp-forest trees are very shallow, rooting systems deriving their support from a common interwoven surface root mat only about 50 cm thick. Individual trees can be pulled over quite easily.
- Below the root mat there is saturated mud incapable of supporting any unbuoyant mechanical equipment.
- Trees may embed themselves to the extent of half or more of their circumference when felled unless they strike a heavy root system. This complicates bucking (cross-cutting) the trees into logs before extraction.

(f) Logging

Swamp forest can be logged by mechanical means - as proved by the barge and winch operations in the freshwater swamp forest around Tamaco in Colombia. Since local swamp forest conditions appear to be similar, there is no reason to suppose that the same system could not be applied in the Palembang areas.

(g) Forest inventory

Conditions for ground inventory work in swamp forest are extremely difficult and unhealthy. However, work could probably be reduced considerably because of the relative ease of forest type stratification (from air photography), and the apparent regular nature of the forest within types. The possibility of using helicopters and random group sampling methods should be considered. It would seem possible to design such an inventory from information already available, i.e. by stratification from air photos, plus an indication of standard deviation and average volume from previous inventory work. Previous inventories are contained in the following excellent publications (these include line summaries but not plot summaries):

Area A : Survey Kelompok Hutan - S. Lugihan - Propinsi Sumatra Selatan, Laporan No. 161 (1970)

Area B : Survey Kelompok Hutan - S. Padang - S. Lugihan, Propinsi Sumatra Selatan, Laporan No. 271 (1971)

Area C : Survey Kelompok Hutan - S. Lugihan - S. Lebong Hitam Propinsi Sumatra Selatan, Laporan No. 236 (1971)

The above publications are issued by the Direktorat Perencanaan, under the Direktorat Jendral Kehutanan, Departemen Pertanian, Jakarta.

(h) Conclusions

No further concessions or licences should be granted in the 1.1 million ha Palembang swamp forest area, until the whole area has been reassessed in terms of total timber, volume and timber utilization potential and reconsidered in terms of the development, at some time in the future, of one large integrated forest industry with possiblities of producing paper pulp (or export paper chips) plywood or block-board veneers and lumber, and lower grade veneers of lumber for domestic purposes. A forest inventory and end-use survey of all significantly represented species is required as soon as possible. At the same time, silvicultural and ecological research should be undertaken to decide means of reforestation in areas not required for agricultural purposes. It is not intended to imply that the area has immediate industrial development prospects. There is however a definite eventual prospect and it is for this reason that the resource should be investigated and guarded.

### 4.2.2 Total remaining wood reserve

Based on the above indications of remaining productive forest, a rough estimate of corresponding commercial wood reserves is given in Table 13.

Table 13

ESTIMATE OF REMAINING WOOD RESERVES

| Resources | Productive area (ha) | Estimated commercial volume (m3/ha) | Estimated total commercial volume ($m^3$) |
|---|---|---|---|
| Production forest reserves | 33 000 | 50 | 1 650 000 |
| Other forests: inland | 60 000 | 50 | 3 000 000 |
| swamp | 63 000 | 40 | 2 520 000 |
| Palembang swamp forest complex | 500 000 | 60 | 30 000 000 |
| Total | 656 000 | - | 36 170 000 |

Notes: 1. The estimated commercial volumes per hectare given for the first two forest groups may be greater than those being achieved at the moment, because of extremely selective logging, almost confined to Dipterocarp species. With improved utilization the volume per hectare could reach as high as 80 to 100 $m^3$/ha.

2. The figure of 60 $m^3$/ha given for the Palembang swamp forest complex assumes a large-scale integrated industrial approach. At the moment, it is doubtful if present logging operations realize more than 20 $m^3$/ha.

Under the circumstances described in Sections 4.3.1 (Timber production and demand) and 4.5.1 (Management plans) it is impossible to give any clear indication of how long remaining wood reserves will last within the Province. All one can reasonably say is that they may prove quite inadequate within ten years unless the swamp forests are brought into full production, log export rationalized, timber utilization improved and destructive agencies controlled.

## 4.3 TIMBER UTILIZATION

### 4.3.1 Timber production and demand

According to the annual report of the Forestry Department, timber production for South Sumatra Province in 1970 was as follows:

Table 14

TIMBER PRODUCTION, SOUTH SUMATRA PROVINCE - 1970

| | Log production ($m^3$) | Sawn-timber production ($m^3$) |
|---|---|---|
| Overseas export | 269 300 | - |
| Interprovincial export | 300 | 19 200 |
| Local use | 104 200 | 17 800 |
| Total | 373 800 | 37 000 |

These figures suggest that:

- local per caput sawn-timber consumption is less than 0.003 $m^3$ per year;
- the estimated 250 small, one-bench sawmills, plus two large ones with a combined 15 000-$m^3$ per year out-turn, cut only 37 000 $m^3$ per year.

Since wood is the main building material outside the city and larger towns these figures appear to be extraordinarily low.

### 4.3.2 Timber manufacture

There are only two major sawmills in the Province, both in Palembang. The P.T. Alwi Assegaf mill contains a large band breakdown and carriage, and a three-band recovery saw. The management claims that production is only 25 $m^3$ per 7-hour day. The N.V. Perusahaan Bahan mill contains three circular-saw benches with a stated production of 25 $m^3$ per day. The small rural sawmills are rudimentary. Most of them have a single circular saw and a simple carriage drawn by a man-operated capstan wheel. These mills are generally underpowered but turn out timber of reasonable quality.

There are no drying kilns, nor has any attempt been made to air-dry timber for local or inter-provincial sale. It is sold green off the bench.

No form of preservation is available and no fungicide or insecticide application is undertaken. There is a great need for timber preservation treatment in order to expand and improve wood utilization. An inexpensive, easy method of treatment such as "dip-diffusion" would be useful in increasing the life of timber for building construction and thus increasing utilization of wood. Pressure treatment of non-desirable species with water-borne preservatives such as copper chrome and arsenic could enable these species to be utilized for railway sleepers, house posts, fence posts. The Railway Department could consider such treatment after making sure that the species under consideration for use can, in fact, be pressure-treated.

### 4.3.3 Species utilization

The main species sawn are: meranti (*Shorea* spp), merawan (*Hopea mengarawan*), and medang (*Dehaasia caesia*), with 90 percent of production in meranti alone. Pulai (*Alstonia pneumatophora*), jelutung (*Dyera costulata*) and prupuk (*Lophopetalum*) are also sawn, but are not liked because they are pale timbers of low natural durability and which, untreated, are prone to sap stain and early decay. In inland areas, seru (*Schima bancana*) and Durian (*Durio zibethinus*) are sometimes sawn.

### 4.3.4 Timber prices

Prices vary from place to place according to a local supply and demand situation which is aggravated by transport problems. A fair indication of price structure is as follows:

| | Rupiah/$m^3$ 1/ | US$/m.b.f. 2/ |
|---|---|---|
| Heavy durable hardwood, i.e. bungur | 17 100 | 97 |
| Durable hardwood, i.e. merawan | 13 500 | 78 |
| Furniture wood, i.e. medang | 11 000 | 63 |
| Medium light hardwood, i.e. meranti | 7 500 | 43 |
| Pale undurable light hardwood, i.e. pulai, prupuk | 4 300 | 24 |

The above prices appear reasonably cheap on world standards, but they are not cheap on local standards. A cubic metre of meranti may represent six weeks wages for an unskilled labourer in Indonesia. The prices also reflect the value of durability in species and the need for preservation treatment.

## 4.4 SILVICULTURE

### 4.4.1 Present situation

The Forest Service's records show that some 5 800 ha were planted in South Sumatra Province during the period 1921 to 1971, including 720 ha within the project area at Sungai Tua near Martapura. Other main planting areas but outside the project area are Semandai with 1 365 ha and Benakat with 1 050 ha. Unfortunately, however, all these areas have suffered extensive and repeated fire damage, so that little remain except the last one to three years' plantings, and even these are unlikely to be successful unless more maintenance is provided. There is, however, a well established plantation at Punti Kayu, 7 km from Palembang, which contains 65 ha of good *Pinus merkusii*. Indications are that these trees are capable of a 2-cm diameter mean annual increment for at least the first 20 years. This is encouraging.

In addition to regular planting, the Forest Service also carries out some alang-alang afforestation work (penghijauan) consisting of planting 25-m-wide strips forming the borders of 25-ha blocks. There is one such scheme in the project area near Martapura. The species used are: *Melaleuca leucadendron*, cashew nut (*Anacardium occidentale*), *Glyricidia* and small amounts of *Pinus merkusii*. It seems a pity that the local fire-hardy grassland pioneer species *Schima bancana* was not used, particularly as it is a timber species. In 1971 the South Sumatra Forest Service received approximately 30 million Rupiahs (US$ 72 000) from national and provincial sources for reforestation work, excluding supervision overheads, which are covered by a separate vote. This is a generous amount which indicates the Government's general concern and willingness to partake in reforestation schemes.

### 4.4.2 Species

Some of the species used for the reforestation work appear to be unfortunate choices, e.g.:

(a) *Swietenia macrophylla*: in all cases observed, even in the Palembang nursery, this species is attacked by the cedar tip borer, suggesting that it is unsuitable for normal reforestation work - unless widely interplanted in enrichment line plantings, as in Venezuela.

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1/ US$ 1.00 = Rupiah 415 (23 August 1971).

2/ Million board feet.

(b) Onglen (Eusideroxylon zwageri): this is a slow growing, heavy hardwood. Evidence from a few undamaged trees at Semandai shows an average diameter of 38 cm at 51 years, which is far too slow. If durability is required it would seem better to use faster-growing species and provide preservation treatment for the wood. If strength is also required, Eucalyptus spp might be considered.

(c) Sungkai (Paronema canescens): this grows easily from cuttings and is somewhat prized as a furniture timber; it is soft but looks like teak and also belongs to the family Verbenaceae. However, it is a small tree up to 60 cm diameter and is believed to be prone to hollowness, and the wood to splitting.

There is a need for species trials; the following might be considered:

| | | |
|---|---|---|
| 1 – 3 | Pinus merkusii | – at least three provenances should be included |
| 4 | P. caribaea | – Honduras variety |
| 5 | Eucalyptus urophylla | – available from Timor |
| 6 | E. deglupta | – available from New Guinea |
| 7 | E. grandis | – Australia |
| 8 | E. robusta | – Australia |
| 9 | E. camaldulensis | – Australia |
| 10 | E. saligna | – Australia |
| 11 | Anthocephalus cadamba | – local |
| 12 | Gmelina arborea | – local |
| 13 | Octomeles sumatrana | – local, wet sites |
| 14 | Terminalia brassii | – New Guinea, wet sites |
| 15 | T. superba | – Africa |
| 16 | T. ivorensis | – Africa |
| 17 | Cordia alliodora | – South America |
| 18 | Entandophragma utile | – Africa |
| 19 | Maesopsis eminii | – Africa |
| 20 | Nauclea diderichii | – Africa |

4.4.3 Future plantation development

In view of the need to produce cheap, bulk, general purpose timber for local consumption, it is considered that the present extensive reforestation approach should be stopped and all reforestation finance and resource be centralized and concentrated on intensive plantation schemes. Only in this way will professional supervision, fire protection, access facilities, equipment and finance be adequate to ensure good results. In the meantime, general forest administration should be confined to fire protection, shifting cultivation eradication, and harvesting and marketing control. A general area, covering both sides of the road between Baturaja and Martapura is indicated on Map 9 as containing a suitable site. The first requirement of such a scheme is to carry out species trials and general feasibility studies. (The method used in Western Samoa would provide information on species adaptability within perhaps two years following establishment 1/).

The area for the proposed scheme is mainly covered by alang-alang and fire-damaged seru forest, though some logged forest exists in Forest Reserve No. 13. The area is gently undulating and free of stones. It lies at approximately 200 m elevation and has a 3 000-mm per year rainfall with a three months' dry season. Two planting techniques need consideration:

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1/ Investigation of tree species and reforestation methods suitable for Western Samoa, by R. Livingstone, Rome, 1973. Mimeo. (UNDP/FAO Project WES/68/004).

(a) Mechanized approach

It is suggested that a flail/chopper 1/ be used, attached to a small bulldozer or a heavy farm tractor with a light blade in front for pushing down any light scrub which might be encountered. An advantage of this machine is that it does not dig deeply and disturb the thin upper layer of more fertile soil. Strips 1.5 m wide would be prepared by the machine at 2.5 m intervals, and planting carried out immediately at 2.5 m spacing down the centre of the strips. Seed of stylo (*Stylosanthes guyanensis*), which is available from Australia, should then be sprinkled in a one-metre-diameter circle around each plant. In this way it is hoped to enrich the soil and avoid further maintenance. Some advantage may be gained from NPK fertilizer at the rate of about 50 g per plant, placed in the planting hole below root level. However, trials would be needed. It is considered that the establishment cost would not exceed US$ 35 per ha under such a system. The bottoms of gullies, and their lower slopes, which usually still contain some green broadleafed vegetation, should not be planted or disturbed. They should be retained as fire breaks.

(b) Manual approach

Areas should be burnt during a safe period and then planted at 2.5 x 2.5 m spacing with a one-metre-diameter circle around the plants seeded with stylo after deep hand hoeing to prepare a seed bed and further retard alang-alang regrowth. Under such circumstances it may be possible to plant areas at a cost of 40 to 50 man-days/ha or US$ 25-30/ha. Again, gullies should not be planted or disturbed.

## 4.5 FORESTRY PLANNING

### 4.5.1 Management plans

No overall forest management plan exists for South Sumatra Province or the project area, and it would not be possible to prepare one until:

(a) the shifting cultivation and fire problem in forest reserves has been overcome;

(b) a provincial annual crop has been agreed upon in relation to existing natural forest resources and any definite future man-made forest projects;

(c) an effective reforestation system has been developed and applied;

(d) log export has been rationalized.

### 4.5.2 Forest development planning

No definite forestry development plans have been prepared at provincial level. At central government level, the only definite plans for South Sumatra Province concern log export. The Master Plan Kehutanan of August 1971 sets target dates for increases in log export within each province. For forest areas within the project area it is felt that log export should be prohibited in view of diminishing forest resources and accompanying environmental hazards. Furthermore, under current marketing conditions,

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1/ e.g. the Yeomans Tritter 2.60 LC manufactured by Grasslands Pty. Ltd., Villawood, N.S.W., Australia. It carries rotating flails or hammers which mash and pulverize the stems and roots of grass and light scrub to leave a well prepared surface mulch. It will work on grades of up to 1:2.5 and will pulverize non-igneous rocks.

log export operations are wasteful of resources because of very restrictive species and quality specifications imposed by importers, and the absence of any attractive local market for lower quality logs.

At the very least, no concessions involving log export should be granted without the following conditions:

(a) clear specification of the species, sizes, and qualities of trees to be harvested;

(b) clear specification of the reforestation technique to be employed, and the species to be planted or cultured;

(c) a fixed target date (within two years) for complete internal conversion of timber production, including provision for seasoning and the preservation treatment of all light hardwoods 1/.

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1/ In Papua New Guinea, for example, timber preservation treatment is compulsory. This has led to an enormous improvement in species utilization. The simple and relatively cheap dip diffusion process is mainly used.

## Chapter 5

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 WATER RESOURCES

### 5.1.1 Hydrometeorologic aspects

(a) Planning of water resources utilization

The records indicate plenty of water in the project area. However, a mean annual rainfall equal to 2 354 mm taken in its absolute value, may be misleading. The following constraints should therefore be taken into account in planning involving the water resources of the area:

(i) high salinity: even at distances more than 50 km from the ocean the salt content of the streamflow waters can be harmful to most crops. Management of this factor might be difficult, because of strong tidal influence;

(ii) uneven distribution of rainfall in time: the data assembled show that more than 80 percent of the annual rainfall occurs during eight months (October-May). The remaining 20 percent (about 470 mm) distributed over four months, would be equal to less than 4 mm/day, and this amount will not satisfy the demands of most crops. Supplementary irrigation should therefore be considered in the planning of water resources (see (v) below);

(iii) flooding: constant annual flooding makes intensive crop production during rainy months hazardous. Flood-control measures will be necessary. Unfortunately, the actual records of peak discharge are too short to evaluate adequately flood occurrences. The flood and risk analysis carried out using the long synthetic data should be used as a first approximation for design purposes;

(iv) water-table: a high water-table in the lower part of the project area presents a problem in water management. To deal with the design variables of the drainage system that should be considered, the rainfall intensity-duration-frequency curves (Figures 8-16) should be used.

(v) irrigation potential: the extent of possible irrigation development along the rivers Ogan and Komering is governed by the flows during dry months. Using a flow occurrence probability of 80 percent, minimum downstream domestic water supply needs for Ogan and Komering of 10 $m^3$/sec and 20 $m^3$/sec, respectively, and a peak monthly irrigation water requirement of 1.5 l/sec/ha, the water balance in the critical month of August will be:

| | Ogan (Baturaja) | Komering (Martapura) |
|---|---|---|
| Mean monthly discharge | 40 $m^3/sec$ | 87 $m^3/sec$ |
| Domestic needs | 10 " | 20 " |
| Available for irrigation | 30 " | 67 " |

The maximum areas which could be irrigated from the rivers Ogan and Komering are 20 000 and 44 500 ha respectively. Any irrigation development in excess of this area will require use of water from the regulated outflow of Lake Ranau.

(b) Records

The hydrometeorologic observations established by the project are well recorded and organized. However, it is recommended that, as soon as an anomaly is detected in the readings, recordings or operation of an instrument, steps be immediately taken to avoid the systematic and cumulative errors that would otherwise be introduced in the records. The evaporation-pan records require particular attention. The method now used involves counting the number of cups (calibrated) necessary to replace the evaporated water during 24 h. It is recommended that a gauge be installed in each pan, to make the measure of the evaporation easier and more accurate by a direct reading of the corresponding scale.

The hydrologists and meteorologists should be constantly alert to any other anomaly that may occur during the operation of the hydrometeorologic network.

5.1.2 Water quality

A study of the chemical characteristics of waters from the various rivers and their tributaries has shown that except in areas where tidal saline water intrudes, the water is of good quality and can be used to irrigate any type of plant on any soil group without harmful effects.

A comparison of the ionic contents from various rivers with the permissible levels of these ions in drinking water indicates that the waters from these rivers are safe from the chemical point of view for drinking. However, the water should be filtered to remove all suspended materials and boiled thoroughly to destroy all micro-organisms.

5.1.3 Groundwater

The most favourable areas for potential groundwater development appear to be the anticlinal structures near Palembang, Perabumulih and Muara Enim and the folded and faulted sediments in the vicinity of Baturaja. Other areas where the Muara Enim coal, the Air Benakat sand and clay, the Baturaja limestone or the Talang Akar shale outcrop or lie at relatively shallow depths, are other possible sites.

Before any answers can be given regarding quantities of groundwater available, a systematic investigation, including test drilling and test pumping, must be undertaken. Because of the complex geologic conditions in the most favourable groundwater areas, the siting of test holes is a critical factor. Each test hole site should be evaluated by aerial photograph interpretation and on-site geologic reconnaissance.

Based on this reconnaissance investigation and the very limited groundwater-data available, the potential for utilizing groundwater for dry-season irrigation is sufficiently favourable to warrant further investigations into hydrogeologic conditions within the project area.

It is specifically recommended that:

1. Wells in the project area should be inventoried. The inventory should include all drilled wells and a representative number of dug wells to provide coverage throughout the project area.

2. Several wells representing different water-bearing zones should be established as observation wells. Water levels should be determined periodically and water samples should be collected for analysis. If a satisfactory drilled well could be located and if equipment is available, an automatic water level recorder should be installed to give a continuous record of groundwater fluctuations.

3. The P.T. Sumbara Shell Company data should be evaluated by a hydrogeologist and if it is found that conditions are favourable for large-scale groundwater development, specific areas should be selected where there is an interest in and a need for developing groundwater.

4. In the area selected, hydrogeologic investigations should be undertaken on a priority basis to determine the groundwater potential. These hydrogeologic studies should include:

- an area study consisting of an analysis of aerial photographs and field geologic and geophysical investigations;
- selection of specific test-drilling sites;
- drilling a pre-determined number of test holes to determine depth and lithologic characteristics of aquifers and water levels of water-bearing zones;
- pumping tests to determine aquifer characteristics;
- collection and analysis of water samples during pumping to detect quality changes with time;
- an analysis of all hydrogeologic data to determine groundwater development potential in the area of study.

5. Based on findings of the first studies undertaken, additional areas should be similarly evaluated as long as the need for groundwater development justifies the cost of exploration.

6. In the interest of public health, groundwater for domestic use should be exploited only in locations well clear of any water courses that are frequently polluted.

## 5.2 LAND SUITABILITY CLASSIFICATION

A study was undertaken on land suitability classification for unimproved upland shifting cultivation; and for upland crops, pasture, tree crops and paddy (wetland) rice under improved cultivation. The results of this study, on which future activities should be based, are shown in Maps 4 to 8, and in Appendixes 5 to 9.

## 5.3 FORESTS AND FOREST PRODUCTION

It is estimated that productive forest resources and other scattered forest hold approximately 156 000 ha of exploitable forest carrying an estimated 7.2 million $m^3$. In addition, the large compact swamp forest complex adjacent to Palembang holds an estimated 500 000 ha of exploitable forest, carrying an estimated 30 million $m^3$ of commercial wood.

Utilization within the project area is extremely poor and very selective with regard to species. Sawmilling is of very elementary standards, and seasoning and timber preservation is not practised. No reliable statistics are available on this subject, even to the extent of the number of sawmills operating. There is no control on log export.

In the absence of overall development plans, obvious needs are as follows:

(a) regional rural fire control;

(b) control of shifting cultivation;

(c) erosion control in steep lands;

(d) species trials, and silvicultural technique improvements;

(e) the establishment of plantations of fast-growing general purpose timbers in selected inland areas;

(f) forest inventory and timber utilization studies in the 1.1-million-ha Palembang swamp forest complex and, if possible, the establishment of a large integrated forest industry;

(g) elimination of log export.

An area between Baturaja and Martapura is indicated as a general location for a plantation project in the order of 1 000 ha of planting per year. The Palembang swamp forest complex is indicated as a site for forest industrial development investigations.

Recommendations for future action are given below. That which concerns fire control is on a national level, while the remainder refer to the project area in particular.

### 5.3.1 Immediate priority

(a) In view of the enormous amount of destruction to natural resources by fire, the Government of Indonesia should consider the establishment of a trial system of rotated shifting cultivation in a limited area, sponsor a national/rural fire-control campaign and development of a rural fire-control organization. The possibility of recruiting additional local help during the periods of high fire danger should also be studied.

(b) The services of a consultant on shifting cultivation and of a forest fire-control expert should be obtained for 18 months to advise on shifting cultivation, fire legislation, equipment, education and publicity requirements and the setting up of regional fire-control authorities, and to supervise fire-control training, practice and publicity.

(c) Scholarships (12 months) for fire-control study and practice should be sought overseas.

(d) The services of a tropical silviculture consultant should be obtained for two-and-a-half months to establish a series of species trials in alang-alang (Schima bancana) areas, and to carry out a cost and feasibility study on a 1 000 ha/year plantation scheme.

(e) Regular reforestation/afforestation should be suspended until adequate fire-control measures are applied. The discontinuance of the penghijauan system should be considered, pending further silvicultural research.

(f) Approval of any application for forest licences or concessions in the coastal swamp forest, including the 430 000 ha concessions referred to in Section 4.2.1.5(b) should be deferred or suspended pending the outcome of the productive forest planting schemes.

(g) Remaining inland, productive forest resources should be appraised in terms of virgin forest and partly cut-over forest, and future cutting regulated in relation to local requirements for at least the next ten years, in order to provide time for production supplementation from the planting schemes.

(h) Discontinuation of selective, one-to-three species cutting, should be enforced, and a list of obligatory felling species drawn up, these species being marked prior to harvest to ensure compliance.

(i) The use of timber preservation treatments (pressure and dip-diffusion processes) should be investigated, and stimulated, to increase forest production. It is suggested that duty be waived on the import of timber-preservation chemicals.

(j) With international assistance, a forest resources survey of coastal swamp forest (approx. 1.1 million ha) should be undertaken covering forest inventory, wood testing and end-use study extending to pulping and agglomerate wood manufacture, logging feasibility and marketing.

(k) Soil and water conservation regulations should be reappraised with adjustment to a critical slope/land-use basis for approving the clearing of land.

(l) Any new fire or soil conservation regulations stemming from the above recommendations should make provision for nomination by the Forestry Department of certain categories of government officers to be ex-officio fire wardens for the purpose of upholding the law and reporting offences.

### 5.3.2 Longer-term recommendations

(a) Log exportation should cease as soon as the permits already issued expire.

(b) Productive forest planting schemes should be increased in strategically selected areas, bearing in mind rational land use; the size and location of future markets; the availability of professional staff for direct supervision, and adequate fire control. Assistance from international loan agencies will be required once species trials have provided results.

(c) Depending on encouraging results being obtained from the forest resources survey, tenders on an international basis should be called for the establishment of a large export-orientated integrated forest industry in the swamp forest, so as to ensure a feed back of treated lower grade material internally, to balance growing demands and dwindling local forest resources.

(d) Depending of the success of the planting schemes, inland forest exploitation should be limited within the capacity of all natural and man-made forest resources.

(e) Areas for future reforestation should be selected and reserved.

(f) People dependent on shifting cultivation of upland rice, should be encouraged to:

- take up permanent cash crops, i.e. rubber, coffee using the taungya system; or
- transfer to newly developed wet rice schemes; or
- move to other industries.

Appendix 1

## GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

(see also Map 2)

| ERA | AGE | GROUP | FORMATION | THICKNESS | LITHOLOGY | WATER-BEARING PROPERTIES |
|---|---|---|---|---|---|---|
| Quaternary | Recent | | Alluvium | Variable | Mainly clays and fine sands, with interbedded gravels. | Poor to fair. Large number of shallow wells are developed in alluvial deposits. Wells usually go dry in dry season. Properly constructed wells in coarser sections of alluvium would likely provide dependable quantities of water for a few families. Shallow aquifers may be polluted. |
| Quaternary-late Tertiary | Recent Pleistocene and Pliocene | | Young volcanics | Highly variable | Includes pumice, volcanic ash, andesite, basalt, dacite, and rhyolite. | Poor to good. Highly variable rock types cause extremely different water-bearing characteristics. Basalts and other porous rocks might prove to be excellent aquifers whereas ash and dense rocks would not yield water. |
| Tertiary | Pleistocene | Palembang Group | Kasai tuff | Up to 1 000 m | Alternating beds of tuffaceous clays, conglomerates and beds of lignite and coal. | Poor to fair. Lithology is generally unfavourable for groundwater development but some tuffaceous units and conglomerates might yield moderate to large quantities of water. |
| Tertiary | Pliocene | Palembang Group | Muara Enim coal | 200 to +800 m | Upper member mainly clay and sandy clay with distinct coal layers; lower member mainly tuffaceous clays, and carbonaceous clays intercalated with fine-grained glauconitic sands. | Fair to good. The lithology is generally unfavourable for the development of large quantities of groundwater. However, lower sand units might prove to be sufficiently permeable to yield moderate to large quantities of artesian water. |
| Tertiary | Miocene | Palembang Group | Air Benakat sand and clay | Highly variable variable, may be as much as 1 000 m | Succession of marine sands and sandy shales and limestones with coal stringers. Sands usually have a high percentage of clay. | Poor to fair. Sands are usually very clayey and not conducive to groundwater development. If sections of clean sands could be tapped downdip of the outcrop, good yields of artesian water might be obtained. |
| Tertiary | Miocene | Telisa Group | Gumai shale | 80 to +1 000 m | Dark sandy shales or marly shales with limestone intercalations. | Poor. Lithologic character and highly variable thickness preclude yield of large quantities of groundwater. The unit would act as a confining layer to impart pressure to more permeable units below and therefore would function as an important part of the hydrogeologic system. |
| Tertiary | Miocene | Telisa Group | Baturaja limestone | 50 to 170 m | Mainly platy limestone with some biohermal organic zones. | Fair to good. Wells penetrating fractured or solutionally enlarged zones downdip from the outcrop probably would supply large quantities of water. |
| Tertiary | Miocene – Oligocene | Telisa Group | Talang Akar shale and sand | 50 to 1 000 m | Upper member is finer grained (2.5 mm) sand with intercalations of shaley sand and coarse grit; lower member consists mainly of thick layers of large (5 mm), angular grains of quartz sand. | Fair to excellent but of limited areal extent. Thick sections of coarse sand would likely yield relatively large quantities of good quality artesian water. Highly variable thickness, structure and small areas of outcrop would limit potential development. |
| Tertiary | Oligocene | Telisa Group | Lahat Tuff-Breccia | Highly variable (does not outcrop in project area) | Tuffs, agglomerates, clay stones, tuff-breccias and lavas with some intercalations of fine sandy clay. | Poor. Highly variable thickness and primarily fine-grained material are not favourable for supplying large quantities of water. |
| Pre-Tertiary | - | | - | Sub-surface depth occurred at 255 m and 2 750 m. Other places over 6 000 m. | Composed of diabase, phillite, biotite granite, dark-green granite, syenite, aplite, schist, diorite and quartzite. | Poor. Water would occur only in limited quantities in fractures or joint systems. Weathered zone would likely supply water adequate for domestic use. |

Appendix 2

RECORDS OF WELLS AND SPRINGS
(see Map 1 for locations)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITY | SOURCE OF DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Upang Delta (transmigration area) | P-1 | 100+ | - | Alluvium | - | Saline | Public Health Department (PHD) | Jetting was stopped at 100+ m by layer of hard rock. Well no longer exists |
| Palembang | P-2 | 110 | - | Air Benakat | - | - | PHD | Abandoned, insufficient yield |
| Palembang | P-3 | 30 | - | Air Benakat | - | Good | PHD | About 30 m from P-2 hand pump |
| Palembang (Sukamiskin) | P-4 | 25 | - | Air Benakat | - | Good | PHD | Hand pump |
| Palembang | P-5 | 228 | 20 | Air Benakat | Dry | - | Driller Ruslani, Gauh Hok Cun Contractor, Jakarta | Drillers log: 0-6 m; red clay with lateritic gravel; 6-228 m; dark grey clay |
| Palembang | P-6 | 80 | 20 | Air Benakat? | Dry | - | Driller Ruslani, Gauh Hok Cun Contractor, Jakarta | Drillers log: 0-6 m; red clay with lateritic gravel; 6-80 m; dark grey clay; drilling by jetting - percussion method; required 25 days to penetrate 80 m |
| Sungai Gerong | P-7 | 25 | - | Alluvium | - | Good | PHD | Hand pump |
| Plaju | P-8 | 25 | - | Alluvium | - | Good | PHD | Hand pump |
| Sekayu | P-9 | 26 | - | Alluvium Air Benakat? | - | Good | PHD | Hand pump |

Appendix 2 (cont'd)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITY | SOURCE OF DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Sekayu | P-10 | 26 | - | Alluvium Air Benakat? | - | Poor, muddy | PHD | - |
| Tanah Abang | P-11 | 25+ | - | Alluvium Air Benakat? | | Good | PHD | Hand pump |
| Gelumbang 1/ | P-12 | 25 | 5 | Kasai Tuff | Dry 4/23/74 | Muddy, not safe | PHD and observation | Well drilled in fine sand. The problem with this well is construction technique, not lack of water |
| Seri Bandung | P-13 | 107 | 10 | Alluvium Kasai Tuff? | - | See Appendix 3 | Observation and Director of Moslem School | Drilled October 1972; supplies about 700 people; 48 $m^3$ elevated storage capacity; average use 12 $m^3/d$; centrifugal pump |
| Tanjung Raja (public works) | P-14 | 33 | 5 | Alluvium | 8.0 1973 | See Appendix 3 | Observation and Public School | Well supplies several houses, not used for drinking; lithology, 0-4 m swampy soil, 4-8 m peat soils, 8-33 m fine sand and clay. Hand pump |
| Tanjung Raja (public works) | P-15 | 6.6 | 100-80-60 | Alluvium | 1.7 5/7/74 | Good | Observation | Well adjacent to P-14; water used for drinking; has never gone dry; near Ogan River |
| Tanjung Raja (hospital) | P-16 | 7.7 | 200-150 | Alluvium | 6.0 5/7/74 | See Appendix 3 | Observation | Well goes dry in dry season; located some distance from Ogan River; dug in sandy clay |

Appendix 2 (cont'd)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITY | SOURCE OF DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Kayuagung | P-17 | 7.3 | 150 | Alluvium | 4.0 5/7/74 | See Appendix 3 | Observation | Well supplies hospital; usually has water all year, went dry in 1972 |
| Perabumulih 2/ | P-18 | 25± | - | Kasai Tuff Muara Enim? | - | Good | PHD | Hand pump |
| Perabumulih | P-19 | 25± | - | Muara Enim | - | Good | PHD | Hand pump |
| Perabumulih | P-20 | 25± | - | - | | Good | PHD | Hand pump |
| Muara Enim | P-21-30 | 12-35 | - | Kasai Tuff and Muara Enim | - | Good | PHD | 10 wells in Muara Enim vicinity equipped with hand pumps |
| Tanjung Enim | P-31 | 93.4 | - | Muara Enim | 4.0 early 1900's | - | Directorate of Geology files | Coal exploration well drilled in early 1900's |
| Baturaja 3/ (Government rest house) | P-32 | 12+ | 5 | ? | Less than 12.0 1967 | See Appendix 3 | Observation and rest house attendant | Well drilled and hand pump installed in 1967; supplies about 20 people; does not go dry; cased to 12 m; drilled in sand |
| Baturaja | P-33 | 12+ | 5 | ? | Less than 12.0 1967 | - | Rest house attendant | Well reported to be across street from P-32 |

Appendix 2 (cont'd)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITY | SOURCE OF DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Baturaja (Government office) | P-34 | 15+ | 5 | ? | 7.0 1967 | Good | Government office staff | Well drilled and hand pump installed in 1967; cased to 15 m; average daily use 800 l; does not go dry. Lithology reported: 0-10 m, sandy clay; 10-15 m, mud; 15 m to > 25 m depth, red sand |
| Baturaja (telecommunications office) | P-35 | 4.6 | 100 | Alluvium | 1.7 4/30/74 | Good | Observation | Dug well equipped with electric pump; supplies office; constructed with concrete curbing and apron |
| Baturaja | P-36 | 5.4 | 100 | Alluvium Kasai Tuff | 3.3 4/30/74 | Good | Observation | Dug well on bank of Ogan River, about 5-6 m above river level |
| Belitang 4/ (FAO rest house) | P-37 | 2 | 100 | Alluvium | 0.5 4/30/74 | Good | Observation | Dug well back of rest house equipped with hand pump and bucket |
| Martapura (Forestry office) | P-38 | 6 | - | Volcanics | - | Good | Forestry Office, Palembang | Equipped with hand pump |
| Martapura (hospital) | P-39 | 14 | 5 | Volcanics | - | Good | Observation and hospital staff | Well drilled and hand pump installed in 1967; pump broken, well no longer used |

Appendix 2 (cont'd)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITY | SOURCE OF DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Martapura 5/ | P-40 | 8.2 | 150 to 4.75 m; 100 to 8.2 m | Alluvium | 7.4 5/1/74 | See Appendix 3 | Observation | Dug well, has never gone dry. Lithology reported: 0-5 m, clay; 5-8.2 m, sand |
| Gunung Batin (Proyek Gula) | P-41 | 6.9 | 100 | Kasai Tuff | 4.7 5/2/74 | See Appendix 3 | Observation | Dug well with hand pump and bucket; constructed in early 1974 to supply houses at sugar plantation |
| Banding Agung 6/ (Government rest house) | P-42 | 2.9 | 100 | Volcanic alluvium | 0.8 5/4/74 | See Appendix 3 | Observation | Dug well with hand pump; supplies rest house |
| West of Banding Agung | P-43 | - | - | Volcanics | Flowing | - | Public Health | Water reported to rise several metres above surface |
| Pulau (agriculture facility) | P-44 | 5.0 | 80 | Alluvium | 4.3 5/10/74 | Good | Observation | Concrete curbing 1 m below surface; well dug in lateritic clay soil; used for drinking; goes dry early in dry season |
| Pulau (agriculture facility) | P-45 | 2.4 | 200 | Alluvium | 1.6 5/10/74 | Good | Observation | Located across road and about 2 m lower than P-44; hand pump broken; goes dry |
| Tanjung Dalam | CS-1 | 155 | 20 | Muara Enim | Dry | - | Driller for Gauh Hok Gun Contractor, Jakarta | Well drilled by contractor for Nigata Gas Project; abandoned as a dry hole |

Appendix 2 (cont'd)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITY | SOURCE OF DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Lubukraman | CS-2 | 64 | 20 | Muara Enim | 9.5 3/74 | Good | Driller and observation | B.M. elev. 27.7 m. Well pumped at 100.8 l/min with drawdown of 10.5 m. Specific capacity 9.6 l/m |
| Gunungagung 7/ | W-14 | 8.7 | 100 | Kasai Tuff | - | - | Groundwater map of Lampung Province | Land surface altitude 32 m. Source map shows selected dug wells in which water levels are periodically monitored |
| Gunungbatin | W-15 | 14.3 | 100 | Kasai Tuff | - | See Appendix 3 | " | Land surface altitude 44 m |
| Menggala | W-16 | 12.9 | 100 | Alluvium | - | See Appendix 3 | " | Land surface altitude 30 m |
| Leke | W-17 | 7.2 | 100 | Kasai Tuff | - | - | " | Land surface altitude 25 m |
| Blambangan | W-18 | 7.6 | 100 | Kasai Tuff | - | - | " | Land surface altitude 44 m |
| Padangratu | W-40 | 5.5 | 100 | Volcanics | - | - | " | Land surface altitude 78 m |
| Dayasakti | W-41 | 6.3 | 100 | Kasai Tuff | - | - | " | Land surface altitude 54 m |
| Gedongnyapah | W-42 | 7.0 | 100 | Kasai Tuff | - | - | " | Land surface altitude 40 m |
| Kotabumi | W-43 | 13.6 | 100 | Volcanics | - | See Appendix 3 | " | Land surface altitude 58 m |

Appendix 2 (cont'd)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITY | SOURCE OF DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Belambangan Umpu | W-44 | 10.7 | 100 | Volcanics | - | - | Groundwater map of Lampung Province | Land surface altitude 65 m |
| Simpang Empat | W-45 | 8.3 | 100 | Volcanics | - | - | " | Land surface altitude 132 m |
| Bandar Dalam | W-46 | 11.5 | 100 | Volcanics | - | - | " | Land surface altitude 69 m |
| Karta | W-47 | 7.2 | 100 | Alluvium | - | - | " | Land surface altitude 33 m |
| Panarangan | W-48 | 8.3 | 100 | Alluvium | - | - | " | - |
| Sawojajar | W-53 | 11.8 | 100 | Kasai Tuff | - | - | " | Land surface altitude 38 m |
| Gunungkemala | CS-3 | 54 | 20 | Kasai Tuff Muara Enim? | 6.5 3/74 | Good | Drillers and observation | Well pumped at 61.7 6.7 l/min with drawdown of 2.5 m. Specific capacity 24.7 l/m |
| Talangjimar | CS-4 | 60 | 20 | Muara Enim | Dry | - | Driller and Nigata Records | Well abandoned as dry hole |
| Cambai | CS-5 | 64 | 20 | Kasai Tuff | 8.0 4/74 | Good | Driller and observation | B.M. elev. 30.05 m. Well pumped at 92.0 l/min with drawdown of 6.5 m. Specific capacity 14.1 l/m |
| Kotabumi | K-1 | 45.0 | - | Volcanics? | - | - | Lampung Hydrological Network Report | Drilled in 1928 |

Appendix 2 (cont'd)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITYA | SOURCE OF SATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Menggala | M-1 | 156.3 | 8 | Palembang-Atlas (Kasai Tuff) | Flowing 5/2/74 | See Appendix 3 | Observation and old Dutch geologic repo reports | Drilled in 1906 on bank of Tulangbawang River, about 5 m above river level; discharge measured to be about 5 1/min on 5/2/74. Water rises less than 1 m above surface; provides domestic supply for village |
| Menggala | M-2 | 182.0 | 8 | Palembang-Atlas (Kasai Tuff) | Flowing 5/2/74 | See Appendix 3 | Observation and old Dutch geologic reports | Drilled in 1907 on terrace above Tulangbawang River; appears to be slightly higher in altitude than M-1; greater depth probably gives greater yield and pressure; discharge measured to be 9 1/min; water rises less than 1 m above surface. Supply for small shops and homes |
| Negararatu | W-54A | 7.8 | 100 | Volcanics | - | - | Observation and old Dutch geologic reports | Land surface altitude 46 m |
| Hanakau | W-54B | 4.9 | 100 | ? | - | - | Observation and old Dutch geologic reports | Land surface altitude 40 m |
| Tanjung Enim | S-1 | Spring | - | Muara Enim | Flowing | Good | PHD | Boxed in to supply several families |

Appendix 2 (cont'd)

| LOCATION | NO. | DEPTH (m) | DIAMETER (cm) | GEOLOGIC FORMATIONS | DEPTH TO WATER (m) AND DATE | WATER QUALITY | SOURCE OF DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Southeast of Perabumulih | S-2 | Spring | - | Muara Enim | Flowing | Good | PHD | Will be boxed in by PHD |
| Dwikory | S-3 | Spring | - | Volcanics | Flowing | See Appendix 3 | Observation | Supplies village of 30-40 houses. Yield estimated to be 50 l/min on 4/5/74. Altitude about 275 m |
| Pasir Putih | S-4 | Spring | - | Alluvium | Flowing | See Appendix 3 | Observation | Several seep springs at head of small valley; supplies good source of water for fish ponds, cattle and domestic use. Reported to have been discovered in 1969 and did not dry in 1972; the springs would not withstand a very long dry period |

1/ In addition to one drilled well, now out of service, there are more than 40 dug wells in the village.

2/ In addition to 3 drilled wells, at least one of which is dry, there are several hundred dug wells in the village.

3/ There are probably several other drilled wells and numerous dug wells in Baturaja.

4/ Another similar well is located across from the rest house; there are many dug wells in the Belitang area.

5/ Numerous other dug wells reported for Martapura.

6/ One of several dug wells at Banding Agung.

7/ All "W" well numbers are from Howard Humphreys and Sons inventory. The wells are a part of a large number of dug well monitored by the Lampung Hydrological Network Project.

Appendix 3

CHEMICAL ANALYSIS OF WATER FROM WELLS

(Analyses in mg/1, except conductivity, pH and SAR)

(see also Appendix 2 and Map 1)

| WELL No. | DEPTH (m) | DATE OF SAMPLE | Ca | Mg | Na | K | Cl | Fe | $CO_3$ | $HCO_3$ | $SO_4$ | TDS 4/ | CONDUCTIVITY (μmho/cm) | pH | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P-13 1/ | 107.0 | 7/5/1974 | 13.5 | 3.6 | 20.0 | 9.5 | 9.3 | – | 0 | 99.3 | 47.9 | 108.8 | 170.0 | 7.0 | 1.3 |
| P-14 1/ | 33.0 | 7/5/1974 | 7.7 | 1.0 | 7.5 | 3.9 | 12.1 | – | 0 | 50.6 | 0 | 54.4 | 85.0 | 6.6 | 0.7 |
| P-16 1/ | 7.7 | 7/5/1974 | 4.1 | 0.4 | 3.9 | 0.7 | 17.9 | – | 0 | 3.1 | 0 | 28.2 | 44.0 | 4.4 | <1.0 |
| P-17 1/ | 7.3 | 7/5/1974 | 6.1 | 0.8 | 7.5 | 1.2 | 21.8 | – | 0 | 0 | 7.0 | 70.4 | 110.0 | 4.0 | <1.0 |
| P-32 1/ | 12+ | 30/4/1974 | 5.1 | 0.7 | 4.5 | 1.9 | 14.4 | – | 0 | 5.0 | – | 33.3 | 52.0 | 5.7 | <1.0 |
| P-40 1/ | 8.2 | 1/5/1974 | 39.5 | 1.9 | 19.4 | 7.9 | 34.5 | – | 0 | 118.4 | 11.0 | 192.0 | 300.0 | 6.6 | <1.0 |
| P-41 1/ | 6.9 | 2/5/1974 | 4.3 | 1.2 | 0.9 | 0.1 | 3.8 | – | 0 | 7.4 | 5.0 | 10.2 | 16.0 | 6.0 | <1.0 |
| P-42 1/ | 2.9 | 4/5/1974 | 19.2 | 0.7 | 9.1 | 4.5 | 15.4 | – | 0 | 65.5 | 7.0 | 76.8 | 120.0 | 7.4 | <1.0 |
| P-45 1/ | – | 11/5/1974 | 7.1 | 0.7 | 2.3 | 0.4 | 12.2 | – | 0 | 2.4 | – | 10.9 | 17.0 | 5.2 | <1.0 |
| M-1 2/ | 156.3 | 1973 | 2.1 | 0.2 | 202.2 | | 68.6 | 0 | 0 | 424.1 | 0 | – | – | 6.0 | 37.0 |
| N-1 3/ | – | 12/11/1973 | 2.9 | 1.7 | 66.0 | 8.0 | 18.7 | 0.3 | – | 26.9 | 1.0 | 350.0 | 575.0 | 7.7 | 7.6 |
| N-1 1/ | – | 2/5/1974 | 5.5 | 1.0 | 153.4 | 10.0 | 44.4 | – | 21.6 | 378.2 | 40.0 | 448.0 | 700.0 | 8.2 | 16.0 |
| M-2 2/ | 182.0 | 1973 | 2.1 | 0.4 | 185.4 | | 31.2 | 0 | 0.0 | 446.4 | 0 | – | – | 6.0 | 36.0 |
| M-2 1/ | – | 2/5/1974 | 6.1 | 1.1 | 142.2 | 10.0 | 32.9 | – | 17.4 | 351.8 | 56.0 | 384.0 | 600.0 | 8.1 | 14.0 |
| W-15 3/ | 14.3 | 12/11/1973 | 2.1 | 0.9 | 13.9 | 1.2 | 9.3 | 0.3 | – | 15.4 | 0 | 68.0 | 70.6 | 5.6 | 2.0 |
| W-16 3/ | 12.9 | 12/11/1973 | 14.1 | 6.2 | 35.4 | 8.9 | 23.3 | 0.8 | – | 16.6 | 4.9 | 188.0 | 244.0 | 7.8 | 2.0 |
| W-43 3/ | 13.6 | 27/11/1973 | 3.5 | 10.4 | 2.0 | 0.2 | 4.5 | 0.5 | – | 18.9 | 1.0 | 30.0 | 26.9 | 6.2 | 0.4 |
| S-3 1/ | – | 3/5/1974 | 6.3 | 1.4 | 1.5 | 0.9 | 8.6 | – | 0 | 6.5 | 8.2 | 10.2 | 16.0 | 6.2 | <1.0 |
| S-4 1/ | – | 11/5/1974 | 6.1 | 1.8 | 1.5 | 0.2 | 10.7 | – | 0 | 5.5 | – | 5.8 | 9.0 | 4.4 | <1.0 |

1/ Analysis by UNDP/FAO Project Laboratory.

2/ Analysis by Directorate of Geology, Bandung.

3/ Analysis by Howard Humphreys and Sons, Lampung Province Hydrological Network Project.

4/ UNDP/FAO analyses reported as "salts".

Appendix 4

# GENERAL LAND SUITABILITY CLASSIFICATION

Three orders of land suitability are used:

S - Suitable land
CS - Conditionally suitable land
N - Unsuitable land

Land suitability classes within the orders indicate decreasing suitability for a defined use. Three classes are recognized for Suitable (S) and Conditionally Suitable (CS) orders, while only one class is identified in the Unsuitable (N) order.

Land suitability subclasses are divisions within classes (except S1) distinguished by the nature of the limitations which have determined their classification. They are denoted by a lower case letter following the class symbol.

The application of this classification to the five land utilization classes - unimproved shifting cultivation and improved cultivation of upland crops, pasture, tree crops and paddy - is presented in Appendixes 5 to 9 and in Maps 4 to 8. The relevant soil mapping units are displayed in Map 3 and their areas in Table A4.1.

## A. LAND SUITABILITY ORDERS AND CLASSES

| Order/Class | Definition |
|---|---|
| S - SUITABLE LAND | Land on which sustained use 1/ for the defined land utilization type is expected to yield benefits that will justify required recurrent inputs without unacceptable risk to land resources on the site or in adjacent areas. Recurrent inputs include repeated material inputs such as fertilizers, insecticides, pesticides, plant material, and routine cultivation practices which are labour and/or power intensive such as soil preparation, simple conservation practices, weeding, etc. Within the project area such inputs are considered moderate; but will require the provision (by government agencies) of important technical advisory services and credit facilities to the farmer. |

1/ "Sustained use" does not necessarily imply continuous cropping, the utilization type can recognize the possibility of fallow periods, natural or otherwise.

| Order/Class | Definition |
|---|---|
| S1 - Highly suitable | Land having no significant or only minor limitations to the sustained application of the defined land utilization type that will not significantly reduce production levels and/or will not raise recurrent and minor inputs for production and/or conservation above a readily acceptable level. |
| S2 - Moderately suitable | Land having limitations which in aggregate are moderately severe for the sustained application of the defined land utilization type that will reduce production levels and/or increase required recurrent and minor inputs for production and/or conservation to the extent that the overall advantage to be gained from the use, although still attractive, will be inferior to that expected on Class S1 land. |
| S3 - Marginally suitable | Land having limitations which in aggregate are severe for the sustained application of the defined land utilization type and will so reduce production levels and/or so increase required inputs on production and/or conservation, that such expenditure will only be marginally justified. |
| CS - CONDITIONALLY SUITABLE LAND | Land having characteristics which, at present, make it unsuitable for sustained use for the defined land utilization type but which, subject to management practices which are not specified in the general definition of the land utilization type, could become suitable.<br><br>The management practices referred to here are exclusively "one time" activities aimed at effecting major, reasonably permanent improvements such as complex land reclamation work which needs to be entrusted to specialists both for planning and execution; usually require the use of special equipment; and involve high or very high costs. In addition, recurrent inputs specified in the general definition of the land utilization type would be required after implementation of the major improvement. |
| CS1 - Conditionally highly suitable | Land having characteristics which, in general, preclude sustained economic application of the defined land utilization type but which could be used and would be equivalent in suitability to land of Class S1 provided the special management practices defined at class level were implemented. |
| CS2 - Conditionally moderately suitable | Land having characteristics which, in general, preclude sustained economic application of the defined land utilization type. Such land, however, could be used provided the special management practices defined at subclass level were implemented but would only be equivalent in suitability to land of Class S2 as moderately severe limitations indicated by the subclass symbol would remain. |
| CS3 - Conditionally marginally suitable | Land having characteristics which, in general, preclude sustained economic application of the defined land utilization type. Such land, however, could be used provided the special management practices defined at subclass level were implemented but would only be equivalent in suitability to land of Class S3, as severe limitations indicated by the subclass symbol would remain. |

| Order/Class | Definition |
|---|---|
| N - UNSUITABLE LAND | Land having characteristics which appear to preclude its sustained use for the defined land utilization type or which would create production, upkeep and/or conservation problems, requiring a level of recurrent inputs unacceptable at the time of interpretation. |
| N1 - Unsuitable | Land having limitations which appear so severe as to preclude any possibility of successful, sustained use of the land in the defined manner; or having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at presently acceptable cost. |

## B. LAND SUITABILITY SUBCLASSES

(It should be noted that the same kind of major limitation denoting subclass may occur in different classes according to the intensity of that limitation.)

| Subclass | Definition |
|---|---|
| e - erosion | Land with an erosion hazard or past erosion damage. |
| s - soil limitation in the root zone | Land comprising soils with problems such as shallowness, unfavourable texture, stoniness or low fertility that are difficult to correct. |
| t - unfavourable topography | Land whose relative position or relief (macro or micro) limits use for crops and paddy (wetland) rice in particular. |
| f - flooding | Land susceptible to flash floods or prolonged deep flooding, or both, which damage the crops or limit choice of crops. |
| d - impeded drainage | Land whose use is limited by excess water due to high water-table, slow permeability or slow surface drainage, or a combination of all three. |
| x - salinity | Land whose major limitation to use is salinity. |
| a - soil acidity | Land comprising soils for which extreme acidity, difficult to correct, is the major limitation for crop production. |

Table A4.1

LAND SUITABILITY AREAS FOR VARIOUS TYPES OF CULTIVATION

| Mapping unit | SUITABILITY CLASS AND SUBCLASS | | | | | Area 1/ (ha) |
|---|---|---|---|---|---|---|
| | Shifting cultivation | Upland crops | Pasture | Tree crops | Paddy | |
| 1 | N1f | N1f | N1f | N1f | CS3x | 76 704 |
| 2 | N1f | CS2s+a | CS2s+a | CS3d | S1/S2a | 143 067 |
| 3 | S3f | S2f | S2s | CS3d | S1 | 12 000 |
| 4 | S3f/N1f | S2f/CS1 | S1/S2f | CS2d/CS3d | S1 | 19 808 |
| 5 | N1d+f | S3d/CS2s | S1/S3f | CS3d | S1 | 37 308 |
| 6 | N1d+f | S3d/CS2a | S1/CS2a | CS3d | S1/S2a | 10 586 |
| 7 | N1d+f | CS2a+s | S3f/CS2a+s | CS3d+s | S1/S2f+a/CS2a/CS3s | 1 226 620 |
| 8 | N1f | CS2a+s | S3f/CS2s | CS3d | S2a+s | 52 959 |
| 9 | N1f | CS2s/CS3a | S3f | CS3d | S2s/S3a | 49 298 |
| 10 | N1d+f | CS2a+s | CS2a+s | CS3d+s | S3s/CS2a/CS3s | 491 026 |
| 11 | N1d | CS2s | S2s | CS3d | S1 | 10 135 |
| 12 | N1s | N1s | N1s | N1s | N1s | 11 399 |
| 13 | N1s,d+f | CS2s/N1s | S2s/CS2s/N1s | CS3d/N1s | S1/S2s/N1s | 86 685 |
| 14 | S2s/N1d | S1/S3d | S1/S2s | S2s/CS3d | S1/N1t | 10 615 |
| 15 | S3s | S3s | S2s | CS2s | N1t | 7 040 |
| 16 | N1e | S3e | S3e | S3e | N1t | 49 746 2/ |
| 17 | S3e | S2e | S2e | S2e | N1t | 42 960 |
| 18 | N1e | S3e | S3e | S3e | N1t | 61 120 |
| 19 | S3s | S2e | S2s | S2s | N1t | 13 020 |
| 20 | S3e | S2e | S2e | S2e | N1t | 7 906 |
| 21 | S3e | S2e | S2e | S2e | N1t | 3 120 |
| 22 | N1e | S3e | S3e | S3e | N1t | 2 040 |
| 23 | N1e | S3e/N1e | S2e/S3e | S2e/CS3e | N1t | 77 960 |
| 24 | S3e | S2e | S2e | S2e | N1t | 11 200 |
| 25 | S3s+e | S2s+e | S2s+e | S2s+e | N1t | 16 520 |
| 26 | S3s | S2s | S2s | S2s | N1t | 783 069 |
| 27 | S3s | S2s | S2s | S2s | N1t | 23 920 |
| 28 | S2s/S3e | S2s+e | S2s+e | S2e/S3s | N1t | 46 720 |
| 29 | S3s | S1/CS2a+s | S1/S2a+s | S1/CS3d | S1/S2a/N1t | 172 990 |
| 30 | S3s | S2s | S2s | S1/S2s | N1t | 45 020 |
| 31 | S3s | S2s | S2s | S1/S2s | N1t | 172 266 |
| 32 | N1s | S3s | S2s | S2s | N1t | 182 253 |
| 33 | S3s/N1s | S2s/S3s | S2s | S2s | N1t | 167 897 |
| 34 | N1s | S2s/N1s | S2e/S3s | S2s/S3s | N1t | 51 160 |
| 35 | S2s | S1 | S1 | S1 | N1t | 32 160 |
| 36 | S3e | S2e | S2e | S2e | N1t | 13 640 |
| 37 | S2s/N1s | S1/S3s | S1/S2e | S2s | N1t | 23 106 |
| 38 | S2s/S3s | S2s | S2s | S2s | N1t | 27 053 |
| Total area (excluding lakes) | | | | | | 4 288 122 |

1/ Area computed using OTT Planimeter.

2/ Includes areas which were not identified on the original soil map.

## Appendix 5

## LAND SUITABILITY FOR UNIMPROVED, UPLAND SHIFTING CULTIVATION

### LAND UTILIZATION TYPE DEFINITION

Rainfed farming of crops other than paddy (wetland) rice in the study area mainly consists of a form of shifting rotation around a settlement site. A tree crop (usually rubber) is established with catch crops being grown for the first three years. Catch crops include upland rice (padi ladang) which is often grown together with maize, groundnuts, beans, chillies, cassava, sweet potato, banana and pineapple. Original opening of the land involves the felling of trees and bushes, collection and burning of debris, uprooting or burning out of stumps, second clearing, reburning and finally hoeing. The land is cleared during the dry season (June to September) in most cases by hand, using axe, parang and hoe. Seed selection is rudimentary (winnowing or floatation), and most seeds are local varieties saved from the previous year's crop. Nurseries are seldom constructed and planting methods are primitive, planting material being dibbled or hoed in.

Planting usually starts in September or October according to the onset of the rains and is carried out by the farmer and his family without external help. Use of fertilizer is rare, although better farmers use compost, urea and superphosphate. Hand weeding is undertaken at least twice, with weeds being either used as compost for bananas or left on the field. Poisonous baits and close fencing protect catch crops against pigs, monkeys and rats; but insect pests and plant diseases are rarely controlled. Harvesting is by traditional hand methods which are both labour and time consuming. Catch crops are inter-cropped with rubber for about three years, after which the rubber is allowed to grow wild. Tapping starts when the trees are four to five years old and continues until they are about 15 years old when the rubber and secondary growth are cleared and burned and the whole cycle renewed.

A farmer and his family seldom cultivate more than 3 ha per year due to restrictions because of lack of man, animal or machine power. The majority of catch crops is used for home consumption with sufficient planting material being reserved for the following year's crop. Any remaining product is sold at the local market or to buyers from the large towns. Prices, however, are generally low because uniform harvest times for each product throughout the area result in glut market periods. Rubber is tapped irregularly, on dry days. Latex is processed in wet brick or sheet form and is stored submerged in streams and ponds close to the village and is sold through middle men when prices rise or there is a need for ready cash.

Land suitability for unimproved, upland, shifting cultivation as given below and in Table A5.1 on an area basis, and as illustrated in Map 4, is a statement of prevailing suitability for rainfed crops other than paddy (wetland) rice in the project area, and is presented to show comparable evaluations between existing crude farming methods employed in present land use and improved farming methods assumed for development alternatives. Because of this, the conditionally suitable order is not relevant to this classification as by definition, neither minor recurrent nor major improvements are considered in the evaluation.

LAND SUITABILITY CLASSIFICATION - UNIMPROVED, UPLAND CULTIVATION
showing identified land units in project area

| Order/Class | Definition | Mapping unit |
|---|---|---|
| S - SUITABLE LAND | | |
| S1 - Highly suitable | Land having no significant or only minor limitations to the sustained application of unimproved, upland, shifting cultivation that will not significantly reduce production levels below a readily acceptable level. | None identified |
| S2 - Moderately suitable | Land having limitations which in aggregate are moderately severe for the sustained application of unimproved, upland, shifting cultivation that will reduce production levels to the extent that the overall advantage to be gained from the use, although still attractive, will be inferior to that expected on Class S1 land. One subclass is identified in the project area: | |
| S2s | Land comprising deep to moderately deep undulating to rolling, well drained, loamy and clayey soils, occasionally with stones in the upper layer, having moderately permeable subsoils and a moderate available water holding capacity. Surface soils have an average to high organic matter content and base saturation of between 35 and 75%. Reserves of weatherable minerals in the subsoil range from fair to very low or nil. Reaction ranges from pH 4.5 to 6.5.<br><br>The main limitations to the application of unimproved, upland, shifting cultivation is the relatively rapid decline in fertility after such areas have been cleared and cultivated for more than two years. Other problems include stoniness and slight to moderate susceptibility to erosion when cleared. | 35, and parts of 14, 28, 37, 38 |
| S3 - Marginally suitable | Land having limitations which in aggregate are severe for the sustained application of unimproved, upland, shifting cultivation and will so reduce production levels that the overall advantage to be gained from the use will only be marginal. Three subclasses are identified in the project area: | |
| S3s | Land comprising deep, moderately deep and shallow, undulating to hilly, well drained, loamy and clayey soils which are occasionally gravelly. They have moderately to slowly permeable subsoils and a moderate to low available water holding capacity. Organic matter content in surface layers is variable, ranging from 1 to over 5%. Base saturation of surface | 15, 19, 26, 27, 30, 31 and parts of 25, 29, 33, 38 |

| Order/Class | Definition | Mapping unit |
|---|---|---|
| S3s (cont'd) | soils is usually less than 50%, although Rendzinas formed on residuum derived from limestone have a base saturation of over 75%. Reserves of weatherable minerals in subsoils are low or nil, excepting Rendzinas which have high reserves. Reaction ranges from pH 4.5 to 5.5, again excepting Rendzinas which have pH values ranging from 6.0 to 7.7.<br><br>Main limitations to the application of unimproved, upland, shifting cultivation include shallowness, stoniness and the rapid decline in fertility after such areas are cleared and cultivated. In addition, these soils are slightly or moderately susceptible to erosion when cleared. | |
| S3e | Land comprising deep to moderately deep, rolling to hilly, well drained, loamy and clayey soils with moderately to slowly permeable subsoils and a moderate available water holding capacity. Organic matter content in surface layers is variable, ranging from 1 to over 5%. Base saturation of surface soils is usually less than 35% but may occasionally be higher. Reserves of weatherable minerals in subsoils are low or nil. Reaction ranges from pH 4.5 to 6.5.<br><br>The main limitation to the application of unimproved, upland, shifting cultivation is the susceptibility to sheet and rill erosion. Other problems include the rapid decline of fertility after clearing and cultivation and the loss of organic matter and degradation of soil structure. | 17, 20, 21, 24, 36 and parts of 25, 28 |
| S3f | Land comprising deep, moderately well to somewhat poorly drained, loamy and clayey soils. Subsoils permeability is moderate and available water holding capacity is moderate to high. These soils have a characteristic micro-relief of abandoned levees and river channels. Organic matter content in surface layers is average, ranging from 2 to 5%. Base saturation of subsoils ranges from 50 to 75% and the reserves of weatherable minerals are fair. Reaction ranges from pH 4.5 to 6.4.<br><br>The main limitation to the application of unimproved, upland, shifting cultivation is the susceptibility of these soils to flash flooding during high water stages of the rivers as well as a relatively high water-table level during the rainy season. | 3 and parts of 4 |

| Order/Class | Definition | Mapping unit |
|---|---|---|
| N – UNSUITABLE LAND | | |
| N1 – Unsuitable | Land having limitations which appear so severe as to preclude any possibility of successful, sustained, unimproved upland shifting cultivation. Four subclasses are identified in the project area. | |
| N1f | Land comprising deep, level, very poorly drained clayey to loamy soils occupying back swamps, tidal swamps and bottom lands and which are subject to deep prolonged flooding by river water and salt water. In the latter case salinity is an additional problem, while soils of the back swamps may be potentially extremely acid. | 1, 2, 8, 9 and parts of 4, 5, 6, 7, 10, 13 |
| N1d | Land comprising deep, level, poorly drained, clayey, loamy and organic soils with a water-table at or near the surface of the greater part of the year. Wetness precludes their use for sustained, unimproved, upland, shifting cultivation and such soils may be extremely acid and of unfavourable texture in the root zone. | 11 and parts of 5, 6, 7, 10, 13, 14, 39 |
| N1s | Land comprising deep or moderately deep, well to excessively drained, gravelly stony and sandy soils on undulating, rolling and hilly terrain. Limitations include low or very low available water holding capacity, low soil fertility, high gravel and stone content, unfavourable sand texture, and susceptibility to erosion on steeper slopes which preclude the sustained application of unimproved upland, shifting cultivation. | 12, 32, 34 and parts of 13, 33, 37 |
| N1e | Land comprising shallow to deep, well to excessively drained soils on hilly or mountainous terrain. The dominant limitation which precludes the sustained application of unimproved, upland, shifting cultivation is the very severe susceptibility to sheet, rill and gully erosion if these areas are cleared. Other problems include rapid decline in fertility if cultivated, and the incidence of stoniness and rockiness in places. | 16, 18, 22, 23 |

Table A5.1

LAND SUITABILITY FOR UNIMPROVED, UPLAND SHIFTING CULTIVATION WITH PROPORTIONAL DISTRIBUTION BY AREA AND PERCENT

| | Class | Soil mapping unit | Area (ha) | % |
|---|---|---|---|---|
| | | ORDER S: SUITABLE LAND | | |
| S1 | Highly suitable | - | - | - |
| S2 | Moderately suitable | 35 | 32 160 | 0.8 |
| S3 | Marginally suitable | 3, 15, 17, 19, 20, 21, 24, 25, 26, 27, 30, 31 and 36 | 1 151 681 | 26.8 |
| S2/S3 | Association of moderately and marginally suitable land | 28, 38 | 73 773 | 1.7 |
| Subtotal area | | | 1 257 614 | 29.3 |
| | | ORDER N: UNSUITABLE LAND | | |
| N1 | Unsuitable | 1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 18, 22, 23, 32, 34 and lakes | 2 636 092 | 61.5 |
| Subtotal area | | | 2 636 092 | 61.5 |
| | | ASSOCIATIONS OF SUITABILITY ORDERS | | |
| S2/N1 | Association of moderately suitable and unsuitable land | 14, 37 | 33 721 | 0.8 |
| S3/N1 | Association of marginally suitable and unsuitable land | 4, 29, 33 | 360 695 | 8.4 |
| Subtotal area | | | 394 416 | 9.2 |
| Total area | | | 4 288 122 | 100.0 |

## Appendix 6

# LAND SUITABILITY FOR UPLAND CROPS ASSUMING IMPROVED CULTIVATION PRACTICES

## LAND UTILIZATION TYPE DEFINITION

The land utilization type for upland crops is not specific for any single crop, but refers to all moderate-rooting cultivated crops adapted to climatic conditions prevailing in the project area, excepting paddy (wetland) rice. Sustained cultivation is envisaged following a prescribed rotation including fallow periods. Sound husbandry is assumed in so far as it is expected that:

- draught animals and, in some instances, tractors will be introduced as a power source for land preparation including the ploughing in of plant residues instead of burning;
- good planting material is available;
- fertilizer application (inorganic and organic) and liming is made in sufficient quantities and in suitable combinations to ensure improvement and maintenance of fertility;
- adequate pest, weed, insect and plant disease control is established;
- simple levelling and erosion control measures are applied.

With the exception of levelling and erosion control measures, all assumed improved cultivation practices are recurrent. Such repeated material inputs are considered moderate; but will necessitate the provision of important technical advisory services and credit facilities to the farmer. Levelling and erosion controls envisaged are "one time" inputs; but only simple measures which may be executed with hand or animal power are assumed.

Land suitability classification is given below, and Table A6.1 shows land suitability class areas while Map 5 indicates their geographical distribution.

## LAND SUITABILITY CLASSIFICATION - UPLAND CROPS ASSUMING IMPROVED CULTIVATION PRACTICES

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| S - SUITABLE LAND | | |
| S1 - Highly suitable | Land having no significant or only minor limitations to the sustained cultivation of upland crops that will not significantly reduce production levels and/or will not raise required recurrent and minor inputs for production and/or conservation above a readily acceptable level. | 35 and parts of 14, 29, 37 |
| S2 - Moderately suitable | Land having limitations which in aggregate are moderately severe for the sustained cultivation of upland crops that will reduce production levels and/or increase required recurrent and minor inputs for production and/or conservation to the extent that the overall advantage to be gained from the use, although still attractive, will be inferior to that expected on Class S1 land. Three subclasses as identified in the project area: | |
| S2f | Land comprising deep, moderately well to somewhat poorly drained, loamy and clayey soils. Subsoil permeability is moderate and available water holding capacity is moderate to high. These soils have a characteristic micro-relief of abandoned levee and river channels. Under improved cultivation practices these soils can be used for cultivation of a variety of crops; but the susceptibility to flash flooding by river water in the rainy season, together with additional drainage problems caused by a periodically high groun-water table make them only moderately suited for the sustained cultivation of upland crops. | 3 and part of 4 |
| S2s | Land comprising deep to moderately deep, well drained, undulating to rolling, clayey or loamy soils, occasionally with stones and gravel in the upper layers. Subsoils are moderately permeable and available water holding capacity is moderate. Main limitations to the sustained cultivation of upland crops include the difficulty in maintaining fertility due to low reserves of weatherable minerals in the subsoil, stoniness, moderately poor soil workability and slight susceptibility to erosion - all of which will tend to increase required recurrent and minor inputs for production and/or conservation. | 19, 26, 27, 30, 31, 38 and parts of 25, 28, 33, 34 |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| S2e | Land comprising deep to moderately deep, well drained, predominantly rolling clayey or loamy soils. Subsoils are moderately permeable and available water holding capacity is moderate. The main limitation to the sustained cultivation of upland crops on these soils is their moderate susceptibility to erosion. In addition, reserves of weatherable minerals are low in the subsoil making for problems in maintaining fertility and clayey soil may have moderately poor workability. Limitations tend to increase required recurrent and minor inputs for conservation and production. | 17, 20, 21, 24, 36 and parts of 25 and 28 |
| S3 - Marginally suitable | Land having limitations which in aggregate are severe for the sustained cultivation of upland crops and will so reduce production levels and/or so increase required inputs on production and/or conservation, that such expenditure will only be marginally justified. Three subclasses are identified in the project area: | |
| S3d | Land comprising deep, level or nearly level, poorly to somewhat poorly drained, clayey or loamy soils with moderate to slowly permeable subsoils. These soils are too wet for upland crops during the greater part of the rainy season when groundwater tables are at or near the surface. Although not commonly flooded by streams or rivers, surface flooding by rainwater may occur for short periods. Other problems include poor workability and low reserves of weatherable minerals in subsoils. A variety of upland crops may be grown during the dry season but the drainage problem limits production to quick growing varieties. | parts of 5, 6, 14 |
| S3s | Land comprising shallow, moderately deep and deep, well to excessively drained, undulating to hilly, loamy or clayey soils which are often gravelly. They have moderately to slowly permeable subsoils and a moderate to low available water holding capacity. Limitations to their sustained use for upland crops include shallowness, stoniness, difficulty in maintaining fertility due to low reserves of weatherable minerals in the subsoil and loss of organic matter content when cultivated, and slight to moderate susceptibility to erosion which will so increase required inputs on production and conservation that such expenditure will only be marginally justified. | 15, 32, parts of 33, 37 |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| S3e | Land comprising shallow to deep, well to excessively drained soils on hilly or mountainous terrain. The dominant limitation to their sustained use for upland crops is the very severe susceptibility to sheet, rill and gully erosion if cleared and cultivated. Other problems include rapid decline in fertility if cultivated and the incidence of stoniness and rockiness in places. Simple erosion control measures may allow the cultivation of upland crops on less severe slopes; but this together with increase in required recurrent inputs on production and conservation will make such expenditure only marginally justified. | 16, 18, 22 and part of 23 |
| CS - CONDITIONALLY SUITABLE LAND | | |
| CS1 - Conditionally highly suitable | Land having characteristics which, in general, preclude sustained, economic cultivation of upland crops as defined for the land utilization type; but which could be used and would be equivalent in suitability to land of Class S1 provided that excess wetness is eliminated by the construction of drainage works, and required recurrent and minor inputs are implemented. | part of 4 |
| CS2 - Conditionally moderately suitable | Land having characteristics which, in general, preclude sustained, economic cultivation of upland crops. Such land, however, could be used provided the special management practices defined at subclass level were implemented but would only be equivalent in suitability to land of Class S2 as moderately severe limitations indicated by the subclass symbol would remain. Two subclasses are identified in the project area: | |
| CS2s | Land having limitations of wetness which, in general, preclude the sustained economic cultivation of upland crops; but could be used for this purpose provided drainage works were constructed and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S2 as moderately severe limitations of poor soil workability, unfavourable texture, and difficulty in maintaining fertility would remain. | 11, parts of 2, 5, 7, 8, 9, 10, 13, 29 |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| CS2a | Land having limitations of wetness which, in general, preclude the sustained economic cultivation of upland crops; but could be used for this purpose provided drainage works were constructed and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S2 as moderately severe soil acidity would limit choice of crop and production. Other problems would include poor soil workability and difficulty in maintaining fertility. | parts of 2, 6, 7, 8, 10, 24 |
| CS3 - Conditionally marginally suitable | Land having characteristics which, in general, preclude sustained, economic cultivation of upland crops. Such land, however, could be used provided the special management practices defined at subclass level were implemented; but would only be equivalent in suitability to land of Class S3 as severe limitations indicated by the subclass symbol would remain. One subclass is identified in the project area: | |
| CS3a | Land having limitations of wetness which, in general, preclude the sustained, economic cultivation of upland crops but could be used for this purpose provided drainage works were constructed and recurrent and minor inputs implemented. Suitability would then be equivalent to land of Class S3 as severe soil acidity would limit choice of crop and production. Other problems would include poor soil workability and difficulty in maintaining fertility. | part of 9 |
| N - UNSUITABLE LAND | | |
| N1 - Unsuitable | Land having limitations which appear so severe as to preclude any possibility of successful, sustained, cultivation of upland crops; or having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at presently acceptable cost. Three subclasses are identified in the project area: | |
| N1f | Land comprising deep, level, very poorly drained clayey to loamy soils which are subject to deep prolonged flooding by salt water and which occupy positions in tidal swamps. Such soils, besides being inundated throughout the year, are also highly saline. | 1 |
| N1s | Land comprising deep to moderately deep, well to excessively drained, gravelly, stony and sandy soils on undulating, rolling and hilly terrain. Limitations include low or very low available water holding capacity, low soil fertility, high gravel and stone content, unfavourable sand content and susceptibility to erosion on steeper slopes. | 12, parts of 13, 34 |

| Order/Class | Definition | Mapping Unit |
| --- | --- | --- |
| N1e | Land comprising shallow to deep, well to excessively drained soils on hilly terrain. The dominant limitation is the very severe susceptibility to sheet, rill and gully erosion if such areas are cleared. Other problems include rapid decline in fertility if cultivated, and the incidence of stoniness and rockiness in places. | part of 23 |

Table A6.1

LAND SUITABILITY FOR UPLAND CROPS ASSUMING IMPROVED CULTIVATION PRACTICES WITH PROPORTIONAL DISTRIBUTION BY AREA AND PERCENT

| Class | | Soil Mapping Unit | Area (ha) | % |
|---|---|---|---|---|
| | | ORDER S: SUITABLE LAND | | |
| S1 | Highly suitable | 35 | 32 160 | 0.8 |
| S2 | Moderately suitable | 3, 17, 19, 20, 21, 24, 25, 26, 27, 28, 30, 31, 36, 38 | 1 218 414 | 28.4 |
| S3 | Marginally suitable | 15, 16, 18, 22, 32 | 302 199 | 7.0 |
| S1/S3 | Association of highly and marginally suitable land | 14, 37 | 33 721 | 0.8 |
| S2/S3 | Association of moderately and marginally suitable land | 33 | 167 897 | 3.9 |
| Subtotal area | | | 1 754 391 | 40.9 |
| | | ORDER CS: CONDITIONALLY SUITABLE LAND | | |
| CS1 | Conditionally highly suitable | - | - | - |
| CS2 | Conditionally moderately suitable | 2, 7, 8, 10, 11 | 1 923 807 | 44.9 |
| CS3 | Conditionally marginally suitable | - | - | - |
| CS2/CS3 | Association of conditionally moderately and marginally suitable land | 9 | 49 298 | 1.1 |
| Subtotal area | | | 1 973 105 | 46.0 |
| | | ORDER N1: UNSUITABLE LAND | | |
| N1 | Unsuitable land | 1, 12 and lakes | 104 129 | 2.4 |
| Subtotal area | | | 104 129 | 2.4 |

Table A6.1 (cont'd)

| Class | | Soil Mapping Unit | Area (ha) | % |
|---|---|---|---|---|
| | | ASSOCIATIONS OF SUITABILITY ORDERS | | |
| S1/CS2 | Association of highly suitable and conditionally moderately suitable land | 29 | 172 990 | 4.1 |
| S2/CS1 | Association of moderately suitable and conditionally highly suitable land | 4 | 19 808 | 0.5 |
| S3/CS2 | Association of marginally suitable and conditionally moderately suitable land | 5, 6 | 47 894 | 1.1 |
| S2/N1 | Association of moderately suitable and unsuitable land | 34 | 51 160 | 1.2 |
| S3/N1 | Association of marginally suitable and unsuitable land | 23 | 77 960 | 1.8 |
| CS2/N1 | Association of conditionally moderately suitable and unsuitable land | 13 | 86 685 | 2.0 |
| Subtotal | | | 456 497 | 10.7 |
| Total area | | | 4 288 122 | 100.0 |

## Appendix 7

# LAND SUITABILITY FOR PASTURE ASSUMING IMPROVED CULTIVATION PRACTICES

## LAND UTILIZATION TYPE DEFINITION

No pasture or forage crop development is found in the project area at present except where grass and legume experimental plots have been established. Livestock, in most instances, simply exist in and around the villages, ruminant animals range-grazing by day and returning to the village at night; or being rounded up periodically after fending for themselves in bush and forest. The carrying capacity of grazing areas is low due to seasonal shortage of grazing and the low nutritive quality of native grasses, especially the widespread alang-alang (Imperata cylindrica) which is only palatable during the young shoot stage of growth. Consequently, suitability evaluation for sustained grass and legume production is made, assuming:

- shallow rooting grasses and legumes, well adapted to local climate and soil conditions are established;
- adequate fertilizer application is made and inoculants and phosphatic fertilizers are applied if required by the legume established;
- fencing and controlled grazing are introduced;
- drinking water is provided;
- fire-breaks are established;
- corrals are built for working the animals;
- weeding, fence and corral maintenance are carried out;
- pharmaceuticals are provided for use against internal parasites and other animal diseases;
- good planting material and sound breeding stock are made available.

It is envisaged that pasture could be established either as a sector of mixed farming providing a source of both animal power and protein; or as ranching in more remote, sparsely populated areas. Inputs required are both recurrent, as in the case of weeding, fertilizer application, inoculation, grazing control, fence and corral maintenance, etc., and "one time" operations such as fencing, corral building and initial purchase of breeding stock and planting material. Levels of input are considered moderate; but will require the provision by government agencies of training in livestock husbandry, veterinary extension services and important farmer credit facilities.

Land suitability classification is given below, followed by Table A7.1 which shows land suitability class areas proportional distribution, while Map 6 indicates their geographical distribution.

LAND SUITABILITY CLASSIFICATION - PASTURE ASSUMING IMPROVED CULTIVATION PRACTICES

| Order/Class | Definition | Mapping Unit |
| --- | --- | --- |
| S - SUITABLE LAND | | |
| S1 - Highly suitable | Land having no significant or only minor limitations to sustained use for pasture that will not significantly reduce production levels and/or will not raise required recurrent and minor inputs for production and/or conservation above a readily acceptable level. | 35, parts of 4, 5, 6, 14, 29, 37 |
| S2 - Moderately suitable | Land having limitations which in aggregate are moderately severe for sustained pasture that will reduce production levels and/or increase required recurrent and minor inputs for production and/or conservation to the extent that the overall advantage to be gained from the use, although still attractive, will be inferior to that expected on Class S1 land. Four subclasses are identified in the project area: | |
| S2f | Land comprising deep, poorly drained, loamy to clayey soils. Subsoil permeability is slow and available water holding capacity is moderate to high. Relief is level to undulating with a microrelief of abandoned levees and river channels. The water-table is at or near the surface for at least six months in most years, and the soils are flooded by river water during the rainy season. The main limitation to the sustained application of pasture is susceptibility to flooding with additional problems of drainage and low fertility which restrict production and limit choice of adapted grasses and legumes to those capable of withstanding waterlogging. | part of 4 |
| S2a | Land comprising deep, poorly to somewhat poorly drained, loamy to clayey soils with slowly permeable subsoils and moderate to high available water holding capacity. Relief is level. The water-table is at or near the surface for less than six months in most years and falls below 1 m during the dry season. The main limitation to the sustained application of pasture is moderately severe soil acidity, additional problems being poor drainage and low fertility which tend to increase required recurrent and minor inputs. | part of 29 |

| Order/Class | Definition | Mapping Unit |
| --- | --- | --- |
| S2s | Land comprising deep, moderately deep and shallow, somewhat poorly, moderately well and well drained, loamy to clayey soils on level, undulating and rolling terrain. Subsoil permeability is moderate to slow and available water holding capacity is moderate to high.<br><br>Soil limitations in the root zone include difficulty in maintaining fertility due to low reserves of weatherable minerals in the subsoil, shallowness, stoniness, unfavourable texture and slight susceptibility to erosion which tend to increase required recurrent and minor inputs and/or reduce production. | 3, 11, 15, 19, 26, 27, 30, 31, 32, 33, 38, and parts of 13, 14, 25, 28, 29, 34, 37 |
| S2e | Land comprising deep and moderately deep, well drained, loamy to clayey soils, which are occasionally gravelly or stony, on rolling to hilly terrain. Permeability in subsoils is moderate, as is available, water holding capacity The principal limitation to the sustained application of pasture is the hazard of sheet and rill erosion. Other problems include difficulty in maintaining soil fertility, organic matter and structure, poor workability and stoniness in places. Limitations are moderately severe and tend to increase required recurrent and minor inputs on production and conservation. | 17, 20, 21, 24, 36, and parts of 23, 25, 28 |
| S3 - Marginally suitable | Land having limitations which in aggregate are severe for sustained pasture and will so reduce production levels and/or so increase required inputs on production and/or conservation, that such expenditure will only be marginally justified. Three subclasses are identified in the project area: | |
| S3f | Land comprising deep, poorly drained, clayey and organic soils on nearly level terrain. Subsoils are generally slowly permeable and available water holding capacity is high. The water-table level is is at or near the surface for up to ten months in most years. During the rainy season these soils are flooded by river water, rainwater, and runoff water from adjacent uplands to depths of 1 m or more. Flooding is the dominant limitation; but in addition problems of poor drainage, low soil fertility, severe soil acidity and poor soil workability exist which reduce production levels whilst choice of grasses and legumes must, from necessity, be restricted to varieties able to withstand waterlogging. | 9, parts of 5, 7, 8 |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| S3s | Land comprising moderately deep, well to moderately well drained, loamy to clayey soils with a high gravel and stone content. Relief is rolling to hilly. Subsoil permeability is moderate as is available water holding capacity. Principal limitations to the sustained application of pasture include stoniness, difficulty in maintaining fertility, organic matter content and structure, and slight to moderate susceptibility to erosion which reduce production levels and/or increase required inputs. | part of 34 |
| S3e | Land comprising shallow to deep, well to excessively drained soils om hilly or mountainous terrain. The dominant limitation to their sustained application to pasture is the very severe susceptibility to sheet, rill and gully erosion if cleared. Other problems include rapid decline in fertility and the incidence of stoniness and rockiness in places. Simple erosion control measures may allow pasture to be established on less steep slopes; but this together with increase in required recurrent inputs on production will make such expenditure only marginally justified. | 16, 18, 22, and part of 23 |
| CS - CONDITIONALLY SUITABLE LAND | | |
| CS1 - Conditionally highly suitable | Land having characteristics which, in general, preclude sustained, economic application of pasture as defined for the land utilization type; but which could be used and would be equivalent in suitability to land of Class S1 provided that special management practices were implemented. | None identified |
| CS2 - Conditionally moderately suitable | Land having characteristics which, in general, preclude sustained, economic application of pasture. Such land, however, could be used provided the special management practices defined at subclass level were implemented but would only be equivalent in suitability to land of Class S2 as moderately severe limitations indicated by the subclass symbol would remain. Two subclasses are identified in the project area: | |
| CS2s | Land having limitations of wetness which, in general, preclude the sustained, economic application of pasture; but could be used for this purpose provided drainage works and flood controls were constructed and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S2 as | parts of 2, 7, 8, 10, 13 |

| Class/Order | Definition | Mapping Unit |
|---|---|---|
| CS2s (cont'd) | moderately severe limitations of poor soil workability, unfavourable texture, and difficulty in maintaining fertility would remain. | |
| CS2a | Land having limitations of wetness which, in general, preclude the sustained, economic application of pasture; but could be used for this purpose provided drainage works and flood controls were constructed and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S2 as moderately severe soil acidity, poor soil workability and difficulty in maintaining fertility would remain as limitations. | parts of 2, 6, 7, 10 |
| CS3 - Conditionally marginally suitable | Land having characteristics which, in general, preclude sustained, economic application of pasture. Such land, however, could be used provided the special management practices defined at subclass level were implemented; but would only be equivalent in suitability to land of Class S3 as severe limitations indicated by the subclass symbol would remain. | none identified |
| N - UNSUITABLE LAND | | |
| N1 - Unsuitable | Land having limitations which appear so severe as to preclude any possibility of successful, sustained application of pasture; or having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at presently acceptable cost. Two subclasses are identified in the project area: | |
| N1f | Land comprising deep, level, very poorly drained, clayey to loamy soils which are subject to deep prolonged flooding by salt water and which occupy positions in tidal swamps. Such soils, besides being inundated throughout the year, are also highly saline. | |
| N1s | Land comprising deep, excessively drained, sandy soils on undulating terrain. Such soils have an unfavourable sand texture (more than 90% sand in the fine earth fraction), low or very low available water holding capacity, low organic matter content in surface soils, low fertility and very low reserves of weatherable minerals in subsoils. | 12 and parts of 13 |

Table A7.1

LAND SUITABILITY FOR PASTURE ASSUMING IMPROVED CULTIVATION PRACTICES WITH PROPORTIONAL DISTRIBUTION BY AREA AND PERCENT

| | Class | Soil Mapping Unit | Area (ha) | % |
|---|---|---|---|---|
| | | ORDER S: SUITABLE LAND | | |
| S1 | Highly suitable | 35 | 32 160 | 0.8 |
| S2 | Moderately suitable | 3, 11, 15, 17, 19, 20, 21, 24, 25, 26, 27, 28, 30, 31, 32, 33, 36, 38 | 1 585 739 | 37.0 |
| S3 | Marginally suitable | 9, 16, 18, 22 | 162 204 | 3.8 |
| S1/S2 | Association of highly and moderately suitable land | 4, 14, 29, 37 | 226 519 | 5.3 |
| S1/S3 | Association of highly and marginally suitable land | 5 | 37 308 | 0.8 |
| S2/S3 | Association of moderately and marginally suitable land | 23, 34 | 129 120 | 3.0 |
| Subtotal area | | | 2 173 050 | 50.7 |
| | | ORDER CS: CONDITIONALLY SUITABLE LAND | | |
| CS1 | Conditionally highly suitable | - | - | - |
| CS2 | Conditionally moderately suitable | 2, 10 | 634 093 | 14.8 |
| CS3 | Conditionally marginally suitable | - | - | - |
| Subtotal area | | | 634 093 | 14.8 |
| | | ORDER N: UNSUITABLE LAND | | |
| N1 | Unsuitable | 1, 12 and lakes | 104 129 | 2.4 |
| Subtotal area | | | 104 129 | 2.4 |

Table A7.1 (cont'd)

| | Class | Soil Mapping Unit | Area (ha) | % |
|---|---|---|---|---|
| | | ASSOCIATIONS OF SUITABILITY ORDERS | | |
| S1/CS2 | Association of highly suitable and conditionally moderately suitable land | 6 | 10 586 | 0.3 |
| S5/CS2/ N1 | Association of moderately suitable, conditionally moderately suitable and unsuitable land | 13 | 86 685 | 2.0 |
| S3/CS2 | Association of marginally suitable and conditionally moderately suitable land | 7, 8 | 1 279 579 | 29.8 |
| Subtotal area | | | 1 376 850 | 32.1 |
| Total area | | | 4 288 122 | 100.0 |

## Appendix 8

# LAND SUITABILITY FOR TREE CROPS ASSUMING IMPROVED CULTIVATION PRACTICES

## LAND UTILIZATION TYPE DEFINITION

The term "tree crop" is defined here as a grouping of all deep rooting, orchard and plantation cash crops, including rubber, oil palm, coconut, coffee and fruits which are well adapted to climatic conditions prevailing in the study area. Such crops are grown in order to obtain a partial product from the plant; a seasonal harvest; and a product whose quality must be constant and adapted to a narrow range of well defined uses. The suitability evaluation for sustained tree crop cultivation is made assuming:

- initial land clearing and preparation using animal power or tractor;
- availability of good planting material;
- adequate application of fertilizers (organic and inorganic) and lime;
- establishment of well-adapted cover plants;
- control of weeds, pests and plant diseases;
- introduction of simple soil erosion control measures where necessary, which can be implemented using hand labour or animal power;
- provision of adequate fire breaks;
- introduction of harvesting (including Hevea tapping) and farm processing techniques to maintain constant quality of the product.

Inputs required are both recurrent, as in the case of fertilizer applications, weeding, pest and disease control; and "one time" operations such as erosion control measures. Levels of input are considered moderate; but will require the provision by government agencies of important extension services and farmer credit facilities.

Forest is not included in the definition. This is because edaphic requirements may or may not be taken into account when creating or maintaining forest. Afforestation may be recommended on soils of widely differing productivity and the choice of where and when to establish or maintain forest is largely dependent on the purpose to be served (i.e. timber production or conservation) and the place of forestry in national and regional development strategy.

Land suitability classification is given below, followed by Table A8.1 showing land suitability class areas and proportional distribution, while Map 7 indicates their geographical distribution.

LAND SUITABILITY CLASSIFICATION – TREE CROPS ASSUMING IMPROVED CULTIVATION PRACTICES

| Order/Class | Definition | Mapping Unit |
| --- | --- | --- |
| S – SUITABLE LAND | | |
| S1 – Highly suitable | Land having no significant or only minor limitations to sustained use for tree crops that will not significantly reduce production levels and/or will not raise required recurrent and minor inputs for production and/or conservation above a readily acceptable level. | 35, parts of 29, 30, 31 |
| S2 – Moderately suitable | Land having limitations which in aggregate are moderately severe for sustained tree crop cultivation that will reduce production levels and/or increase required recurrent and minor inputs on production and/or conservation to the extent that the overall advantage to be gained from the use, although still attractive, will be inferior to that expected on Class S1 land. Two subclasses are identified in the project area: | |
| S2s | Land comprising deep and moderately deep, well drained, predominantly undulating, loamy to clayey soils which occasionally contain gravel and stones in upper layers and have moderate subsoil permeability and available water holding capacity. Soil limitations in the root zone include difficulty in maintaining fertility due to low reserves of weatherable minerals in the subsoil, stoniness, shallowness, unfavourable texture, and slight susceptibility to erosion which tend to increase required recurrent and minor inputs and/or reduce production. | 19, 26, 27, 32, 33, 37, 38, and parts of 14, 25, 30, 31, 34 |
| S2e | Land comprising deep and moderately deep, well drained, loamy to clayey soils which are occasionally gravelly or stony, on rolling to hilly terrain. Subsoil permeability and available water holding capacity are moderate. The principal limitation to the sustained cultivation of tree crops is the hazard of sheet and rill erosion. Other problems include difficulty in maintaining fertility, organic matter content and structure, poor workability, shallowness and stoniness in places. Limitations are moderately severe and tend to increase required recurrent and minor inputs on production and conservation. | 17, 20, 21, 24, 36, and parts of 23, 25, 28 |
| S3 – Marginally suitable | Land having limitations which in aggregate are severe for sustained tree crop cultivation and will so reduce production levels and/or so increase required inputs on production and/or conservation, that such expenditure will only be marginally justified. Two subclasses are identified in the project area: | |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| S3s | Land comprising moderately deep and deep, well to moderately well drained, loamy to clayey soils which may have a high gravel or stone content, on rolling to hilly terrain. Subsoil permeability and available water holding capacity are moderate. Principal limitations to the sustained cultivation of tree crops are shallowness, stoniness, difficulty in maintaining fertility, organic matter content and structure and slight to moderate susceptibility to erosion which reduce production levels and/or increase required inputs. | parts of 28, 36 |
| S3e | Land comprising shallow to deep, well to excessively drained soils on hilly or mountainous terrain. The dominant limitation to their sustained application to tree crops in the very severe susceptibility to sheet, rill and gully erosion if cleared. Other problems include rapid decline in fertility and the incidence of shallowness, stoniness and rockiness in places. Simple erosion control measures may allow the cultivation of tree crops on less steep slopes; but this, together with increase in required production inputs, will make such expenditure only marginally justified. | 16, 18, 22 |
| CS - CONDITIONALLY SUITABLE LAND | | |
| CS1 - Conditionally highly suitable | Land having characteristics which, in general, preclude sustained, economic application of tree crops as defined for the land utilization type; but which could be used and would be equivalent in suitability to land of Class S1 provided that special management practices were implemented. | none identified |
| CS2 - Conditionally moderately suitable | Land having characteristics which, in general preclude sustained, economic application of tree crops. Such land, however, could be used provided the special management practices defined at subclass level were implemented; but would only be equivalent in suitability to land of Class S2 as moderately severe limitations indicated by the subclass symbol would remain. Two subclasses are identified in the project area: | |
| CS2d | Land having limitations of wetness caused by a seasonally high groundwater-table and periodic flooding which, in general preclude the sustained, economic application of tree crops; but could be used for this purpose provided drainage works and flood controls were constructed and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S2 as the pronounced ridge and swale micro-relief characteristic of these soils would make water-table level difficult to control, possibly leading to periods of excessive wetness in the root zone in places and even water shortage elsewhere. | parts of 4 |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| CS2s | Land with shallow effective soil depth which, in general, precludes the sustained, economic application of tree crops; but could be used for this purpose provided deep planting holes, stone and rock removal and deepening of the topsoil were effected. Suitability would then be equivalent to land of Class S2 as even after improvements suggested, effective soil depth could only be increased to a limited degree and would remain a moderately severe limitation. | 15 |
| CS3 - Conditionally marginally suitable | Land having characteristics which, in general, preclude sustained, economic application of tree crops. Such land, however, could be used provided the special management practices defined at subclass level were implemented; but would only be equivalent in suitability to land of Class S3 as severe limitations indicated by the subclass symbol would remain. Three subclasses are identified in the project area: | |
| CS3d | Land having limitations of wetness which, in general, preclude the sustained, economic application of tree crops but could be used for this purpose provided drainage works were constructed and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S3 as water-table level would still be high enough to limit mature, deep-rooting plants during the rainy season despite drainage measures. Other problems include poor soil workability, difficulty in maintaining fertility and moderately severe to severe soil acidity. | 2, 3, 5, 6, 8, 9, and parts of 4, 7, 10, 13, 14, and 29 |
| CS3s | Land having limitations of wetness which, in general, preclude the sustained, economic application of tree crops; but could be used for this purpose provided drainage works were constructed and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S3 as problems of severe soil acidity, poor workability, low fertility (including possible trace element deficiencies), unfavourable texture and subsidence in the case of organic soils would remain as severe limitations. | 7, 10 |
| CS3e | Land having limitations resulting from very severe accelerated erosion which, in general, preclude the sustained, economic application of tree crops; but could be used for this purpose provided costly and labour-intensive conservation measures such as contour and mini-hexagonal terraces were applied and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S3 erosion control would be impractical on steeper slopes. Other problems include difficulty in maintaining fertility, shallowness and stoniness | part of 23 |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| CS3e (cont'd) | in places as well as difficulties in harvesting the product due to the steeply sloping nature of the terrain. | |
| N - UNSUITABLE LAND | | |
| N1 - Unsuitable | Land having limitations which appear so severe as to preclude any possibility of successful, sustained application of tree crops; or having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at presently acceptable cost. Two subclasses are identified in the project area: | |
| N1f | Land comprising deep, level, very poorly drained, clayey to loamy soils which are subject to deep prolonged flooding by salt water and which occupy positions in the tidal swamps. Such soils, besides being inundated throughout the year, are also highly saline. | 1 |
| N1s | Land comprising deep excessively drained, sandy soils on undulating terrain. Such soils have an unfavourable sand texture (more than 90% sand in the fine earth fraction), low or very low available water holding capacity, low organic matter content in surface soils, low fertility and very low reserves of weatherable minerals in subsoils. | 12 and part of 13 |

Table A8.1

LAND SUITABILITY FOR TREE CROPS ASSUMING IMPROVED CULTIVATION PRACTICES WITH PROPORTIONAL DISTRIBUTION BY AREA AND PERCENT

| | Class | Soil Mapping Unit | Area (ha) | % |
|---|---|---|---|---|
| | | ORDER S: SUITABLE LAND | | |
| S1 | Highly suitable | 35 | 32 160 | 0.8 |
| S2 | Moderately suitable | 17, 19, 20, 21, 24, 25, 26, 27, 32, 33, 36, 37, 38 | 1 351 664 | 30.6 |
| S3 | Marginally suitable | 16, 18, 22 | 112 906 | 2.6 |
| S1/S2 | Association of highly and moderately suitable land | 30, 31 | 217 286 | 5.1 |
| S2/S3 | Association of moderately and marginally suitable land | 28, 34 | 97 880 | 2.3 |
| Subtotal area | | | 1 775 896 | 41.4 |
| | | ORDER CS: CONDITIONALLY SUITABLE LAND | | |
| CS1 | Conditionally highly suitable land | - | - | - |
| CS2 | Conditionally moderately suitable land | 15 | 7 040 | 0.2 |
| CS3 | Conditionally marginally suitable land | 2, 3, 5, 6, 7, 8, 9, 10, 11 | 2 032 999 | 47.4 |
| CS2/CS3 | Association of conditionally moderately and marginally suitable land | 4 | 19 808 | 0.4 |
| Subtotal area | | | 2 059 847 | 48.0 |
| | | ORDER N: UNSUITABLE LAND | | |
| N1 | Unsuitable | 1, 12 and lakes | 104 129 | 2.4 |
| Subtotal area | | | 104 129 | 2.4 |

Table A8.1 (cont'd)

| | Class | Soil Mapping Unit | Area (ha) | % |
|---|---|---|---|---|
| | | ASSOCIATIONS OF SUITABILITY ORDERS | | |
| S1/CS3 | Association of highly suitable and conditionally marginally suitable land | 29 | 172 990 | 4.1 |
| S2/CS3 | Association of moderately suitable and conditionally marginally suitable land | 14, 23 | 88 575 | 2.1 |
| CS3/N1 | Association of conditionally marginally suitable and unsuitable land | 13 | 86 685 | 2.0 |
| Subtotal area | | | 348 250 | 8.2 |
| Total area | | | 4 288 122 | 100.0 |

Appendix 9

## LAND SUITABILITY FOR PADDY (WETLAND) RICE ASSUMING IMPROVED CULTIVATION PRACTICES

### LAND UTILIZATION TYPE DEFINITION

Determining land suitability for paddy is complicated by the need for controlled flooding. The water (apart from irrigated areas) comes from direct rainfall, natural flooding by rise of water in rivers and streams, diversion from stream channels, and by runoff and seepage from adjacent higher areas. In addition to the amount, distribution and dependability of the water supply, its salinity and other chemical qualities and the silt load are of importance in growth of rice.

In this study, land suitability evaluations for the sustained cultivation of paddy (wetland) rice are made assuming that land placed in orders S and CS receives sufficient water and has characteristics which allow water to be held on the surface for periods long enough to mature one crop of rice in most years. In this regard, construction of paddy bunds and drainage/irrigation ditches are considered essential required inputs and it is assumed that these are constructed by the farmer himself or by the farmer with government sponsored technical and mechanical aid. However, large-scale irrigation/drainage, flood control structures and land reclamation projects are not included in this initial assumption. In addition it is assumed that the following recurrent and minor inputs are implemented:

- land preparation including levelling and puddling utilizing animal-drawn implements:
- field sanitation and bund and ditch maintenance;
- proper preparation and protection of nursery sites;
- use of well-dressed seed of varieties well adapted to prevailing climate and soil conditions;
- row planting to facilitate weed, pest and disease control;
- adequate fertilizer and lime application in required amounts and combinations;
- harvest by sickle;
- drying before storage in rat-proof stores.

With the exception of initial bund, drainage/irrigation ditch construction, the majority of inputs are recurrent and minor. Levels of inputs are considered moderate for the project area; however, they will require the provision of important extension services and farmer credit facilities by government agencies.

Land suitability classification is listed below. Table A9.1 gives land suitability class areas and proportional distribution, while Map 8 indicates their geographical distribution.

LAND SUITABILITY CLASSIFICATION - PADDY (WETLAND) RICE ASSUMING IMPROVED CULTIVATION PRACTICES

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| S - SUITABLE LAND | | |
| S1 - Highly suitable | Land having no significant or only minor limitations to the sustained cultivation of paddy (wetland) rice that will not significantly reduce production levels and/or will not raise required recurrent and minor inputs above a readily acceptable level. | 3, 4, 5, 11, and parts of 2, 6, 7, 13, 14 |
| S2 - Moderately suitable | Land having limitations which in aggregate are moderately severe for the sustained cultivation of paddy (wetland) rice that will reduce production levels and/or increase required recurrent and minor inputs for production and/or conservation to the extent that the overall advantage to be gained from the use, although still attractive, will be inferior to that expected on Class S1 land. Three subclasses are identified in the project area: | |
| S2f | Land comprising deep, level, poorly to very poorly drained clayey to loamy soils with slowly permeable subsoils and high available water holding capacity. The principal limitation to the sustained cultivation of paddy is excessive flooding by river overflow which remains long enough to damage the crop. Other problems include difficulty in maintaining fertility and moderately severe soil acidity. | part of 7 |
| S2a | Land comprising deep, level, poorly to very poorly drained clayey to loamy soils with slowly permeable subsoils and high available water holding capacity. Very strong acidity is the main limitation as it limits availability of plant nutrients. Response to fertilizers is low on these soils unless they are limed, which raises recurrent inputs on production. | parts of 2, 6, 7, 8, 29 |
| S2s | Land comprising deep, level, poorly to very poorly drained, clayey to loamy soils with slowly permeable subsoils and high available water holding capacity. The main limitation is low fertility which requires heavy fertilization to correct deficiencies which raises required recurrent inputs on production. Other problems may include very strong acidity and excessive flooding and occasional lack of water. | parts of 8, 9, 13 |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| S3 - Marginally suitable | Land having limitations which in aggregate are severe for the sustained cultivation of paddy (wetland) rice and will so reduce production levels and/or conservation, that such expenditure will only be marginally justified. Two subclasses are identified in the project area: | |
| S3a | Land comprising deep, level, poorly to very poorly drained, clayey or loamy soils with slowly permeable subsoils and high available water holding capacity. Soil reaction is extremely acid, with pH values below 4.5 on dried surface soil. In addition, most areas of these soils are subject to prolonged flooding from rivers or runoff water. Extreme acidity is the main limitation to sustained paddy cultivation as it limits availability of plant nutrients. Response to fertilizers is very low unless the soils are heavily limed which raises recurrent inputs on production to such a level that such expenditure will only be marginally justified. | part of 9 |
| S3s | Land comprising deep, level to nearly level, poorly to very poorly drained soils with organic surface layers 40 cm or more thick. Subsoils are moderately permeable. Main limitations include poor workability of organic surface soils, low fertility (including possible trace element deficiency), very strong acidity and prolonged flooding in places, all of which raise required inputs on production to such a level that such expenditure will only be marginally justified. | part of 10 |
| CS - CONDITIONALLY SUITABLE LAND | | |
| CS1 - Conditionally highly suitable | Land having characteristics which, in general preclude the sustained, economic cultivation of paddy (wetland) rice as defined for the land utilization type; but which could be used and would be equivalent in suitability to land of Class S1 provided that special management practices were implemented. | none identified |
| CS2 - Conditionally moderately suitable | Land having characteristics which, in general, preclude the sustained, economic cultivation of paddy (wetland) rice. Such land, however, could be used provided the special management practices defined at subclass level were implemented; but would only be equivalent in suitability to land of Class S2 as moderately severe limitations indicated by the subclass symbol would remain. One subclass is identified in the project area: | |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| CS2a | Land subject to deep, prolonged flooding or permanent inundation which, in general, precludes the sustained, economic cultivation of paddy; but could be used for this purpose provided flooding control was established through the construction of major drainage/irrigation works, and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S2 as very strong acidity would remain as a limitation, and response to fertilizers would be low without liming, thus raising recurrent inputs on production. | parts of 7, 10 |
| CS3 - Conditionally marginally suitable | Land having characteristics which, in general, preclude the sustained, economic cultivation of paddy (wetland) rice. Such land, however, could be used provided the special management measures defined at subclass level were implemented; but would only be equivalent in suitability to land of Class S3 as severe limitations indicated by the subclass symbol would remain. Two subclasses are identified in the project area: | |
| CS3x | Land of the tidal swamps regularly inundated by sea water which, in general, precludes the sustained, economic cultivation of paddy; but could be used for this purpose provided reclamation works were constructed and required recurrent and minor inputs were implemented. Suitability would then be equivalent to land of Class S3 as salinity would remain too high for optimum rice yields due to the lack of adequate sources of non-saline water necessary for the drainage/irrigation desalinization process. | 1 |
| CS3s | Land comprising deep, poorly drained organic soils having characteristics which, in general, preclude the sustained, economic cultivation of paddy; but which could be used for this purpose provided drainage/irrigation works were constructed capable of maintaining flooding level and required recurrent and minor inputs were implemented. Suitability would then be equivalent to Class S3 as poor soil workability, very strong acidity, low fertility and danger of subsidence would remain limitations. | parts of 7, 10 |
| N - UNSUITABLE LAND | | |
| N1 - Unsuitable | Land having limitations which appear so severe as to preclude any possibility of successful, sustained paddy (wetland) rice cultivation; or having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at presently acceptable cost. Two subclasses are identified in the project area: | |

| Order/Class | Definition | Mapping Unit |
|---|---|---|
| N1s | Land comprising deep, excessively drained, sandy soils on undulating terrain. Such soils have an unfavourable sand texture (more than 90% sand in the fine earth fraction), low or very low available water holding capacity, low organic matter content in surface soils, low fertility and very low reserves of weatherable minerals in subsoils. Water cannot be held on the surface for periods long enough to mature one crop of rice. | 12, part of 13 |
| N1t | Land comprising a wide range of soils, varying in depth, texture, reaction, fertility, amounts of coarse fragments and slope. Relief may be undulating, rolling hilly or mountainous; but in all cases slopes are too steep or topographic position is too high for water to be impounded successfully for paddy (wetland) rice. | 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 35, 36, 37, 38, and parts of 14, 29 |

Table A9.1

LAND SUITABILITY FOR PADDY (WETLAND) RICE ASSUMING IMPROVED CULTIVATION PRACTICES WITH PROPORTIONAL DISTRIBUTION BY AREA AND PERCENT

| | Class | Soil Mapping Unit | Area (ha) | % |
|---|---|---|---|---|
| | | ORDER S: SUITABLE LAND | | |
| S1 | Highly suitable | 3, 4, 5, 11 | 79 251 | 1.9 |
| S2 | Moderately suitable | 8 | 52 959 | |
| S3 | Marginally suitable | - | - | - |
| S1/S2 | Association of highly and moderately suitable land | 2, 6 | 153 653 | 3.6 |
| S2/S3 | Association of moderately and marginally suitable land | 9 | 49 298 | 1.1 |
| Subtotal area | | | 335 161 | 7.8 |
| | | ORDER CS: CONDITIONALLY SUITABLE LAND | | |
| CS1 | Conditionally highly suitable | - | - | - |
| CS2 | Conditionally moderately suitable | - | - | - |
| CS3 | Conditionally marginally suitable | 1 | 76 704 | 1.8 |
| Subtotal area | | | 76 704 | 1.8 |
| | | ORDER N: UNSUITABLE LAND | | |
| N | Unsuitable | 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 35, 36, 37, 38, and lakes | 1 888 321 | 44.0 |
| Subtotal area | | | 1 888 321 | 44.0 |
| | | ASSOCIATION OF SUITABILITY ORDERS | | |
| S1/S2/CS2/CS3 | Association of highly suitable, moderately suitable, conditionally moderately suitable and conditionally marginally suitable land | 7 | 1 226 620 | 28.6 |
| S1/S2/N1 | Association of highly suitable, moderately suitable and unsuitable land | 29, 13 | 259 675 | 6.1 |
| S3/CS2/CS3 | Association of marginally suitable, conditionally moderately suitable and conditionally marginally suitable land | 10 | 491 026 | 11.4 |
| S1/N1 | Association of highly suitable and unsuitable land | 14 | 10 615 | 0.3 |
| Subtotal area | | | 1 987 936 | 46.4 |
| Total area | | | 4 283 122 | 100.0 |

Appendix 10

SUMMARY OF FOREST INVENTORY RESULTS IN THREE SEPARATE AREAS OF SWAMP FOREST
(see Map 9 )

| Species | AREA "A" | | | | AREA "B" | | | | AREA "C" | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (vol/ha/m3) by diameter classes | | | | (vol/ha/m3) by diameter classes | | | | (vol/ha/m3) by diameter classes | | | |
| | 35-49 | 50 | 35 | % | 35-49 | 50 | 35 | % | 45-49 | 50 | 35 | % |
| MERANTI + Shorea spp | 2.59 | 4.32 | 6.91 | 11.97 | 1.56 | 6.69 | 8.25 | 9.75 | 6.33 | 21.40 | 27.83 | 22.29 |
| PULAI + Alstonia pneumatophora | 1.62 | 19.70 | 21.32 | 36.93 | 3.35 | 35.22 | 38.57 | 45.60 | 0.36 | 5.89 | 6.25 | 5.02 |
| PRUPUK + Lophopetalum | 3.48 | 1.34 | 4.82 | 8.35 | 0.81 | 0.87 | 1.68 | 1.99 | 6.71 | 6.97 | 13.68 | 10.98 |
| DJELUTONG + Dyera costulata | 1.26 | 1.80 | 3.06 | 5.30 | 1.16 | 2.77 | 3.93 | 4.65 | 0.66 | 6.06 | 6.72 | 5.39 |
| Subtotal 4 species | 8.95 | 27.16 | 36.11 | 62.55 | 6.88 | 45.55 | 52.43 | 61.99 | 14.06 | 40.32 | 54.38 | 43.68 |
| TERENTANG + Campnosperma auriculata | 2.03 | 1.83 | 3.86 | 6.69 | 2.18 | 3.59 | 5.77 | 6.82 | | | | |
| RETIAU + Ganua motleyana | 2.02 | 1.37 | 3.39 | 5.87 | 0.68 | 0.68 | 1.36 | 1.61 | | | | |
| LABUK + Endospermum malaccense | 0.88 | 1.40 | 2.28 | 2.69 | | | | | 0.55 | 0.53 | 1.08 | 0.87 |
| Other species | 3.44 | 1.85 | 5.29 | 10.41 | 1.70 | 2.46 | 4.16 | 4.90 | 17.64 | 19.18 | 36.82 | 29.56 |
| Total floaters | 17.32 | 33.61 | 50.93 | 88.21 | 11.44 | 52.28 | 63.72 | 75.32 | 32.25 | 60.03 | 92.28 | 74.11 |
| MENGGERIS + Koompassia malaccensis | 0.30 | 1.32 | 1.62 | 2.81 | 0.90 | 3.06 | 3.96 | 7.68 | | | | |
| BENKAL + Nauclea-orientalis | 1.24 | 0.62 | 1.86 | 3.22 | 0.15 | 0.04 | 0.19 | 0.22 | 0.32 | 0.21 | 0.53 | 0.43 |
| Other species | | | | | 1.10 | 2.25 | 3.35 | 3.96 | 0.22 | 0.36 | 0.58 | 0.46 |
| Total sinkers | 1.54 | 1.94 | 3.48 | 6.03 | 2.15 | 5.35 | 7.50 | 8.86 | 0.54 | 0.57 | 1.11 | 0.89 |
| Total commercial | 18.86 | 35.55 | 54.41 | 94.26 | 13.59 | 57.63 | 71.22 | 83.18 | 33.50 | 60.60 | 93.39 | 75.04 |
| Total non-commercial | 1.53 | 1.80 | 3.33 | 5.76 | 4.86 | 8.50 | 13.36 | 16.82 | 10.74 | 20.41 | 31.15 | 24.06 |
| TOTAL | 20.39 | 37.35 | 57.74 | 100.00 | 18.45 | 66.13 | 84.58 | 100.00 | 43.53 | 81.01 | 124.54 | 100.00 |

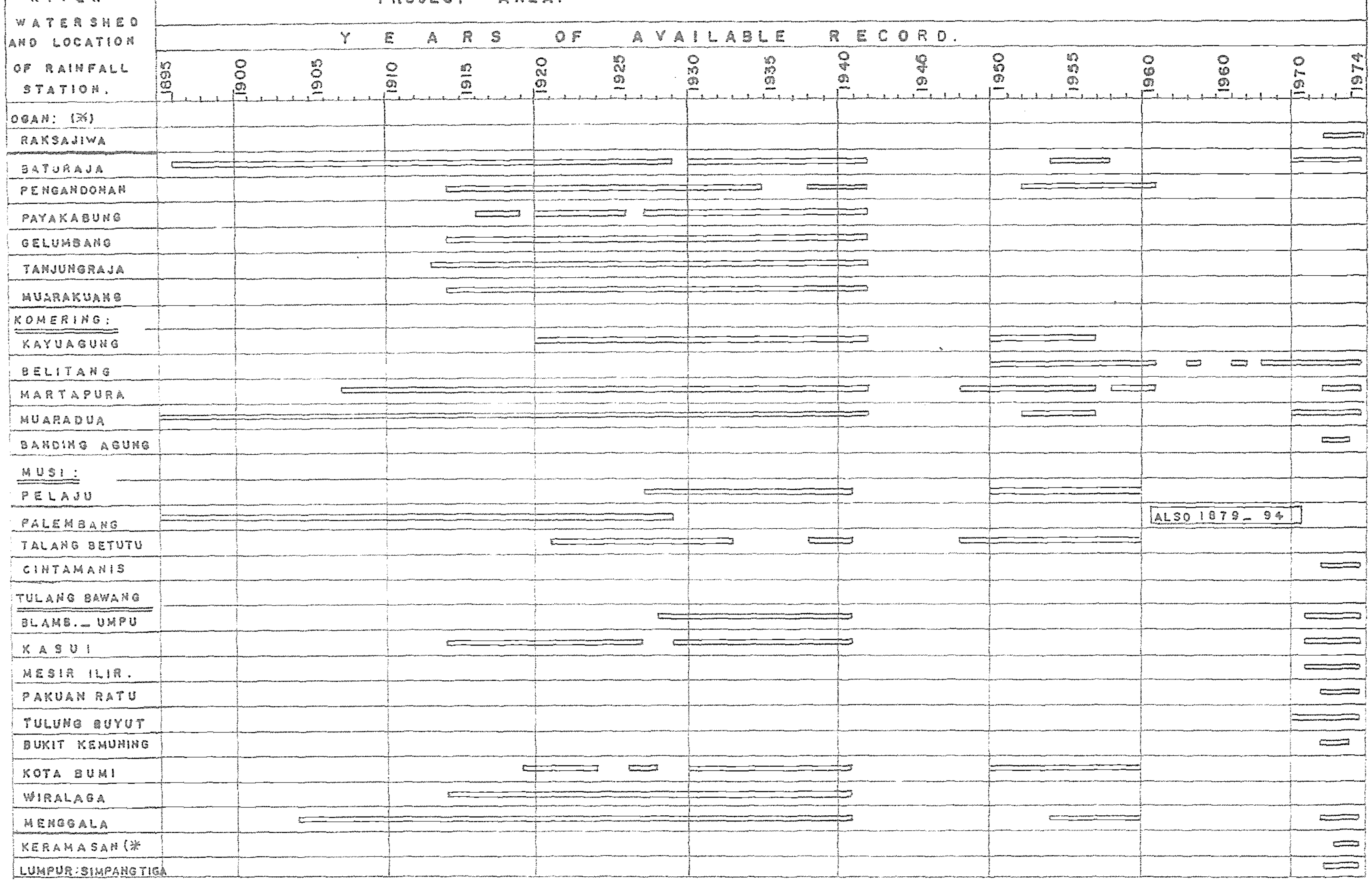
## Appendix 11

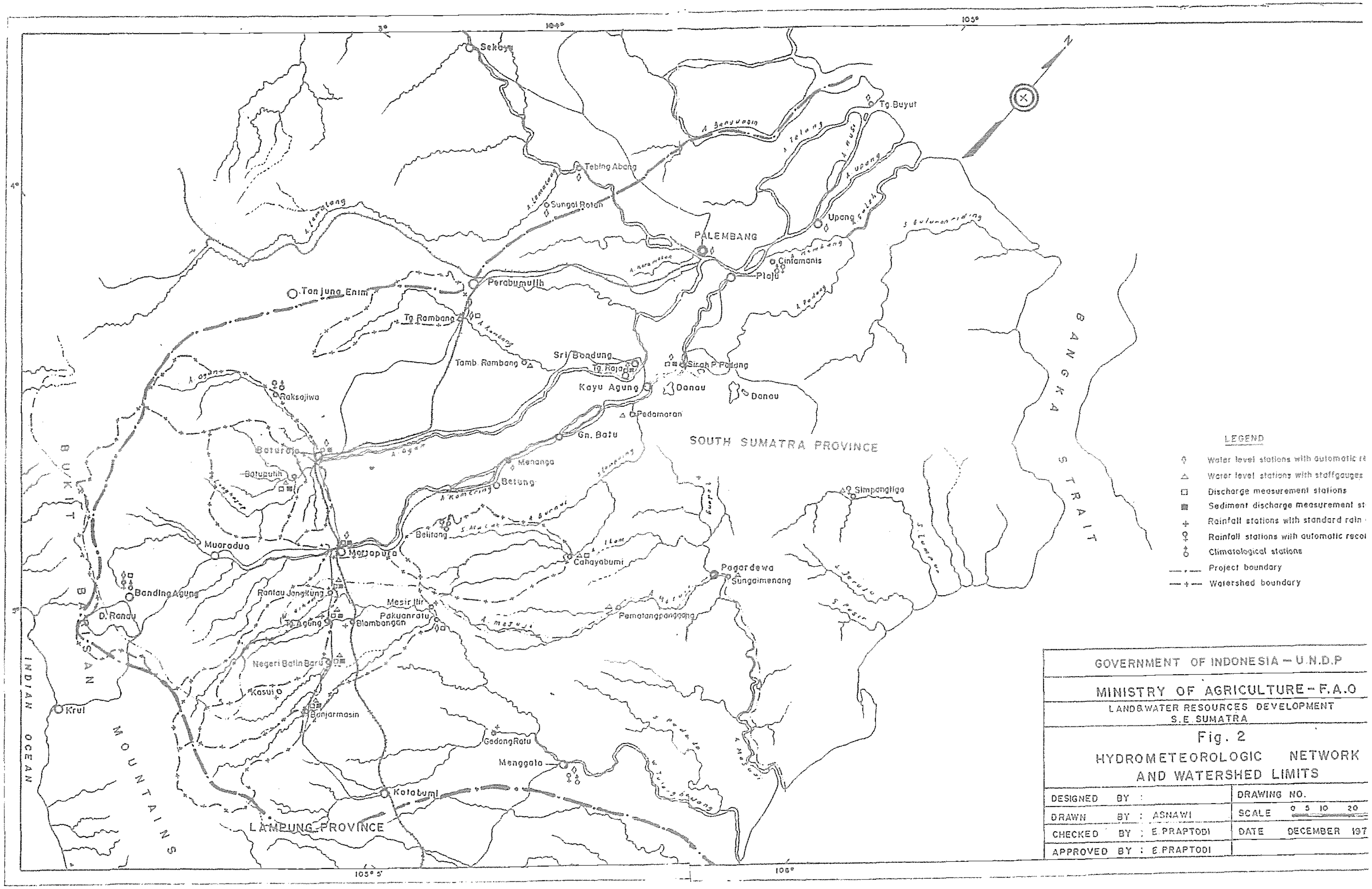
LIST OF PREDOMINANT FOREST SPECIES IN PALEMBANG SWAMP FOREST

| No. | Local name | Scientific name | Estimated total volume % | Specific gravity | Properties and uses |
|---|---|---|---|---|---|
| 1. | Meranti | Shorea ovalis (Dipterocarpaceae) | 10-25 | 0.55 | All belong to the light Red Meranti Group and are included in Malayan Forest Service Trade Leaflet (MFS/TL) No. 8 & 9. They are suitable for general construction, furniture, panelling and plywood. The wood is attractive and finishes well. It usually contains a high percentage of silica which makes it difficult to work, but can be peeled successfully and planes and turns easily to a smooth surface (MFS/TL No. 35 and Malayan Forester, Vol. XIII). |
| 2. | Meranti | Shorea leprosula (Dipterocarpaceae) | | | |
| 3. | Meranti, paja | Shorea platycarpa (Dipterocarpaceae) | | | |
| 4. | Meranti | Shorea dasyphylla (Dipterocarpaceae) | | | |
| 5. | Mesawa | Anisoptera marginata (Dipterocarpaceae) | | 0.59 | |
| 6. | Pulai | Alstonia pneumatophora | 5-40 | 0.34 | Easy timber to work, giving a good finish. Prone to blue sapstain when green but not during seasoning. Brown in colour. Has been peeled successfully. |
| 7. | Prupuk | Lophopetalum spp | 8-12 | 0.45 | Seasons very well. Easy to work, giving a good finish. Moderately durable, (MFS/TR Nos. 36 & 34). Strength at least comparable with Meranti. Appears suitable for plywood, general construction and furniture. |
| 8. | Jelutong | Dyera costulata | 4-6 | 0.43 | Documented in MFS/TL No. 13. Easy to work and finishes well, but not very strong or durable; also very prone to sapstain if not treated. Good for internal construction when strength is not required. More suitable for special purposes, such as drawing boards, blackboards, wooden models, battens for plywood chests, clogs, etc. It is particularly good wood for pattern-making and has proved successful for battery separators. Timber test results in MFS/TL No. 34. |
| 9. | Ketiau | Ganua motleyana | 1-6 | 0.56 | Included in the Nyatoh group in Malaysia MFS/TL No. 13. Timber test results in MFS/TL No. 34. Works and finishes well, but not as hard or strong as other Nyatoh (Palaquim spp). Suitable for flooring, furniture, joinery, construction plywood, door and window frames. |
| 10. | Idjuk | Myristica spp | 1-5 | 0.70 | All included in the Penarahan group in Malaysia (MFS/TL No. 18). The species which produce dark coloured wood provide a high quality timber. The lighter coloured timber does not produce as good a finished appearance as Meranti, though it could be mixed with Meranti for general carpentry work. It is not durable and should be treated. |
| 11. | Pianygu | Horafieldia spp | | 0.45 | |
| 12. | Myristica mandaranhan | | | 0.62 | |
| 13. | Sungkit spp | | | 0.60 | |

| No. | Local name | Specific name | Estimated total volume % | Specific gravity | Properties and uses |
|---|---|---|---|---|---|
| 14. | Terentang puteh | Campnosperma auriculata | 1–6 | 0.40 | Both species are common in Malaysia and documented in MFS/TL No. 12. Timber test results in MFS/TL No. 34. A poor timber generally of unattractive grey appearance. Trees are usually smallish and carry some degree of spongey heart defect. It can be peeled. The main demand is for matches and match box manufacture. |
| 15. | Terentang meran | Campnosperma macrophylla | | 0.48 | |
| 16. | Menggeris | Koompassia malaccensis | 0–5 | 0.95 | Known as Kempas in Malaysia. Documented in MFS/TL No. 10. A strong and fairly durable timber suitable for parquet flooring, railway sleepers and heavy construction. Timber test results in MFS/TL No. 34. Has been peeled successfully to produce core veneer and slices to produce decorative veneer. Abnormal tissue (included phloem) often found in the wood to produce mechanical weakness. |
| 17. | Labu | Endospermum malaccensis | 0–3 | 0.45 | Known as Sesendok in Malaysia. A light, soft, and fairly weak timber. Timber test results in MFS/TL No. 34, but machines well to a smooth finish: MFS/TL No. 35. Seasons well with low shrinkage rate: MFS/TL No. 36. Suitable for furniture and plywood. |
| 18. | Balan | Palaquium rostratum | 0–1 | 0.61 | Included in the Nyatoh group in Malaysia and documented in MFS/TL No. 13. A first class general utility wood suitable for all forms of internal construction. Selected wood is very attractive and in demand for high-grade furniture manufacture. The timber is prone to insect attack if not treated. |
| 19. | Benkal | Nauclea orientalis | 0–3 | 0.58 | Known as Hempayan in Malaysia, but no information received. In other places, Papua New Guinea and Samoa, the genera produces an attractive golden yellow coloured wood, strong, fairly durable and prized for decorative furniture. |
| 20. | Geronggang | Cratoxylon arborescens | 0–1 | 0.47 | Documented in MFS/TL No. 12. Timber seasons and works well and can be mixed with light Red Meranti, though it is not as strong. Has an attractive salmon pink colour. It is very suitable for furniture, internal joinery, and making small household utensils. Timber test results are given in MFS/TL No. 34. |
| 21. | Simpur | Dillenia scortechium | 0–1 | 0.84 | The mechanical properties of D. grandifolia are given in MFS/TL No. 34 and are probably similar to D. scortechium. It is somewhat inferior timber; heavy but rather weak. It has reasonable working properties. |
| 22. | Simpur rawan | Wormia pulachella | 0–1 | 0.85 | Like No. 21, also a member of the family Dilleniaceae. Properties probably very similar. |

Fig. 1 : CHART OF LENGTH OF MONTHLY RAINFALL RECORDS IN THE PROJECT AREA.




GOVERNMENT OF INDONESIA – U.N.D.P
MINISTRY OF AGRICULTURE – F.A.O
LAND & WATER RESOURCES DEVELOPMENT
S.E SUMATRA
Fig. 2
HYDROMETEOROLOGIC NETWORK
AND WATERSHED LIMITS
DESIGNED BY :
DRAWN BY : ASNAWI
CHECKED BY : E. PRAPTODI
APPROVED BY : E. PRAPTODI
DRAWING NO.
SCALE 0 5 10 20
DATE DECEMBER 197
LEGEND
Water level stations with automatic re
Water level stations with staffgauges
Discharge measurement stations
Sediment discharge measurement st
Rainfall stations with standard rain
Rainfall stations with automatic recor
Climatological stations
Project boundary
Watershed boundary
SOUTH SUMATRA PROVINCE
LAMPUNG PROVINCE
BANGKA STRAIT
BUKIT BARISAN MOUNTAINS
INDIAN OCEAN
PALEMBANG
Sekayu
Tebing Abang
Sungai Rotan
Tg. Buyut
Upang
Cintamanis
Plaju
Perabumulih
Tanjung Enim
Tg. Rambang
Tamb. Rambang
Sri Bandung
Tg. Raja
Kayu Agung
Sirah P. Padang
Donau
Pedamaran
Gn. Batu
Raksajiwa
Baturaja
Batuputih
Menanga
Betung
Belitang
Cahayabumi
Simpangtiga
Muaradua
Martapura
Banding Agung
D. Ranau
Rantau Jengkung
Mesir Ilir
Pakuanratu
Tg. Agung
Blambangan
Pagardewa
Sungaimenang
Pematangpanggang
Negeri Batin Baru
Kasui
Banjarmasin
Krui
Gedong Ratu
Menggala
Kotabumi
104°
105°
105° 5'
106°
N

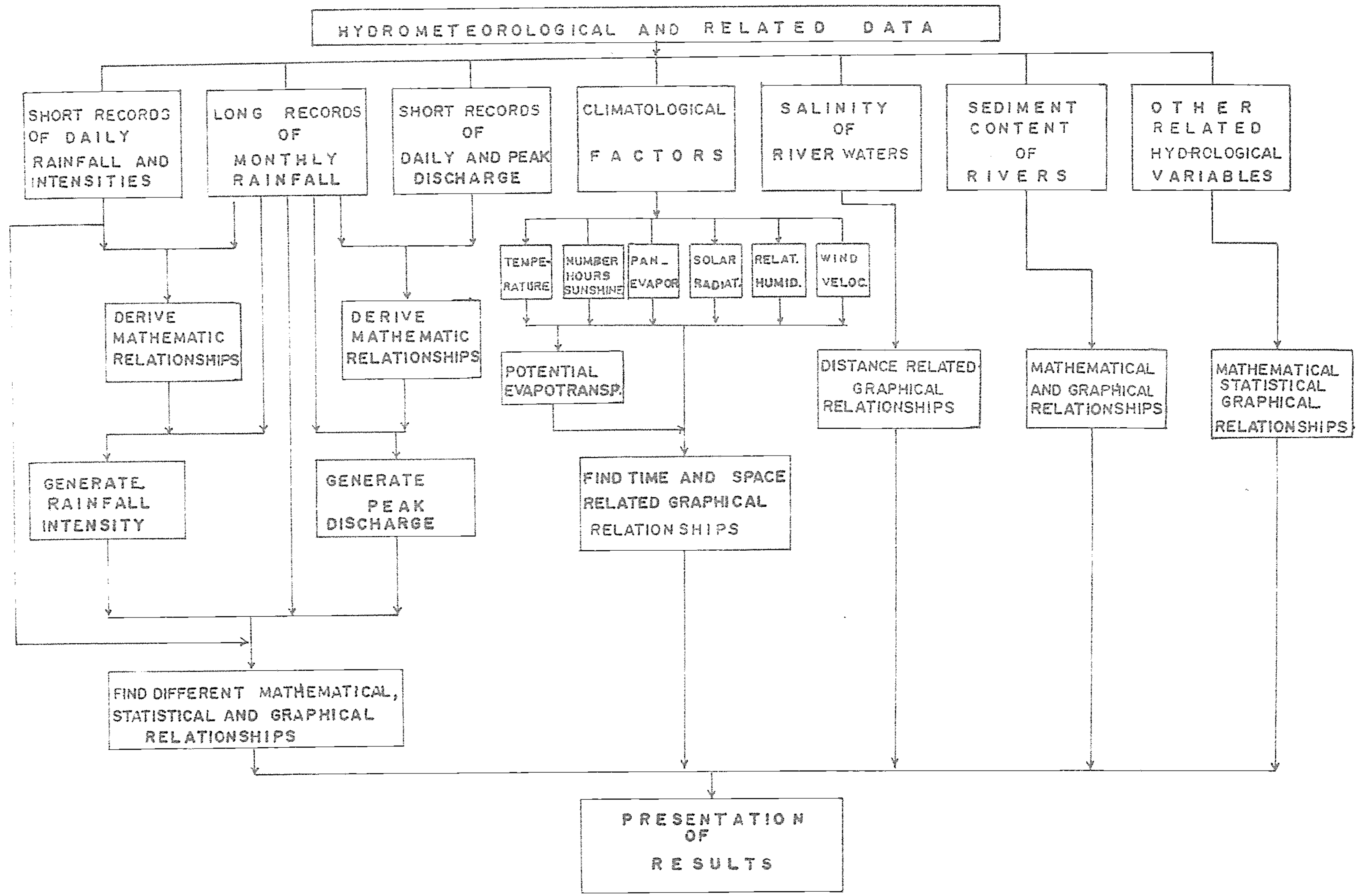



Fig. 3 _ Schematic flow chart of data processing._

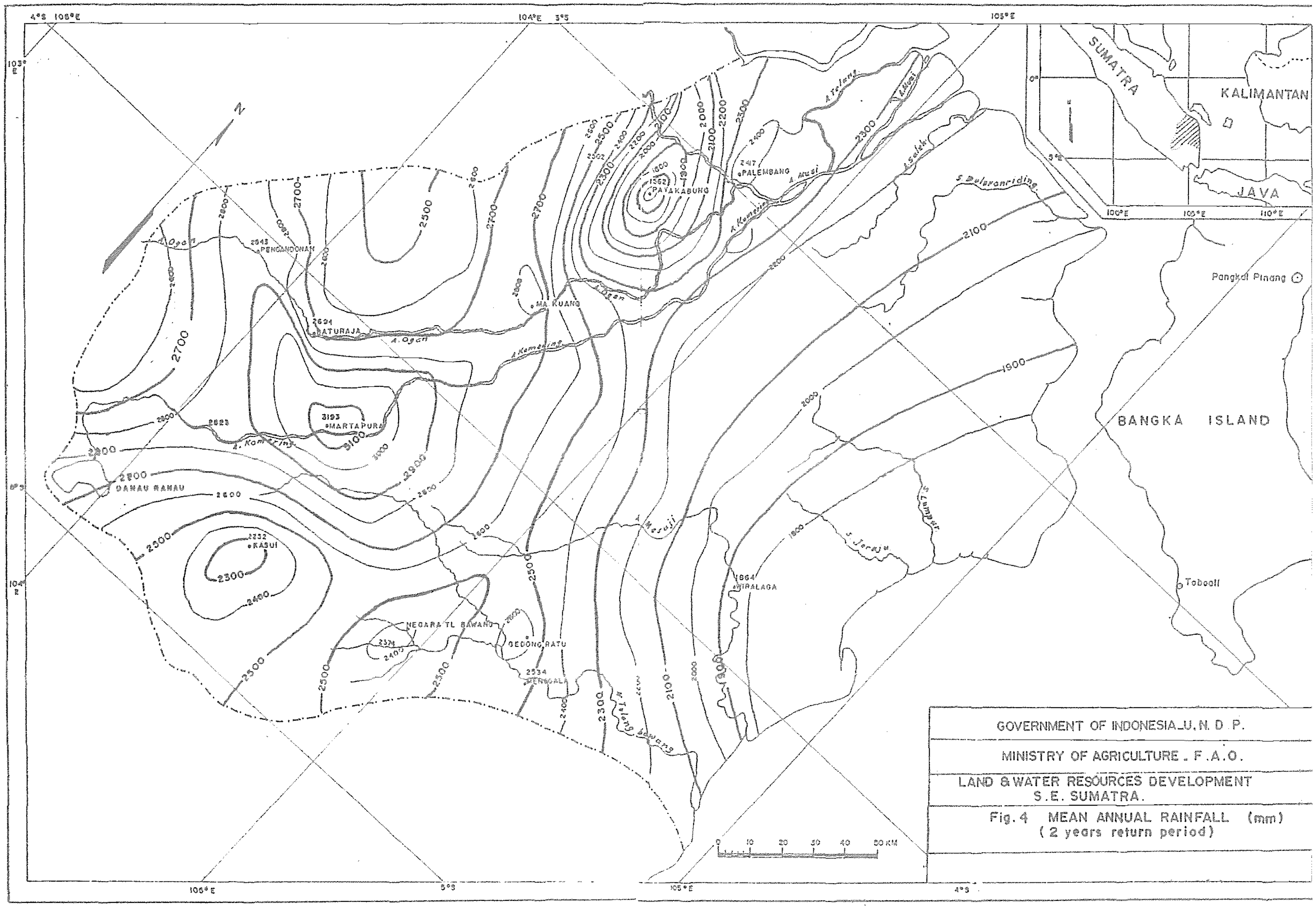



Fig. 4 MEAN ANNUAL RAINFALL (mm)
(2 years return period)

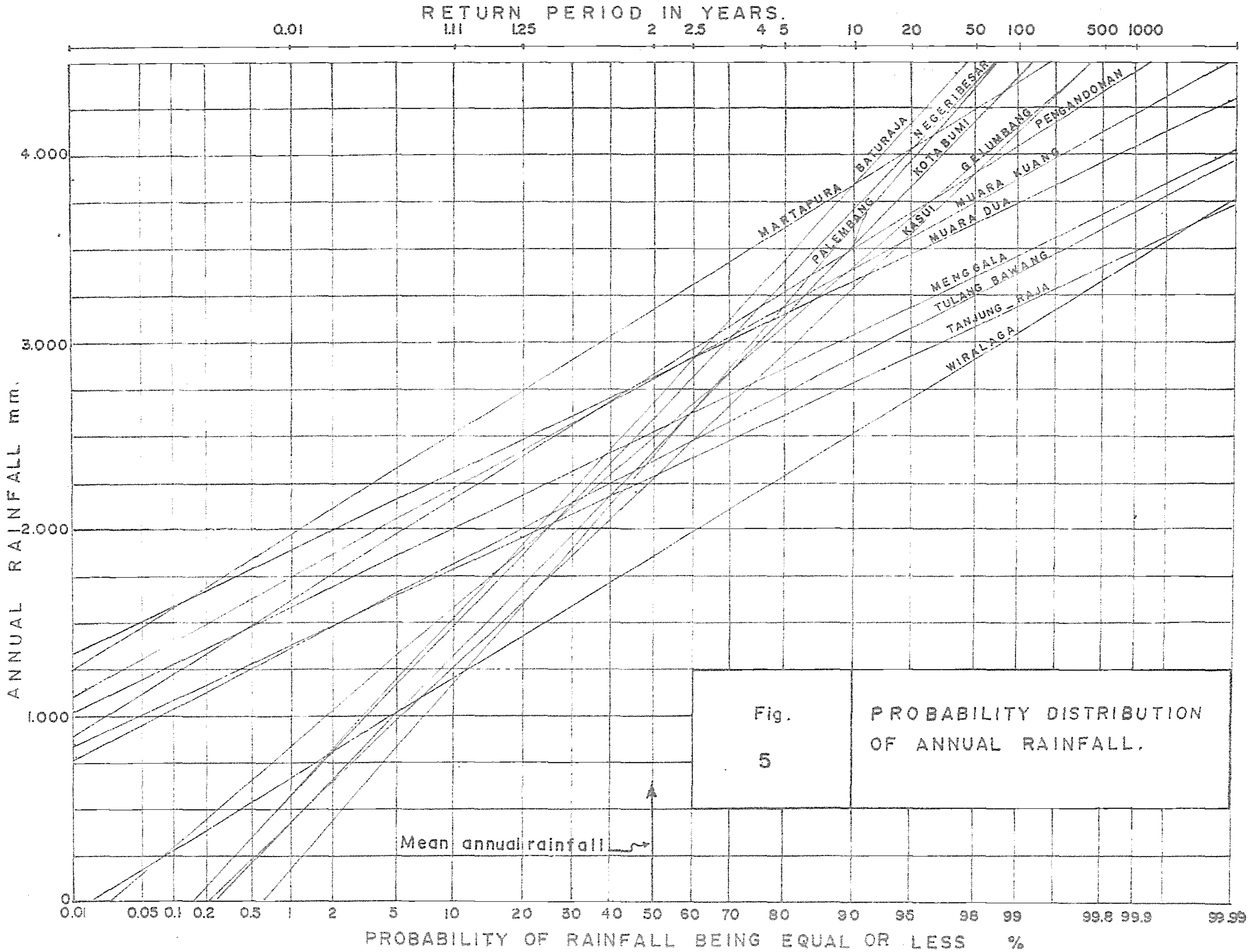



Fig. 5 PROBABILITY DISTRIBUTION OF ANNUAL RAINFALL.

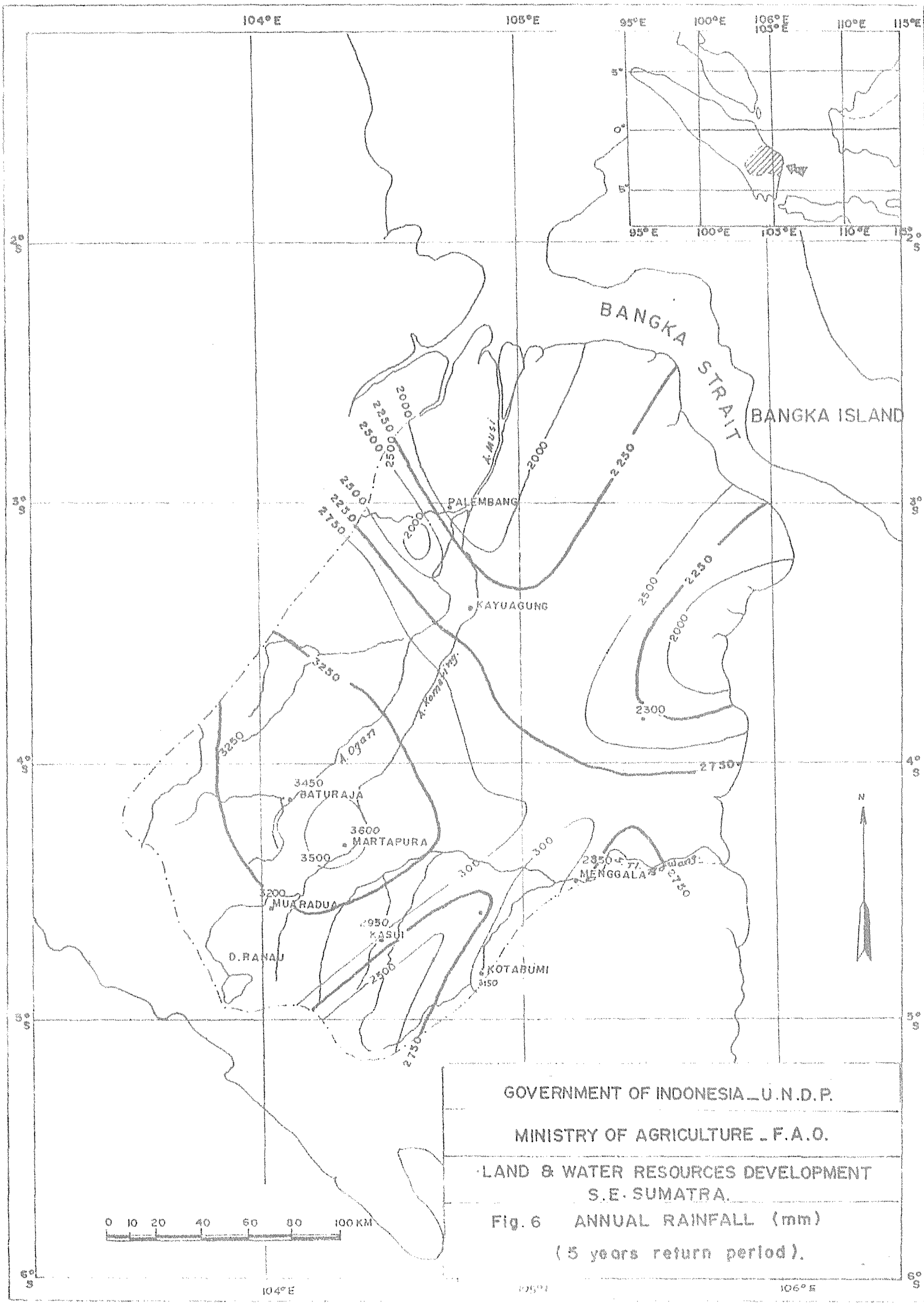



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Fig. 6 ANNUAL RAINFALL (mm)
(5 years return period).

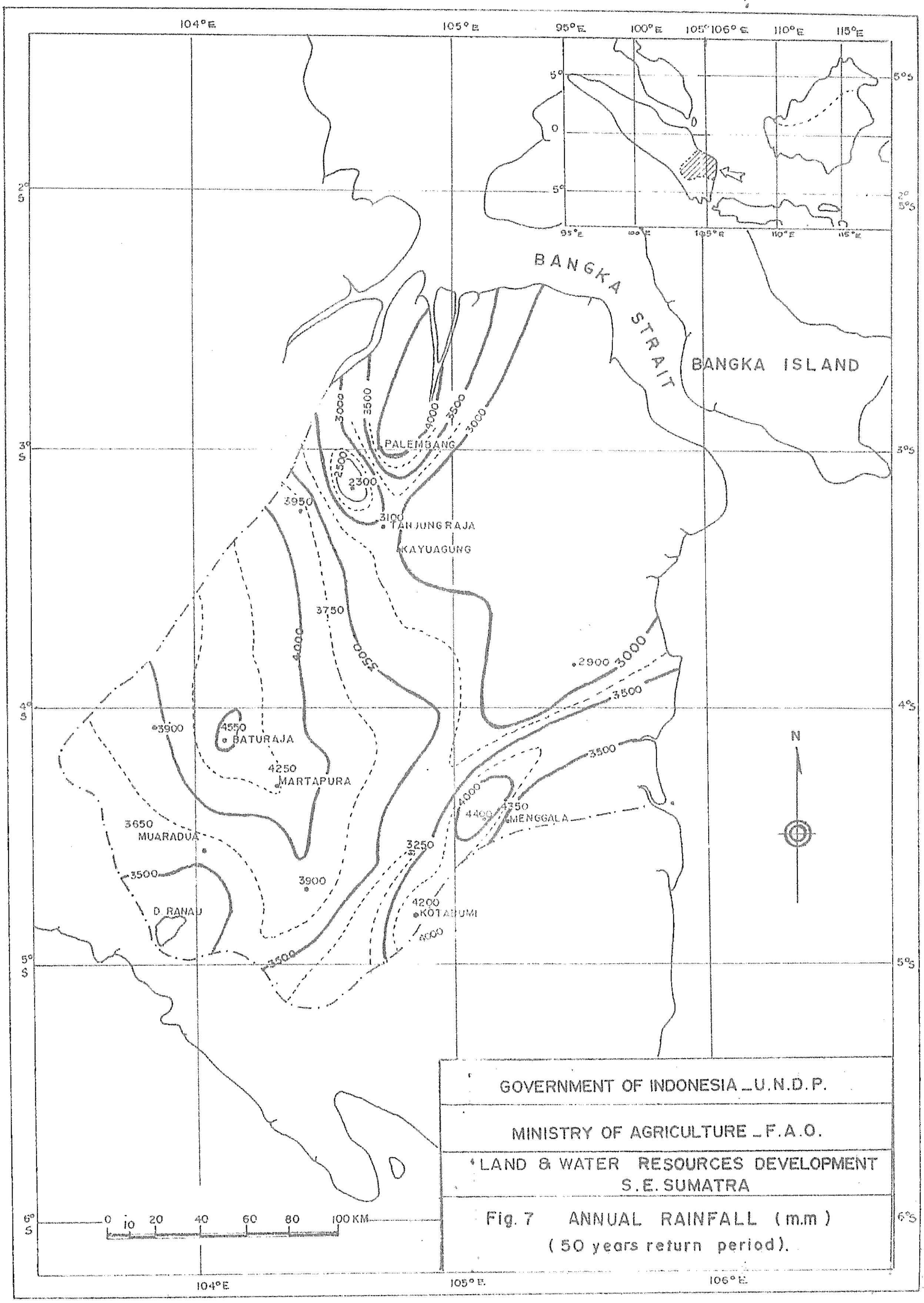


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Fig. 7 ANNUAL RAINFALL (m.m)
(50 years return period).

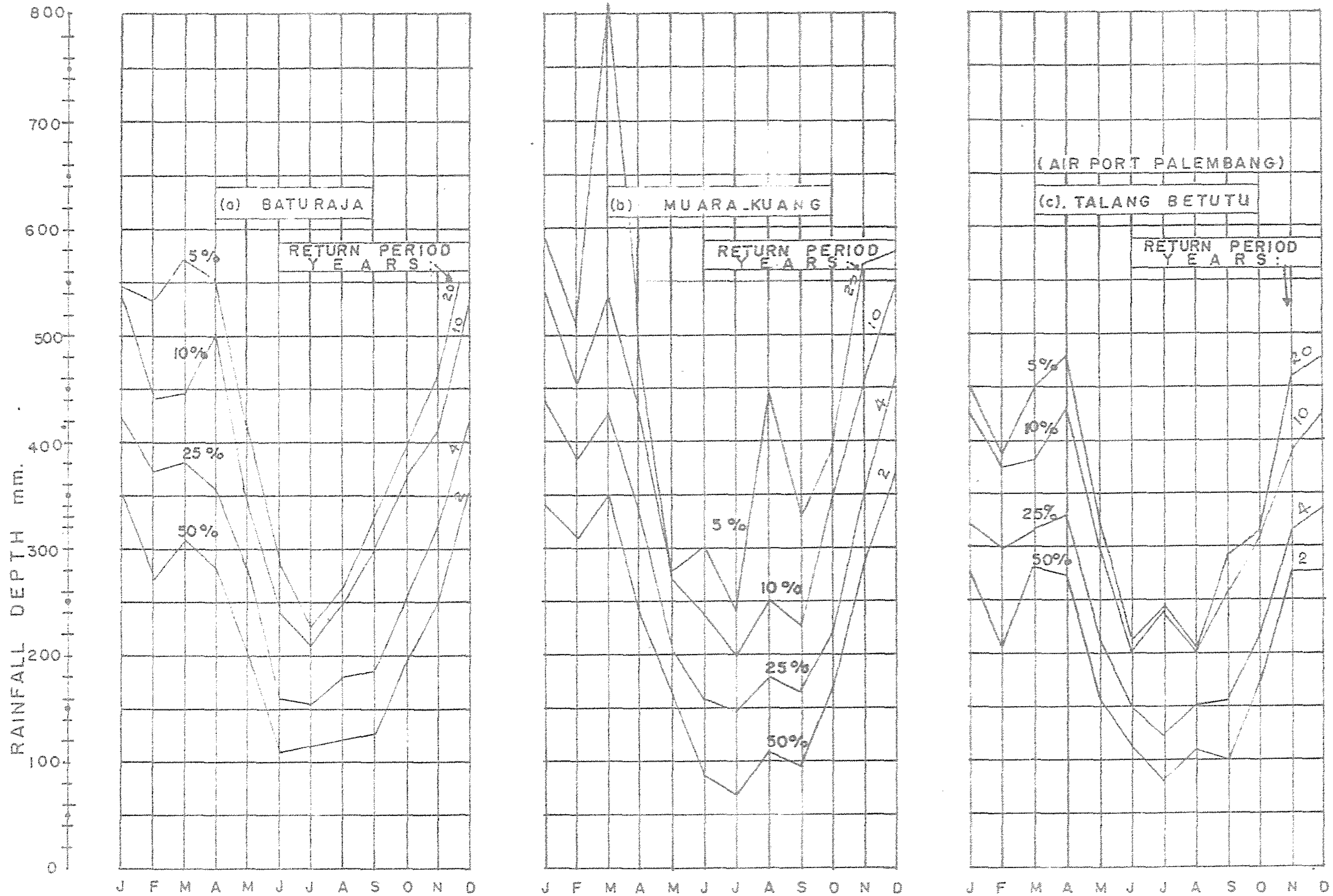



Fig. 8 RELATIVE FREQUENCY OF MONTHLY RAINFALL %

(CONT)

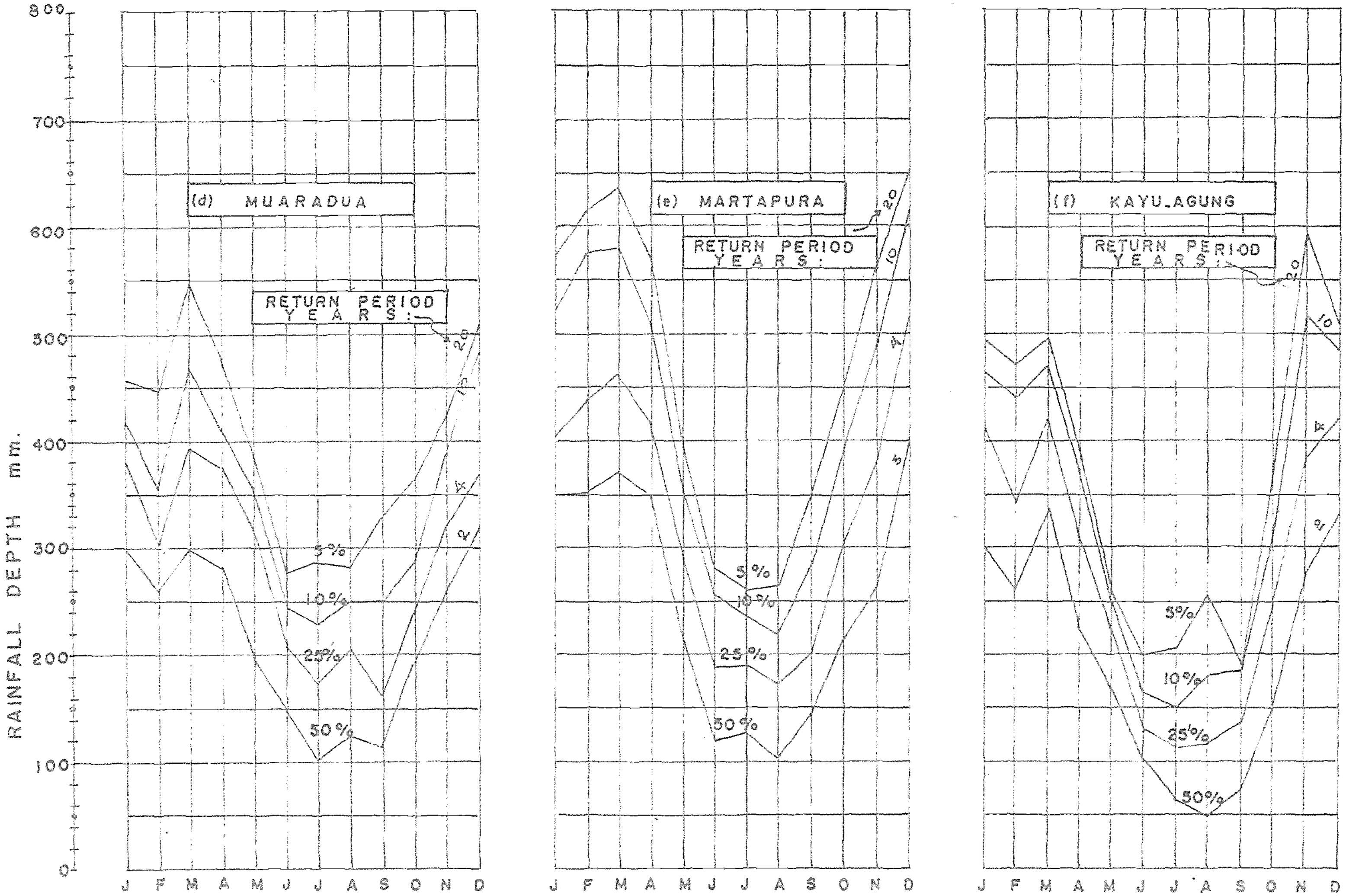



Fig. 8 RELATIVE FREQUENCY OF MONTHLY RAINFALL %

(CONT)

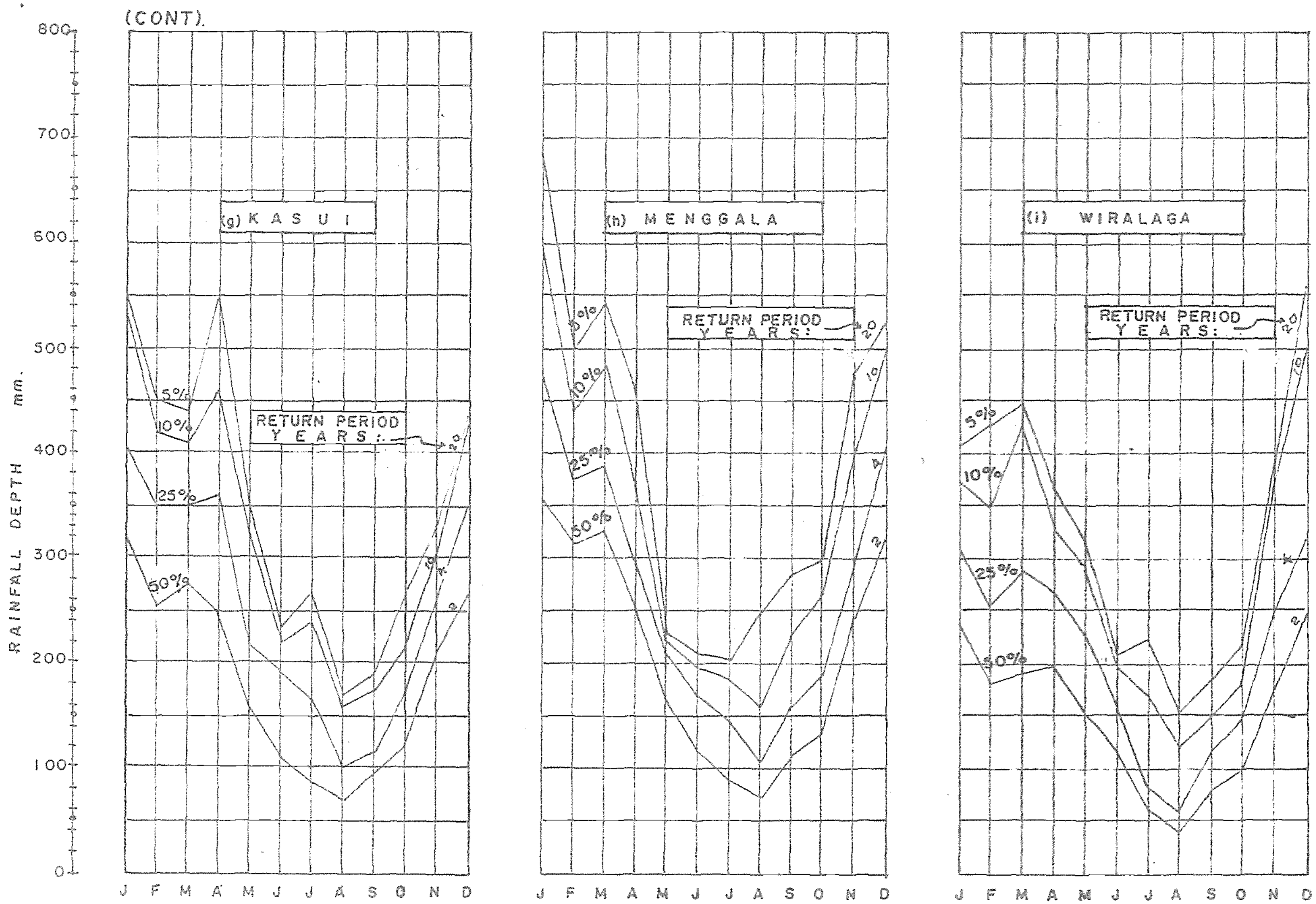



Fig. 8 RELATIVE FREQUENCY OF MONTHLY RAINFALL %.

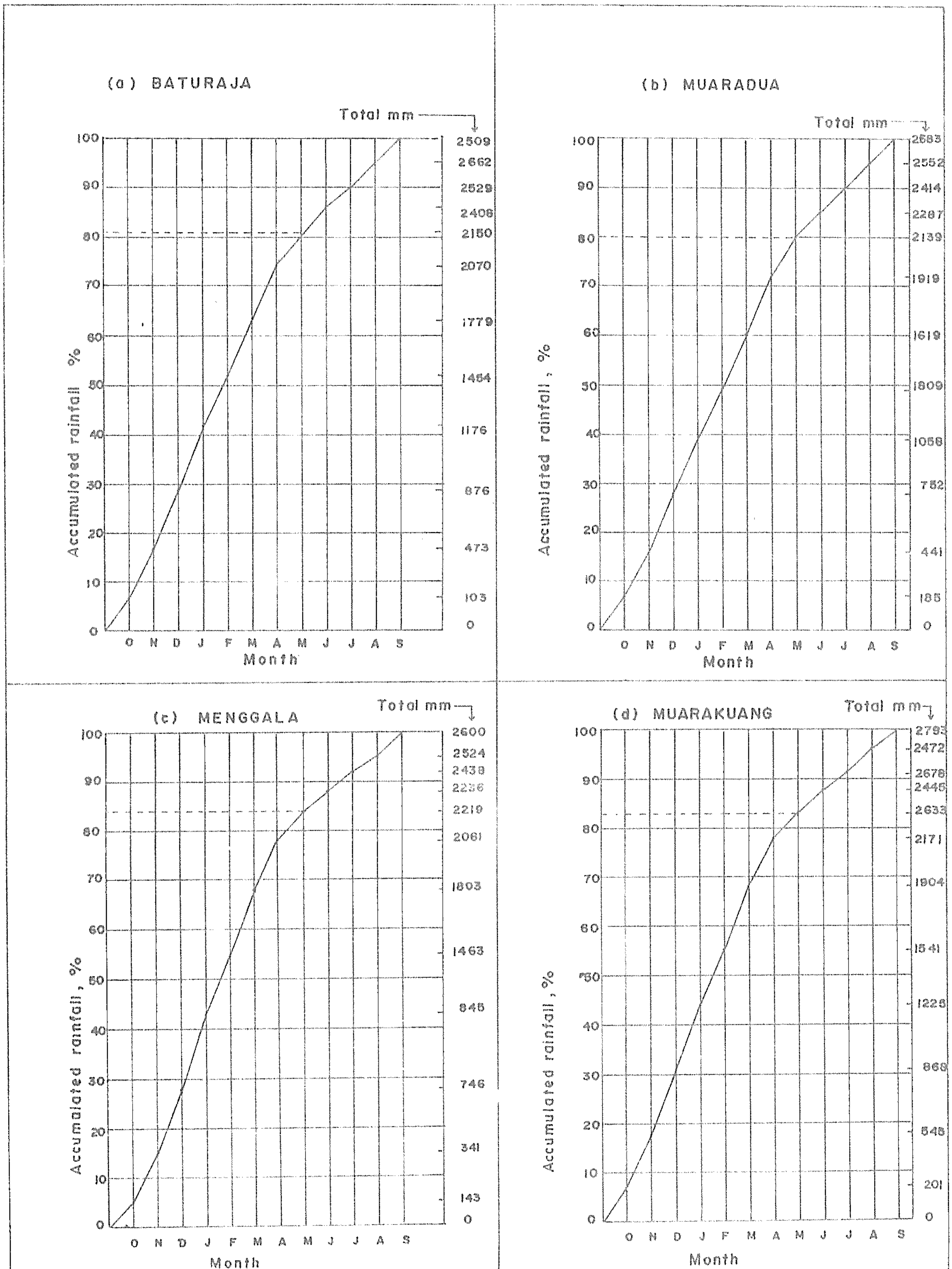



Fig. 9 Percentage distribution of mean monthly rainfall.

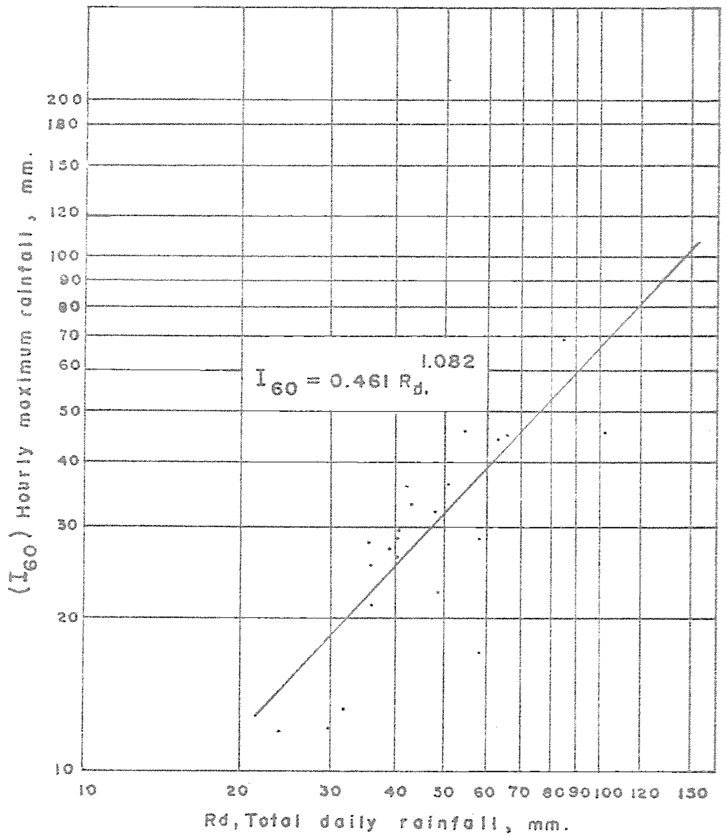



Fig. 10. _Relationship of total daily rainfall and maximum hourly rainfall ($I_{60}$)

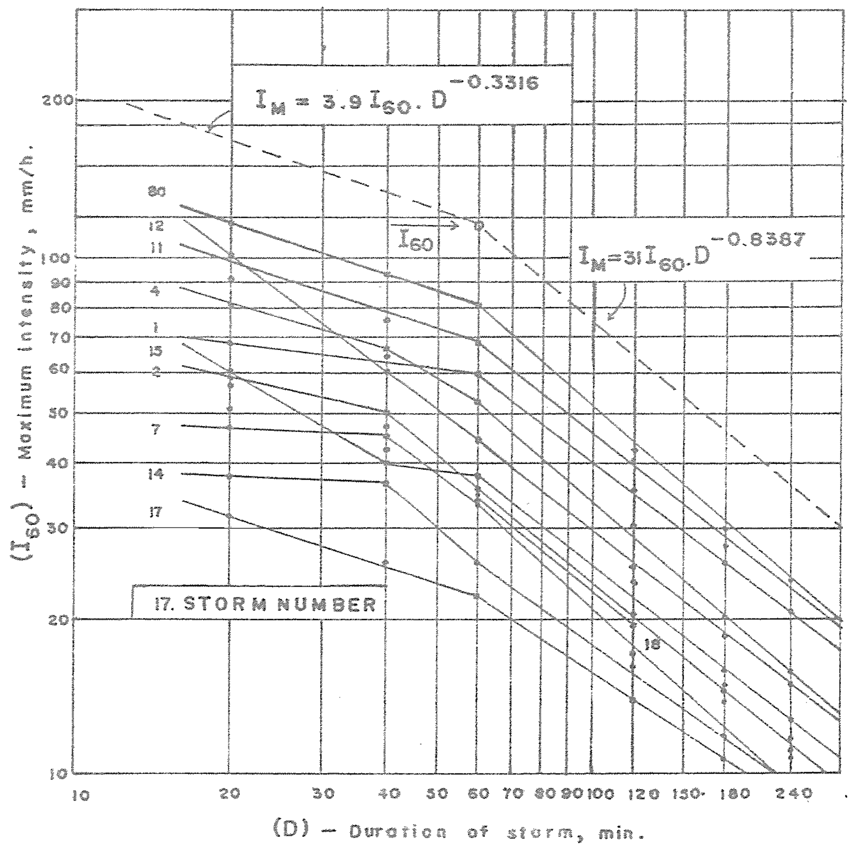
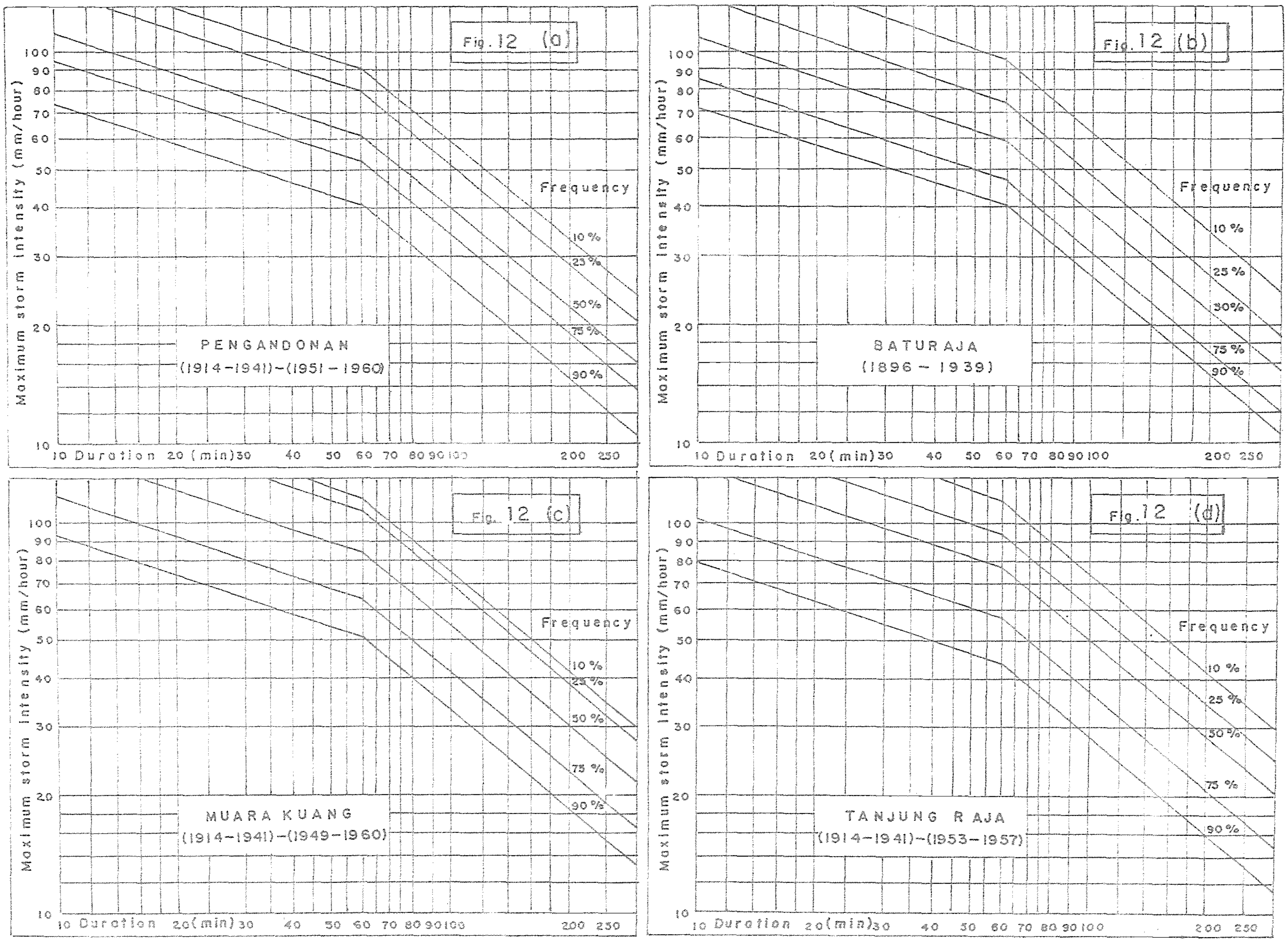



Fig. 11 _Relationship of storm duration and maximum rainfall intensity

Fig. 12. STORM DURATION / FREQUENCY / INTENSITY AT VARIOUS LOCATIONS



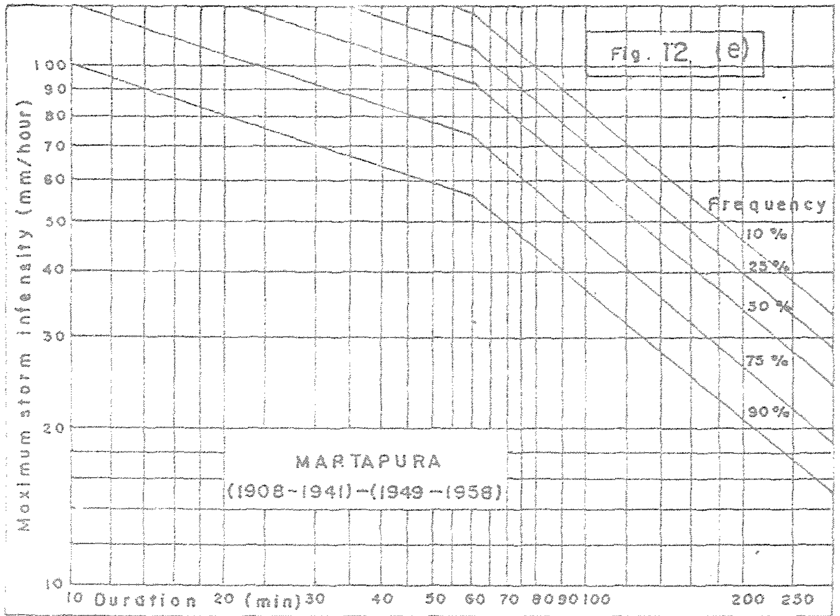


Fig. 12 (e)
Maximum storm intensity (mm/hour)
Frequency
10 %
25 %
50 %
75 %
90 %
MARTAPURA
(1908-1941)-(1949-1958)
Duration (min)
10 20 30 40 50 60 70 80 90 100 200 250

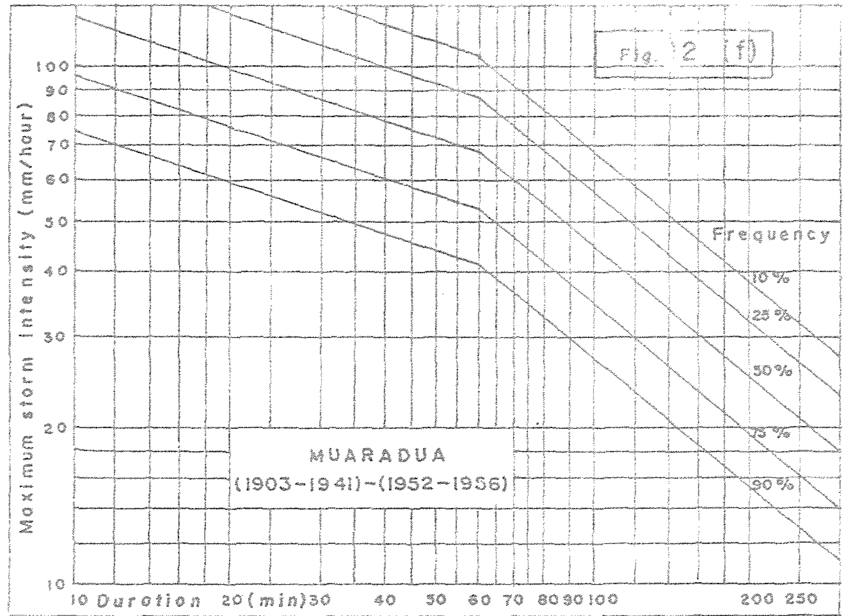


Fig. 12 (f)
Maximum storm intensity (mm/hour)
Frequency
10 %
25 %
50 %
75 %
90 %
MUARADUA
(1903-1941)-(1952-1956)
Duration (min)
10 20 30 40 50 60 70 80 90 100 200 250

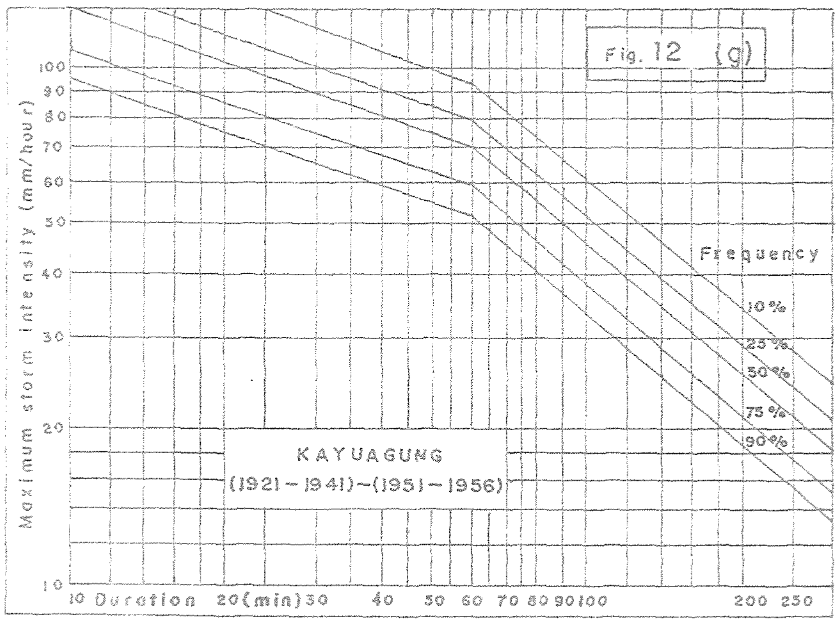


Fig. 12 (g)
Maximum storm intensity (mm/hour)
Frequency
10 %
25 %
50 %
75 %
90 %
KAYUAGUNG
(1921-1941)-(1951-1956)
Duration (min)
10 20 30 40 50 60 70 80 90 100 200 250

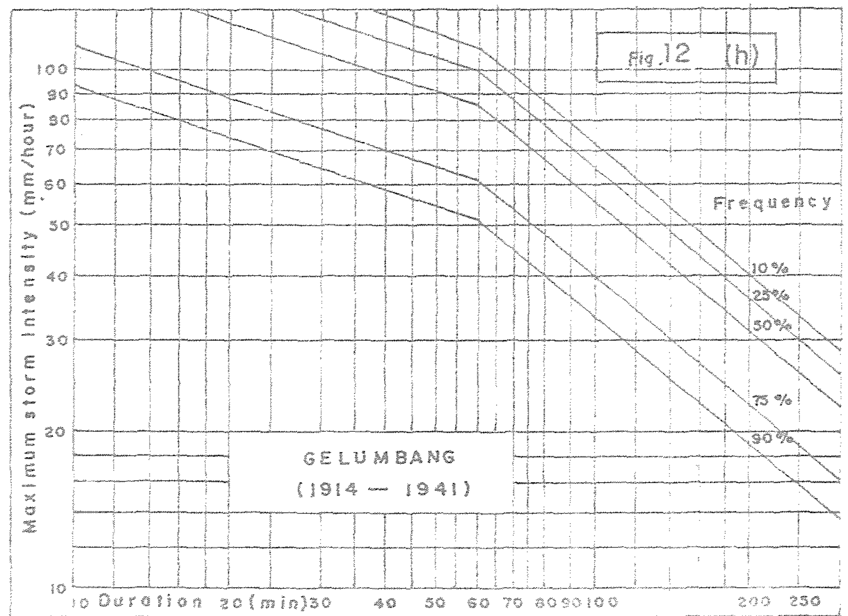


Fig. 12 (h)
Maximum storm intensity (mm/hour)
Frequency
10 %
25 %
50 %
75 %
90 %
GELUMBANG
(1914 — 1941)
Duration (min)
10 20 30 40 50 60 70 80 90 100 200 250

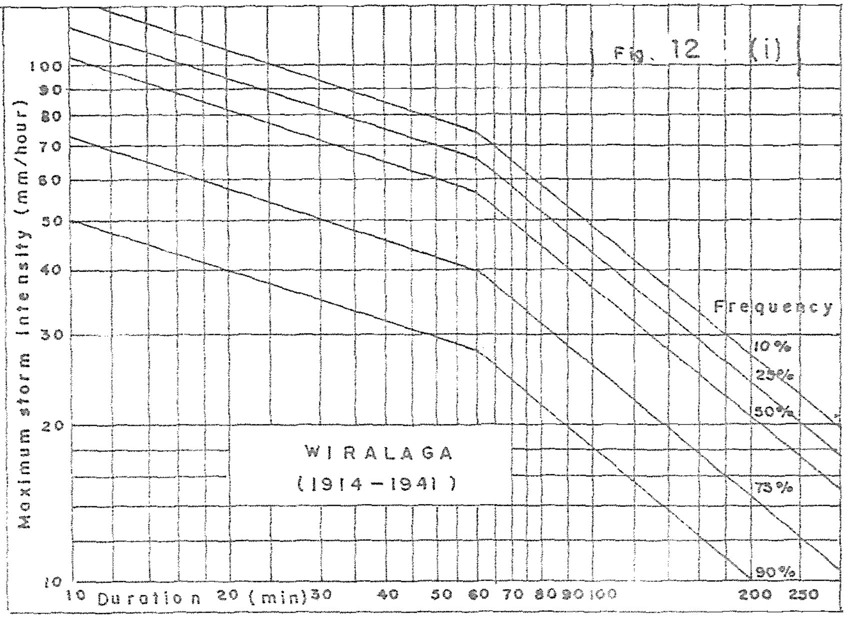


Fig. 12 (i)
WIRALAGA
(1914 – 1941)
Frequency
10 %
25 %
50 %
75 %
90 %
Maximum storm intensity (mm/hour)
100
90
80
70
60
50
40
30
20
10
10 Duration 20 (min) 30 40 50 60 70 80 90 100 200 250

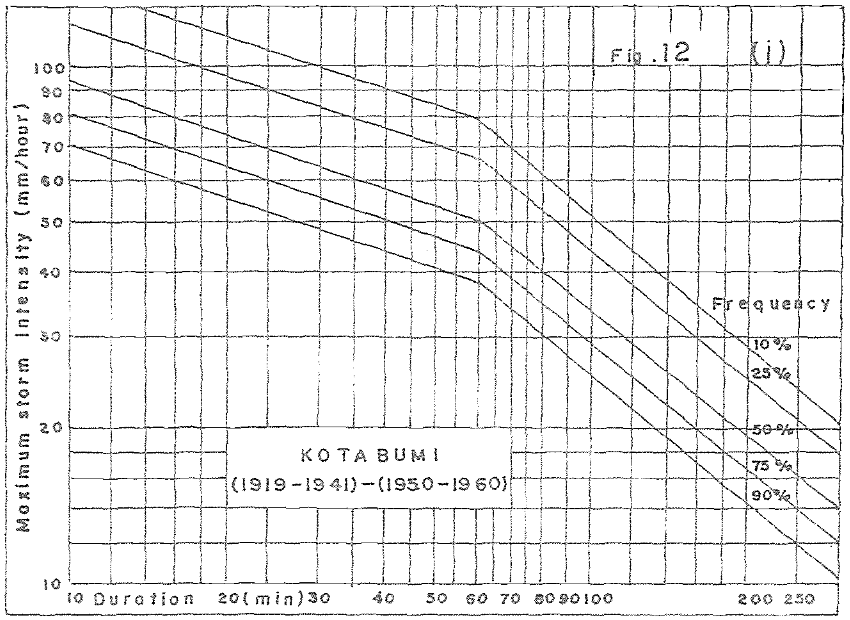


Fig. 12 (j)
KOTABUMI
(1919 – 1941) – (1950 – 1960)
Frequency
10 %
25 %
50 %
75 %
90 %
Maximum storm intensity (mm/hour)
100
90
80
70
60
50
40
30
20
10
10 Duration 20 (min) 30 40 50 60 70 80 90 100 200 250

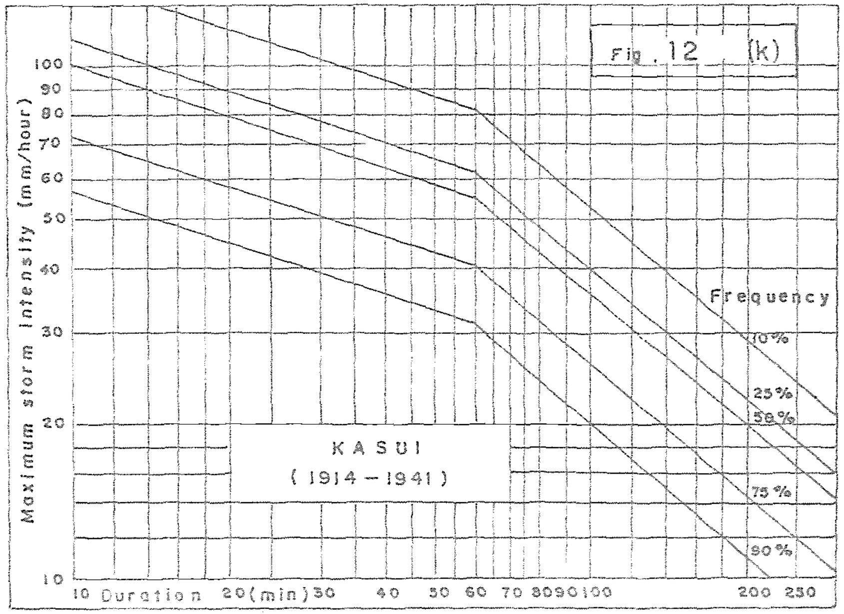


Fig. 12 (k)
KASUI
(1914 – 1941)
Frequency
10 %
25 %
50 %
75 %
90 %
Maximum storm intensity (mm/hour)
100
90
80
70
60
50
40
30
20
10
10 Duration 20 (min) 30 40 50 60 70 80 90 100 200 250

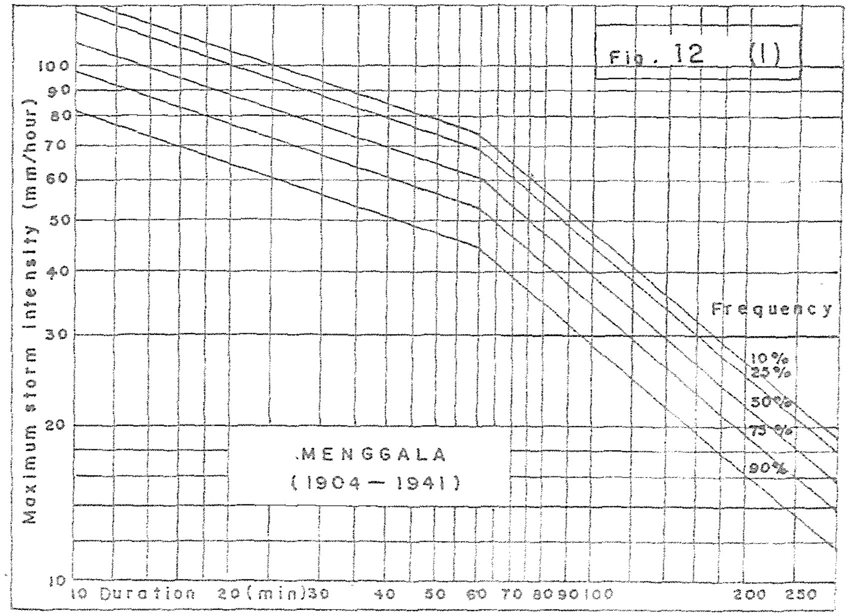


Fig. 12 (l)
MENGGALA
(1904 – 1941)
Frequency
10 %
25 %
50 %
75 %
90 %
Maximum storm intensity (mm/hour)
100
90
80
70
60
50
40
30
20
10
10 Duration 20 (min) 30 40 50 60 70 80 90 100 200 250

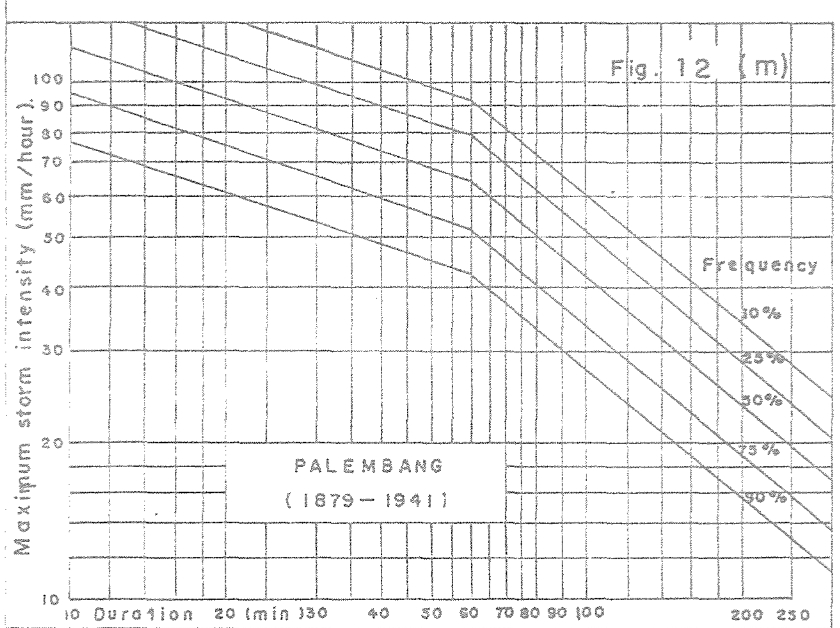


Fig. 12 (m)
Maximum storm intensity (mm/hour).
Frequency
10%
25%
50%
75%
90%
PALEMBANG
(1879 – 1941)
Duration (min)

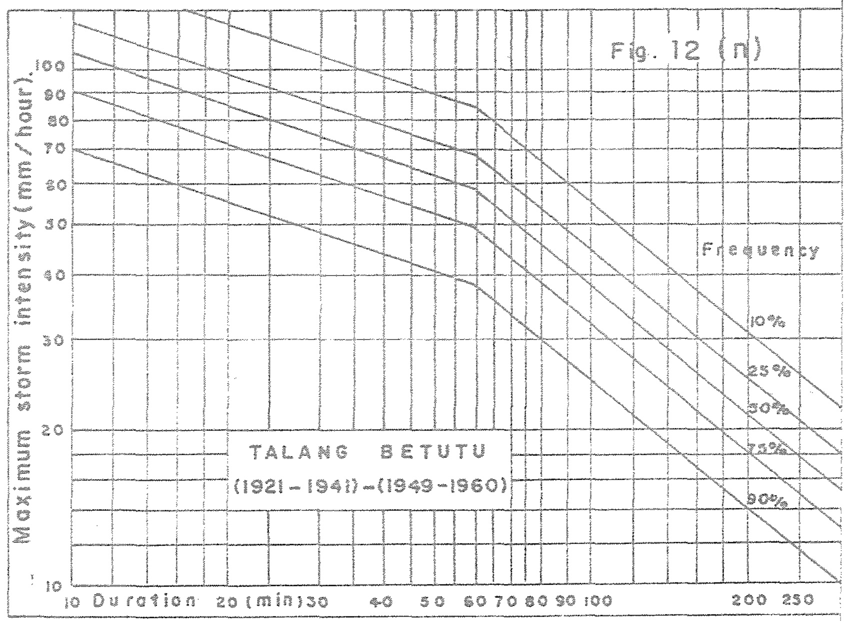


Fig. 12 (n)
Maximum storm intensity (mm/hour).
Frequency
10%
25%
50%
75%
90%
TALANG BETUTU
(1921 – 1941) – (1949 – 1960)
Duration (min)

Fig. 13 Map of maximum rainfall intensities, in mm/h (2-year/15 minute storms)

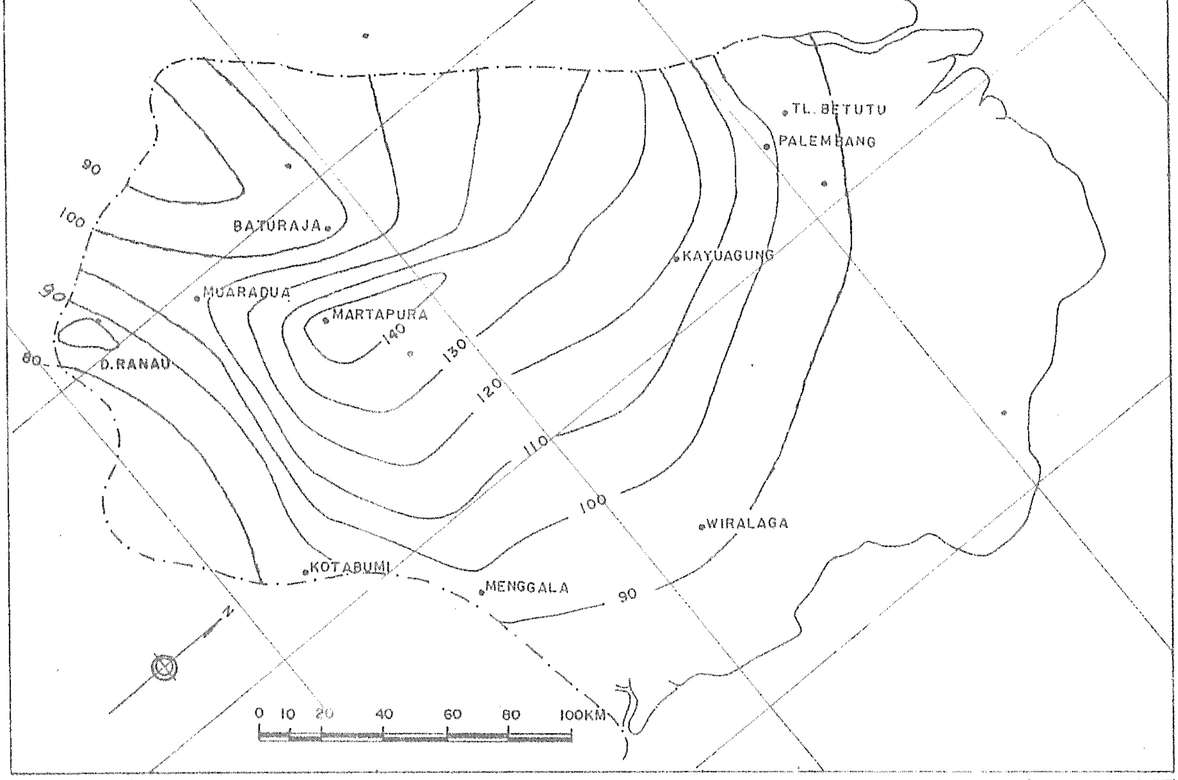
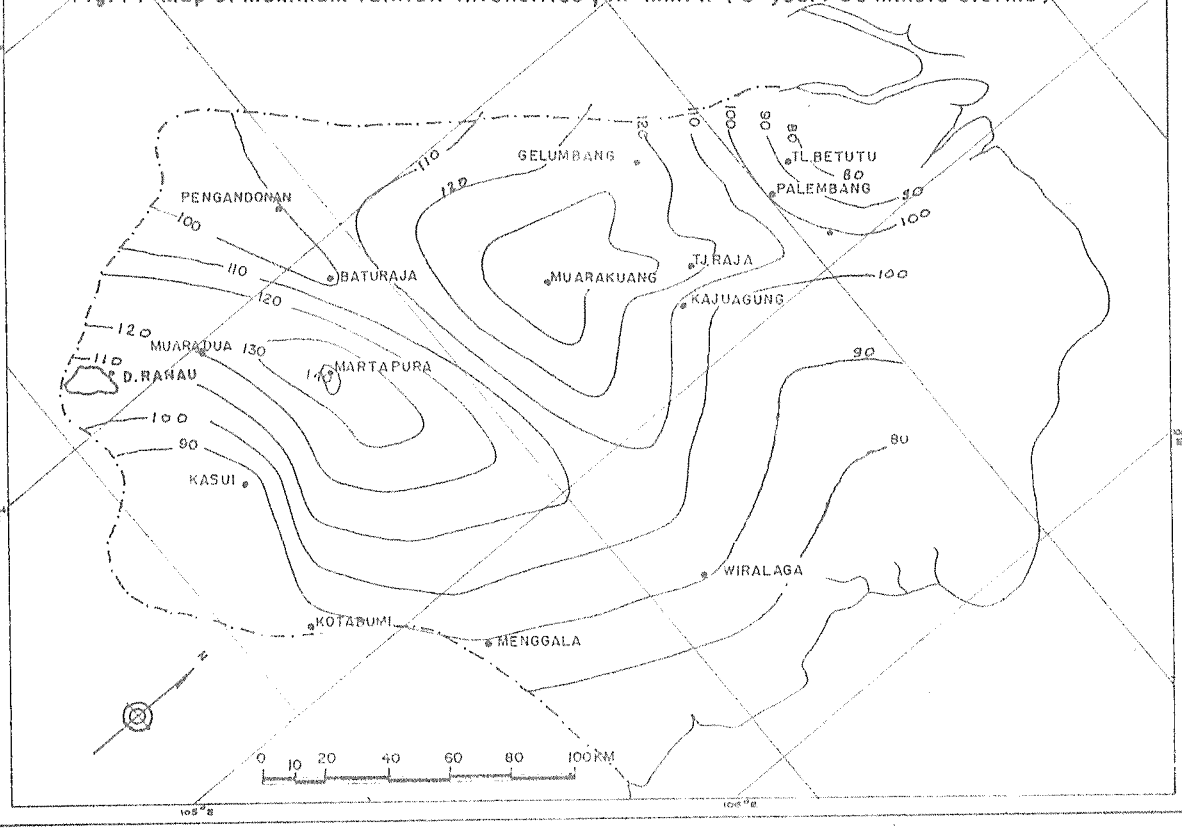



Fig. 14 Map of maximum rainfall intensities, in mm/h (5-year/30 minute storms)



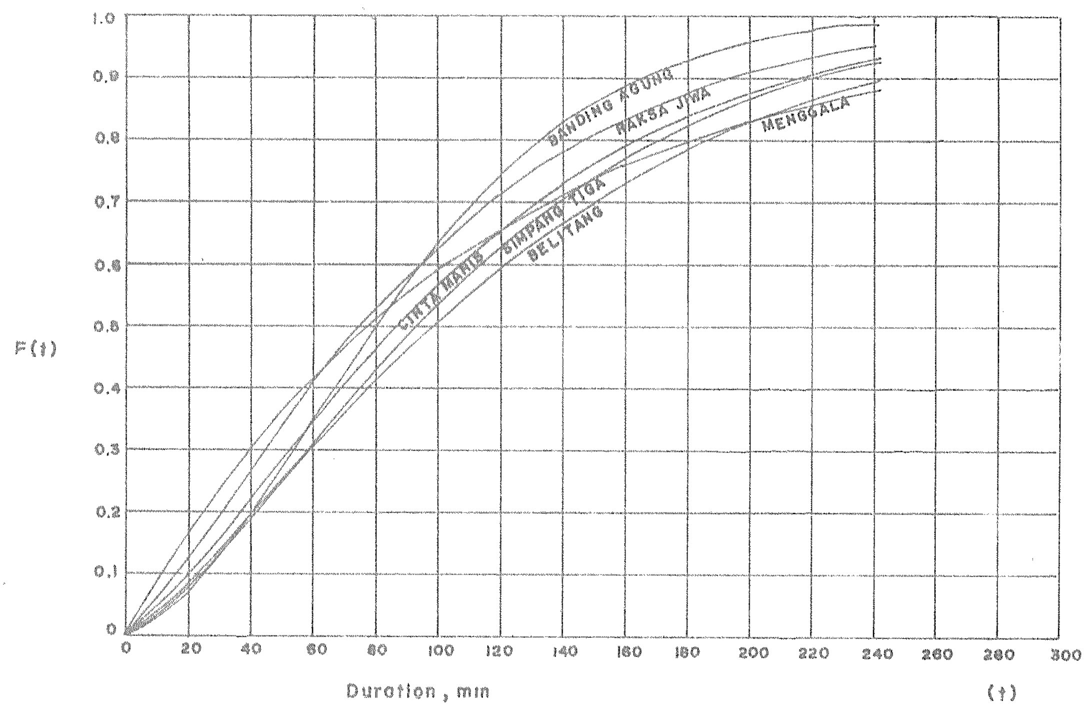



Fig. 15 Cumulative distribution of storm rainfall duration (t)

$$F(t) = 1 - e^{-\left(\frac{t}{\sigma}\right)^{\eta}}$$

Parameters of the Weibull distribution of storm rainfall duration, six stations

| station | $\eta$ | $\sigma$ |
|---|---|---|
| Menggala | 0.99 | 113 |
| Belitang | 1.31 | 180 |
| Cintamanis | 1.33 | 114 |
| Banding Agung | 1.65 | 100 |
| Simpang Tiga | 1.40 | 122 |
| Raksa Jiwa | 1.26 | 101 |

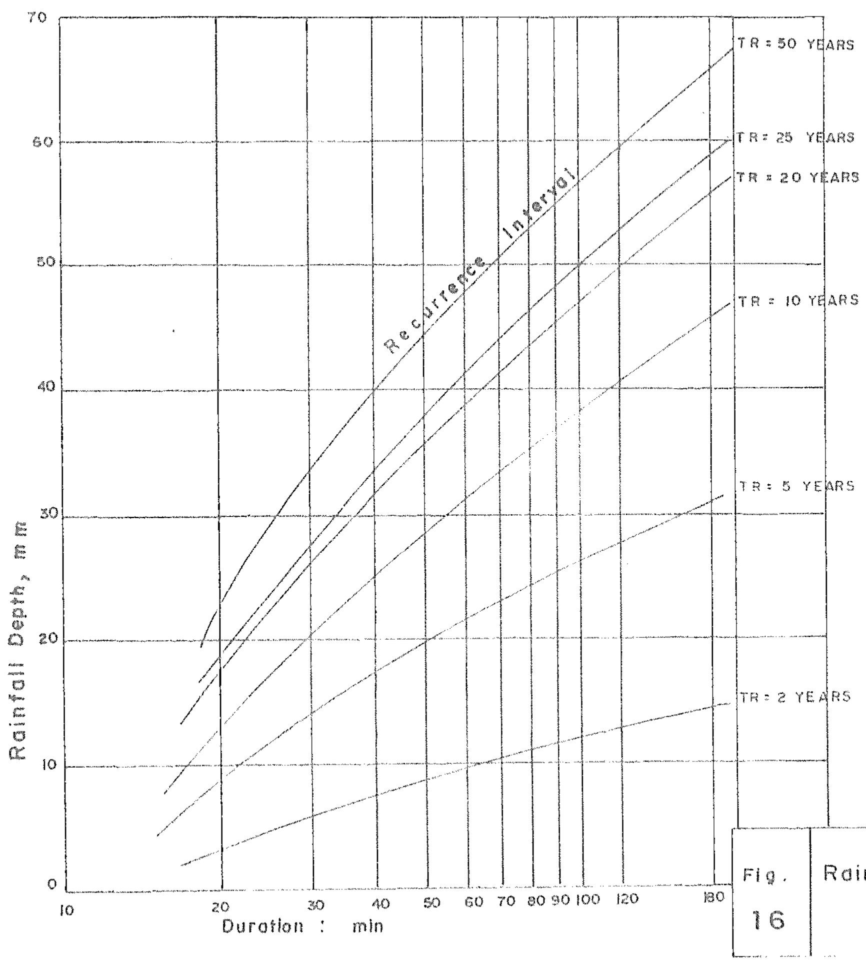



Fig. 16 Rainfall Depth Duration Curves (average Project area)

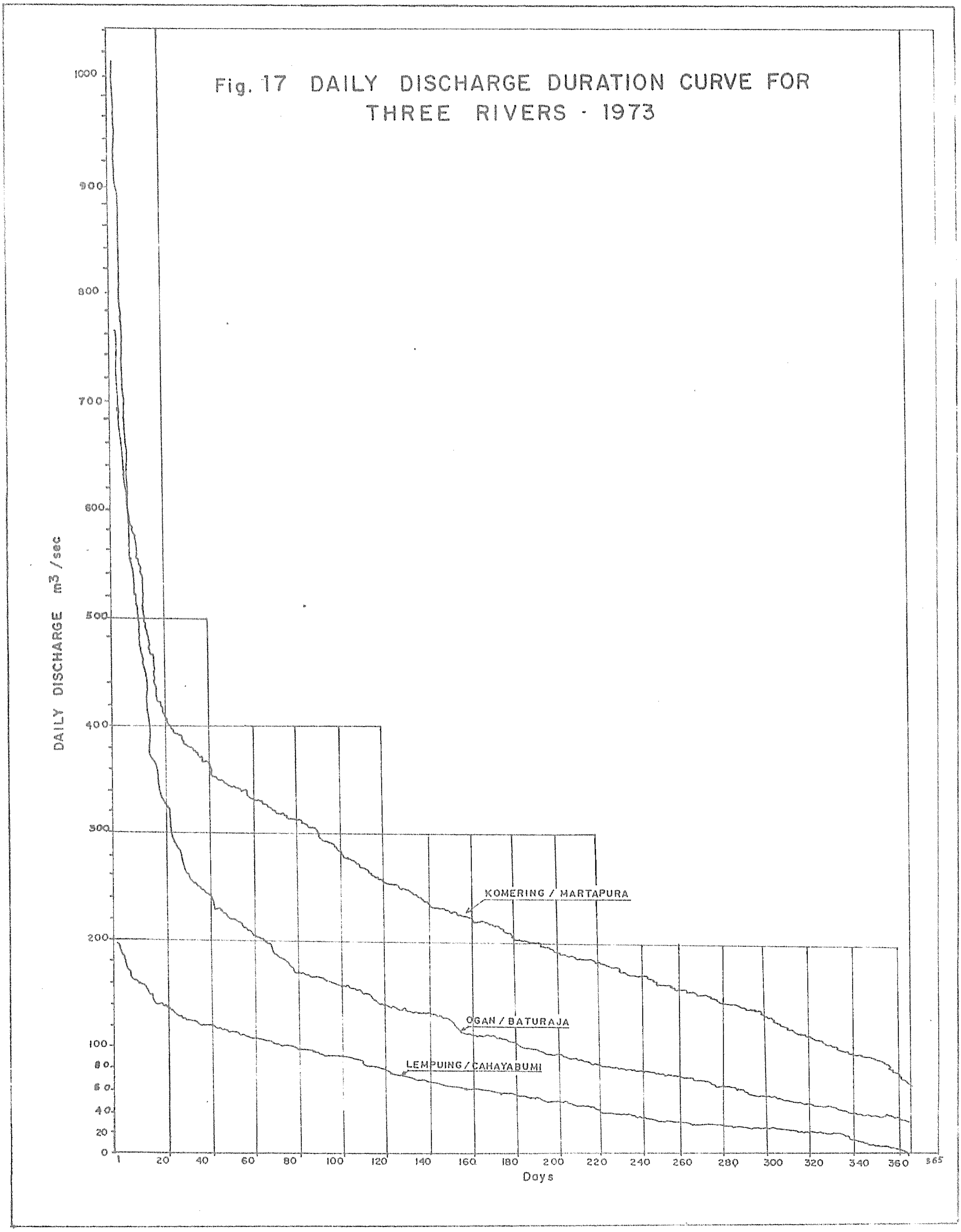


Fig. 17 DAILY DISCHARGE DURATION CURVE FOR THREE RIVERS - 1973
DAILY DISCHARGE m3 /sec
1000
900
800
700
600
500
400
300
200
100
80
60
40
20
0
KOMERING / MARTAPURA
OGAN / BATURAJA
LEMPUING / CAHAYABUMI
1
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
365
Days

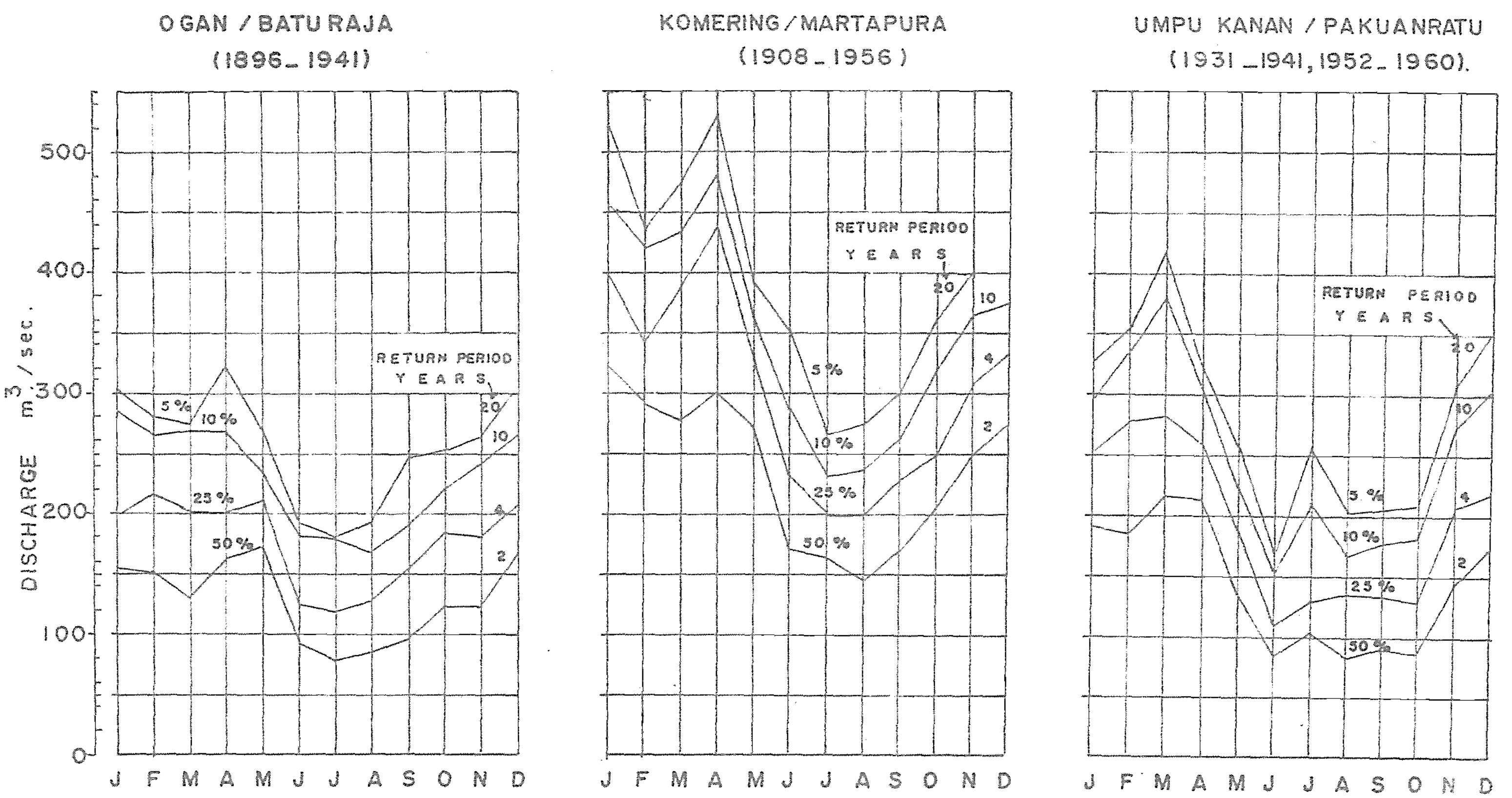



Fig. 18 : RELATIVE FREQUENCY OF MONTHLY SIMULATED DISCHARGE %.

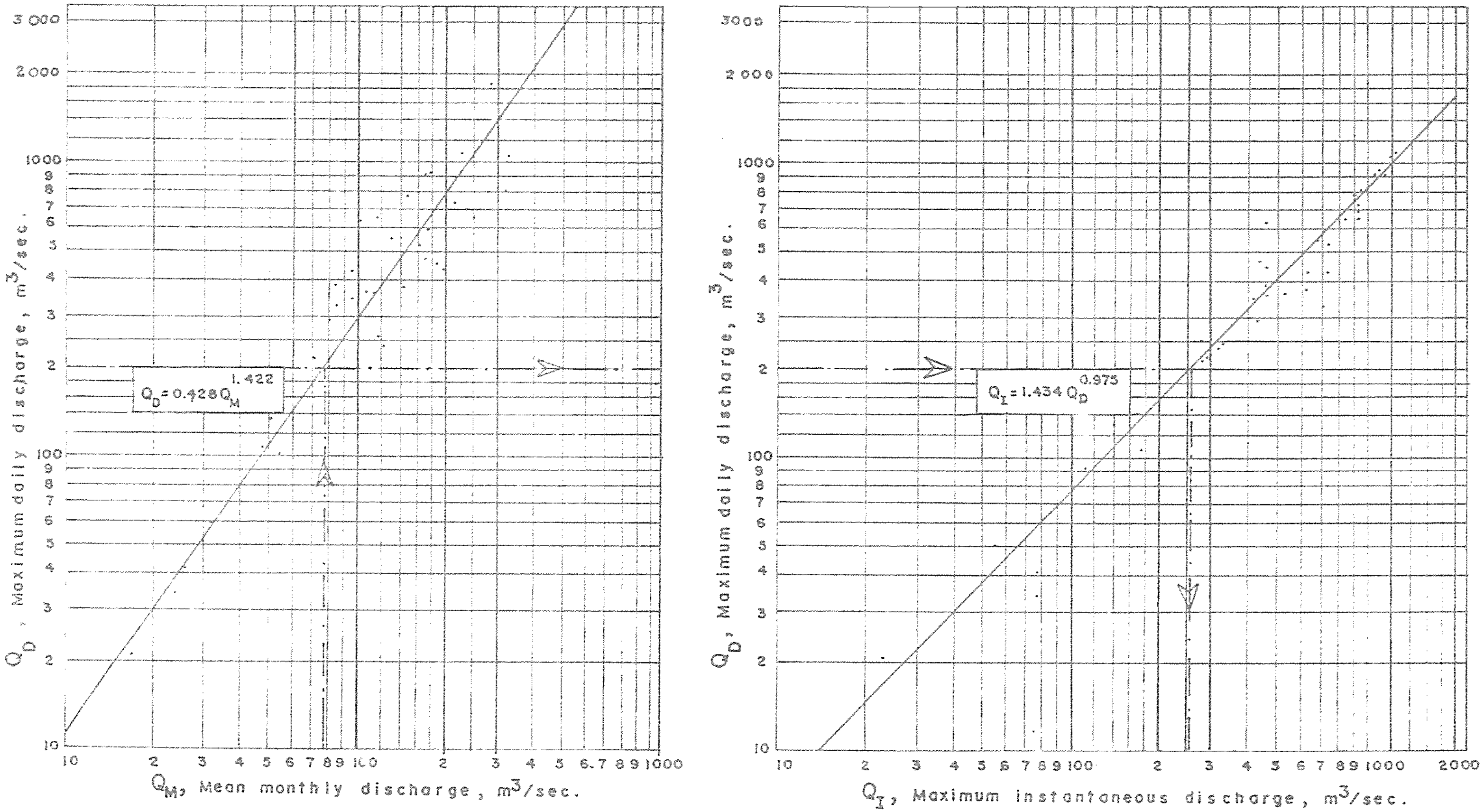



Fig. 19 - Relationship of mean monthly, maximum daily and maximum instantaneous discharge

OGAN RIVER AT BATURAJA.

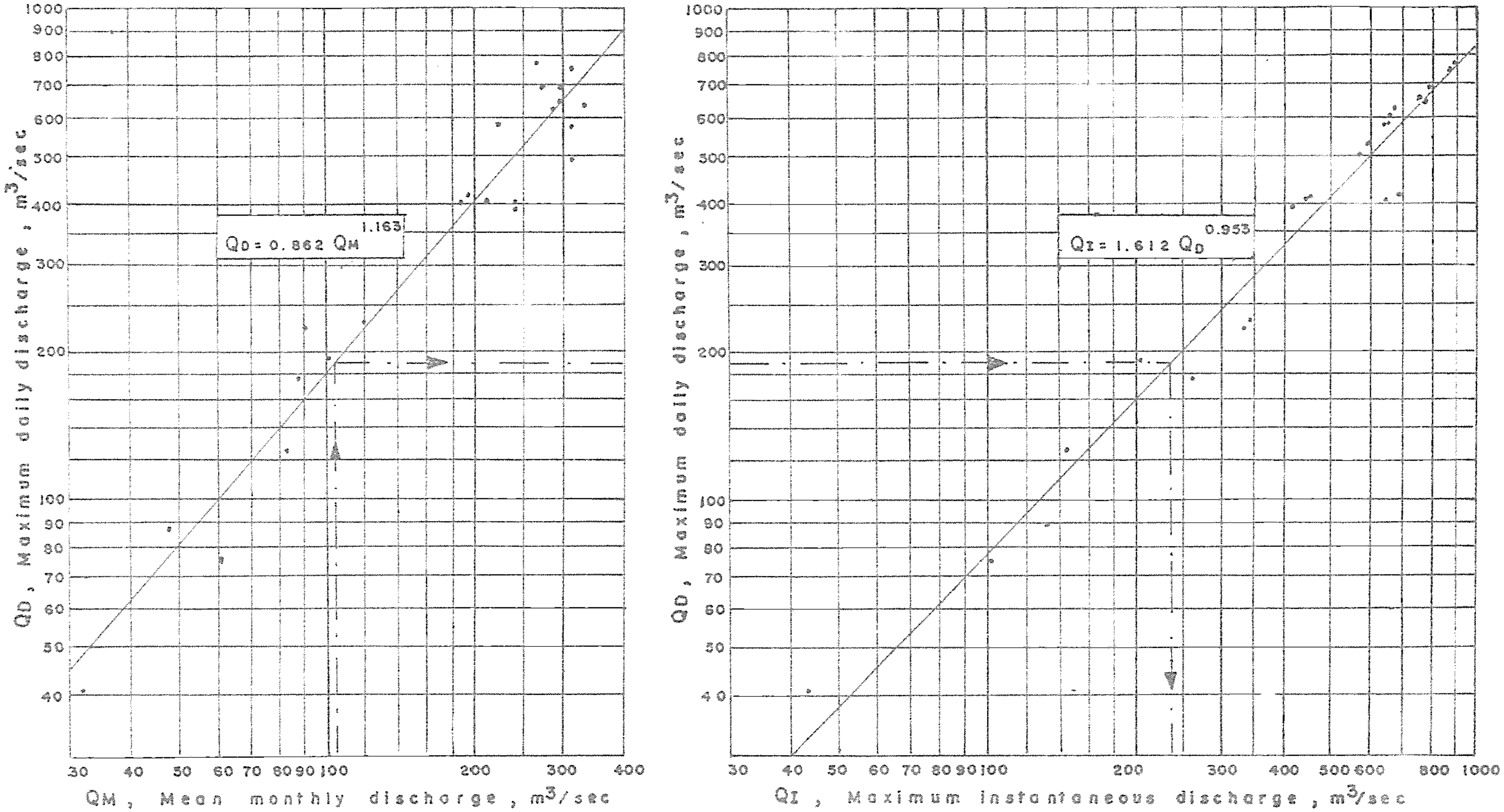



Fig. 20 Relationship of mean monthly, maximum daily and maximum instantaneous discharge

KOMERING RIVER AT MARTAPURA

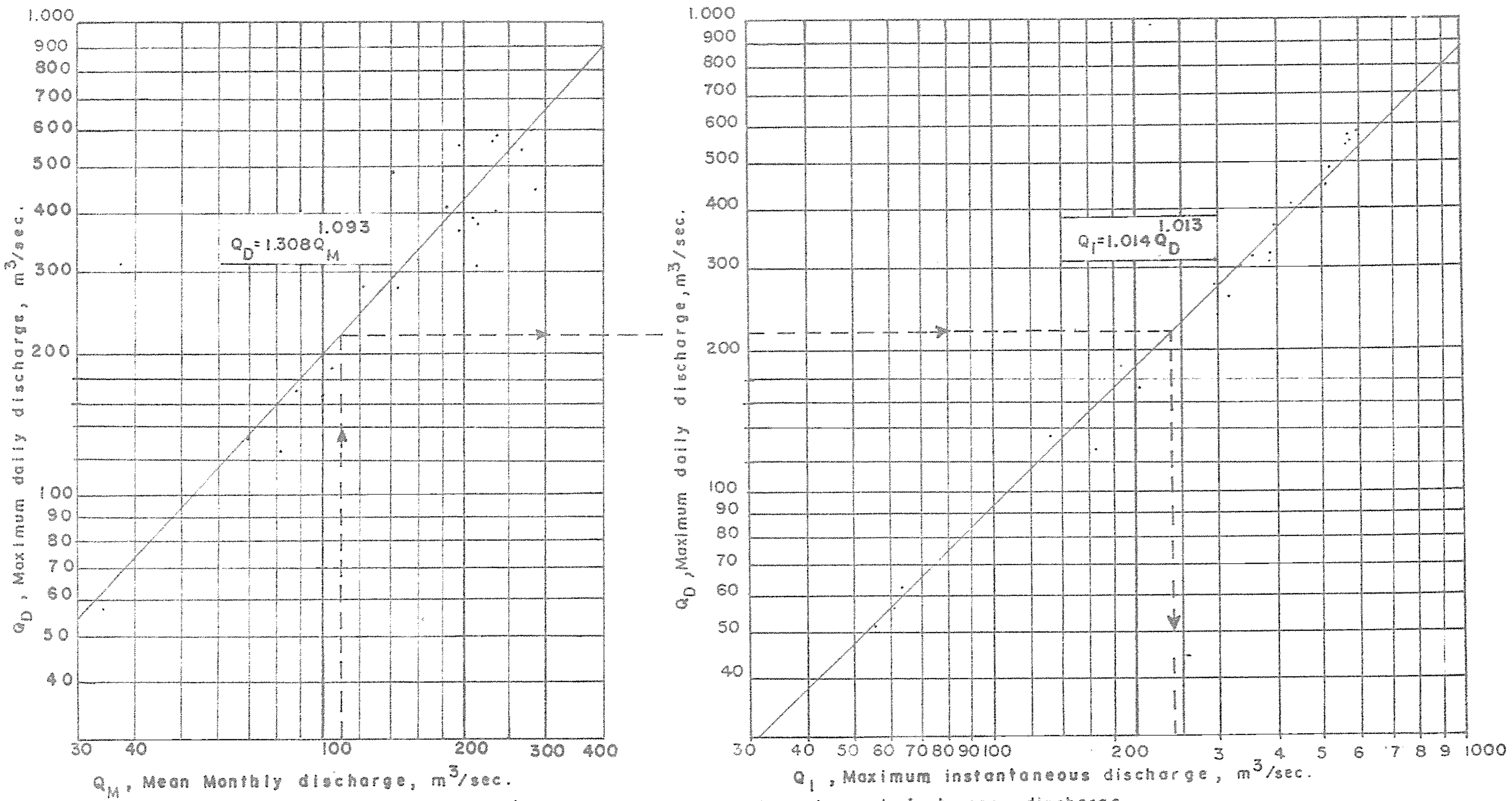
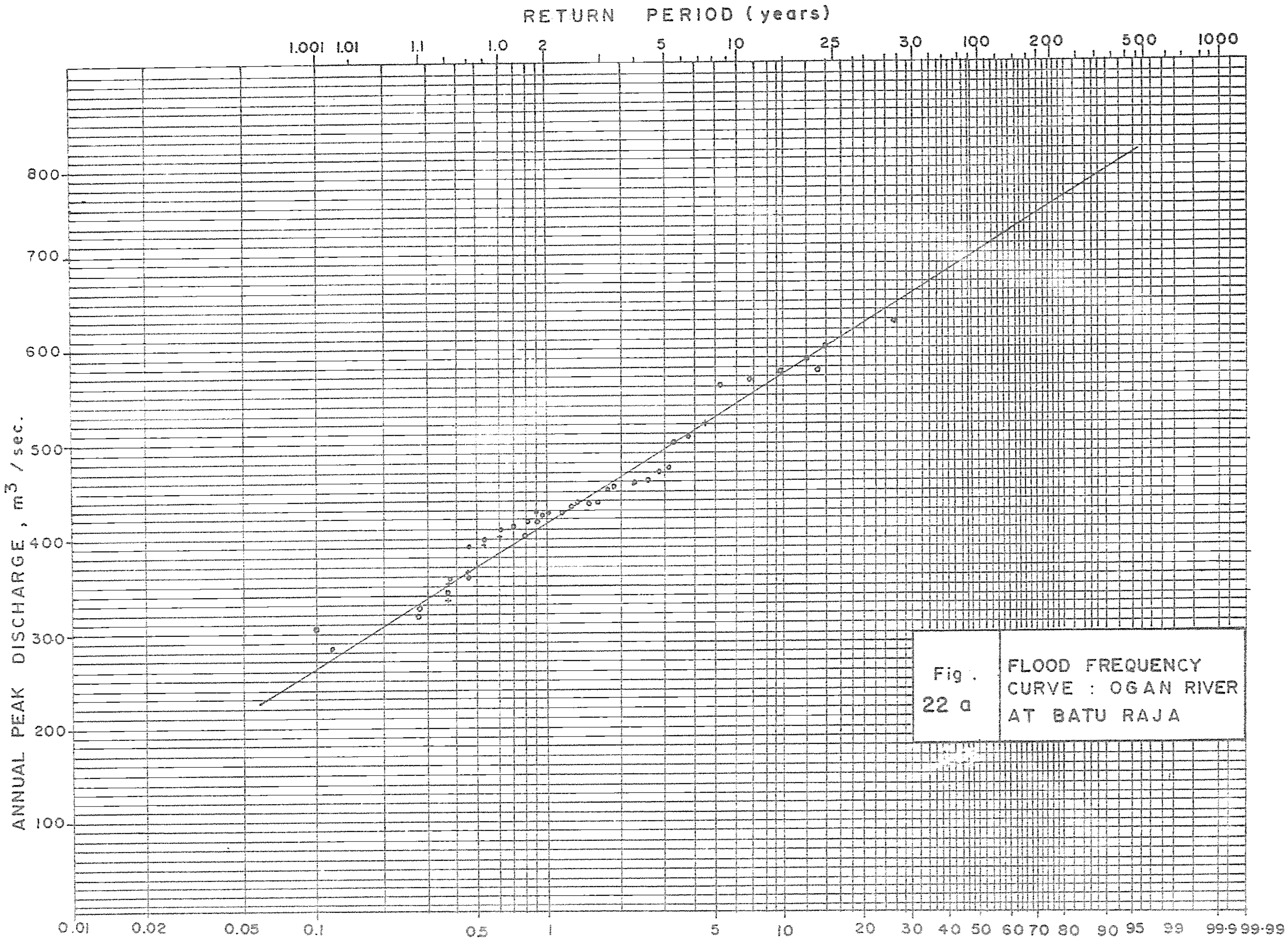



Fig. 21 Relationship of mean monthly, maximum daily and maximum instantaneous discharge

Umpu Kanan river of Pakuan Ratu.

Fig. 22 FLOOD FREQUENCY CURVE - OGAN, KOMERING AND UMPU KANAN RIVERS



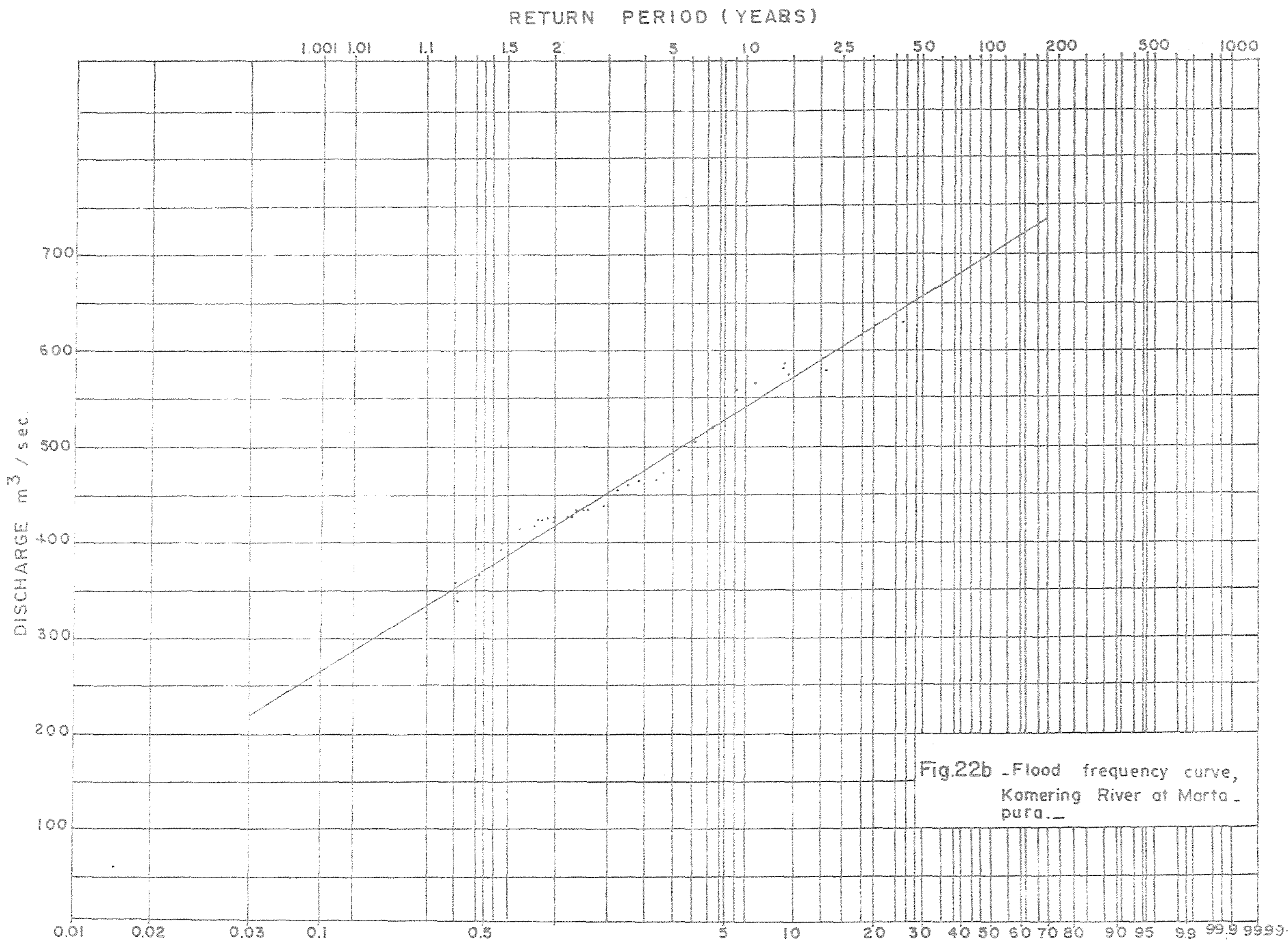



Fig.22b – Flood frequency curve, Komering River at Martapura.

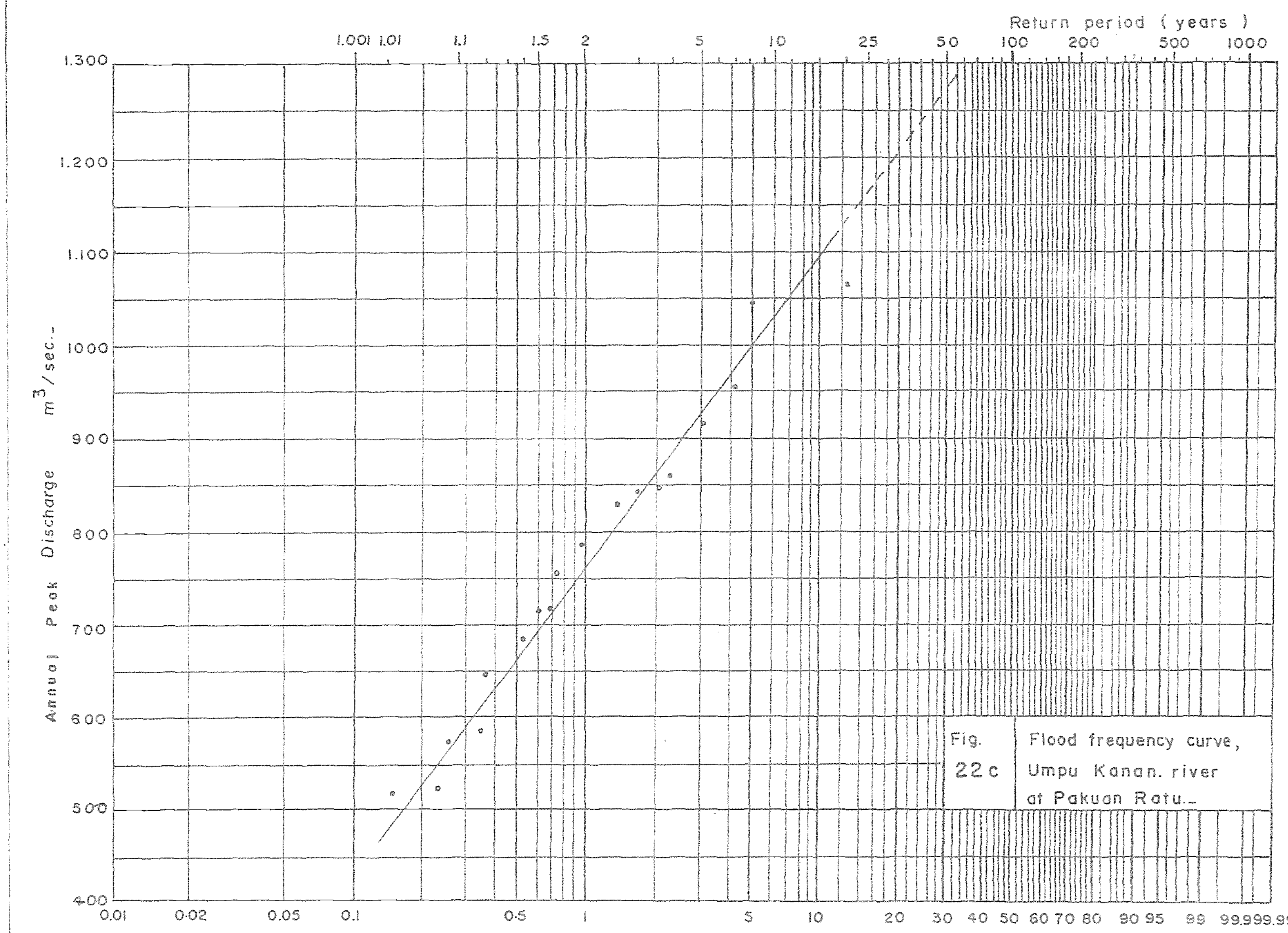



Fig. 22c Flood frequency curve, Umpu Kanan. river at Pakuan Ratu.

Fig. 23 - RELATION BETWEEN EXPECTED LIFE OF PROJECT AND DESIGN DISCHARGE - OGAN, KOMERING AND UMPU KANAN RIVERS.

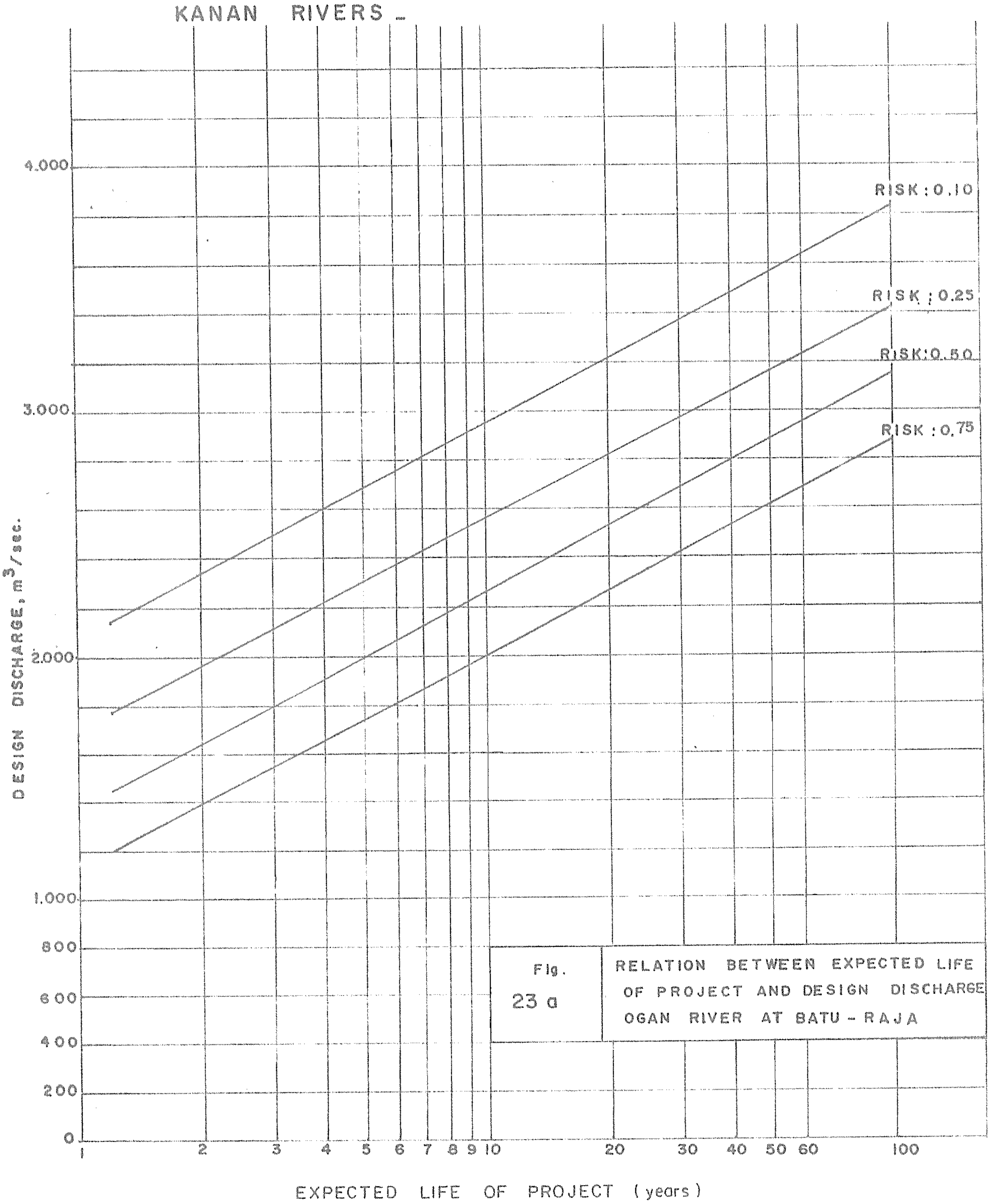



Fig. 23 a RELATION BETWEEN EXPECTED LIFE OF PROJECT AND DESIGN DISCHARGE OGAN RIVER AT BATU-RAJA

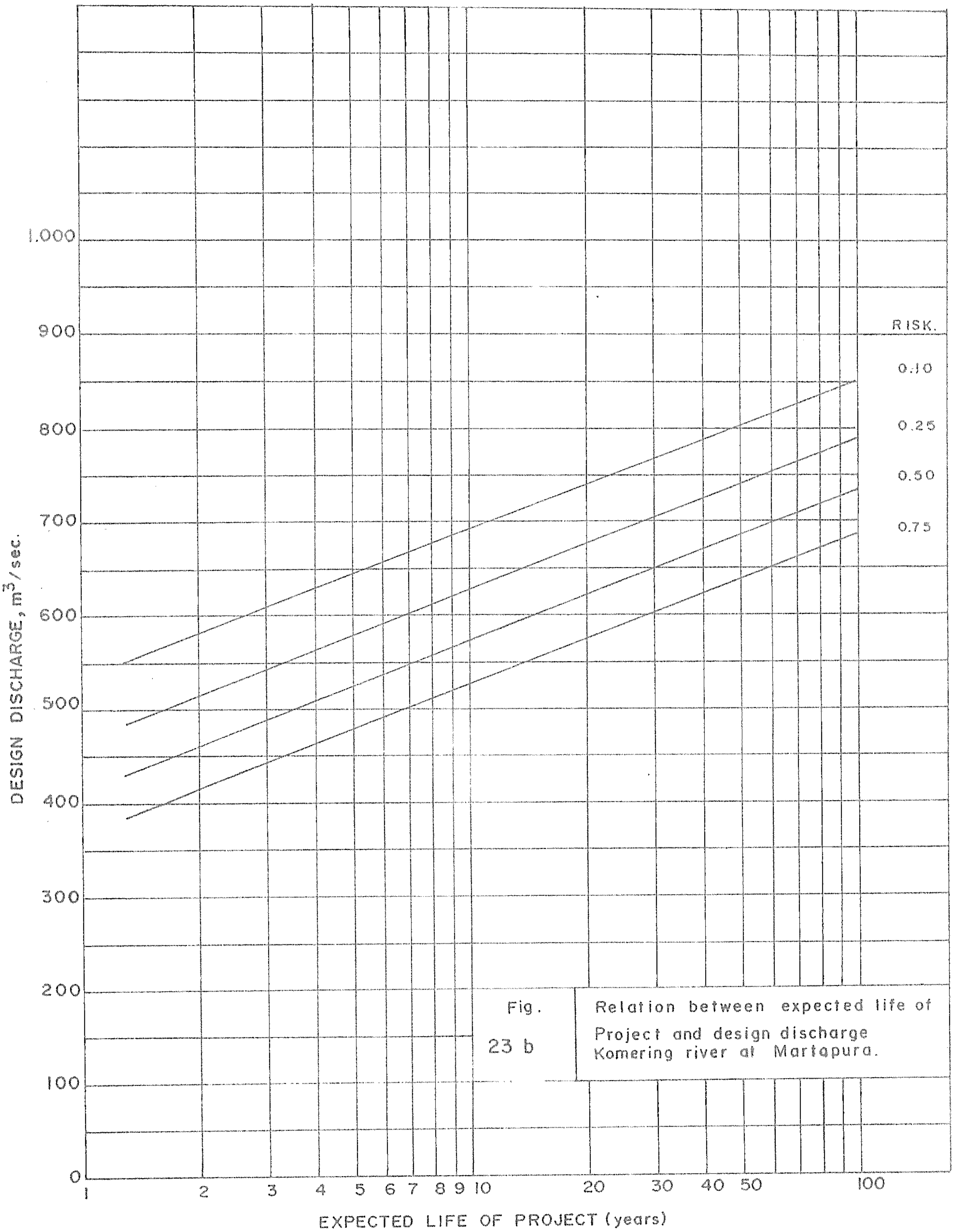



Fig. 23 b Relation between expected life of Project and design discharge Komering river at Martapura.

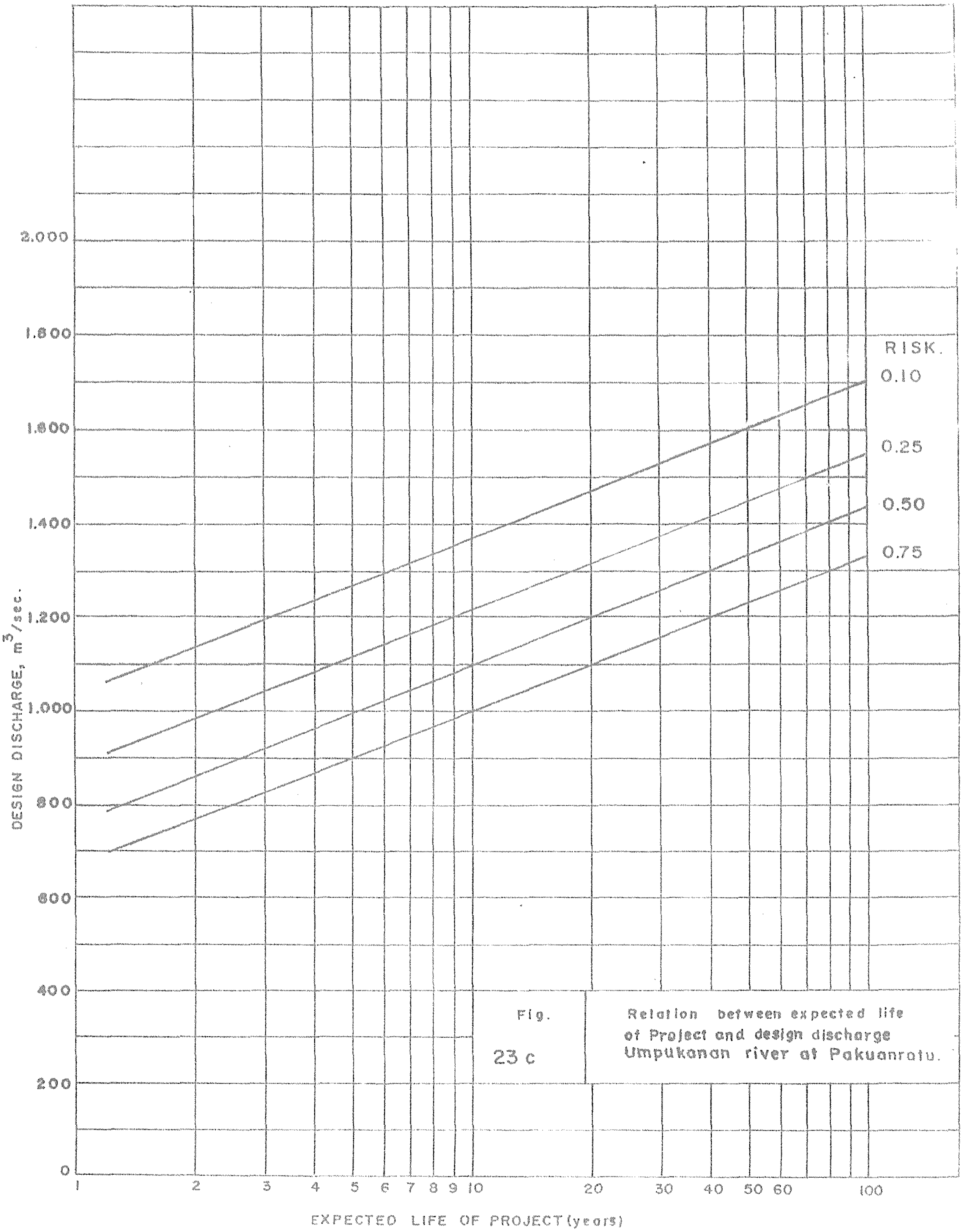



Fig. 23 c Relation between expected life of Project and design discharge Umpukanan river at Pakuanrotu.

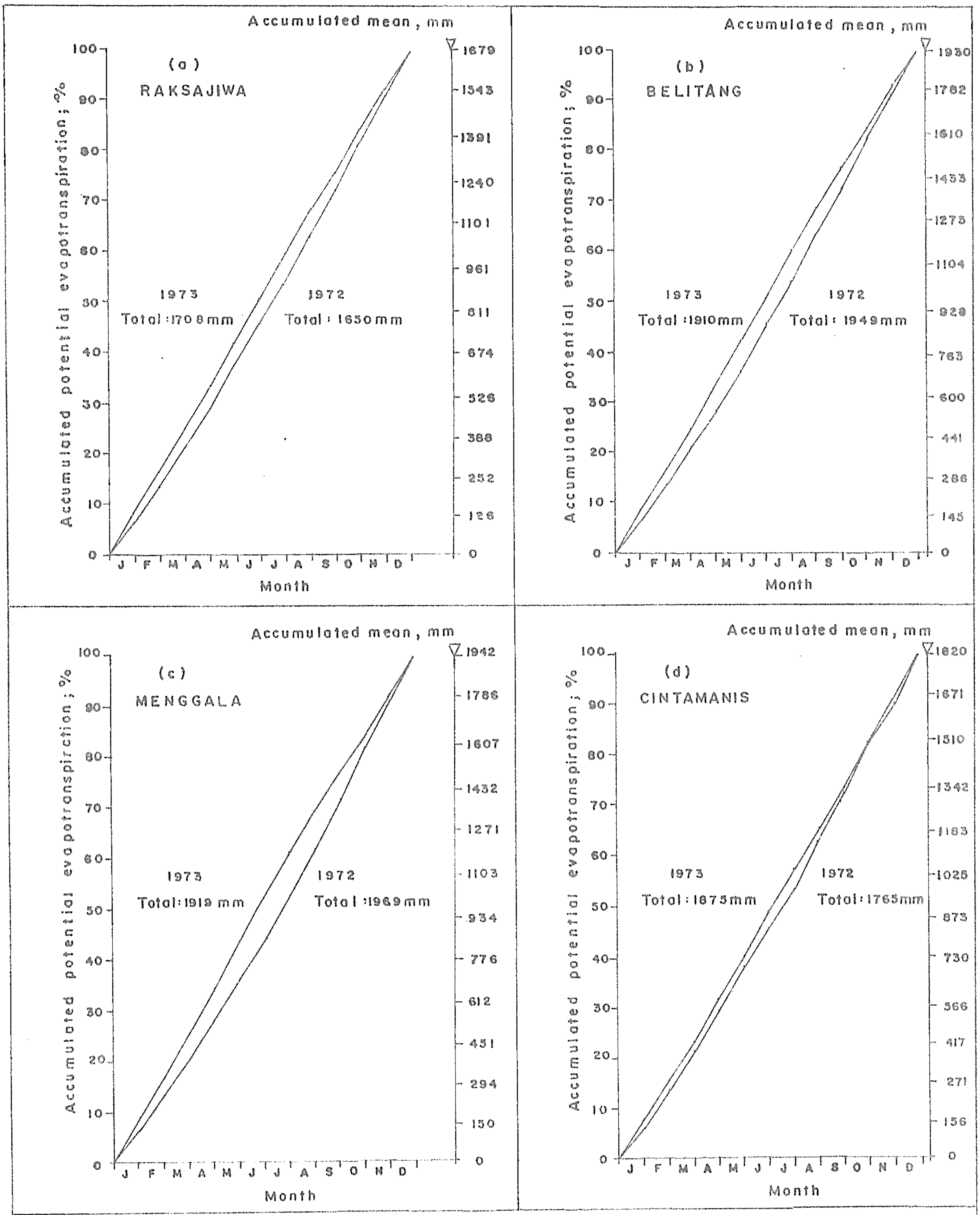



Fig. 24 Percentage distribution of monthly potential evapotranspiration.

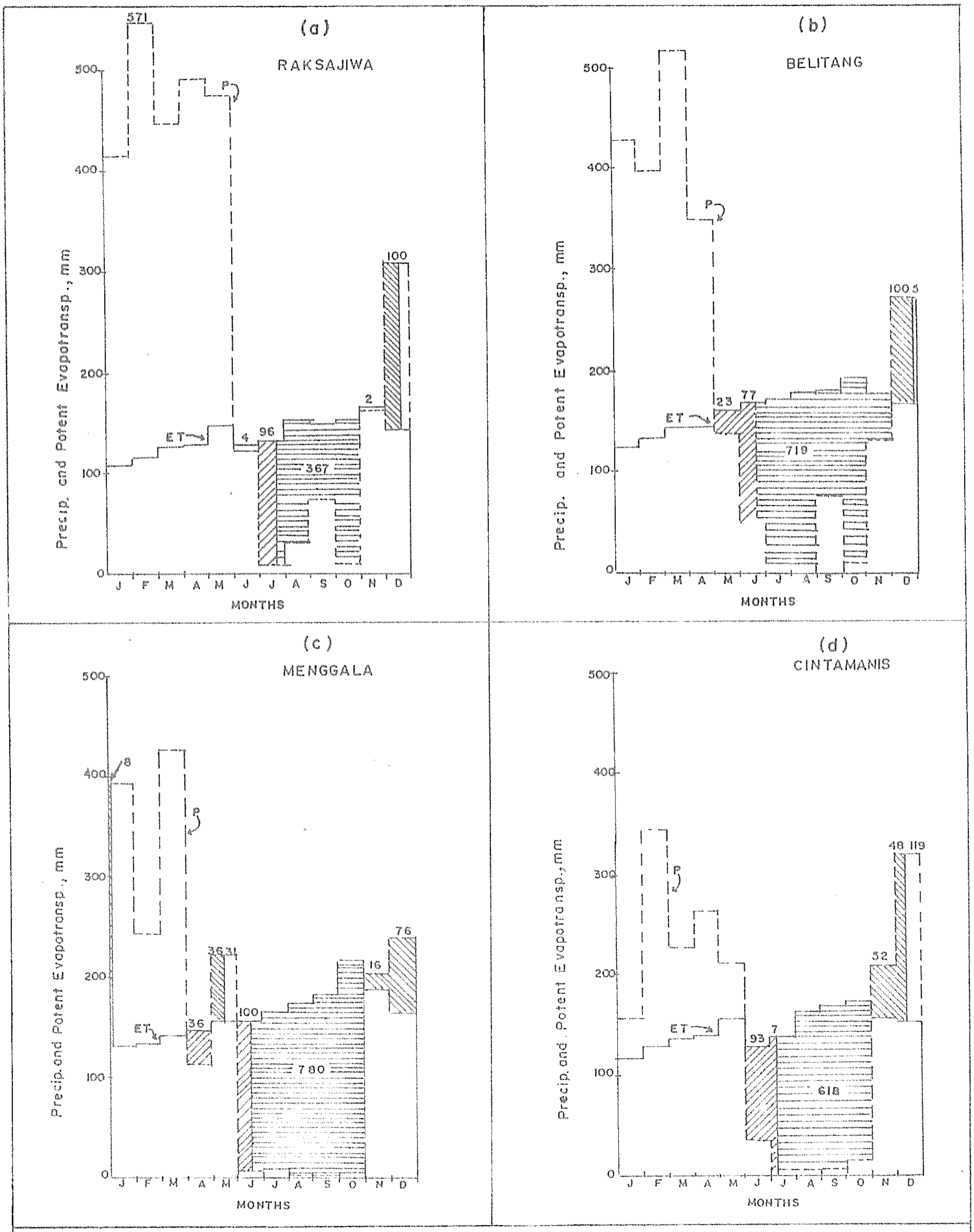



Fig. 25 HYDROLOGIC BALANCE . 1972

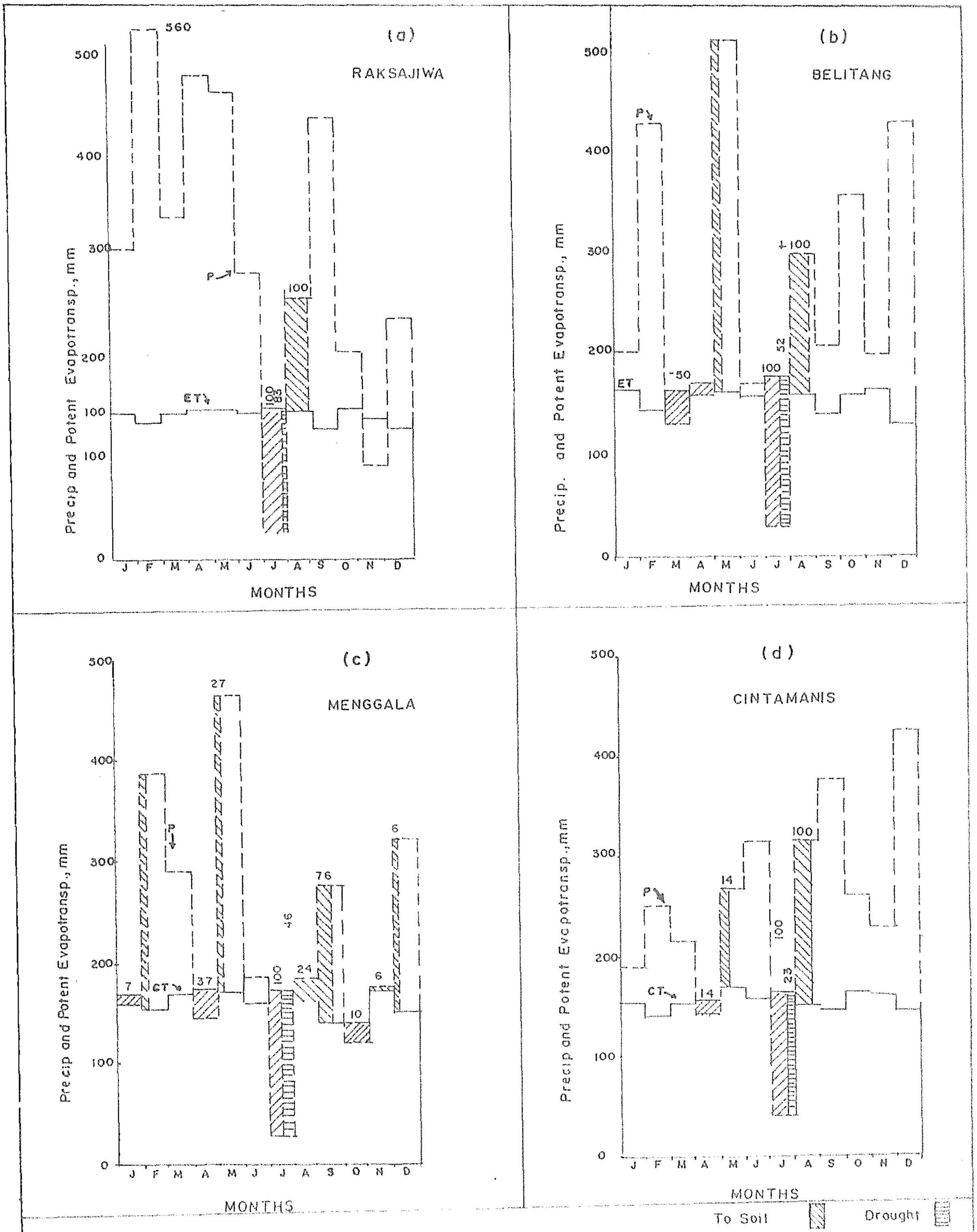



Fig. 26 Hydrologic balance : 1973

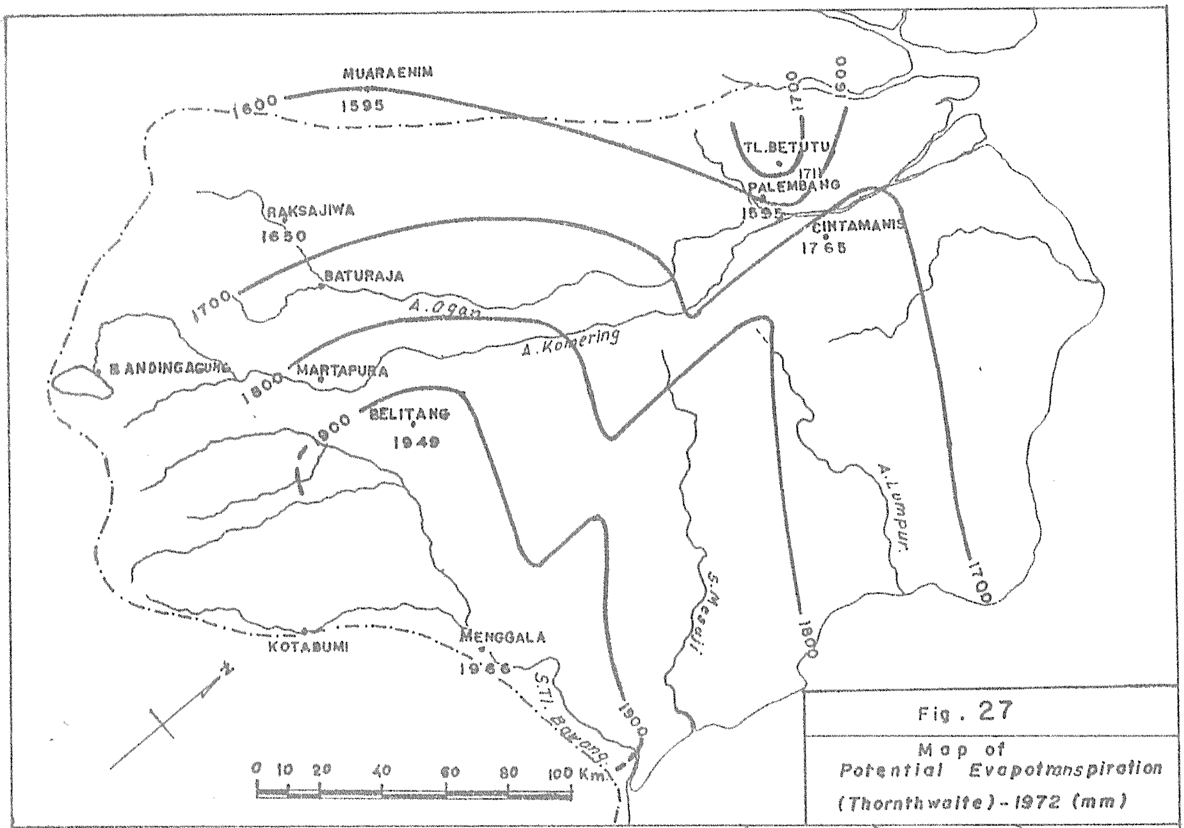



Fig. 27
Map of Potential Evapotranspiration (Thornthwaite) - 1972 (mm)

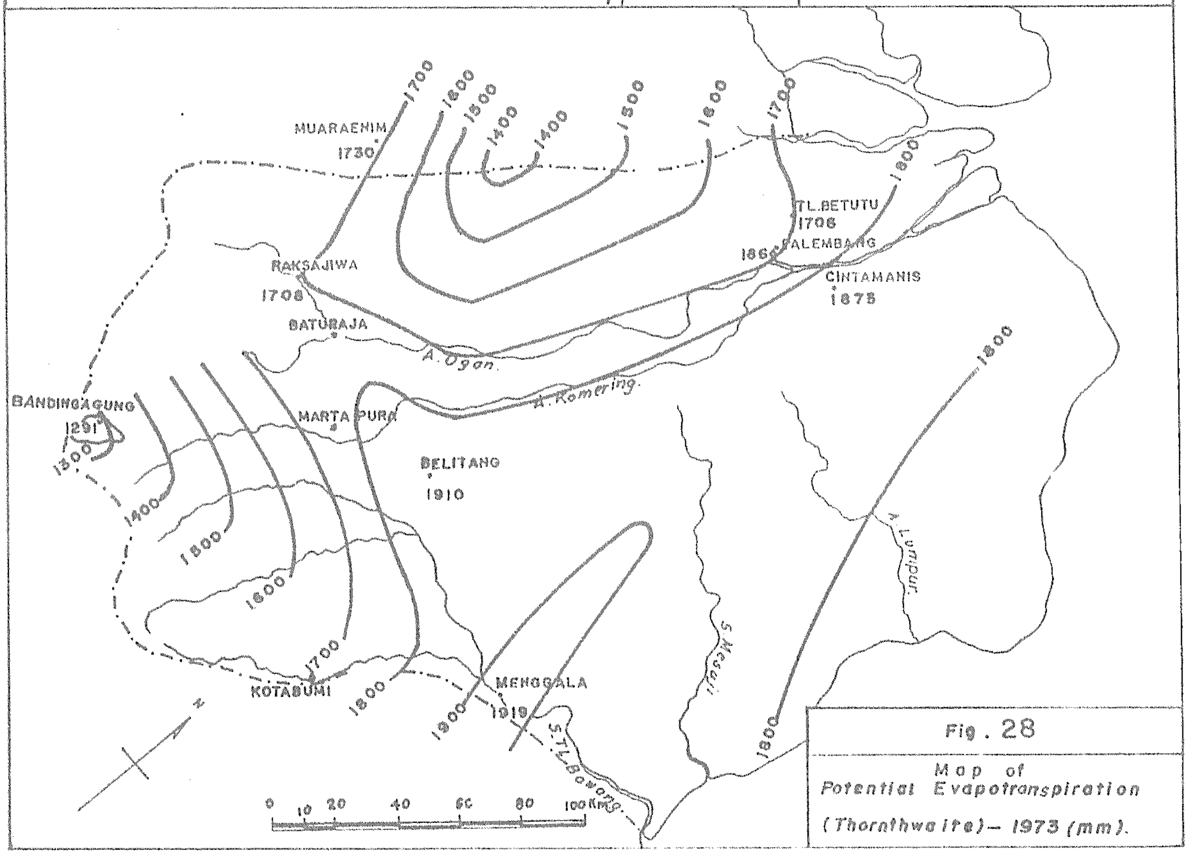



Fig. 28
Map of Potential Evapotranspiration (Thornthwaite) – 1973 (mm).

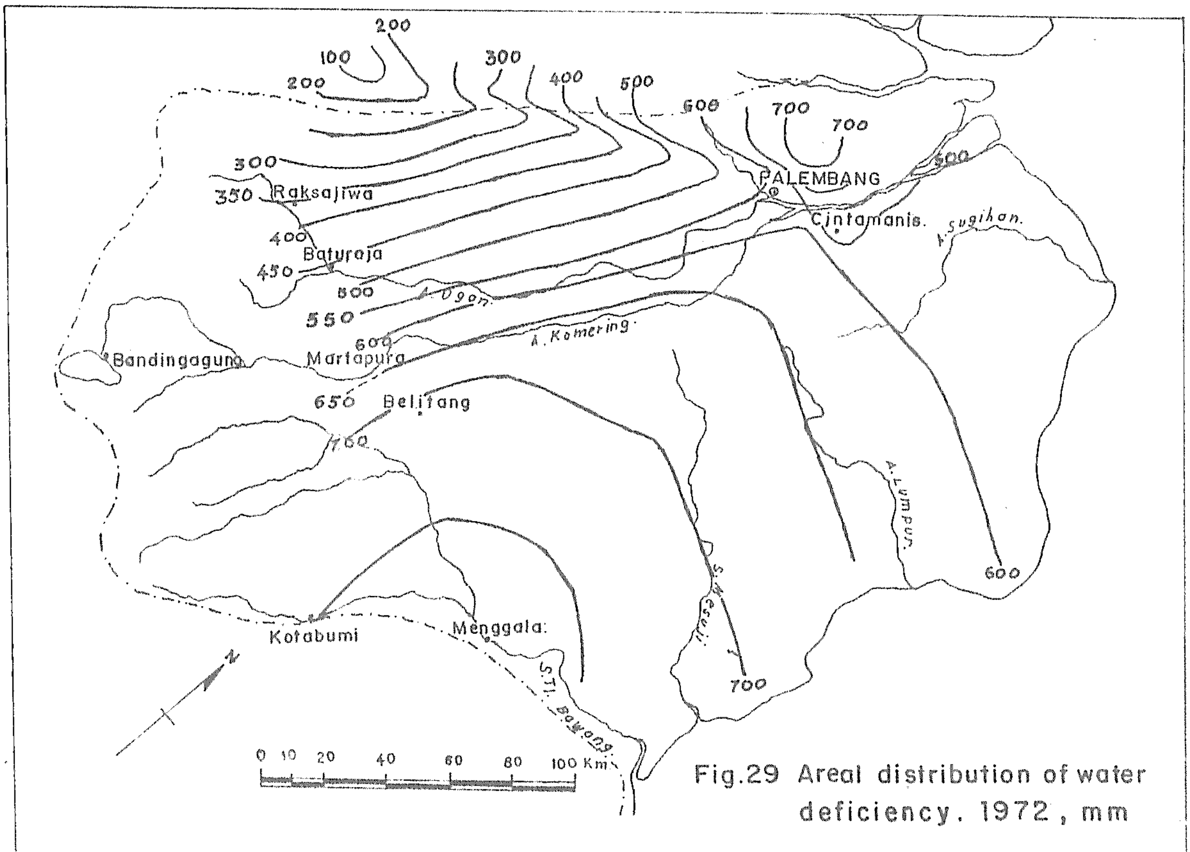



Fig.29 Areal distribution of water deficiency. 1972, mm

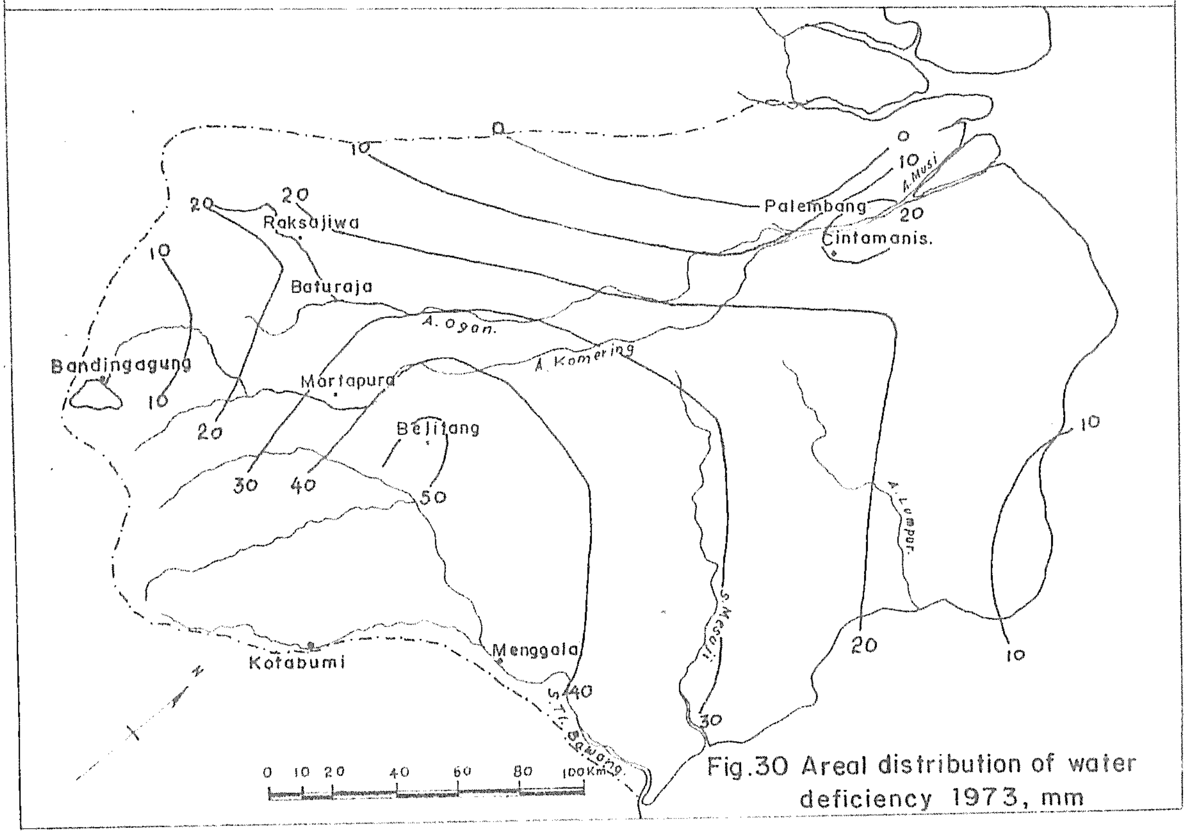



Fig.30 Areal distribution of water deficiency 1973, mm

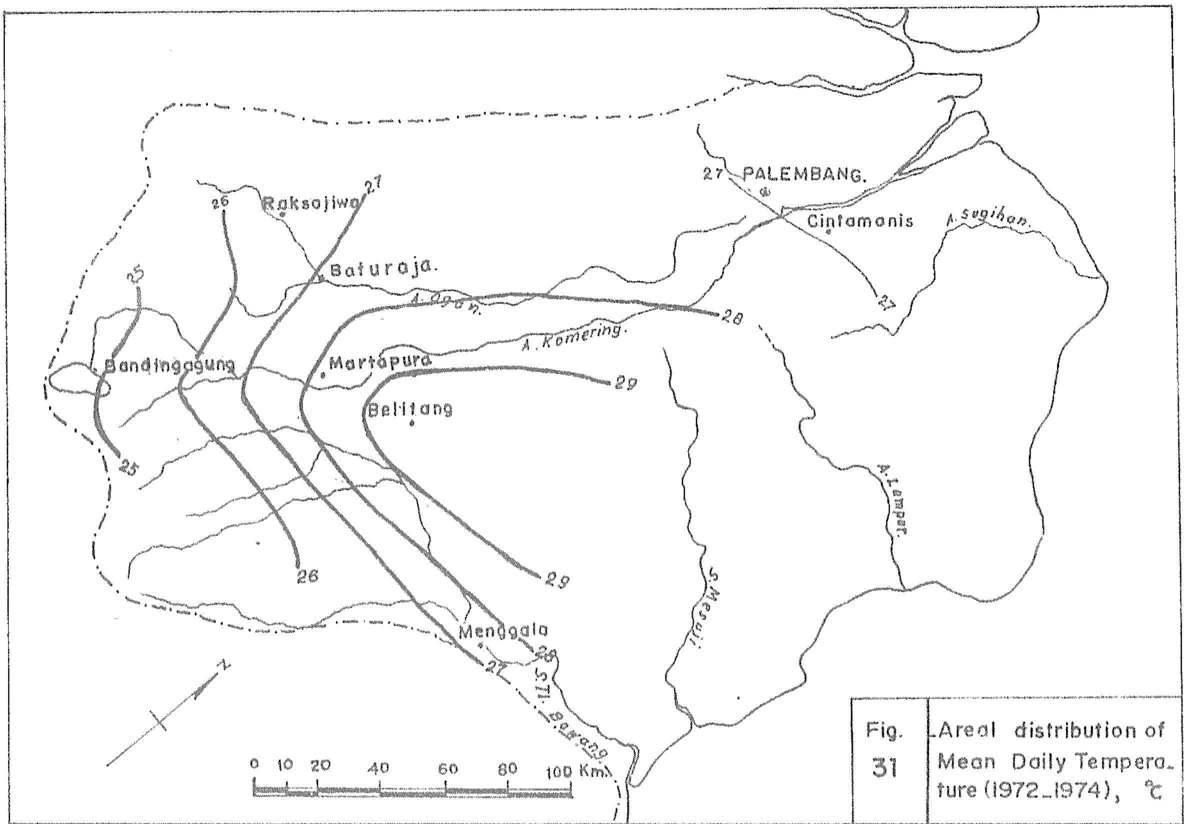



Fig. 31 Areal distribution of Mean Daily Temperature (1972_1974), °C

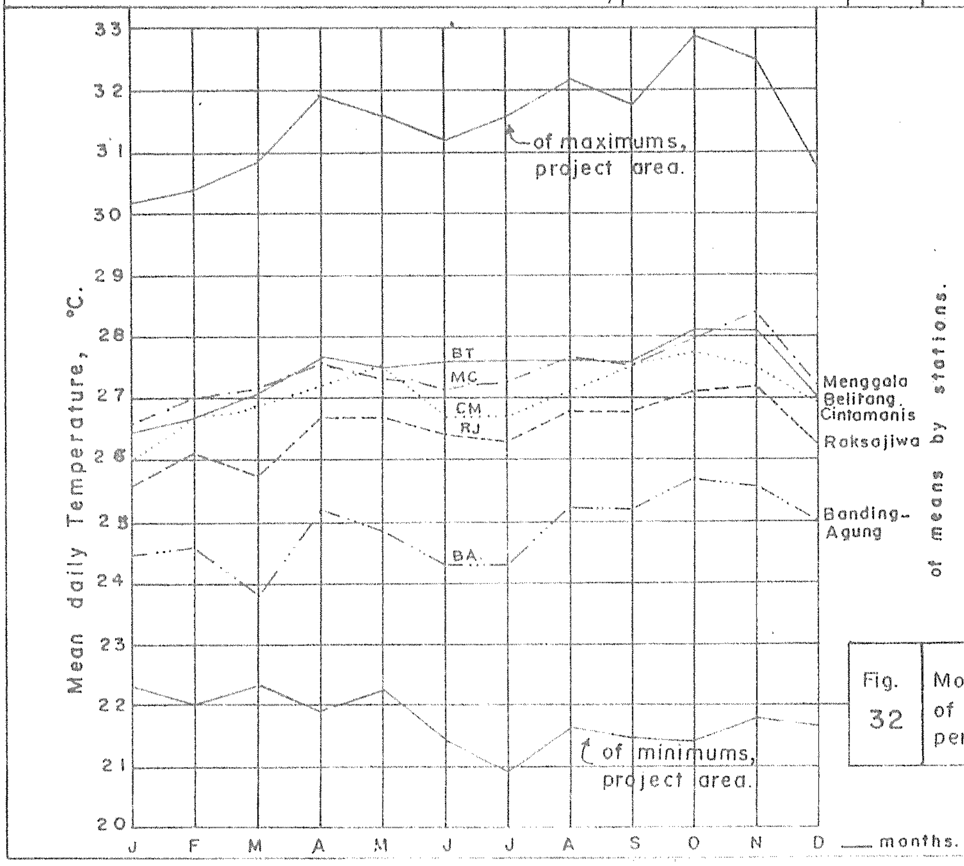



Fig. 32 Monthly distribution of Mean Daily Temperature (1972_1974), °C

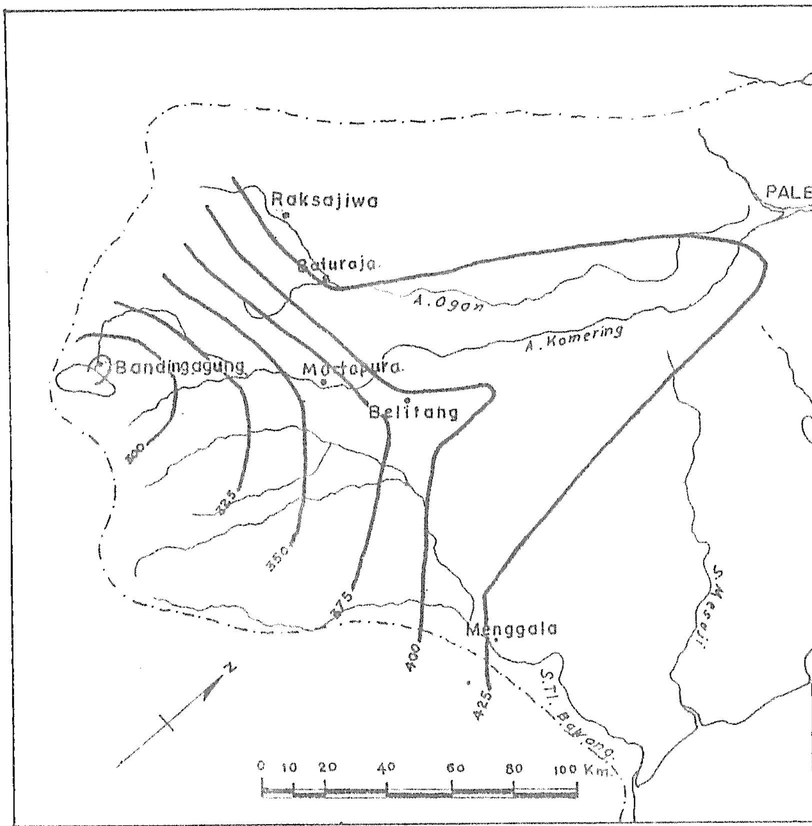



Fig. 33 _Areal distribution of Solar Radiation (1972_1974) gm.cal/cm²/day.

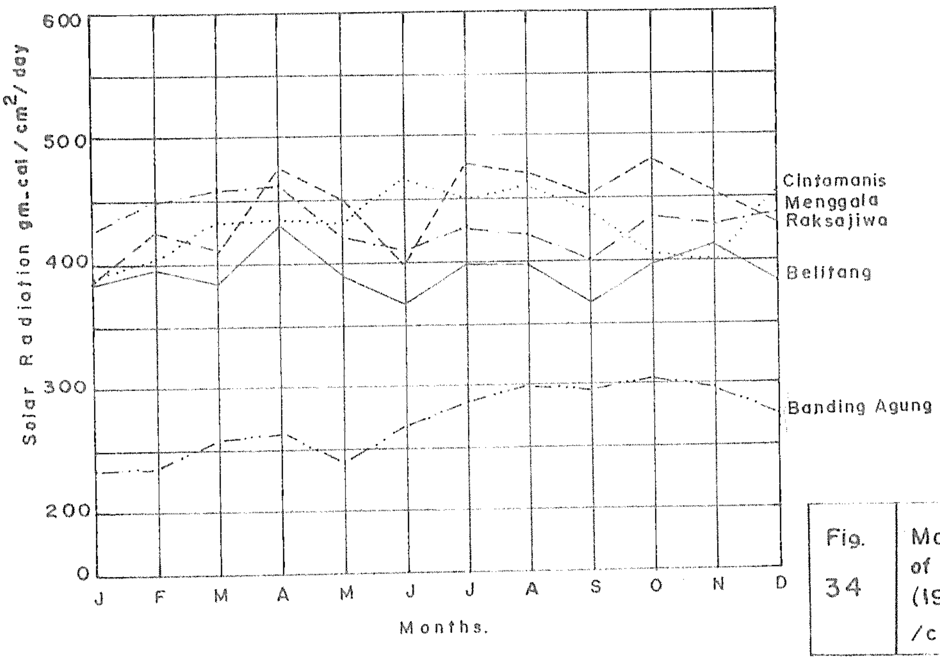



Fig. 34 Monthly variation of solar Radiation (1972-1974) gm.cal /cm²/day.

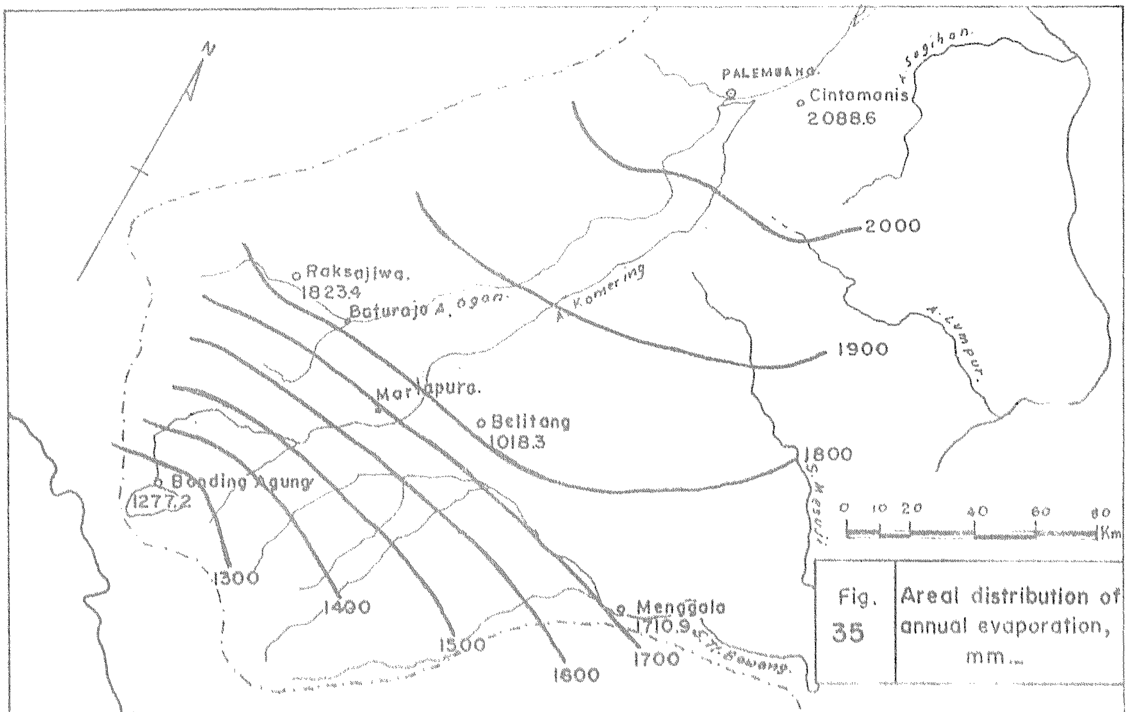



Fig. 35 Areal distribution of annual evaporation, mm.

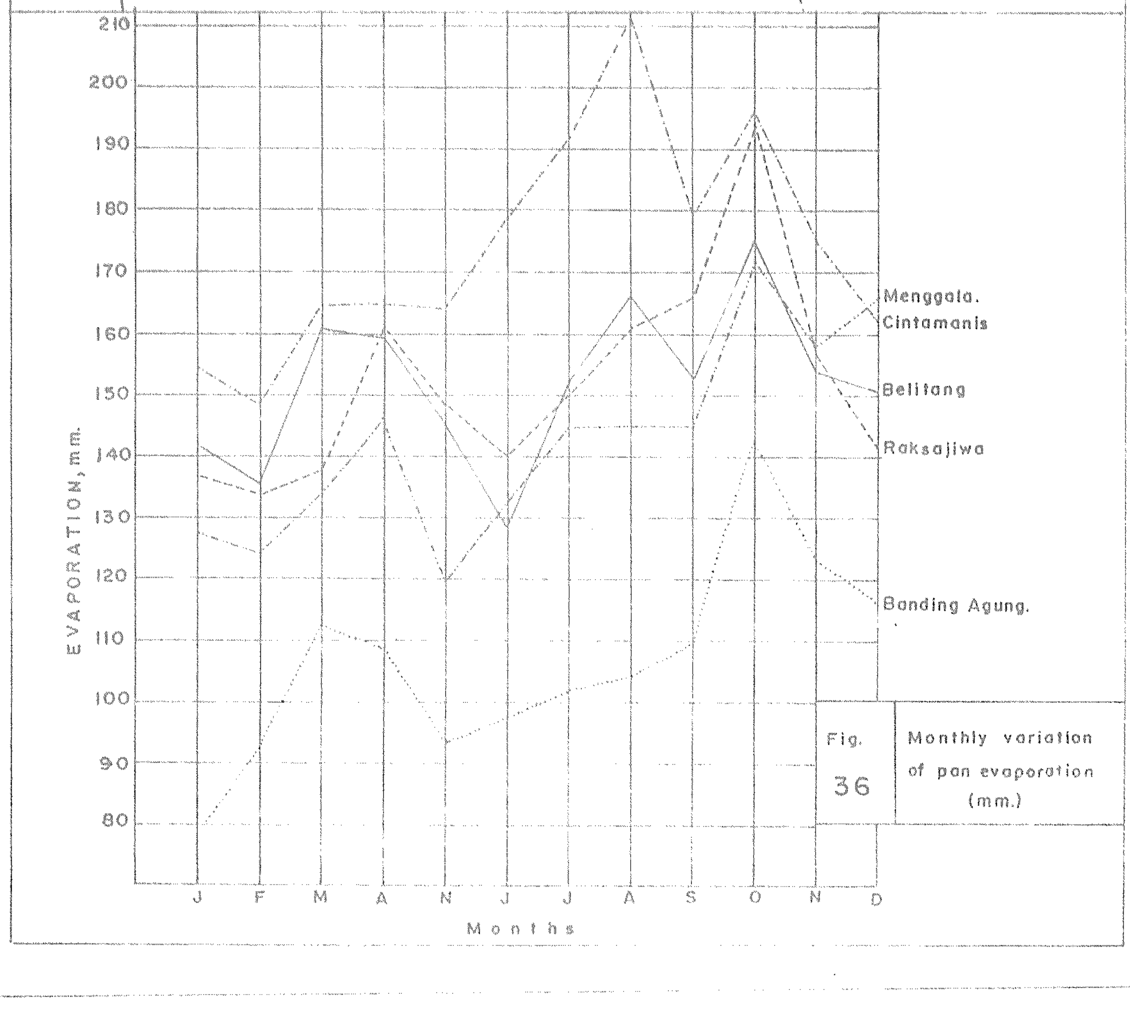



Fig. 36 Monthly variation of pan evaporation (mm.)

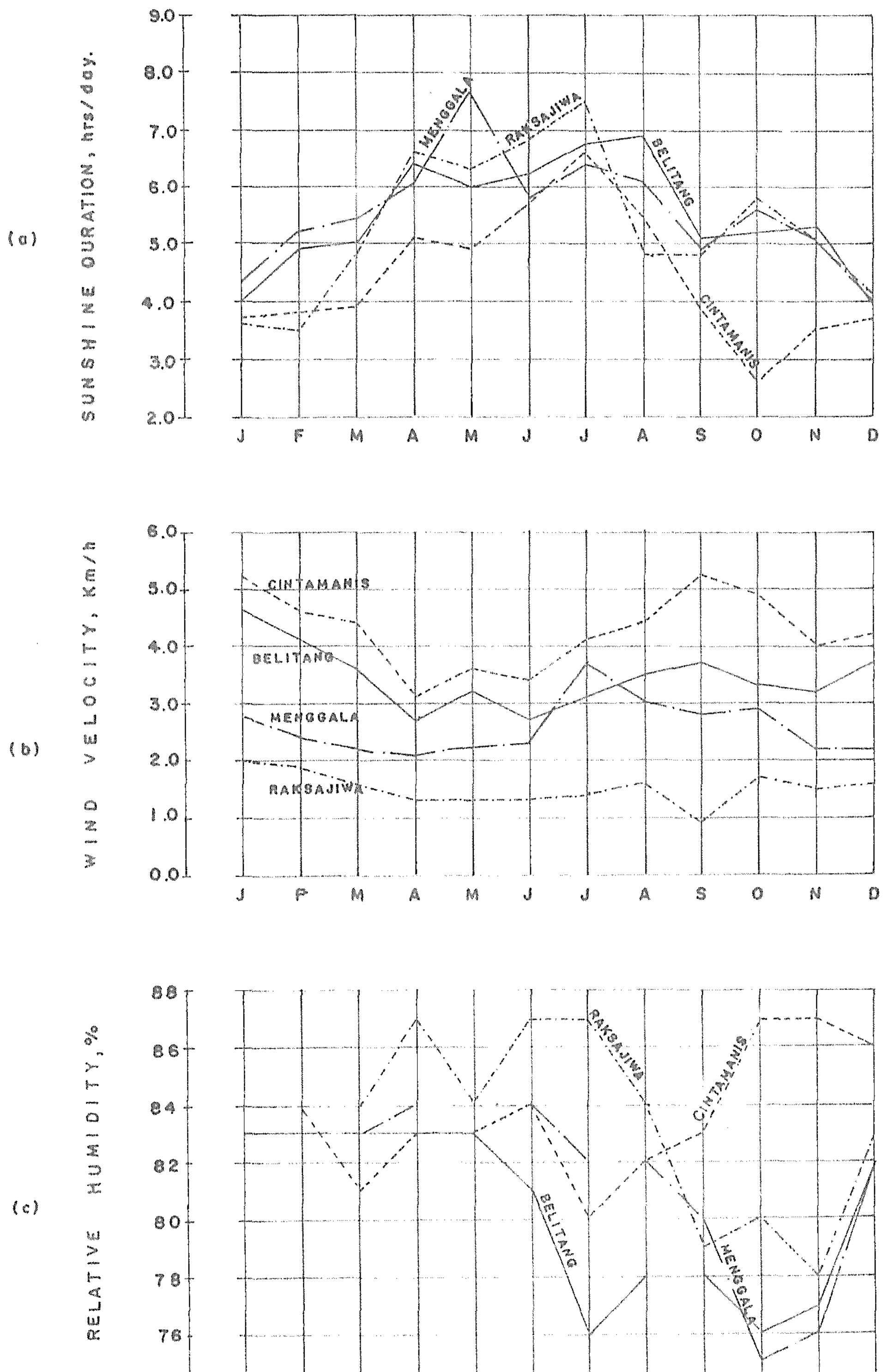
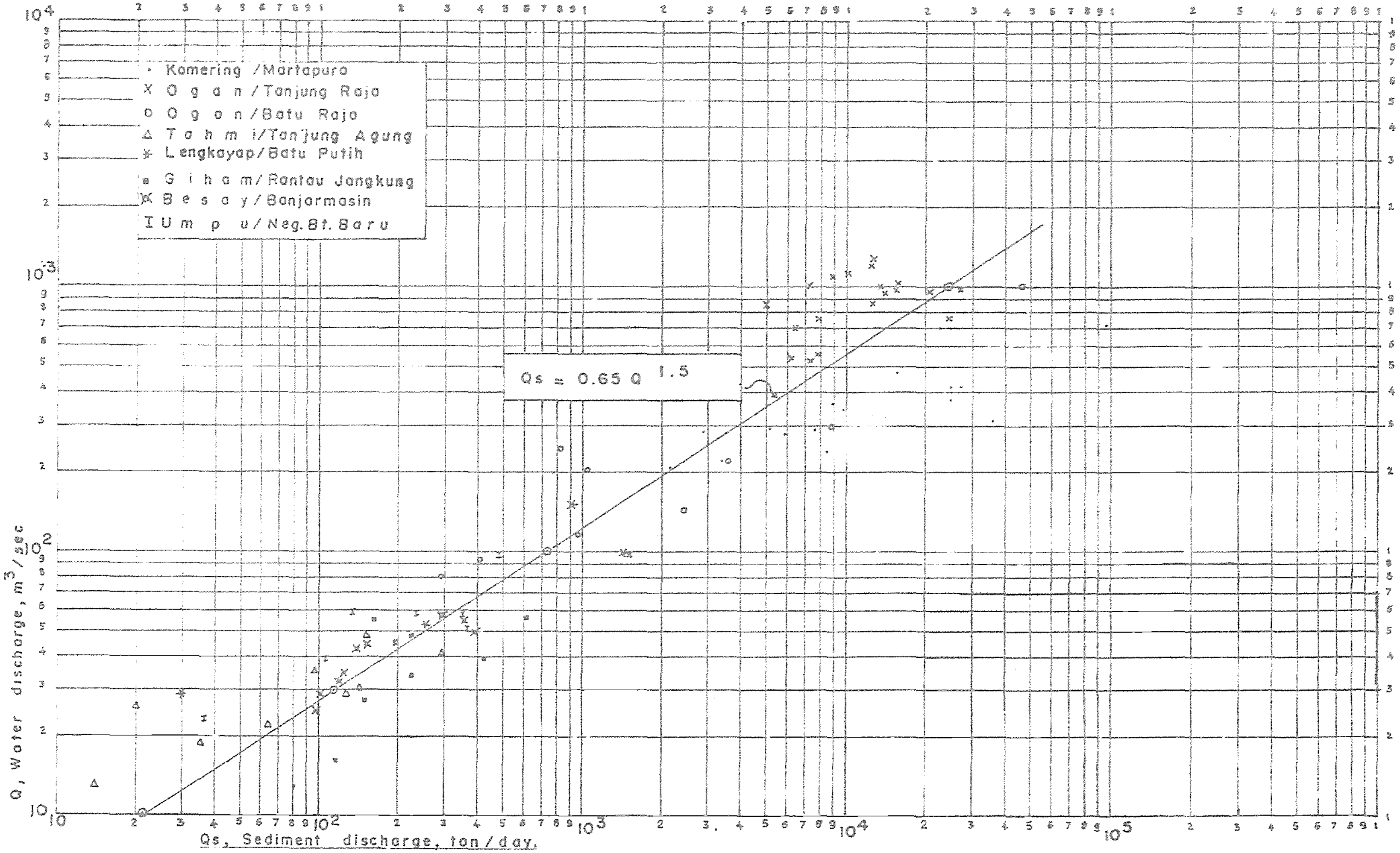
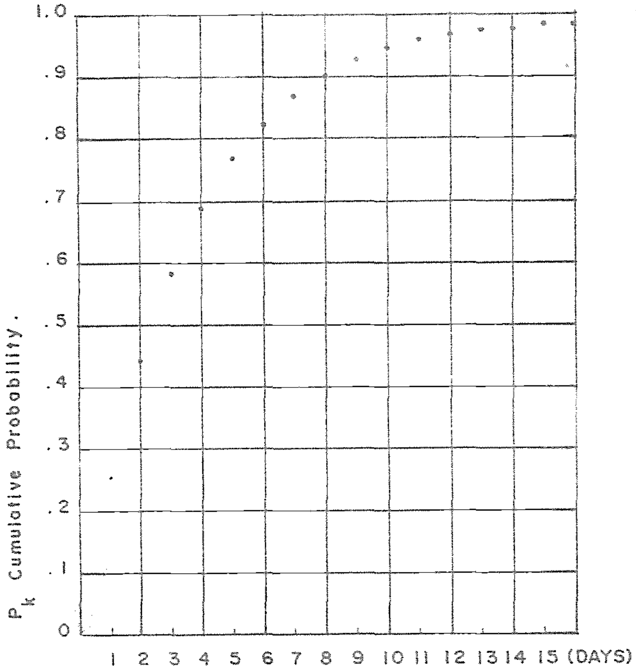



Fig. 37 - MONTHLY VARIATION OF MEAN SUNSHINE DURATION, WIND VELOCITY AND RELATIVE HUMIDITY, by STATIONS (1972 - 1974).

Fig. 38 GENERAL SEDIMENT - RATING CURVE FOR PROJECT AREA






X= Length of dry-day sequences.

Fig. 39 Cumulative frequency distribution of length of dry-day sequences, average project area.

$$P_k = 0.255 \sum_{x=1}^{k} (0.745)^{x-1}$$

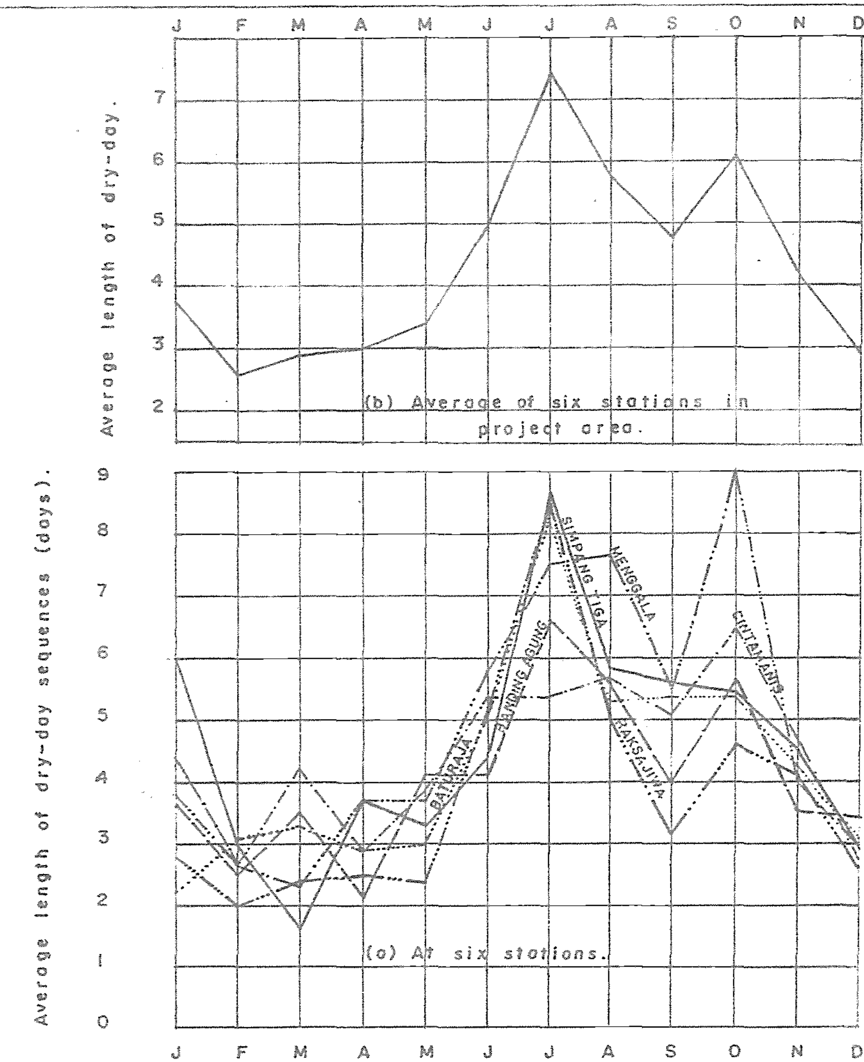



Fig. 40 Monthly variation of average dry-day sequences

Dry-day : rainfall < 6 mm

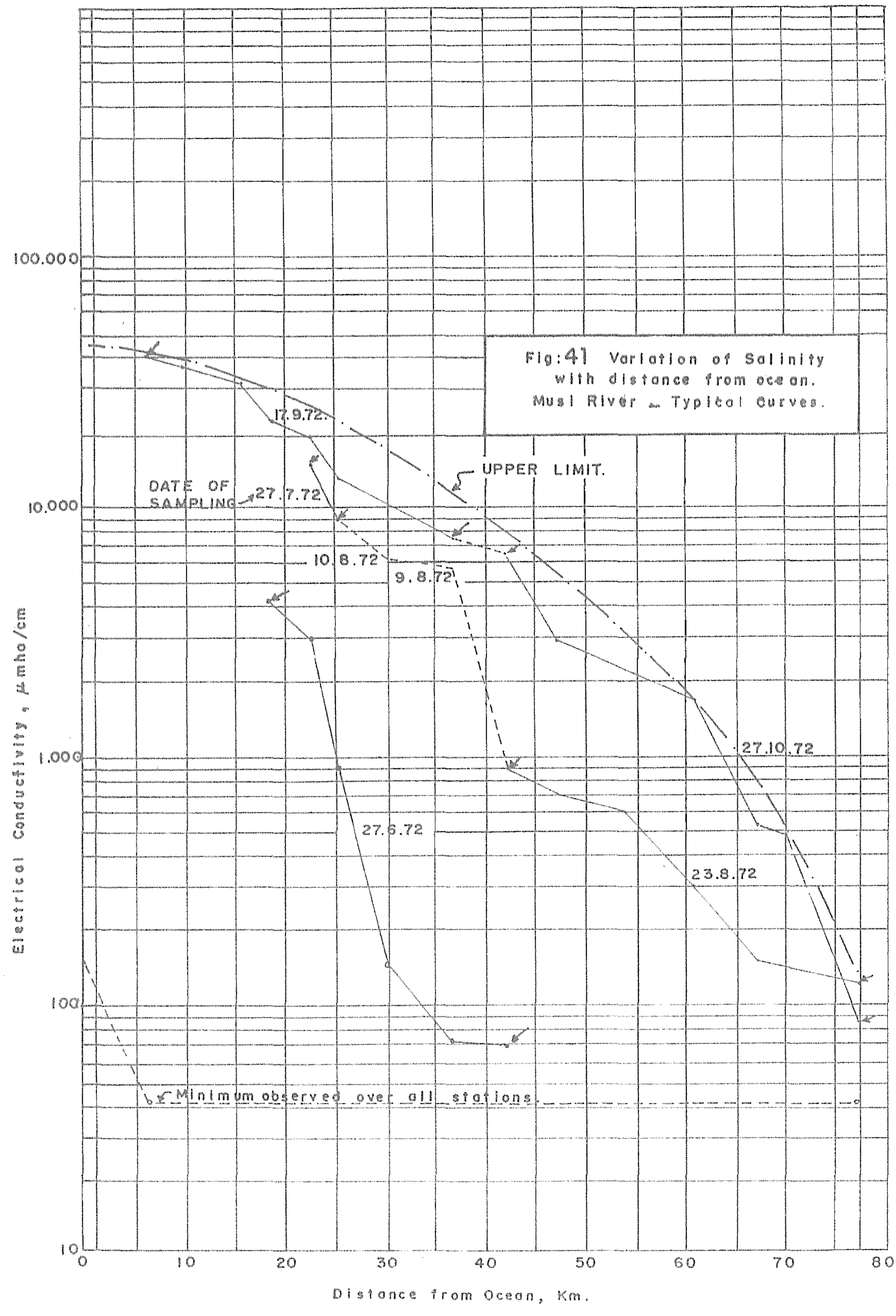


Fig:41 Variation of Salinity with distance from ocean. Musi River — Typical Curves.
100.000
10.000
1.000
100
10
Electrical Conductivity, µmho/cm
0
10
20
30
40
50
60
70
80
Distance from Ocean, Km.
17.9.72.
UPPER LIMIT.
DATE OF SAMPLING
27.7.72
10.8.72
9.8.72
27.10.72
27.6.72
23.8.72
Minimum observed over all stations.

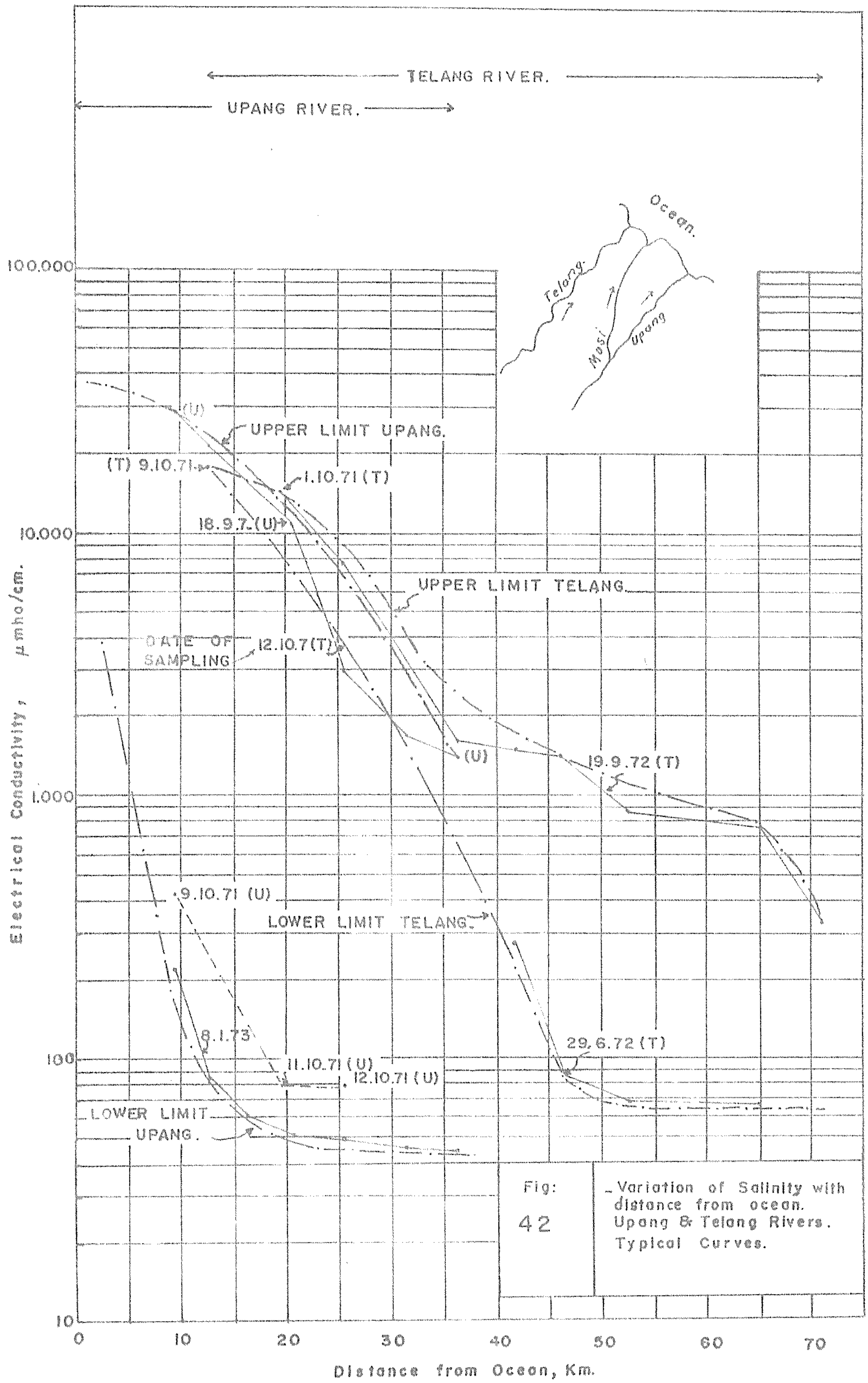



Fig: 42 _ Variation of Salinity with distance from ocean. Upang & Telang Rivers. Typical Curves.

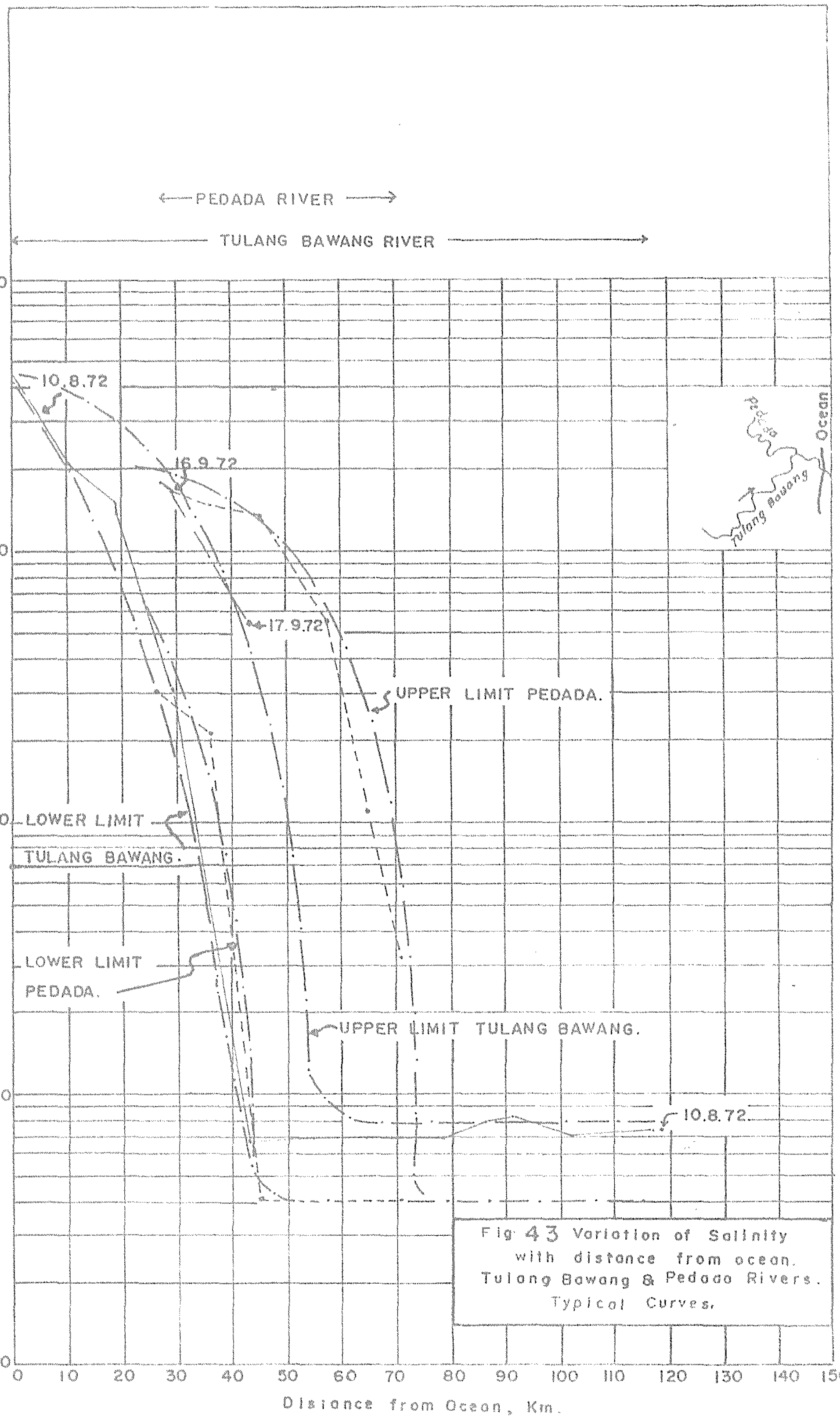



Fig 43 Variation of Salinity with distance from ocean. Tulang Bawang & Pedada Rivers. Typical Curves.

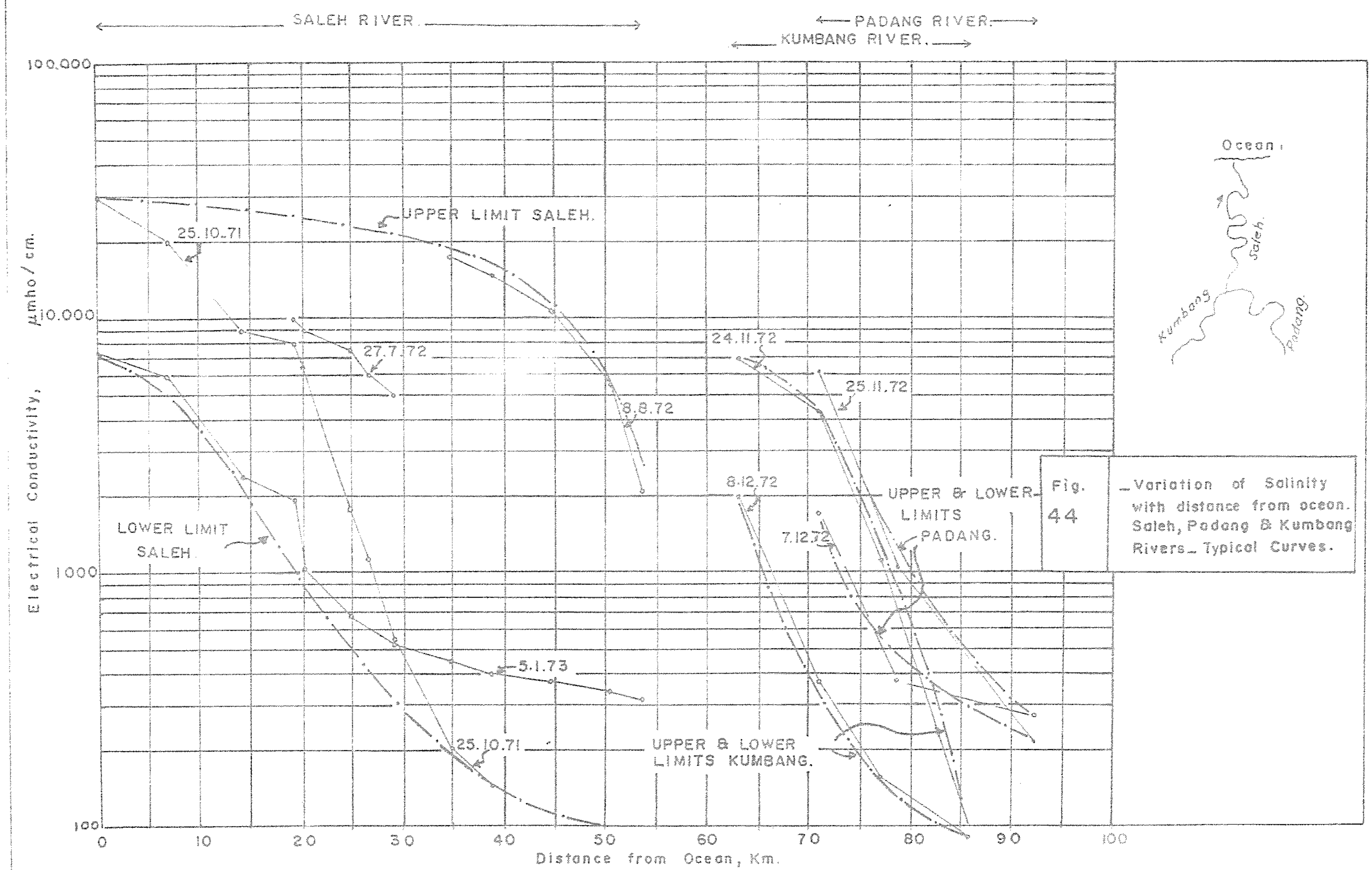



Fig. 44 — Variation of Salinity with distance from ocean. Saleh, Padang & Kumbang Rivers — Typical Curves.

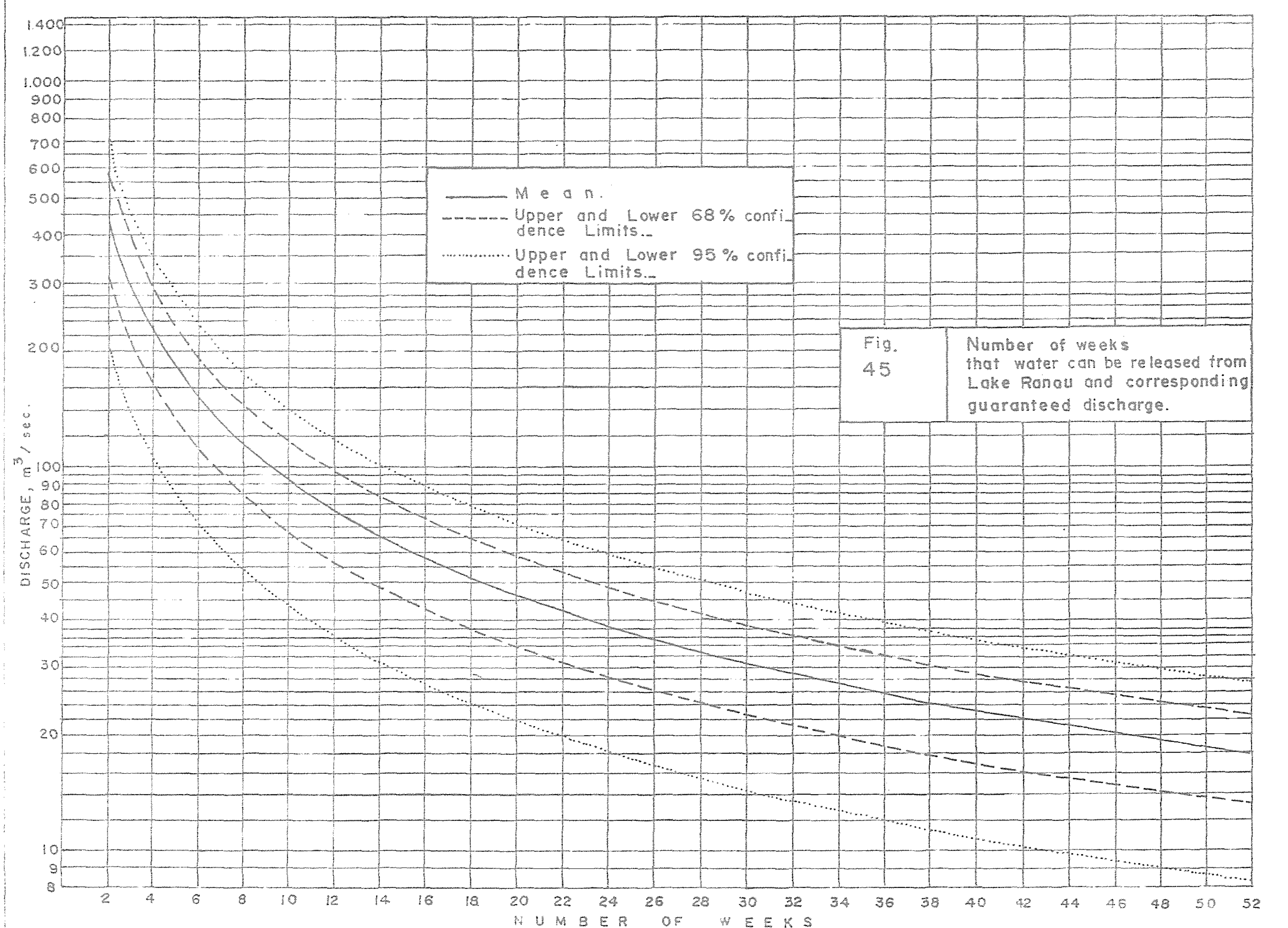



Fig. 45 Number of weeks that water can be released from Lake Ranau and corresponding guaranteed discharge.

Fig. 46

# MONTHLY MEAN RO/RF COEFFICIENTS (December 1972 - July 1974)

| Streamflow/Discharge station at | Watershed Area $km^2$ | Months of year | | | | | | | | | | | | Mean Dec - May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | D | J | F | M | A | M | J | J | A | S | O | |
| Ogan / Baturaja | 2095.5 | 0.86 | 0.60 | 0.52 | 0.49 | 0.65 | 0.81 | 0.70 | 0.91 | 3.72 | 0.71 | 0.61 | 1.52 | 0.62 |
| Komering / Martapura | 3638.0 | 0.24 | 0.57 | 0.76 | 0.62 | 0.75 | 0.80 | 1.04 | 1.54 | 2.88 | 0.59 | 0.88 | 1.18 | 0.74 |
| Lengkayap / Batuputih | 977.1 | 0.93 | 0.66 | 0.53 | 0.63 | 0.79 | 0.91 | 0.65 | 0.95 | 2.88 | 0.56 | 0.66 | 0.71 | 0.70 |
| Lempuing / Cahyabumi | 1163.8 | 0.40 | 0.40 | 0.84 | 0.78 | 1.09 | 0.69 | 0.38 | 0.84 | 0.70 | 0.51 | 0.50 | 0.27 | 0.70 |
| Giham / Rantau Jangkung | 532.0 | 0.16 | 0.24 | 0.43 | 0.55 | 0.67 | 0.73 | 0.72 | 0.71 | 3.06 | 0.27 | 2.09 | 7.24 | 0.56 |
| Tahmi / Tanjung Agung | 502.0 | 0.11 | 0.45 | 0.52 | 1.10 | 1.02 | 0.73 | 0.76 | 0.75 | 2.34 | 0.35 | 1.69 | 3.39 | 0.76 |
| Umpu / Negeri Batin Baru | 566.0 | 0.14 | 0.38 | 0.63 | 0.73 | 0.83 | 0.70 | 0.63 | 0.98 | 2.84 | 0.31 | 4.69 | 9.77 | 0.65 |
| Besay / Banjarmasin | 591.0 | 0.47 | 0.58 | 0.60 | 0.99 | 0.93 | 0.75 | 1.47 | 4.02 | 3.78 | - | - | - | 0.81 |
| Umpu Kanan / Pakuan Ratu | 3588.0 | 0.07 | 0.28 | 0.45 | 0.48 | 0.71 | 0.56 | - | 0.72 | 2.63 | 0.20 | 1.08 | 1.44 | 0.50 |
| Total number of observations | | 13 | 16 | 17 | 16 | 16 | 17 | 16 | 16 | 17 | 13 | 13 | 14 | |
| Mean ($\mu$) | | 0.46 | 0.49 | 0.62 | 0.73 | 0.86 | 0.76 | 0.78 | 1.33 | 2.63 | 0.47 | 1.27 | 2.35 | |
| Standard deviation ($\delta$) | | 0.56 | 0.20 | 0.28 | 0.35 | 0.34 | 0.11 | 0.39 | 1.63 | 1.79 | 0.32 | 1.26 | 3.03 | |
| Coefficients of variability % | | 121 | 41 | 45 | 48 | 39 | 14 | 50 | 122 | 68 | 68 | 99 | 129 | |

← USE THESE MONTHS ONLY → (D – M)

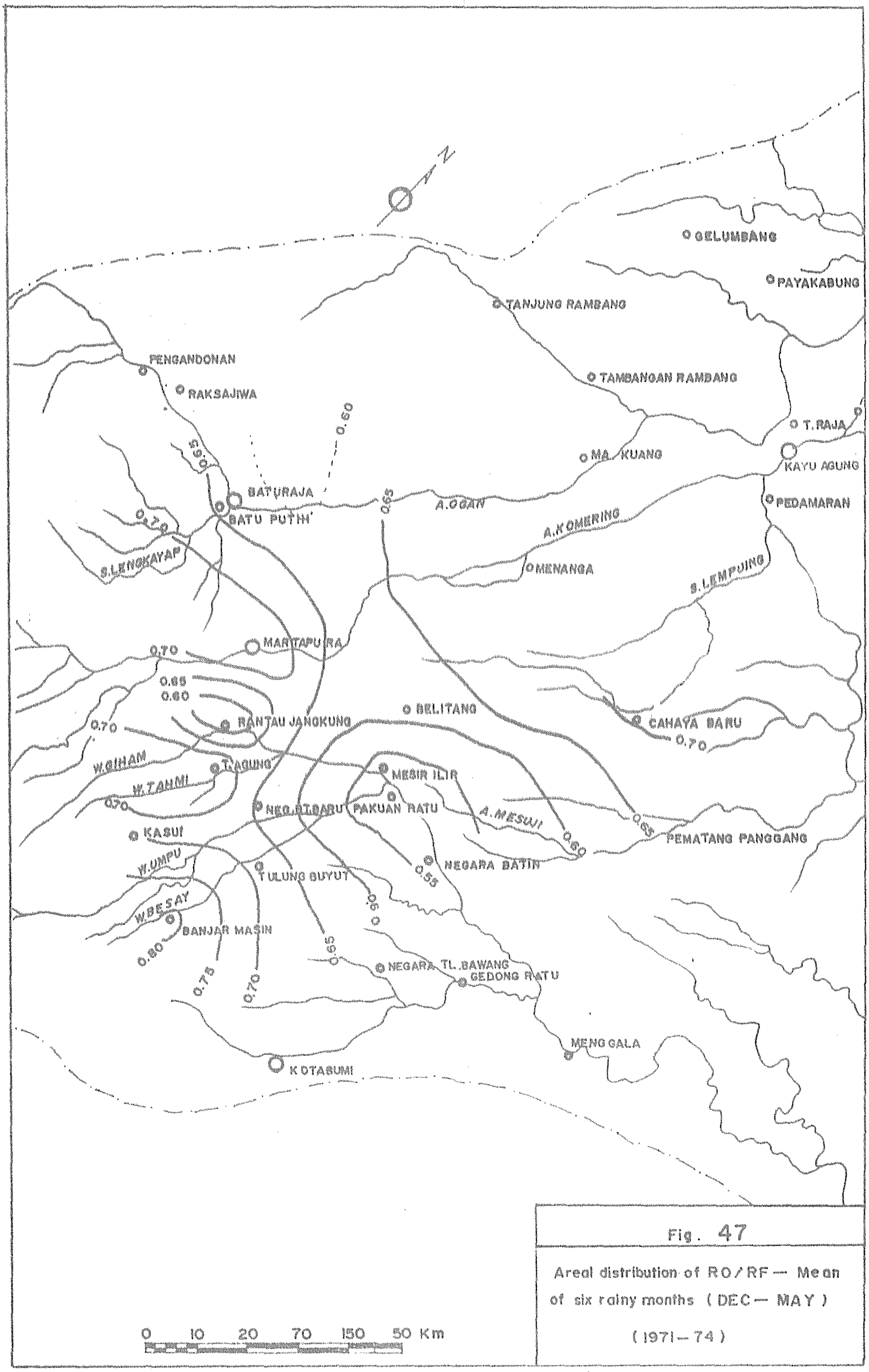



Fig. 47

Areal distribution of RO/RF — Mean of six rainy months (DEC — MAY) (1971–74)

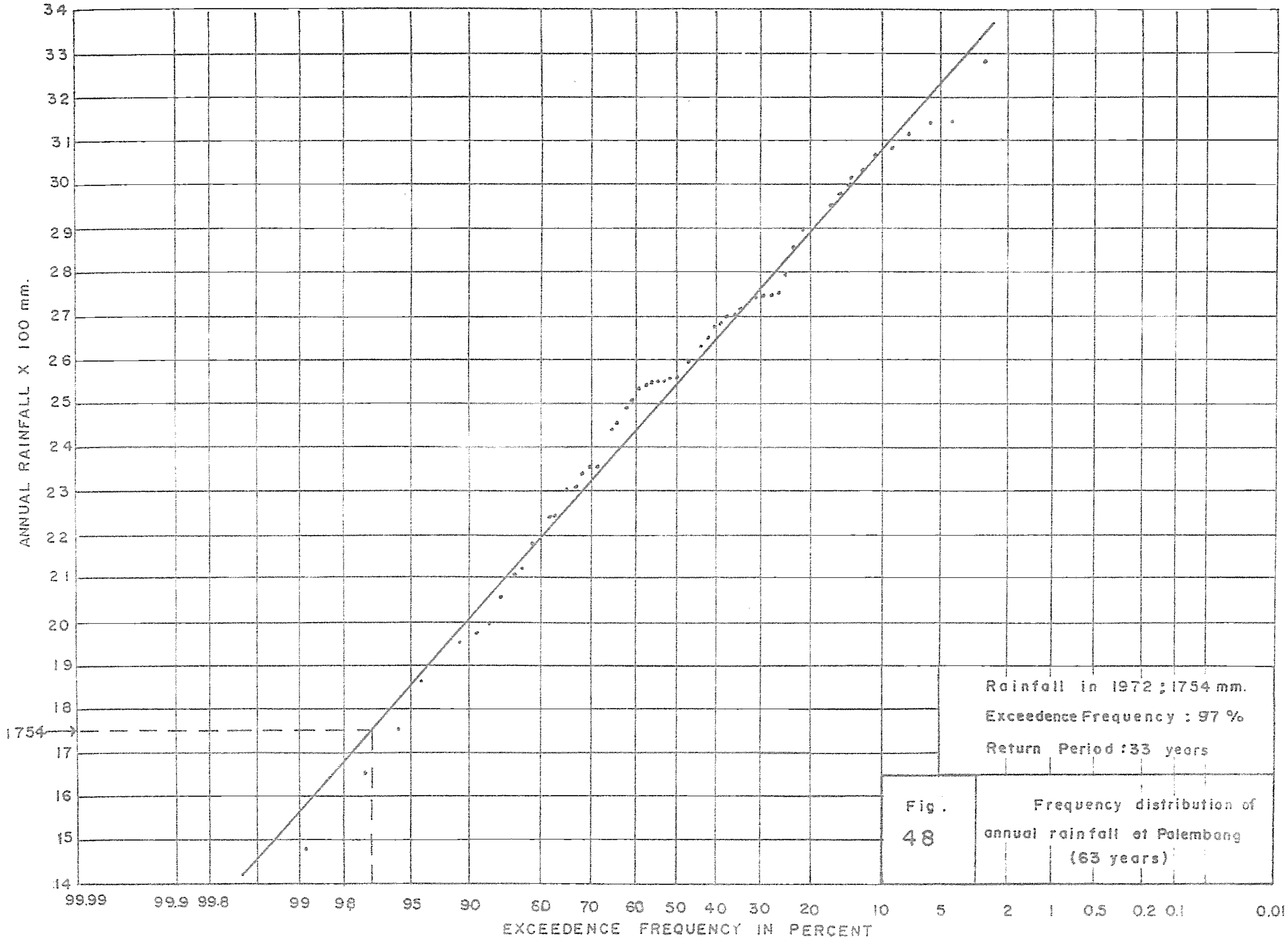



Fig. 48 Frequency distribution of annual rainfall at Palembang (63 years)

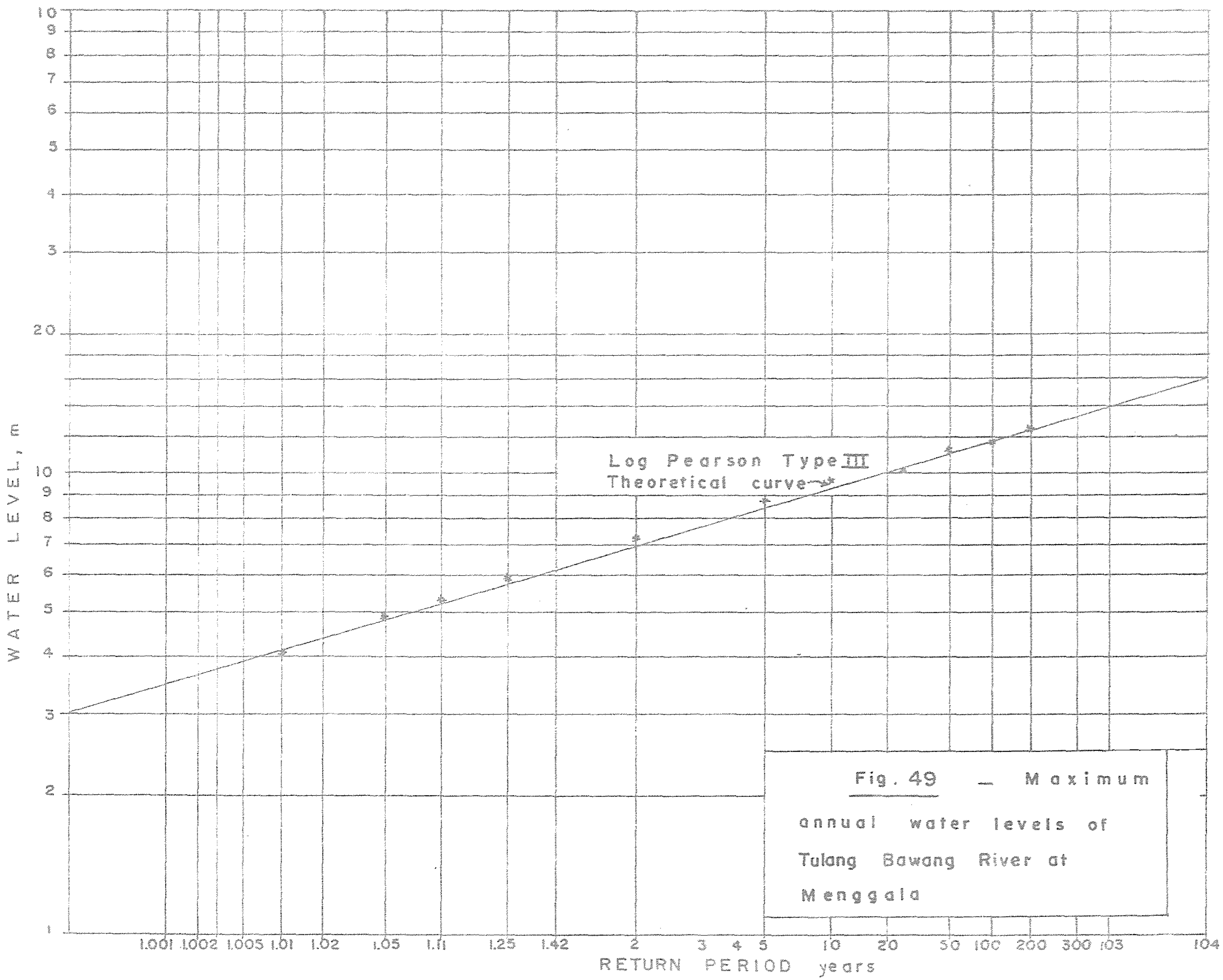



Fig. 49 — Maximum annual water levels of Tulang Bawang River at Menggala

M/H9392/E/5.76/1/150