LAO PEOPLE'S DEMOCRATIC REPUBLIC
MINISTRY OF AGRICULTURE AND FORESTRY

FEASIBILITY STUDY
ON
AGRICULTURAL AND RURAL DEVELOPMENT PROJECT
IN
THE SUBURBS OF VIENTIANE

ANNEX

JULY 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

LAO PEOPLE'S DEMOCRATIC REPUBLIC
MINISTRY OF AGRICULTURE AND FORESTRY

FEASIBILITY STUDY
ON
AGRICULTURAL AND RURAL DEVELOPMENT PROJECT
IN
THE SUBURBS OF VIENTIANE

ANNEX

JULY 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

FEASIBILITY STUDY
ON
AGRICULTURAL AND RURAL DEVELOPMENT PROJECT
IN
THE SUBURBS OF VIENTIANE

ANNEX

Table of Contents

ANNEX I

METEOROLOGY AND HYDROLOGY

ANNEX I

METEOROLOGY AND HYDROLOGY

Table of Contents

List of Tables

List of Figures

BIBLIOGRAPHY

1. Final Report on Nam Ngum Hydro-electric Project, First Stage

   Nippon Koei Co., Ltd., Tokyo, Japan, 1972

2. Report on Vientiane Flood Control Project

   Appendix C-Hydrology, prepared for U.S. Agency for International Development by Mark L. Nelson. Wintrop wells and Sidney C. Knutson

   U.S. Army Engineer Division, North Pacific, Portland, Oregon, October 1971.

1. Meteorology

1.1 Rainfall

(1) Rain gauges and records

Three rain gauges are located in and around the Project area. All stations are registered with Meteorological and Hydrological Department, Ministry of Agriculture and Forestry. Their locations are shown in Fig. I-1.

The rainfall is usually measured two times in a day, usually at 7:00 a.m. and 7:00 p.m. The summation of records at 7:00 a.m. and 7:00 p.m. on the previous day is recorded as the daily rainfall on the previous day.

Daily rainfall records for the above three stations are collected from the Meteorological and Hydrological Department.

Name of Rain Gauge	Period of Data Collected
Vientiane	1967 - 1987
Tha Ngon	1967 - 1985
Salakham	1972 - 1985

The missing records at Tha Ngon and at Salakham are estimated on monthly basis by normal-ratio method.

The consistency of the data recorded is examined by double-mass curve. The result shows good consistency of the data as shown in Fig. I-2.

(2) Rainfall data

The monthly rainfall histograms of three gauges show a peak in August as shown in Fig. I-3. More than 80% of annual rainfall occurs during the period from May to September. The dry season usually extends from October to April. The annual rainfall varies from 1,300 to 2,300 mm and averages 1,608 mm at Vientiane. The monthly rainfall data of the above three gauges are shown in Table I-1.

Because of inadequate distribution of rain gauges, Thiessen polygons are unable to be applied to estimate areal rainfall in the Project area. As shown in Table I-1, at Vientiane, the rainfall is in-between of Tha Ngon and Salakham. The rainfall appears to increase from the south to the north. The rainfall at Vientiane located the nearest to the Project area is therefore applied to the irrigation and agronomic studies for the Project.

1.2 Climate Other Than Rainfall

1.2.1 Meteorological stations

Three meteorological stations, i.e. Vientiane, Tha Ngon and Salakham, are located in and around the Project area, and their locations are shown in Fig. I-1.

The Vientiane meteorological station is located about 10 km west of the Project area. The station has been operated since 1949 under favorable conditions.

The Tha Ngon meteorological station is located near the Nam Ngum river, about 10 km northwest of the Project area, and the Salakham station at about 15 km south of the Project area. Although the observations were started in 1972 for the Tha Ngon station and 1973 for the Salakham station, they were sometimes interrupted, resulting in limited usefulness of the observed data at both stations.

Among the three meteorological stations, Vientiane has the longest and most reliable observation data, and is located at the nearest place to the Project area. Therefore, the data at Vientiane will be used in the irrigation and agronomic studies of this Project. The data from Tha Ngon and Salakham stations are used only for reference checks on the Vientiane data. The meteorological data at Vientiane is summarized in Table I-2, and are analyzed as explained below.

1.2.2 Meteorological data

(1) Mean and maximum temperature

The Project area is situated under a tropical monsoon climate. The mean annual temperature is 26.5°C with a mean annual range of 6.7°C. From November to February, the weather is cool with a mean temperature of 23.6°C; March to October is the warm season, having a mean temperature of 28.0°C as shown in

Fig. I-4. The daily maximum temperature of more than 31°C is usually recorded between March and July.

(2) Minimum temperature

Since low temperatures greatly affect agronomic planning for the Project, the records of minimum temperature are examined. The extreme minimum temperatures recorded in the past 20 years are shown in Table I-3 and summarized as follows.

(Unit: °C)

	Jan.	Feb.	Mar.	Nov.	Dec.
Extreme min. temp.	4.7	10.7	11.5	10.6	5.3
Ave. of lowest temp.	12.5	14.6	17.3	15.6	12.3

To clear the occurrence pattern of minimum temperature, the daily records of temperature are examined for the recent three years (1985-1987). The results are shown in Table I-4. The records of daily minimum temperature from 1985 to 1987 are shown in Fig. I-5.

(3) Humidity

The mean monthly relative humidity varies from 64% in March to 79% in August. The monthly maximum humidity is between 87 and 95%, while the monthly minimum humidity varies from 40% to 64%.

(4) Evaporation

Evaporation from Class A-pan averaged 4.2 mm/day and 1,530 mm per annum. It varies from 3.7 mm/day in January to 5.1 mm/day in April.

(5) Wind

The wind is observed at 15 m above ground surface at Vientiane meteorological station. The average daily wind run is about 147 km/day (1.70 m/sec). It seasonally varies from 174 km/day (2.01 m/sec) in May to 133 km/day (1.54 m/sec) in October.

(6) Sunshine hours

The mean daily sunshine hours is 6.7 hours/day. It averages 7.7 hours/day for the period from October to April and 5.3 hours/day for May to September.

2. Hydrology

2.1 Streamflow in the Nam Ngum River

(1) Surface water catchment

The Nam Ngum river is one of the major tributaries of the Mekong river. It takes its origin in Tran Ninh Plateau with an elevation of 1,000 to 1,500 m above sea level. It flows down for about 240 km to reach the Nam Ngum dam constructed in 1971. The Nam Lik river, the largest tributary of the Nam Ngum river, joins the Nam Ngum at 4 km downstream from the Nam Ngum dam. After joining the Nam Lik, the Nam Ngum river flows down for about 80 km southerly to reach Tha Ngon and another 80 km easterly to flow into the Mekong river. The boundary of the surface water catchment area is shown in Fig. I-6.

The surface water catchment area of the Nam Ngum river above the Nam Ngum dam is 8,460 km^2. It increases to 14,200 km^2 after joining the Nam Lik at Ban Tha Lat. The catchment area of the Nam Ngum river is 16,500 km^2 at Tha Ngon and is 17,340 km^2 at Pak Ngum, the confluence with the Mekong river.

The catchment area at the Nam Ngum dam occupies about a half of the total catchment area at Tha Ngon, and the effective storage of the reservoir created by the dam is estimated at 4.7 billion m^3 which correspond to about 45% of annual inflow to the reservoir (10.3 billion m^3)/1. From these facts, it is obvious that the streamflow of the Nam Ngum river is significantly regulated by the reservoir.

(2) Water level gauges and records

Although there are many water level gauges and streamflow measuring stations in the Nam Ngum and Nam Lik rivers, some of them are closed or have long gaps of data as shown in Fig. I-7. The following stations are considered to be usable for the present study.

/1 : Refer to bibliography of this Annex.

Name of Gauge	Location	Catchment Area	Opened Year	Condition
Tha Lat	about 160 km from Mekong	14,200 km^2	1966	fair
Tha Ngon	about 80 km from Mekong	16,500 km^2	1960	good

The discharge measurements at these stations have been made by the Meteorological and Hydrological Department. It is proved that the rating curve at Tha Ngon developed in 1973 (see Fig. I-8) is still applicable for estimation of recent discharges after checking with recent measurement data.

The water level and streamflow records of the above stations are collected from Lower Mekong Hydrologic Yearbook as follows:

Name of Gauge	Period of Data Collected
Tha Lat	1967/68, 1973/74-1983/84* 1985/86-1986/87*
Tha Ngon	1967/68-1984/85, 1985/86-1986/87* 1987/88
Vientiane (Wat Sop, Mekong river)	1967/68 - 1986/87*

* : with many gaps

The consistency of the streamflow data recorded are checked using double-mass-curve analysis. The analysis involves plotting of discharge at Tha Ngon vs. average rainfall of three rain gauges mentioned in the previous section. The result indicates some change in the slope of the curve in 1971 or 1972 as shown in Fig. I-9. This change in the slope of the curve may be caused by the construction of the Nam Ngum dam in 1971, and the flow characteristics of the Nam Ngum river are considered to be changed thereafter. Therefore, only the streamflow records after the hydrological year of 1972/73 will be used for the present study. The records before 1972/73 are useful for reference checks on the recent data.

(3) Discharge data

The mean monthly discharges of the Nam Ngum river at Tha Ngon are shown in Table I-5. Those in 1985/86 and 1986/87, which are missing, are estimated from the discharge data of the Mekong river at Vientiane by the correlation and regression method. The mean annual discharge thus estimated is about 680 m^3/sec with averaged mean monthly discharges varying from 210 m^3/sec in April and 1,840 m^3/sec in September. The lowest mean monthly discharge recorded is 93 m^3/sec in April 1976.

(4) Sediment load

The sampling and analyses of sediment load in the Nam Ngum river at Tha Ngon have been conducted by Institute of Irrigation and Micro-hydropower, Ministry of Agriculture and Forestry. Their results kept in the raw condition are processed in this study as shown in Table I-6. The sediment-discharge relation is clarified based on these data as follows and its rating curve is shown in Fig. I-10:

$$S = 0.0014 \times Q^{2.2468}$$

where, S : suspended sediment (ton/day)
Q : water discharge (m^3/sec)

The daily suspended sediment in the Nam Ngum river is computed based on mean daily discharge data. Then, the annual suspend sediment is calculated for three selected years, i.e. 1977/78, 1981/82 and 1984/85, when the annual mean discharges are respectively the smallest, the largest and the medium. The results are as follows:

		1977/78	1981/82	1984/85
Annual mean discharge	(m^3/sec)	447	991	710
Annual total discharge	(10^6 m^3)	14,100	31,300	22,400
Annual total suspended sediment	(10^6 ton)	1.12	6.73	2.30

2.2 Streamflow in the Hong Seng and the Houei Ma Hiao Rivers

2.2.1 Surface water subareas in the Vientiane Plain

The movement of waters within the Vientiane Plain was studied by USAID/GOL Vientiane Laos Flood Control Project in 1971. Their findings were published by U.S. Army Engineering Division, North Pacific, Portland, Oregon in October 1971/2.

According to the above publication, the Vientiane Plain can be divided into several subareas as designated in Fig. I-1 by the alphabet A, B, C, D, E, F, G and H from the viewpoint of surface water hydrology. Among them, Subareas A, B, C, and D have a relation with drainage of the Project area.

(1) Subarea A

The major part of this area drains naturally to the Hong Seng river, a tributary of the Houei Ma Hiao river, though a portion of this area drains to the Mekong river. The total drainage area is 85.8 km^2 including Wat Tay Airport area of 9.4 km^2.

(2) Subarea B

This area, which drains an area of 7.5 km^2, is treated separately from Subarea A because the major part of this area drains to the marsh That Luang (Subarea C).

/2 : Refer to bibliography of this Annex.

(3) Subarea C

This area is mostly covered by the marsh That Luang. The total area is 45.3 km^2. In 1983, a channel was excavated from the southern end of the marsh to the Houei Dua river in order to drain excess water in the marsh to the Mekong river.

(4) Subarea D

This area, which covers 55.6 km^2, is located in-between the Hong Seng area (Subarea A) and the Houei Ma Hiao area (Subarea E). In 1977, a channel was excavated in the depression of this area (called Bung Khat Khao) to connect the Hong Seng river with the Houei Ma Hiao river. The most part of the Project area is included in this area.

(5) Contiguous subareas

Subarea E is the main catchment area of the Houei Ma Hiao river. This river joins the Mekong river at 70 km downstream from Vientiane. Subarea F is the Nam Kho and Nam Khem river basins. Subarea G is the Houei Vixay river basin which drains directly to the Mekong river. Subarea H is the area between subarea B and Ban Ma Hiao which drains directly into the Mekong river.

2.2.2 Discharge measurement

(1) Measuring sites

To clarify the movement of streamflow in the Vientiane Plain, the discharge measurement and field investigation were made by the JICA team at the following three sites:

i) No. 1 Gauge : Bridge on the Ban Sam Khe Road over the Houei Ma Hiao river

This point is located at the downstream end of the subarea D. The discharge at this point mainly consists of the discharge of the Hong Seng river (85.8 km^2)

and the runoff from both the subarea D (55.6 km^2) and subarea C (45.3 km^2).

ii) No. 2 Gauge : Bridge on the Ban Nong Nieng Road over the Hong Seng river

This point is located at the upstream end of subarea D, so the discharge at this point mainly consists of the discharge of the Hong Seng river and the runoff from the subarea C.

iii) No. 3 Gauge : Culvert on the Ban Houa Khoua Road in the marsh That Luang

This point is located at the boundary between subarea C and D, so the discharge at this point is nearly equal to the runoff from the subarea C (the marsh That Luang).

(2) Results of the measurement

The measurements were made at the above three sites on the same day, and the results are shown in Table I-7. Rating curves are established based on these results for the respective sites as given in Fig. I-11, I-12 and I-13. The previous measurements for No.2 and No.3 sites made by Nippon Koei in 1960 and 1961 and by Vientiane Municipality in 1980 and 1981 are also indicated in the rating curves for reference. The cross section of each gauge site was also surveyed by the JICA team and the result is given in Fig. I-14, I-15 and I-16.

These investigations revealed the following:

i) The water in the Hong Seng river scarcely flows into the marsh That Luang but flows into the Houei Ma Hiao river.

ii) The water in the marsh That Luang can flow into the Houei Ma Hiao river only when the water level in the Hong Seng river is low. The discharge from the marsh That Luang, however, is less than 20% of the discharge of the Hong Seng at the Gauge No.2 though its catchment is more than half of that of the Hong Seng.

iii) When the discharge in the Hong Seng river is large, the back water affects the water level in the marsh. Thus there is no outflow from the marsh to the Houei Ma Hiao river.

iv) In the rainy season, the water level in the Hong Seng river at Gauge No. 2 appears to be normally between EL 164.0 m and EL 164.5 m.

v) The difference of water level between Gauges No.1 and No. 2 is between 0.40-0.55 m. So the hydraulic gradient between two gauges varies from 1/7,000 to 1/11,000.

vi) The Hong Seng river may have a flow capacity of about 40 m^3/sec at the Gauge No.1 at water level EL 165.3 m, at which the bridge is not submerged, unless obstacles such as fish traps are settled in the river. Besides there is a culvert on the road about 300 m east from the bridge, with an approximate flow capacity of 10 m^3/sec. So, the combined flow capacity of the bridge and culvert is estimated to be approximately 50 m^3/sec.

3. Water Resources

3.1 Rainfall

(1) Continuation and frequency of drought

The continuation and frequency of drought are analyzed from the daily rainfall data recorded at Vientiane for 21 years (1967-1987).

In the dry season from October to April, frequency of the longest continuous dry days in every year is counted, assuming that daily rainfall less than 1 mm is treated as no rainfall, because such a small rainfall is not effective for crop growth.

Longest Continuous Dry Days in Every Year	Frequency	
	(Nos. of Time)	(%)
less than 30	0	0
less than 60	3	14.3
less than 90	7	33.3
less than 120	7	33.3
less than 150	4	19.1
Total	21	100.0

In the rainy season, from May to September, frequency of the longest continuous drought days in every year is also analized as follows:

Longest Continuous Dry Days in Every Year	Frequency	
	(Nos. of Time)	(%)
3	1	4.8
4	2	9.5
5	1	4.8
6	5	23.8
7	5	23.8
8	1	4.8
9	4	18.9
10	0	0
11	1	4.8
12	1	4.8
Total	21	100.0

(2) Dependable rainfall

Using the rainfall data, the frequency analysis is made on annual rainfall and probable rainfall with return periods of 2-years, 5-years, 10-years and 20-years are estimated by means of logarithmic Pearson Type III distribution as shown in Fig. I-17. The results are summarized below:

(Unit: mm)

Station	Return Period in Years			
	2-years	5-years	10-years	20-years
Annual Rainfall at Vientiane	1,590	1,370	1,270	1,190

The irrigation planning necessitates a knowledge of seasonal distribution of rainfall in a year as well as annual rainfall. So, the above dependable rainfall calculated is distributed to each month in proportion to the ratio of monthly rainfall to annual rainfall as shown below:

(Unit: mm)

Return Period in Years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
2-years	0	11	38	79	224	273	285	299	283	77	0	0	1,569
5-years	0	0	32	68	193	235	245	258	244	67	0	0	1,342
10-years	0	0	30	63	179	218	227	238	226	62	0	0	1,243
20-years	0	0	28	59	167	204	213	223	211	58	0	0	1,163

In this calculation, the monthly rainfall of less than 10 mm is conservatively considered nil, thus the total rainfall becomes less than that calculated by the frequency analysis.

3.2 Streamflow

(1) Dependable low flow

Irrigation water for the Project will be taken from the Nam Ngum river at Tha Ngon. The minimum mean daily discharge at Tha Ngon is studied for the period from 1972/73 to 1987/88 except 1985/86 in which the data are not available. The minimum mean daily discharges shown in Table I-8 are subjected to frequency analysis by means of logarithmic Pearson Type III distribution as shown in Fig. I-18. The results are summarized as follows:

	Return Period in Years			
	2-years	5-years	10-years	20-years
Dependable mean daily discharge (m^3/sec)	166	91	73	60
Gauge height (m)	3.6	2.95	2.75	2.6
Water level EL (m)	153.6	152.95	152.75	162.6

(2) Season of low flow

In the irrigation study, it may be worthwhile to know time when minimum river discharge occurs every year. In this view, an analysis was made on the frequency of occurrence of minimum discharge in each stage of the month (January to May) based on the data from 1967/68 to 1987/88. The result is summarized below:

Frequency of Occurrence of Minimum Discharge

	Jan.			Feb.			Mar.			Apr.			May			Total
	1-10	11-20	21-31	1-10	11-20	21-28	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31	
Nos.of time	2	0	0	0	0	1	0	1	2	3	2	4	4	0	1	20

(3) Suitability of water quality

Chemical analyses were made on the river water sampled from the Nam Ngum, the Nam Khem and the Houei Ma Hiao as shown in Table I-9. The results show that all the water are classified as C1-S1 according to the standards of the United States Department of Agriculture. This classification indicates excellent water quality for irrigation with respect to alkalinity and salinity.

4. Flood Study

4.1 Flood in the Nam Ngum River

(1) Maximum mean daily discharge

The purpose of the flood study in the Nam Ngum river is to estimate the high water level at Tha Ngon for planning of a pump station proposed in the Project.

The maximum mean daily discharge at Tha Ngon is studied for the period of 1972/73 to 1987/88 except 1985/86 and 1986/87 in which the data are not available. These data are shown in Table I-10. The examination is made for the mean daily discharge on each day before and after the maximum mean daily discharge was recorded. As a result, it is concluded that the maximum mean daily discharge recorded can be considered as the peak discharge.

Frequency analyses are made for those data by applying the logarithmic Pearson Type III distribution. The frequency data are plotted on logarithmic frequency paper as shown in Fig. I-19 and the results are summarized below:

Return Period in Years	Discharge (m^3/sec)	Water Level EL (m)
2	2,650	165.1
5	3,270	166.6
10	3,650	167.2
25	4,110	167.7
50	4,430	168.4
100	4,750	168.6
200	5,060	169.1
1,000	5,770	169.7

(2) The maximum experienced flood discharges

The maximum experienced flood discharges of various rivers in the south-east Asia are plotted against respective drainage areas, and an envelop curve is drawn by connecting control points whose basins are similar to that of the Nam Ngum river both climatically and topographically. The plotted curve is shown in Fig. I-20. Moreover, several spillway design floods of various dam projects in Indochina are also plotted in the same figure/1. The estimated flood discharge for the Nam Ngum river at Tha Ngon is confirmed to be appropriate by referring to those plotted data and the envelope curve.

4.2 Flood in the Mekong River

The great efforts have been made to protect Vientiane and its vicinity areas from the flood of the Mekong river. A dike, which starts from near Kao Liao and ends near Nong Heo, is being constructed under the Project of Flood Protection and Reclamation of Swamp and Marsh land in the Vientiane Plain. The total length of the dike will be about 40 km. About 70% of the dike has been already constructed. Besides, many dikes are being constructed between Nong Heo and the confluence with the Nam Ngum river (60 km). More than 20 outlets equipped with control gates are also constructed at confluence of the Mekong river and rivulets in the plain. One of these structures was constructed at Ban Ma Hiao where the Houei Ma Hiao river flows into the Mekong river, preventing the water of the Mekong from entering into the Houei Ma Hiao river.

Owing to these facilities, the menace of the flood from the Mekong river to Vientiane and conjugated areas has been remarkably mitigated.

The flood discharge in the Mekong river at Vientiane was estimated by U.S. Army Engineering Division, North Pacific, Portland, Oregon in 1971/2. The flood discharge is again calculated in this study using additional data since 1972 to 1986 as shown in Table I-11. The frequency analysis is made as shown in Fig. I-21 and the results are tabulated below:

/1, /2 : Refer to bibliography of this Annex.

Return Period in Years	Estimated Flood		GH/1 (m)
	In 1971 (m^3/sec)	In This Study (m^3/sec)	
2	17,000	16,700	11.5
5	20,500	19,300	12.0
10	22,000	20,800	12.4
25	24,000	22,500	12.7
50	26,000	23,700	13.0
100	27,000	25,000	13.2
1,000	31,500	28,300	13.5

/1: Gauge height

4.3 Flood in the Hong Seng and the Houei Ma Hiao Rivers

4.3.1 The Hong Seng river

The purpose of the flood study described in this section is to clarify the movement of water in the Project area in the rainy season.

As described before, three major rivers exist in and around the Project area, i.e. the Hong Seng, the Houei Ma Hiao and the Nam Khem rivers. Among them, the main stem of the Nam Khem river is located outside of the Project area. So it may not seriously affect the drainage in the Project area.

The Hong Seng river flows into the Project area and is connected with the Houei Ma Hiao river in the Beung Khat Kao swamp. The flood discharge in the Hong Seng for 10-year frequency storm rainfall is estimated at 30 m^3/sec/2. In this calculation, the storage function of the Hong Seng catchment area and the back water effect from the Mekong to the Houei Ma Hiao through the free outlet at Ban Ma Hiao are taken into account.

An outlet structure equipped with a flap gate has been recently constructed at the mouth of the Houei Ma Hiao to prevent the water of the Mekong from flowing into the Houei Ma Hiao. When the water level in the Mekong is higher than that of the Houei Ma Hiao, the water in the the Mekong does not flow into the Houei Ma Hiao and the water in the Houei Ma

/2 : Refer to bibliography of this Annex.

Hiao is stagnated. Other hydrological conditions in the Hong Seng catchment area have not changed significantly since 1971. The peak runoff from the catchment of the Hong Seng in case of no back water effect from the Mekong is also estimated at about 45 m^3/sec/2.

Although no back water is expected from the Mekong as such, the water in the Houei Ma Hiao backs up until the water in the Mekong recedes, resulting in the deceleration of current in the Houei Ma Hiao and Hong Seng. Accordingly, the magnitude of the peak discharge appears to be in between 30 and 45 m^3/sec.

4.3.2 Other runoff to the Houei Ma Hiao river

(1) Drainage area

As described in the preceding section, there extends 55.6 km^2 of additional catchment between the Hong Seng and the Houei Ma Hiao rivers. This area includes the most part of the Project area. Of 55.6 km^2, the paddy fields occupy about 2,830 ha and the remaining 2,730 ha is upland and hilly area. The runoff characteristics from paddy fields and that from uplands are generally quite different. So the runoff from each area is studied separately.

(2) Runoff from paddy fields

The runoff from the paddy fields by 10-year frequency storm rainfall is estimated at 5.4 lit/sec/ha as mentioned in Annex IV Irrigation and Drainage. So the total runoff from the paddy field into the Houei Ma Huai river is estimated at about 15 m^3/sec.

(3) Runoff from uplands and others

The upland area is divided into small sub-areas according to the topographic condition. The runoff from each sub-area is estimated by applying triangular unit hydrography and 10-year frequency storm rainfall as mentioned in Annex IV Irrigation and Drainage. Because of the peculiar configuration of the area, most of uplands are remoted from the Houei Ma Hiao river. Paddy fields extend between uplands and the Houei Ma Hiao river. The drainage canals are proposed to smoothly convey the excess water from the uplands to the Houei

---

/2: Refer to bibliography of this Annex.

Ma Hiao river. Those triangular hydrographs estimated for respective sub-areas are synthesized by taking into account the time required for water flowing down from the edge of upland area to the Houei Ma Hiao river. The velocity of current is assumed at 0.9 m/sec, which corresponds to the maximum allowable velocity for drainage canals. As a result, the synthesized hydrograph has a peak discharge of 30 m^3/sec.

(4) Total discharge in the Houei Ma Hiao river

The peak discharge in the Houei Ma Hiao river is approximately 85 m^3/sec including 40 m^3/sec from the Hong Seng river. Bridges and culverts on the river, located at the southern edge of the Project area, have a combined flow capacity of about 50 m^3/sec. The balance of water will therefore be stagnated in canals and fields.

Table I-1 Monthly Rainfall (1/2)

at Vientiane (Unit:mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1967	2.3	12.6	6.0	94.2	159.9	221.8	327.3	209.8	488.9	N	21.2	N	1,544.0
1968	0.9	N	100.6	88.8	301.8	243.5	258.2	206.8	272.0	27.7	T	N	1,500.3
1969	19.6	N	42.4	40.9	204.3	295.9	402.1	128.9	247.9	49.9	14.3	N	1,446.2
1970	0.5	N	31.2	56.9	306.4	377.2	215.8	624.9	420.5	53.8	T	0.1	2,087.3
1971	N	7.3	13.9	34.1	294.0	274.8	289.4	226.4	163.4	103.5	0.8	18.2	1,425.8
1972	N	6.8	36.8	167.6	115.6	312.8	246.1	306.7	166.3	148.4	8.2	5.8	1,521.1
1973	N	N	37.0	36.4	308.3	200.7	298.6	263.9	361.3	25.7	T	N	1,531.9
1974	T	1.6	36.7	97.4	100.5	159.2	255.7	368.4	187.1	92.6	29.7	0.2	1,329.1
1975	23.5	26.3	13.2	21.8	347.0	473.9	177.5	430.4	289.7	194.4	8.5	N	2,006.2
1976	N	23.0	111.9	126.9	121.7	167.3	167.6	403.1	416.7	76.7	N	N	1,614.9
1977	15.2	N	35.1	69.0	151.9	231.0	211.1	174.8	190.3	26.5	16.5	22.8	1,144.2
1978	1.6	17.8	51.1	145.9	328.4	254.9	354.6	293.6	381.4	128.9	28.5	N	1,986.7
1979	N	21.0	0.1	61.8	344.7	333.3	150.1	117.8	253.1	19.2	N	N	1,301.1
1980	N	18.6	68.8	61.0	319.5	611.0	461.5	342.9	353.4	54.7	T	N	2,291.4
1981	N	0.3	19.6	124.2	311.1	238.5	635.0	210.0	224.8	117.8	40.5	T	1,921.8
1982	N	6.1	60.8	69.6	239.3	95.4	253.8	484.0	319.5	90.2	22.2	0.6	1,641.5
1983	53.1	5.7	9.0	58.1	97.6	243.8	217.9	360.8	247.1	67.9	N	7.2	1,368.2
1984	N	10.6	3.4	88.9	148.3	148.1	421.0	388.9	267.1	142.1	17.3	N	1,635.7
1985	24.8	64.7	4.9	10.8	135.3	223.5	257.4	191.9	258.8	81.4	N	N	1,253.5
1986	N	3.2	1.5	118.8	383.4	256.2	308.9	318.3	275.3	66.7	N	21.0	1,753.3
1987	T	13.9	100.6	127.0	63.6	473.8	175.0	356.0	260.7	93.4	3.2	N	1,667.2
AVE.	7.4	11.7	35.9	76.5	228.2	268.8	294.8	301.8	290.0	79.0	10.9	2.9	1,607.9
%	0.5	0.7	2.2	4.8	14.2	16.4	18.3	18.8	18.0	4.9	0.7	0.2	100.0

Note: T-trace N-nil

at Salakham (Unit:mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1972	N	N	13.0	83.5	72.4	332.2	196.8	223.8	93.8	125.5	23.2	5.6	1,169.8
1973	N	N	11.8	32.3	160.9	128.5	275.2	221.3	398.9	15.6	N	6.4	1,250.9
1974	N	5.4	62.8	59.3	86.9	160.4	276.6	419.5	71.8	18.4	25.7	N	1,186.8
1975	10.7	16.6	14.0	1.0	285.6	357.7	245.6	233.8	216.8	82.6	N	N	1,464.4
1976	N	26.0	N	130.3	152.6	163.7	198.2	269.8	305.3	43.0	3.3	N	1,292.2
1977	12.6	N	17.7	82.8	145.3	188.6	216.8	207.3	161.1	30.0	10.3	11.9	1,084.4
1978	3.9	9.6	48.5	127.7	274.2	204.0	313.1	222.1	253.6	74.4	22.6	N	1,553.7
1979	N	13.5	0.5	53.9	136.2	156.4	123.3	178.4	177.2	3.0	N	N	842.4
1980	N	3.0	10.4	63.0	282.5	467.0	392.4	420.8	292.9	56.1	3.0	N	1,991.1
1981	N	N	24.3	75.4	257.5	237.2	445.7	224.8	223.0	160.8	23.2	N	1,671.9
1982	N	1.2	39.2	69.0	167.7	114.0	357.2	403.6	330.2	75.6	6.6	3.6	1,567.9
1983	42.4	6.5	9.7	36.0	66.4	217.7	185.9	302.8	214.3	58.3	N	5.2	1,145.2
1984	N	19.5	3.5	49.9	197.7	137.2	327.6	345.2	184.9	112.9	11.4	N	1,389.8
1985	37.0	84.0	2.0	32.8	94.5	199.4	255.4	232.8	182.0	94.0	N	N	1,213.9
AVE.	7.6	13.2	18.4	64.1	170.0	218.9	272.1	279.0	221.8	67.9	9.2	2.3	1,344.6
%	0.6	1.0	1.4	4.8	12.6	16.3	20.2	20.7	16.5	5.0	0.7	0.2	100.0

Note: T-trace N-nil

Table I-1 Monthly Rainfall (2/2)

at Tha Ngon (Unit:mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1967	5.2	30.2	17.4	49.6	170.0	210.2	150.8	210.6	544.2	8.0	6.0	N	1,402.2
1968	T	N	31.6	144.8	499.0	383.4	330.4	273.4	407.4	31.2	7.8	N	2,109.0
1969	47.8	N	118.2	34.0	271.8	396.2	596.4	239.0	310.0	27.8	N	N	2,041.2
1970	0.6	N	34.6	63.1	340.0	629.9	289.9	617.8	408.1	58.0	T	0.2	2,442.2
1971	N	2.3	10.7	20.5	254.2	343.9	255.8	236.2	234.1	123.6	3.0	12.4	1,496.7
1972	N	11.2	93.2	74.1	125.6	216.0	180.4	317.9	120.5	233.9	12.9	2.6	1,388.3
1973	N	N	66.8	61.7	242.7	276.6	321.5	310.8	309.6	21.1	N	4.2	1,615.0
1974	T	0.1	57.0	60.3	121.9	304.9	280.5	453.9	157.3	59.5	39.5	0.8	1,535.7
1975	29.5	17.1	57.4	30.6	417.7	402.9	224.5	494.7	325.0	187.3	7.1	6.4	2,200.2
1976	N	31.8	83.0	106.6	268.4	247.0	337.8	265.9	344.6	28.6	8.7	N	1,722.4
1977	16.4	N	7.8	142.2	215.6	242.2	338.8	354.0	214.7	50.0	9.0	6.2	1,596.9
1978	8.5	5.6	71.4	175.5	360.4	256.4	434.0	261.1	247.1	53.6	28.2	N	1,901.8
1979	N	12.4	1.2	74.0	470.6	240.6	172.9	220.4	192.4	7.9	N	N	1,392.4
1980	N	3.0	97.4	74.5	289.4	543.2	442.5	341.5	430.4	71.2	N	N	2,293.1
1981	N	N	17.4	125.7	347.6	227.2	707.7	249.4	362.7	146.8	18.1	N	2,202.6
1982	N	6.4	36.2	105.1	177.8	204.0	369.5	548.3	450.5	91.2	6.4	N	1,995.4
1983	53.2	10.8	15.6	30.8	67.3	304.9	249.5	399.9	292.2	78.7	N	5.7	1,508.6
1984	N	39.8	5.4	33.3	358.0	198.4	398.6	480.9	192.4	140.6	10.9	N	1,858.3
1985	20.4	31.9	31.0	56.5	191.2	490.8	359.8	214.2	249.5	170.3	2.2	N	1,817.8
AVE.	9.6	10.7	44.9	77.0	273.1	322.0	339.0	341.6	304.9	83.6	8.4	2.0	1,816.8
%	0.5	0.6	2.5	4.2	15.0	17.7	18.7	18.8	16.8	4.6	0.5	0.1	100.0

Note: T-trace N-nil

Table I-2 Meteorological Data at Vientiane

(Average from 1968 to 1987)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean temperature (°C)													
	22.4	24.7	27.4	29.0	28.7	28.4	28.1	27.6	27.6	27.0	24.9	22.3	26.5
Mean of daily maximum temperature (°C)													
	28.1	30.4	33.0	34.1	32.8	31.9	31.4	30.8	31.0	30.9	29.5	27.9	31.0
Mean of daily minimum temperature (°C)													
	16.7	19.0	21.8	24.0	24.6	25.1	24.9	24.8	24.2	23.2	20.3	16.8	22.1
Extreme minimum temperature (°C)													
	4.7	10.7	11.5	17.5	18.9	21.8	22.0	21.7	21.1	16.8	10.6	5.3	-
Mean relative humidity (%)													
	68	65	64	66	73	77	78	79	78	74	69	67	72
Mean of daily maximum humidity (%)													
	92	89	87	88	93	94	94	95	95	93	90	92	92
Mean of daily minimum humidity (%)													
	43	42	40	44	54	61	62	64	62	54	48	43	51
Evaporation from class A-pan (mm/day)													
	3.7	4.2	4.6	5.1	4.6	4.2	4.0	3.7	4.1	4.4	4.3	3.9	4.2
Wind velocity (m/sec) /1													
	1.6	1.6	1.6	1.9	2.0	1.8	1.8	1.8	1.6	1.5	1.6	1.6	1.7
Daily sunshine hours													
	8.3	7.6	7.0	7.5	6.7	5.0	4.7	4.3	5.7	7.3	7.9	8.3	6.7
Monthly rainy days /2													
	1	2	4	8	16	19	19	21	18	7	2	1	118
Monthly rainfall (mm)													
	7	12	36	77	228	269	295	302	290	79	11	3	1,608

/1 : 15m above ground surface
/2 : Excluding trace

Table I-3 Extreme Minimum Temperature at Vientiane

(unit : °C)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1968	12.2	13.8	17.0	20.0	21.0	22.0	22.0	23.4	22.5	19.8	17.5	15.0
1969	16.0	11.8	20.5	17.5	19.5	23.3	22.8	23.0	21.1	20.8	13.2	11.0
1970	14.5	13.8	20.0	18.1	22.7	23.3	22.8	22.1	22.8	20.0	16.0	14.5
1971	7.3	13.1	16.0	21.3	21.6	23.0	22.7	22.9	22.7	16.8	10.6	14.3
1972	11.9	15.5	14.2	21.2	22.9	22.6	23.7	22.1	23.0	22.2	19.4	15.5
1973	14.8	16.2	19.5	21.9	22.9	22.9	23.0	21.7	23.2	17.7	12.8	7.6
1974	4.7	10.7	14.2	20.2	22.5	23.4	22.5	22.9	22.8	21.6	18.0	15.7
1975	14.1	15.4	20.1	21.0	22.3	23.0	22.8	22.8	22.0	21.5	11.7	5.3
1976	7.3	13.8	16.8	20.3	18.9	21.8	22.8	22.9	23.0	21.9	13.3	12.9
1977	15.5	13.9	14.0	20.3	21.8	24.0	22.0	23.0	21.8	20.8	13.1	14.6
1978	14.5	15.1	18.8	20.0	21.2	23.4	22.8	23.0	22.7	15.3	15.9	11.8
1979	17.2	15.2	19.1	22.3	22.0	22.3	23.5	23.0	23.0	18.6	14.4	12.7
1980	14.0	15.2	18.2	18.5	21.0	23.0	22.6	23.2	23.0	18.7	18.7	13.7
1981	10.9	16.6	18.7	20.5	22.1	23.1	22.0	23.0	22.4	21.0	15.4	11.8
1982	14.4	14.8	20.5	18.8	23.0	23.7	23.3	22.7	22.5	21.8	18.8	9.1
1983	10.8	16.4	17.0	22.9	23.8	22.2	22.7	22.9	21.6	20.5	10.9	10.9
1984	10.9	13.4	15.5	21.7	21.3	23.0	22.0	22.5	22.0	18.2	17.5	14.0
1985	15.7	15.7	16.2	21.7	22.8	22.5	22.5	23.5	21.2	20.0	19.3	9.8
1986	9.0	16.5	11.5	20.9	22.0	23.7	22.9	23.0	21.7	20.0	16.2	15.0
1987	14.5	14.8	19.0	21.0	23.0	23.4	23.7	22.3	21.5	19.0	19.3	10.0
Ave.	12.5	14.6	17.3	20.5	21.9	23.0	22.8	22.8	22.3	19.8	15.6	12.3

Table I-4 Frequency Distribution of Daily Minimum Temperature

(at Vientiane 1985, 1986 and 1987)

Degree of Temperature (°C)		Jan. 1-10	Jan. 11-20	Jan. 21-31	Feb. 1-10	Feb. 11-20	Feb. 21-28	Mar. 1-10	Mar. 11-20	Mar. 21-31
		Number of Days								
less than	10.0	1	0	0	0	0	0	0	0	0
"	11.0	1	0	0	0	0	0	0	0	0
"	12.0	2	1	0	0	0	0	1	0	0
"	13.0	2	2	0	0	0	0	2	0	0
"	14.0	2	0	1	0	0	0	2	0	0
"	15.0	1	1	3	1	0	0	1	0	0
"	16.0	2	1	5	2	0	0	0	0	0
"	17.0	4	9	4	7	1	0	1	2	0
"	18.0	4	6	9	4	4	2	1	1	0
more than	18.0	11	10	11	16	25	22	22	27	33

Degree of Temperature (°C)		Oct. 1-10	Oct. 11-20	Oct. 21-31	Nov. 1-10	Nov. 11-20	Nov. 21-30	Dec. 1-10	Dec. 11-20	Dec. 21-31
		Number of Days								
less than	10.0	0	0	0	0	0	0	1	0	1
"	11.0	0	0	0	0	0	0	1	1	1
"	12.0	0	0	0	0	0	0	1	1	0
"	13.0	0	0	0	0	0	0	1	4	2
"	14.0	0	0	0	0	0	0	1	1	4
"	15.0	0	0	0	0	0	0	3	2	2
"	16.0	0	0	0	0	0	0	2	5	4
"	17.0	0	0	0	0	0	1	2	3	6
"	18.0	0	0	0	0	0	2	1	9	5
more than	18.0	30	30	33	30	30	27	17	4	8

Table I-5 Mean Monthly Discharge at Tha Ngon

(Unit: m^3/sec)

Hydro.year	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1972/73	144	122	291	835	2,260	1,840	1,000	525	329	202	165	149	655
1973/74	129	157	363	1,280	1,630	2,960	1,240	425	247	168	139	130	739
1974/75	136	168	331	647	1,340	1,770	835	431	216	153	132	120	523
1975/76	124	185	791	1,500	2,247	2,790	1,290	515	284	191	157	135	851
1976/77	93.2	174	465	705	1,480	1,524	1,270	705	290	155	142	450	621
1977/78	380	235	216	728	1,170	1,400	469	260	149	128	110	114	447
1978/79	124	327	816	1,910	2,770	2,010	793	278	138	293	333	322	843
1979/80	326	430	642	762	1,060	1,600	603	369	282	256	261	267	572
1980/81	274	365	799	1,270	1,910	2,210	796	428	357	347	351	333	787
1981/82	259	450	835	2,200	2,470	2,410	1,410	514	378	327	299	335	991
1982/83	371	343	535	882	1,600	1,560	1,410	471	370	339	324	330	711
1983/84	326	280	388	936	1,670	1,600	852	510	363	343	330	257	655
1984/85	255	379	526	1,500	1,490	1,340	884	473	432	445	404	390	710
1985/86	113	166	596	1,074	1,170	2,210	1,052	808	485	277	178	132	688
1986/87	125	330	490	924	1,460	1,240	1,011	562	308	269	234	185	595
1987/88	177	194	450	445	1,012	1,024	768	424	392	365	362	294	492
Average	210	269	533	1,100	1,671	1,843	980	481	314	266	245	246	680

Table I-6 Observation of Suspended Sediment

(at Tha Ngon)

Date	Water Discharge (m^3/sec)	Suspended Sediment (kg/sec)	(ppm)	(ton/day)
Nov. 7 '86	366	11.67	32	1,008
Dec. 23 '86	196	3.18	16	275
Jan. 31 '87	338	0.68	2	59
Feb. 10 '87	334	10.05	30	868
Mar. 10 '87	248	1.83	7	158
May 5 '87	279	9.28	33	802
Jun. 30 '87	705	4.47	6	386
Jun. 23 '87	310	9.31	30	804
Aug. 31 '87	760	99.3	131	8,580
Sep. 9 '87	942	82.2	87	7,102
Sep. 16 '87	647	41.1	64	3,551
Sep. 23 '87	667	47.98	72	4,146
Sep. 25 '87	823	119.3	145	10,308
Sep. 26 '87	918	107.7	117	9,305
Sep. 27 '87	1,130	137.8	122	11,907
Sep. 28 '87	1,111	51.15	46	4,419
Sep. 26 '87	981	26.69	27	2,306
Oct. 10 '87	591	36.79	62	3,179
Oct. 17 '87	539	33.46	62	2,891
Oct. 27 '87	513	12.77	25	1,103
Oct. 30 '87	470	61.99	132	5,356
Nov. 13 '87	412	31.56	77	2,727
Nov. 17 '87	389	6.57	17	568
Nov. 22 '87	470	41.33	88	3,571
Nov. 27 '87	473	26.84	57	2,319
Dec. 12 '87	417	13.38	32	1,156
Dec. 23 '87	405	28.75	71	2,484
Jan. 14 '88	284	3.68	13	318
Jan. 26 '88	353	13.52	38	1,168
Feb. 9 '88	346	14.56	42	1,258
Mar. 10 '88	264	4.89	19	423
Apr. 29 '88	258	1.11	4	96
May 10 '88	339	6.78	20	586
May 20 '88	291	4.51	16	390
Jun. 14 '88	479	22.3	47	1,927
Average			51	2,786
Maximum			145	11,907
Minimum			2	59

Table 1-7 Discharge Measurement in the Hong Seng and the Houei Ma Hiao Rivers

Date	No.1 Gauge/1				No.2 Gauge/1				No.3 Gauge/1			
	WL (m)	GH/2 (m)	Q (m^3/sec)	v (m/sec)	WL (m)	GH/2 (m)	Q (m^3/sec)	v (m/sec)	WL (m)	GH/2 (m)	Q (m^3/sec)	v (m/sec)
Aug. 27 '88	164.02	1.20	5.96	0.180	164.52	1.15	5.93	0.312	164.89	0.96	1.08	0.420
Aug. 30 '88	163.92	1.40	6.38	0.205	164.47	1.10	5.13	0.276	164.83	0.90	1.75	0.611
Sep. 1 '88	163.94	1.42	6.00	0.192	164.45	1.08	4.75	0.276	164.77	0.84	1.11	0.600
Sep. 6 '88	164.27	1.75	16.32	0.442	164.71	1.34	8.16	0.393	164.97	1.04	0.63	0.197
Sep. 7 '88	164.37	1.85	19.27	0.622	164.77	1.40	10.30	0.467	165.15	1.22	no flow	
Average	164.10		10.79		164.58		6.85		164.92		1.14	

/1 : Zero of gauge elevation
No.1 EL 162.52 m
No.2 EL 163.37 m
No.3 EL 163.93 m
/2 : Gauge height

Table I-8 Minimum Mean Daily Discharge at Tha Ngon

No.	Hydrological year (Apr.-Mar.)	Date	GH /1 (m)	Discharge (m^3/sec)
1	1972/73	May 3	2.30	59
2	1977/78	Feb. 23	2.56	73
3	1976/77	Apr. 17	2.68	79.8
4	1974/75	Mar. 28	2.80	88
5	1978/79	Jan. 4	2.98	103
6	1975/76	May 6	3.00	105
7	1973/74	Apr. 26	3.10	115
8	1987/88	Apr. 4	3.45	146
9	1986/87	Mar. 30	3.52	154
10	1980/81	Apr. 10	3.68	173
11	1984/85	Apr. 22	4.06	215
12	1982/83	May 21	4.02	215
13	1983/84	Mar. 16	4.08	218
14	1981/82	Apr. 30	4.12	222
15	1979/80	Jan. 3	4.20	232
			Average	147

/1 : Gauge height

Table I-9 Chemical Analyses of River Water

Date: Aug.27, 1988

Items		Nam Khem at Tha Ngon	Nam Ngum at Tha Ngon	Houei Ma Hiao at Ban Sam Khe
pH		6.73	7.31	6.28
EC	(micro mhos/cm)	113	115	129
Ca	(meq/l)	0.148	0.436	0.319
Mg	(meq/l)	0.091	0.587	0.333
Na	(meq/l)	0.620	0.149	0.454
K	(meq/l)	0.024	0.014	0.038
Alk	(meq/l)	0.152	1.017	0.640
Cl	(meq/l)	0.610	0.061	0.418
SO_4	(meq/l)	0.084	0.096	0.149
NH_4-N	(mg/l)	0.071	0.083	0.099
COD Mn	(mg/l)	4.279	1.459	5.602
Tot.Fe	(mg/l)	1.353	0.357	1.229
(NO_3+NO_2)-N	(mg/l)	0.065	0.124	0.051
PO_4-P	(mg/l)	0.020	0.008	0.024
Tot.P	(mg/l)	0.028	0.022	0.030
Si	(mg/l)	2.700	7.300	3.300
Oxygen	(mg/l)	1.142	6.314	3.276
TSS	(mg/l)	32.000	2.000	36.000
Tot.N	(mg/l)	0.078	0.017	0.141
Temperature	(°C)	29.0	27.4	29.6
Oxygen	(Sat.%)	14.8	80.0	43.0

Table I-10 Maximum Mean Daily Discharge at Tha Ngon

No.	Hydrological year (Apr.-Mar.)	Date	GH /1 (m)	Discharge (m^3/sec)
1	1981/82	Sep. 11	17.62	4,110
2	1975/76	Sep. 7	17.06	3,620
3	1973/74	Sep. 12	16.68	3,370
4	1978/79	Aug. 1	16.36	3,200
5	1980/81	Aug. 1	15.96	3,010
6	1972/73	Aug. 28	15.12	2,870
7	1982/83	Oct. 3	15.47	2,810
8	1976/77	Sep. 24	14.4	2,440
9	1979/80	Sep. 9	14.24	2,380
10	1983/84	Sep. 15	13.99	2,310
11	1984/85	July 16	14.01	2,310
12	1974/75	Sep. 10	13.54	2,170
13	1987/88	Aug. 26	12.51	1,890
14	1977/78	Sep. 25	11.9	1,730
			Average	2,730

/1 : Gauge height

Table I-11 Maximum Mean Daily Discharge at Vientiane

No.	Hydrological year(Apr.-Mar.)	Date	GH /1 (m)	Discharge (m^3/sec)
1	1966/67	Sep. 4		25,900
2	1971/72	Aug. 22	12.51	22,900
3	1978/79	Aug. 16	12.08	21,300
4	1924/25	Aug. 29		21,200
5	1980/81	Sep. 8	11.93	20,600
6	1929/30	Aug. 23-24		20,500
7	1945/46	Aug. 21		20,300
8	1942/43	Aug. 13		20,100
9	1973/74	Aug. 29	11.68	19,700
10	1941/42	Aug. 13		19,400
11	1946/47	Sep. 18		19,400
12	1923/24	Aug. 22-23		19,300
13	1969/70	Aug. 21	11.82	19,100
14	1939/40	Aug. 22		19,100
15	1970/71	Aug. 15	11.86	19,100
16	1917/18	Aug. 12		19,000
17	1914/15	Sep. 4		18,400
18	1922/23	Aug. 31		18,300
19	1938/39	Aug. 28		18,300
20	1976/77	Aug. 17	11.27	18,200
21	1918/19	Aug. 16		18,100
22	1930/31	Aug. 13		18,100
23	1947/48	Aug. 14		18,100
24	1955/56	Sep. 5		18,000
25	1961/62	Sep. 10		17,900
26	1940/41	Aug. 9		17,900
27	1960/61	Aug. 20		17,800
28	1926/27	Aug. 20		17,700
29	1959/60	Aug. 30		17,600
30	1935/36	Aug. 16		17,600
31	1927/28	Aug. 2		17,500
32	1937/38	Sep. 8		17,300
33	1952/53	Sep. 10		17,300
34	1913/14	Aug. 24		17,300
35	1985/86	Sep. 3	11.5	17,100
36	1936/37	Sep. 13		17,000
37	1964/65	Aug. 27		16,900
38	1921/22	Oct. 3		16,800
39	1982/83	Aug. 26	10.74	16,600
40	1981/82	Aug. 8	10.75	16,600
41	1975/76	Sep. 5	10.79	16,400
42	1933/34	Aug. 26		16,300
43	1956/57	Aug. 24		16,300
44	1951/52	Aug. 25		16,300
45	1974/75	Sep. 3	10.32	15,900
46	1931/32	Aug. 19		15,800
47	1943/44	Aug. 26		15,800
48	1963/64	Aug. 11		15,700
49	1954/55	Sep. 2-3		15,700
50	1948/49	Sep. 7		15,600
51	1928/29	Jul. 20		15,500
52	1984/85	Jul. 18	10.28	15,400
53	1962/63	Aug. 26		15,300
54	1950/51	Sep. 5		15,200
55	1979/80	Sep. 15	10.2	15,200
56	1934/35	Aug. 27		14,900
57	1932/33	Oct. 17		14,900
58	1949/50	Oct. 1		14,800
59	1968/69	Aug. 18	10.16	14,700
60	1983/84	Aug. 8	9.97	14,600
61	1977/78	Aug. 2	9.93	14,400
62	1944/45	Sep. 2		14,300
63	1972/73	Aug. 27	9.86	14,200
64	1953/54	Aug. 29		14,100
65	1925/26	Aug. 1		14,000
66	1915/16	Aug. 23		13,900
67	1986/87	Aug. 1-2	9.84	13,400
68	1967/68	Aug. 24	9.17	12,900
69	1965/66	Oct. 31		12,800
70	1920/21	Sep. 21		12,600
71	1916/17	Sep. 13		12,300
72	1958/59	Jul. 28		11,500
73	1957/58	Oct. 2		11,300
		Average		16,900

/1 : Gauge height

Table 1-12 Stagnation-outflow Calculation

Time in hour	Runoff upland field	Runoff paddy field	Discharge in Hong Seng	Total (m^3/sec)	Flow Capacity (m^3/sec)	Balance (m^3/sec)	Stagnated Water ($1000m^3$)	Outflow (m^3/sec)	Outflow ($1000m^3$)
0			40	40	50				
2	3		40	43	50				
4	10		40	50	50				
6	17	2	40	59	50	9	32		
8	23	6	40	69	50	19	101		
10	29	10	40	79	50	29	173		
12	30	15	40	85	50	35	230		
14	26	15	40	81	50	31	238		
16	23	15	40	78	50	28	212		
18	19	15	40	74	50	24	187		
20	16	15	40	71	50	21	162		
22	13	15	40	68	50	18	140		
24	9	15	40	64	50	14	115		
26	6	15	35	56	50	6	72		
28	4	15	35	54	50	4	36		
30	2	15	35	52	50	2	22		
32	1	15	35	51	50	1	11		
34		15	35	50	50		4		
36		15	35	50	50				
38		15	30	45	50			5	18
40		15	30	45	50			5	36
42		15	30	45	50			5	36
44		15	30	45	50			5	36
46		15	30	45	50			5	36
48		15	30	45	50			5	36
50		15	30	45	50			5	36
52		14	30	44	50			6	40
54		13	30	43	50			7	47
56		10	30	40	50			10	61
58		7	30	37	50			13	83
60		5	30	35	50			15	101
62		2	30	32	50			18	119
64		1	30	37	50			13	112
66			30	35	50			15	101
68			30	32	50			18	119
70			30	30	50			20	137
72			30	30	50			20	144
74			30	30	50			20	144
76			30	30	50			20	144
78			30	30	50			20	144
						Total	1,735		1,728

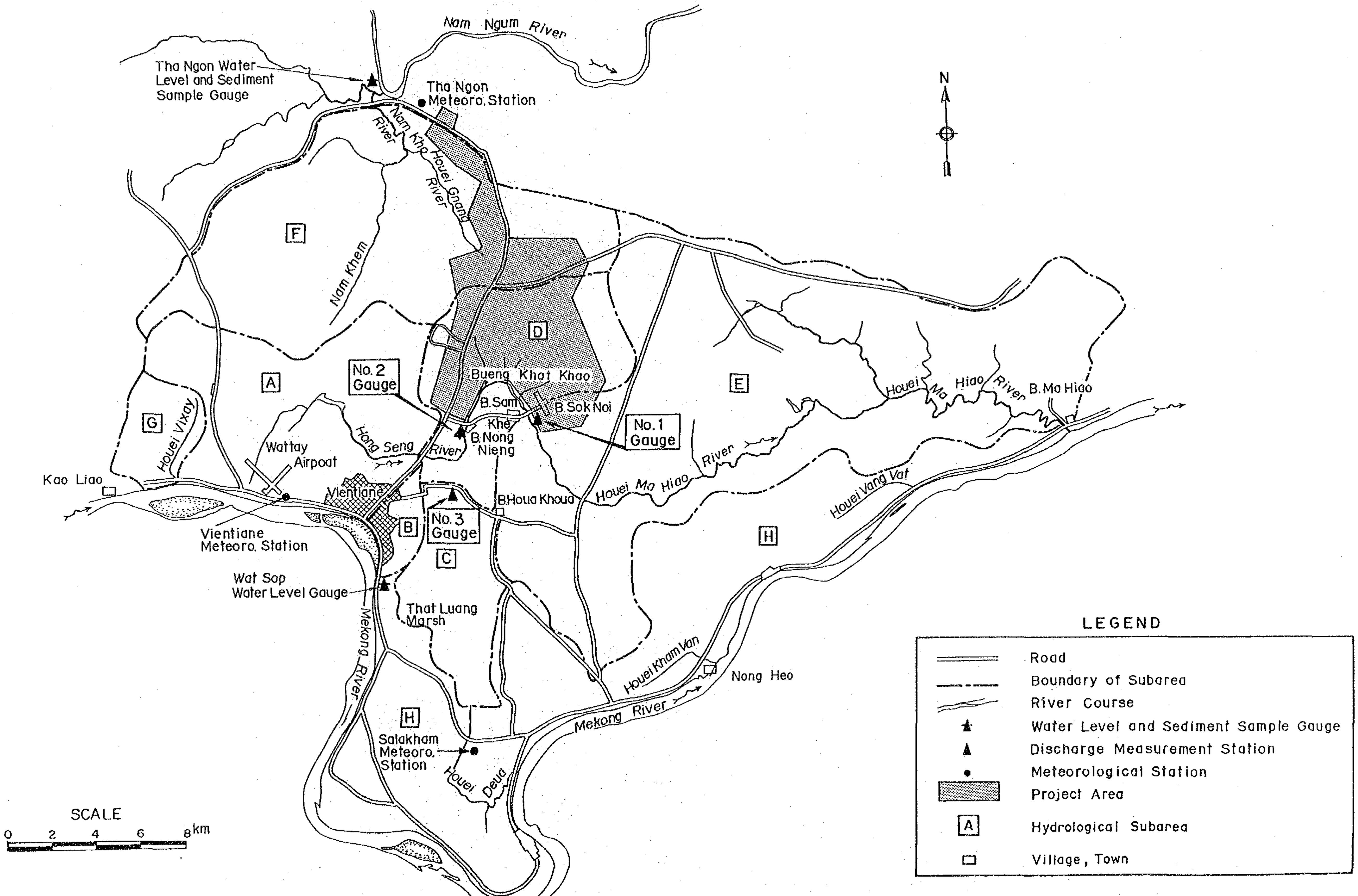


Fig. I-1 METEOROLOGICAL AND HYDROLOGICAL MAP IN THE VIENTIANE PLAIN

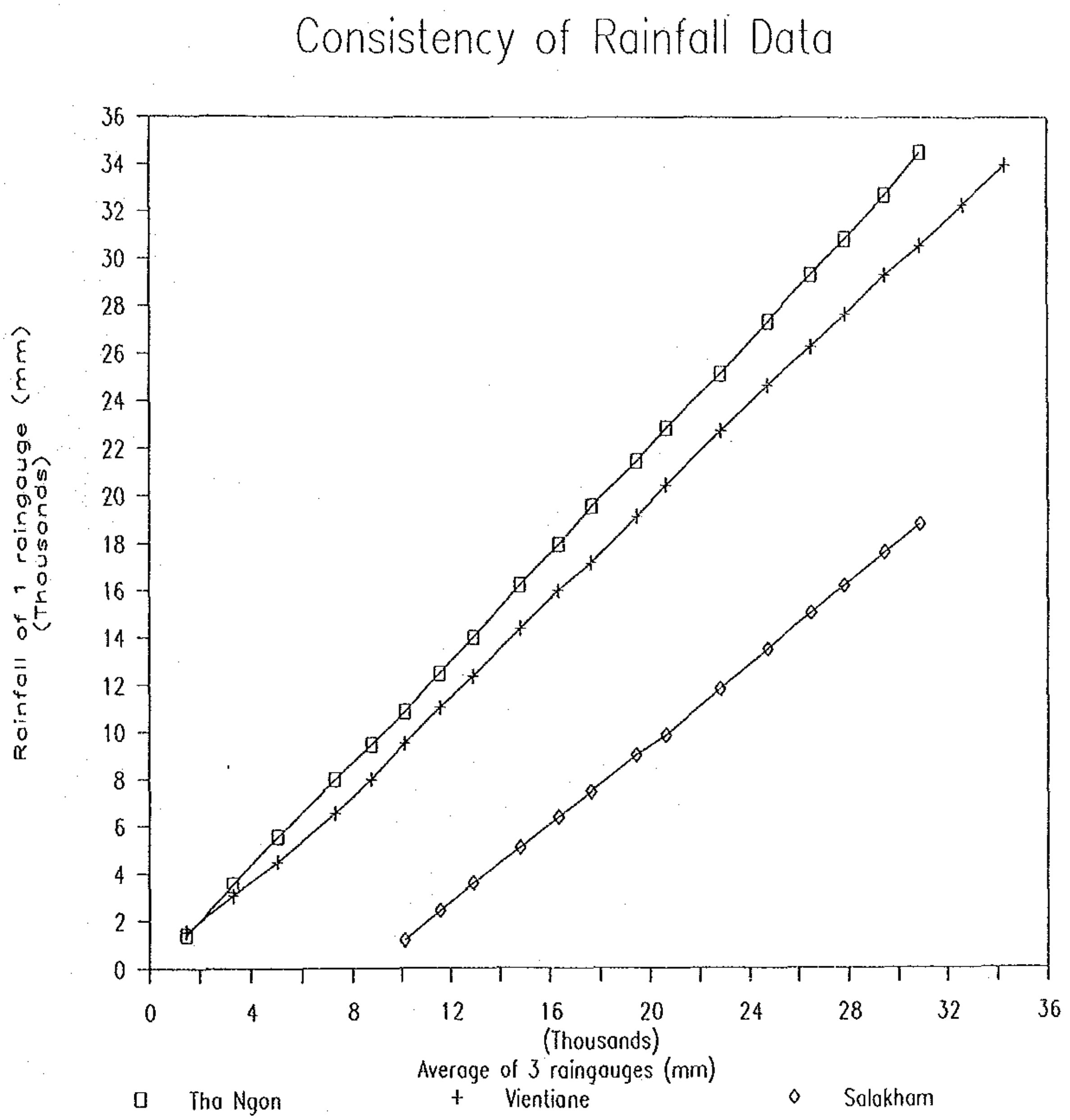


Fig. I-2 CONSISTENCY OF RAINFALL DATA

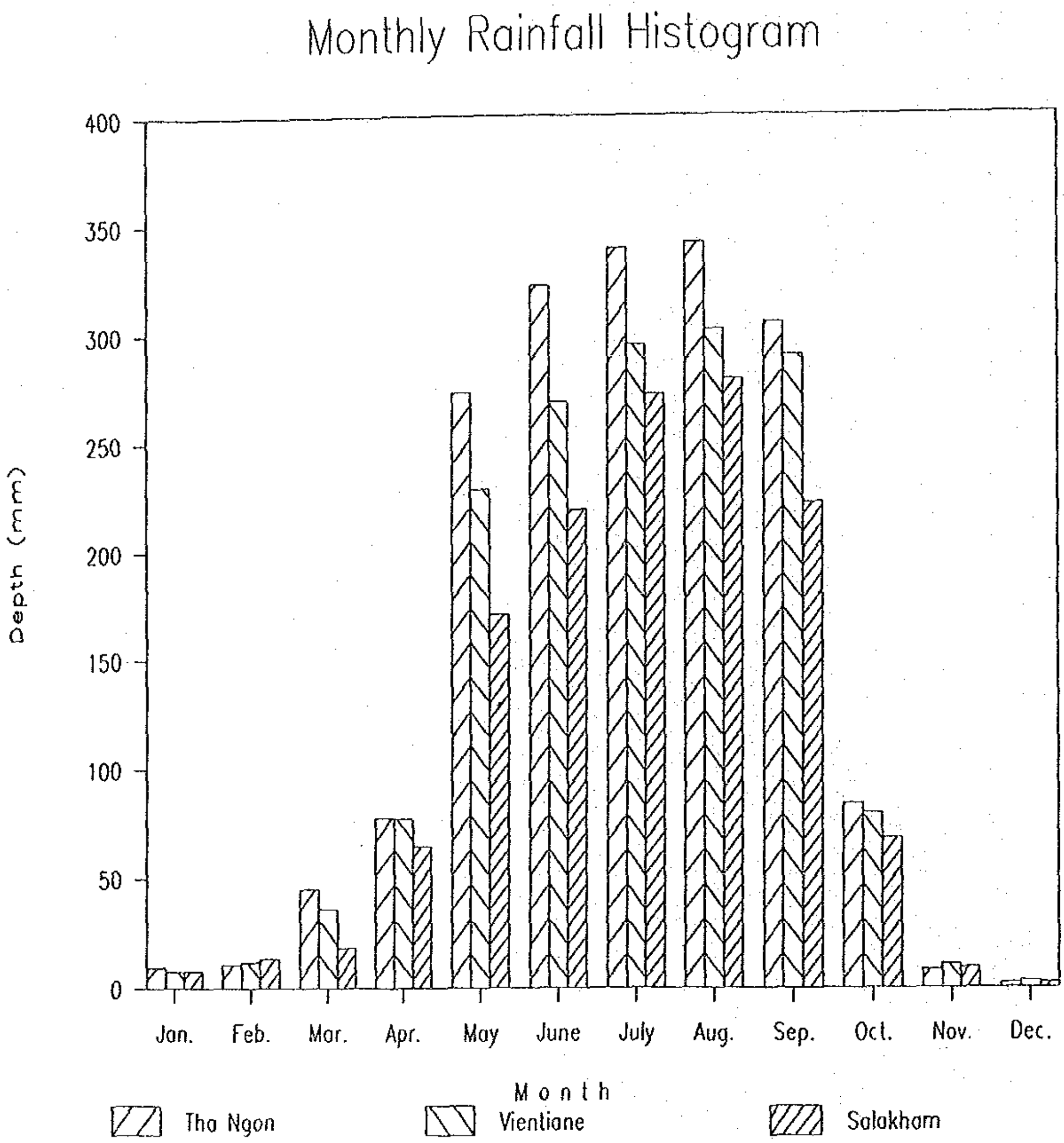


Fig. I-3 MONTHLY RAINFALL HISTOGRAM

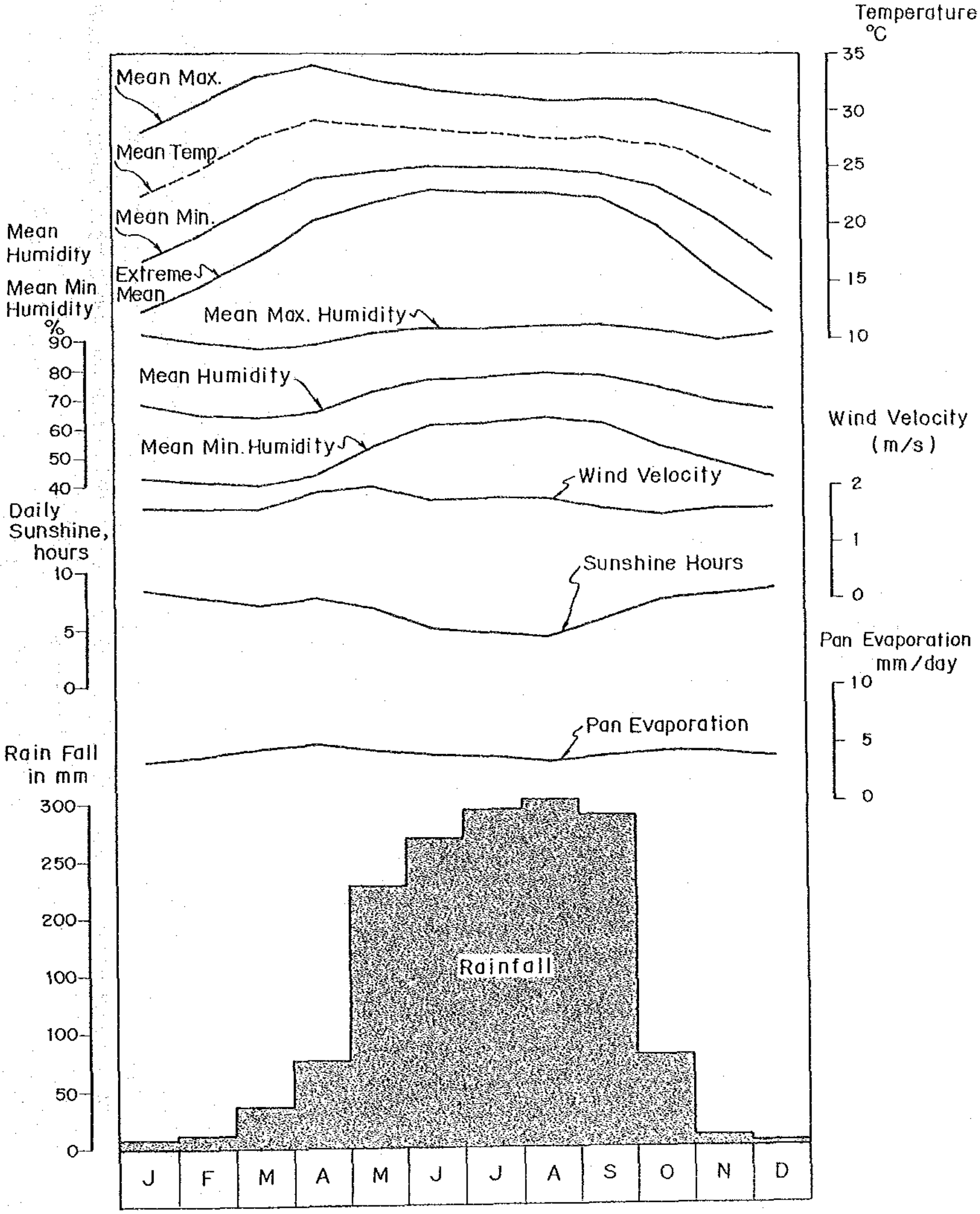


Fig. I-4 METEOROLOGICAL DATA

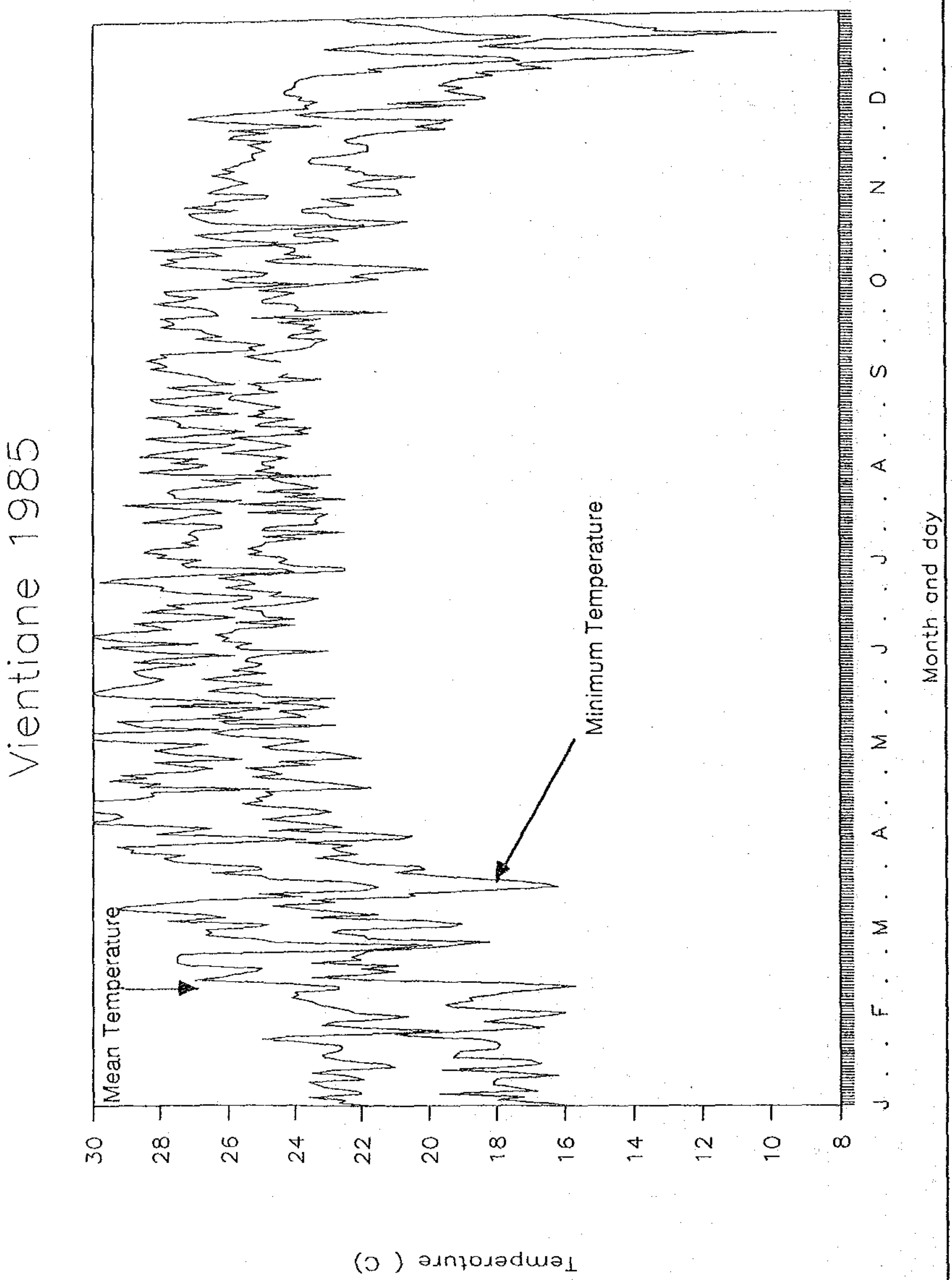


Fig. I-5 DAILY MINIMUM TEMPERATURE FROM 1985 TO 1987 (1/3)

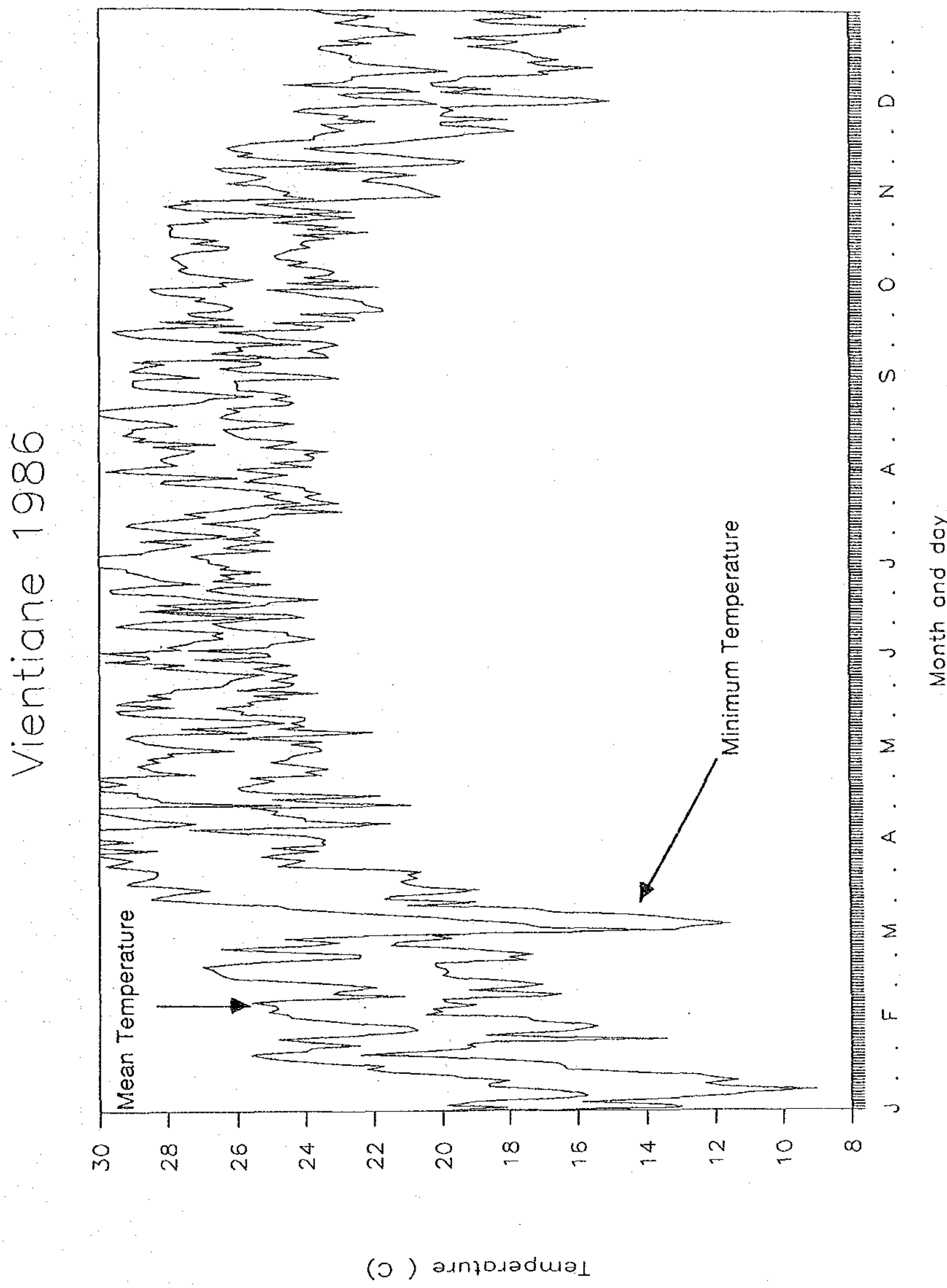


Fig. I-5 DAILY MINIMUM TEMPERATURE FROM 1985 TO 1987 (2/3)

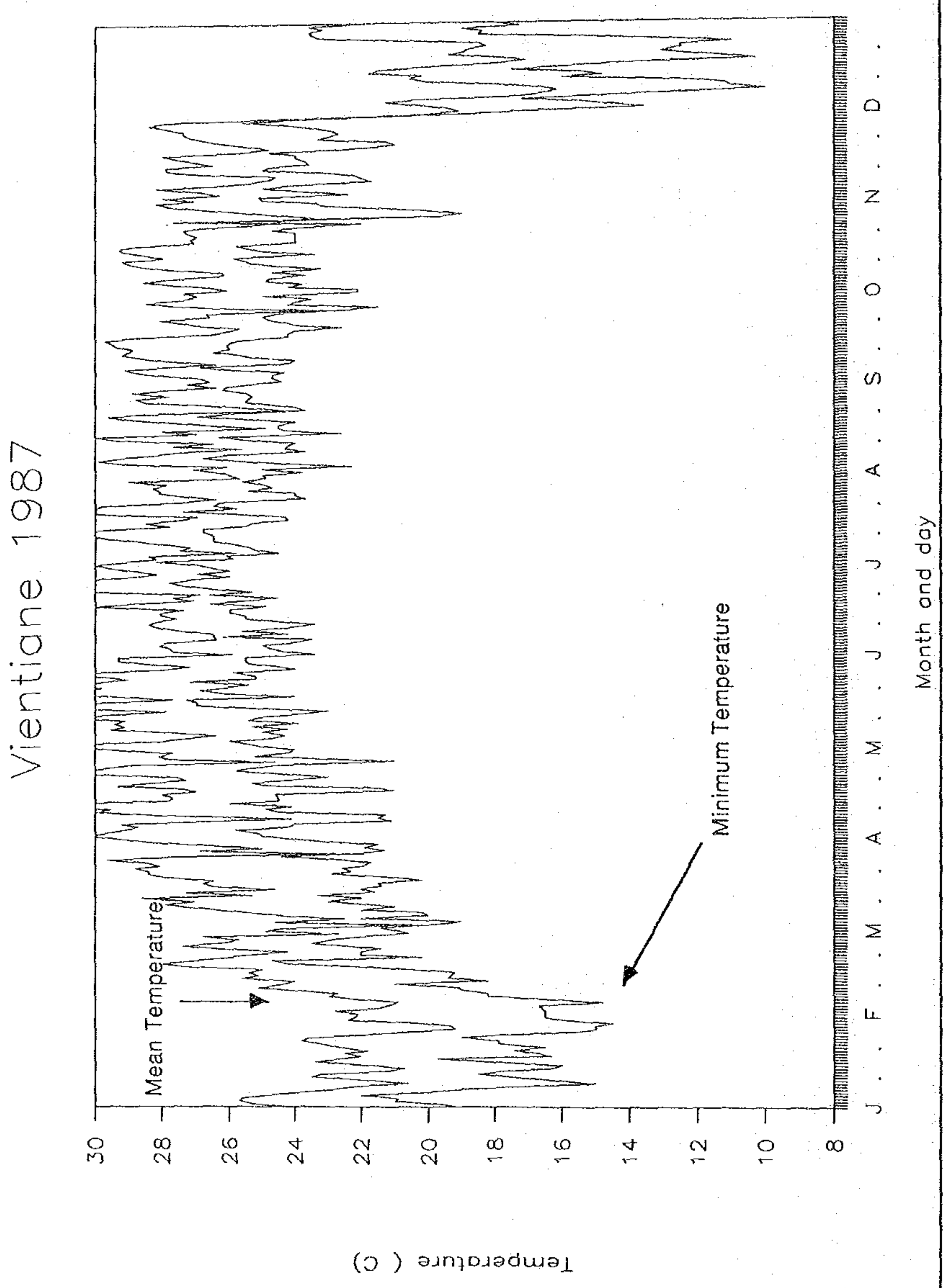


Fig. I-5 DAILY MINIMUM TEMPERATURE FROM 1985 TO 1987 (3/3)

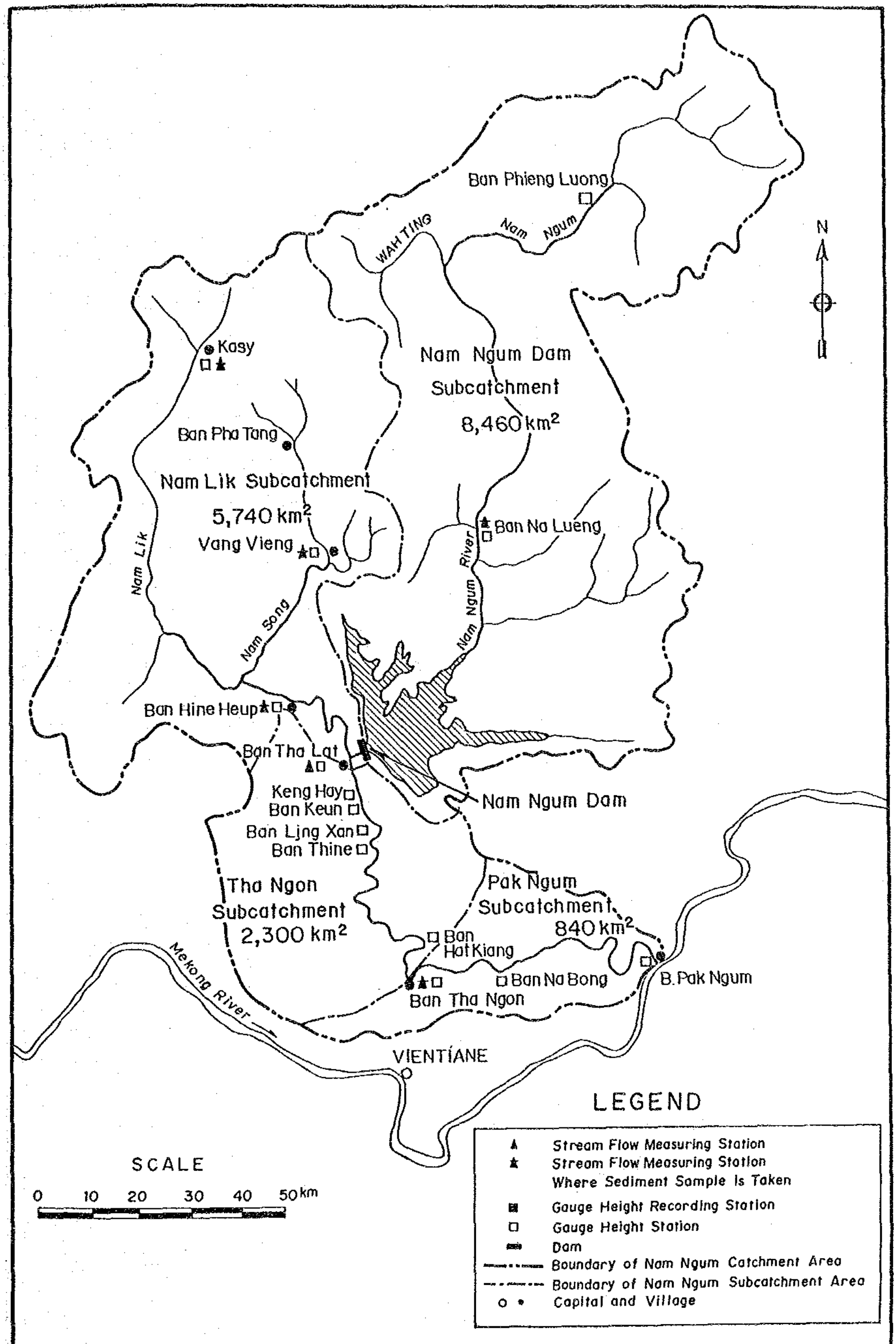


Fig. I-6 THE NAM NGUM RIVER BASIN

	1960	1960s										1970s										1980s									
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
NAM NGUM RIVER																															
Ban Phieng Luong																											△	◬	◬		
Ban Na Lueng																											⊙	⊙	⊙		
Ban Tha Lat				◬	◬	◬	○	⊙	⊙	⊙	⊙	⊙	○	⊙	⊙	⊙	○	⊙	⊙	⊙	⊙	○	⊙	⊙	○	○	○	○	○		
Keng Hay								△	△	△	△	△	△	△	△		△	△													
Ban Keun																			△	◬	◬	◬									
Ban Ling Xan																				△	△	△									
Ban Thine																			△	△	△	△	△								
Ban Hat Klang																			△	△											
Ban Tha Ngon	◬	◬	◬	◬	◬	◬	◬	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	○	○	⊙	○	⊙	⊙	⊙	○	○	○	○	⊙	⊙		
Ban Na Bong																							◬	◬	◬	◬	△	△	△		
Ban Pak Ngum	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	◬	△	◬	△	△	◬	△	△	△	△	△	△	△	△		
NAM LIK RIVER																															
Muong Kasi																												○	⊙		
Ban Na Kout																															
Ban Hine Heup				○	○	△	○	⊙	○	⊙	○	⊙	⊙	⊙	⊙		○	○	○	○		○	○	○	○	○	○	⊙	⊙		
Vang Vieng																						○	○	○	○	○	⊙	⊙	⊙		

◬ – Water Level Records Are Available For a Complete Year
△ – Water Level Records Are Available With Gaps
⊙ – Discharge Records Are Available For a Complete Year
○ – Discharge Records Are Available With Gaps

Fig. I-7 WATER LEVEL GAUGES AND AVAILABLE RECORDS

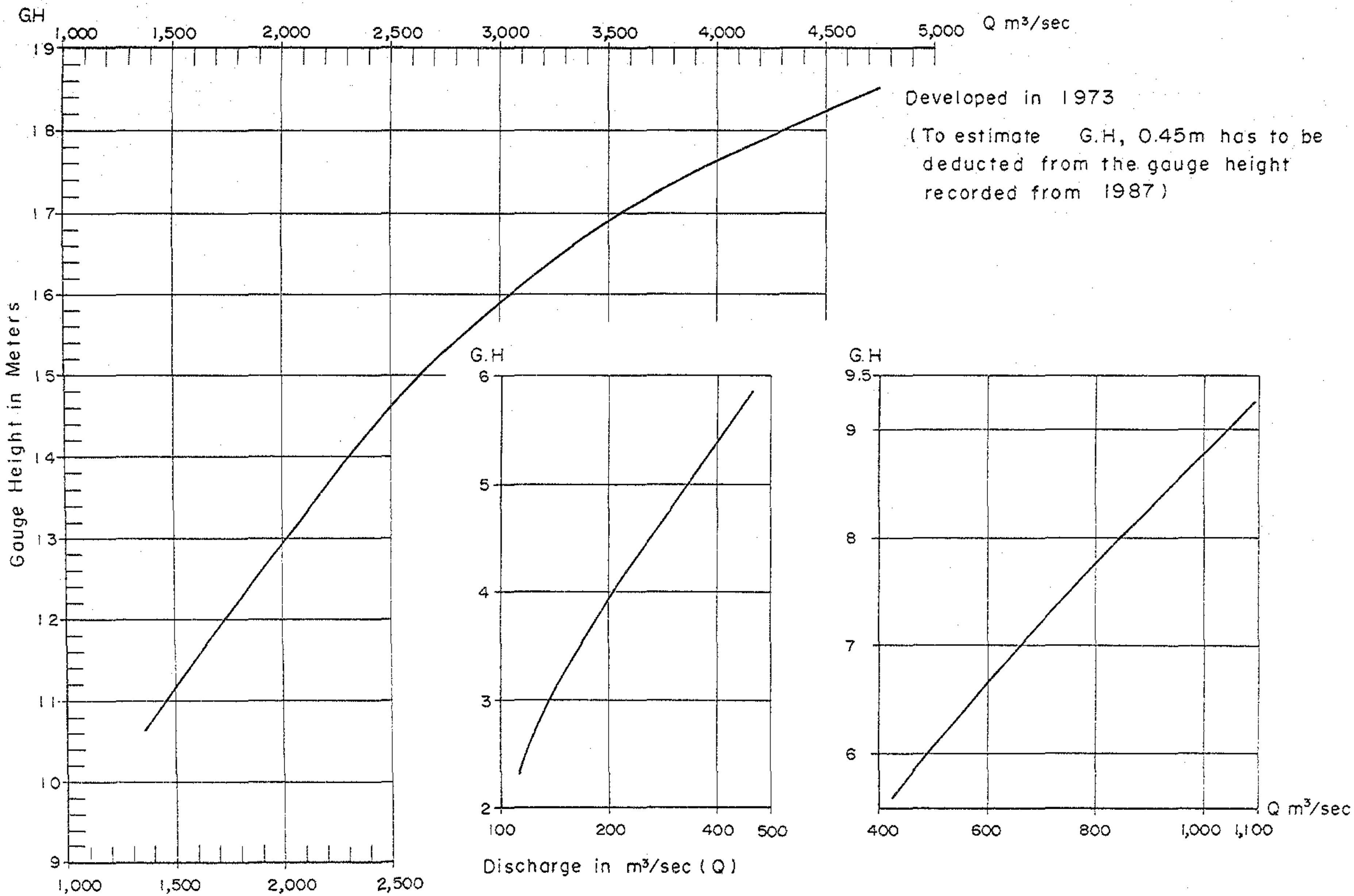


Fig. I-8 RATING CURVE FOR THA NGON IN THE NAM NGUM RIVER

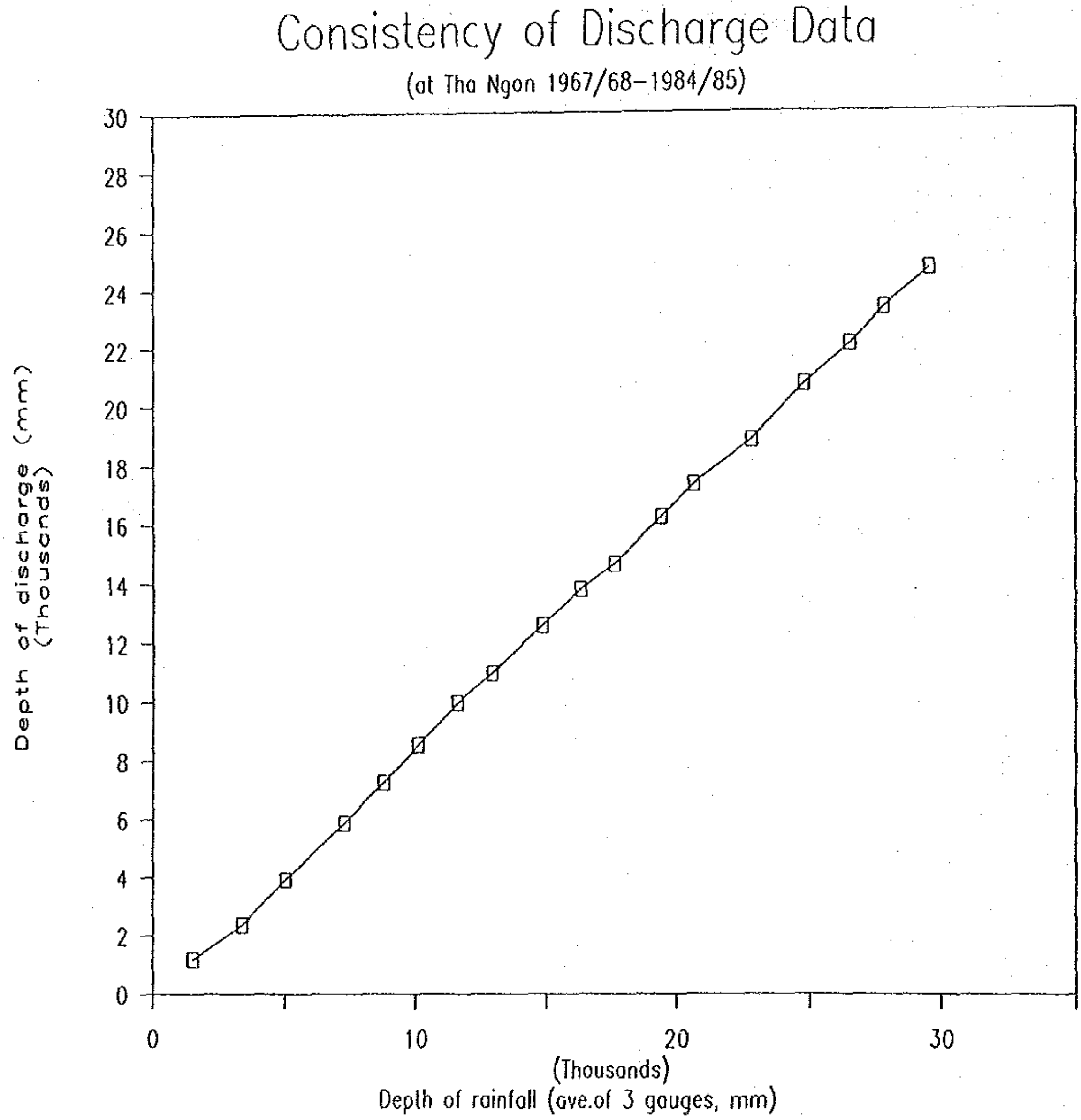


Fig. I-9 CONSISTENCY OF DISCHARGE DATA

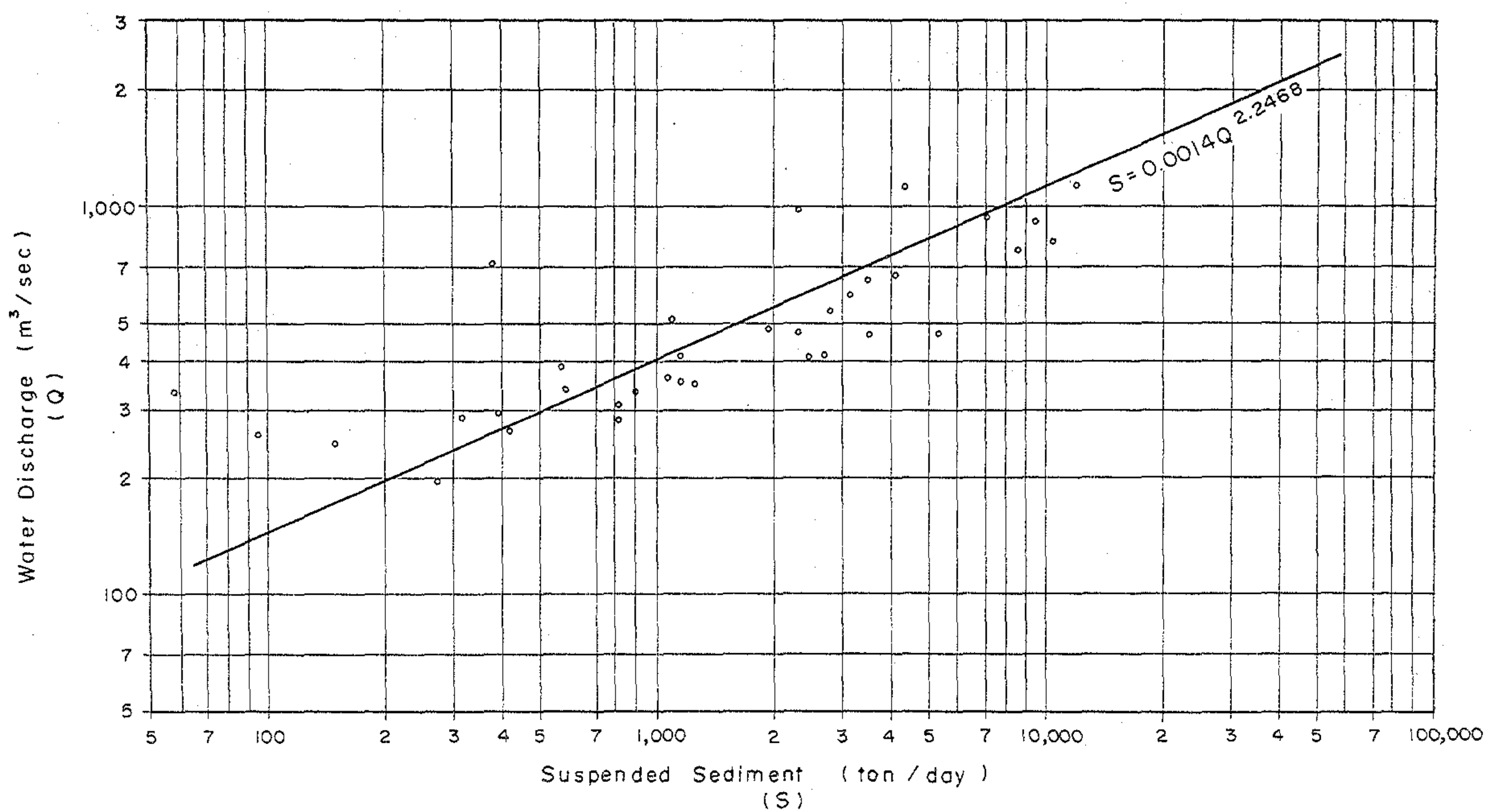


Fig. I-10 SEDIMENT RATING CURVE IN THE NAM NGUM RIVER AT THA NGON

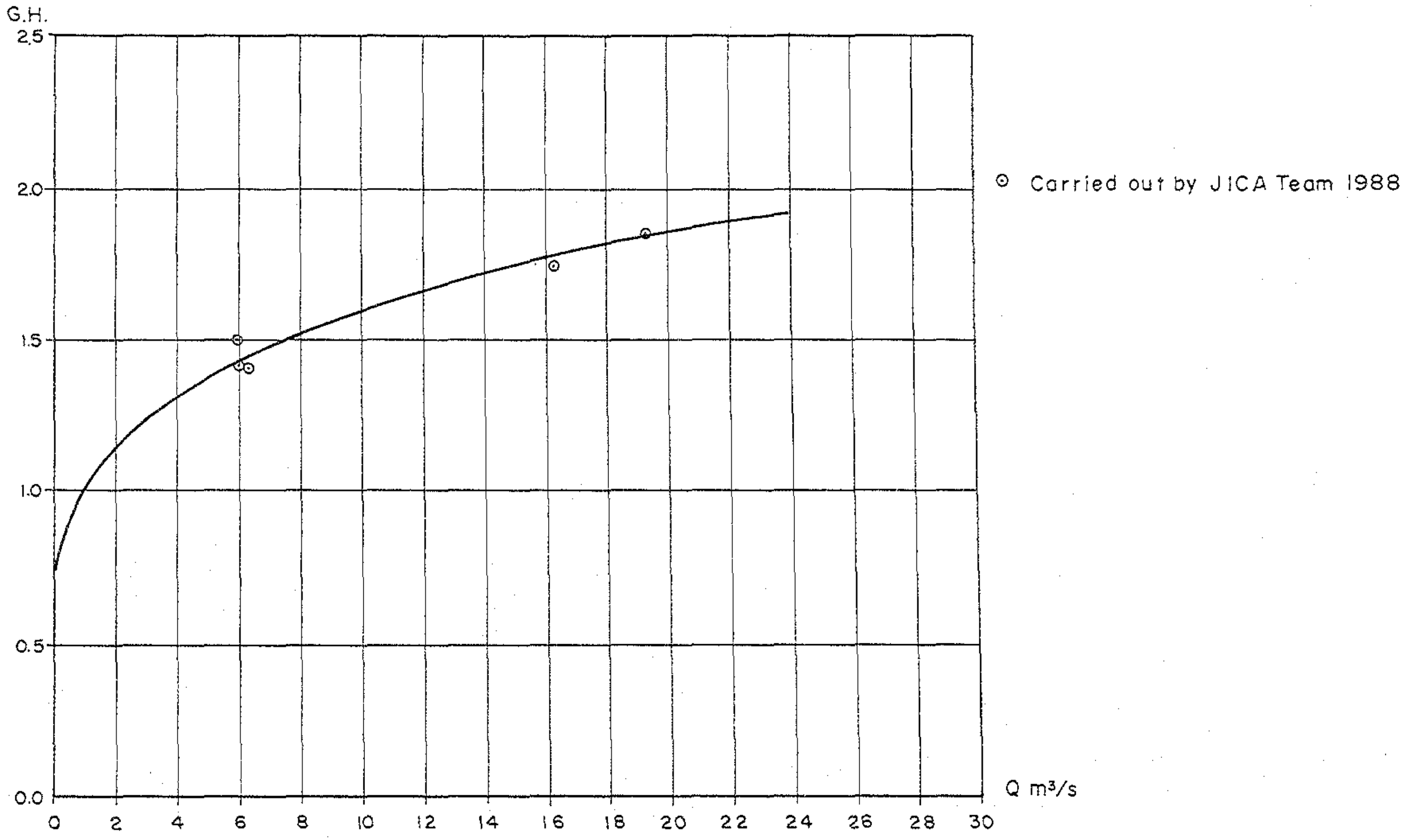


Fig. I-11 RATING CURVE AT NO.1 GAUGE
(SAM KHE)

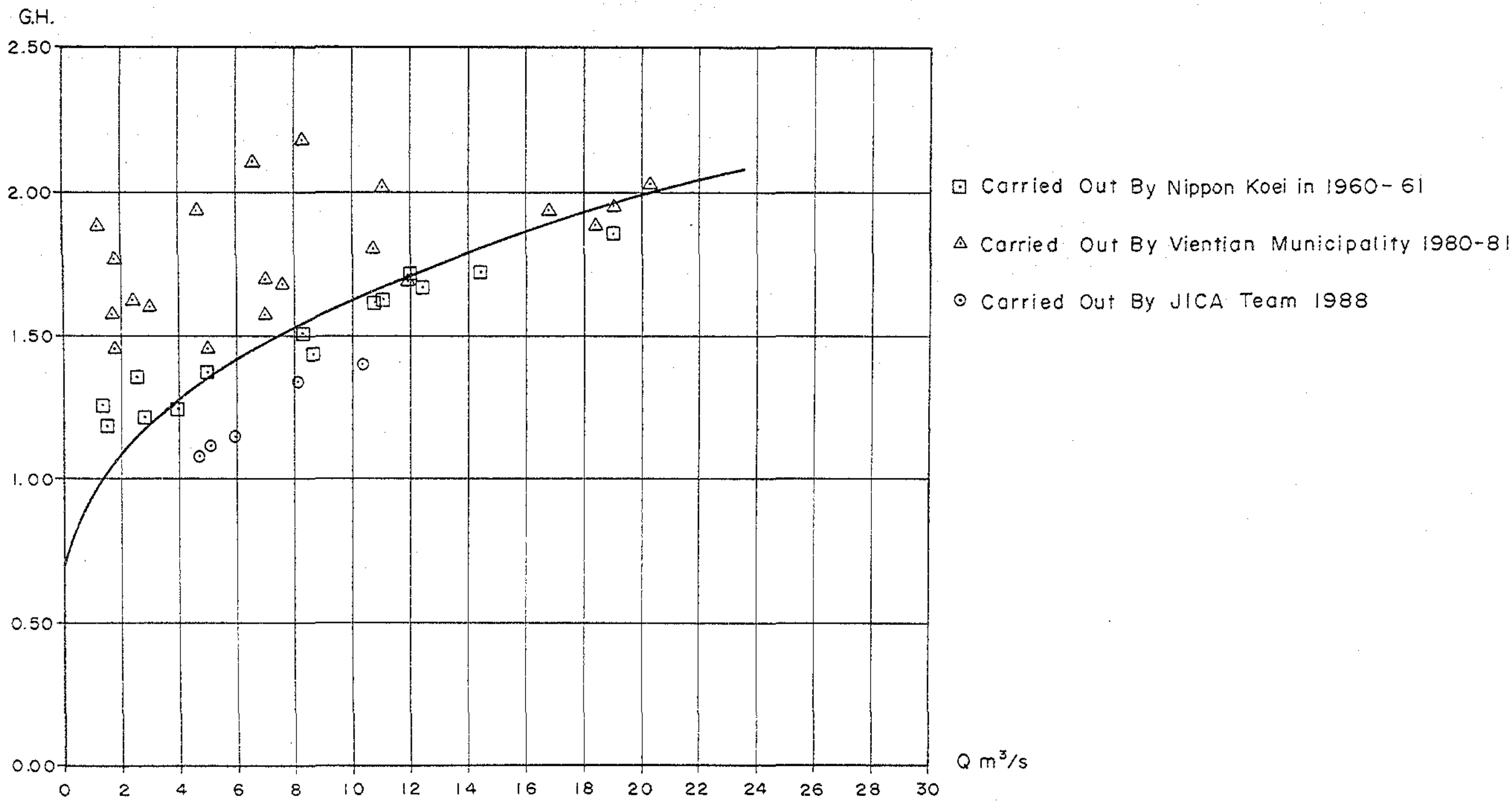


Fig. I-12 RATING CURVE AT NO.2 GAUGE
(NONG NIENG)

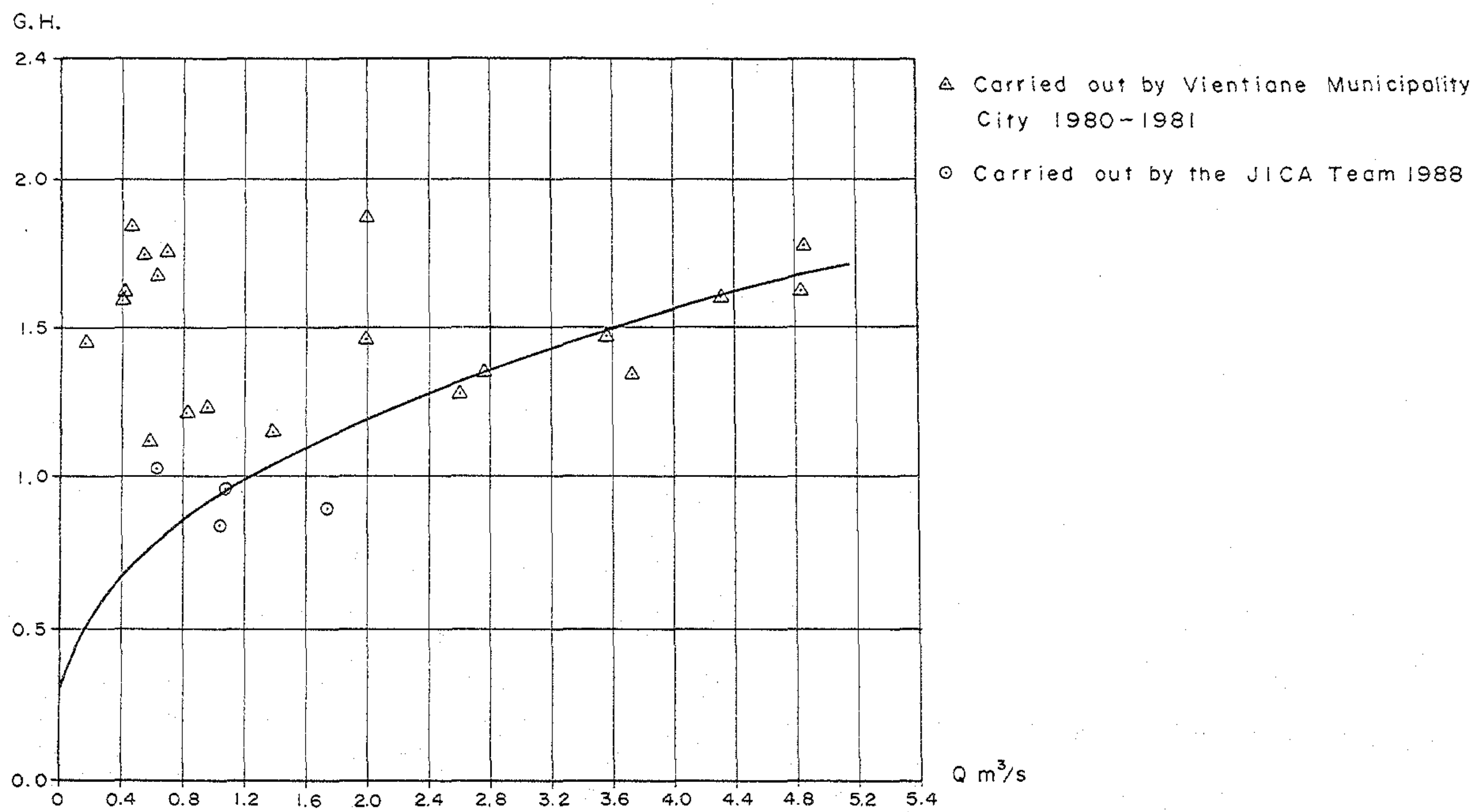
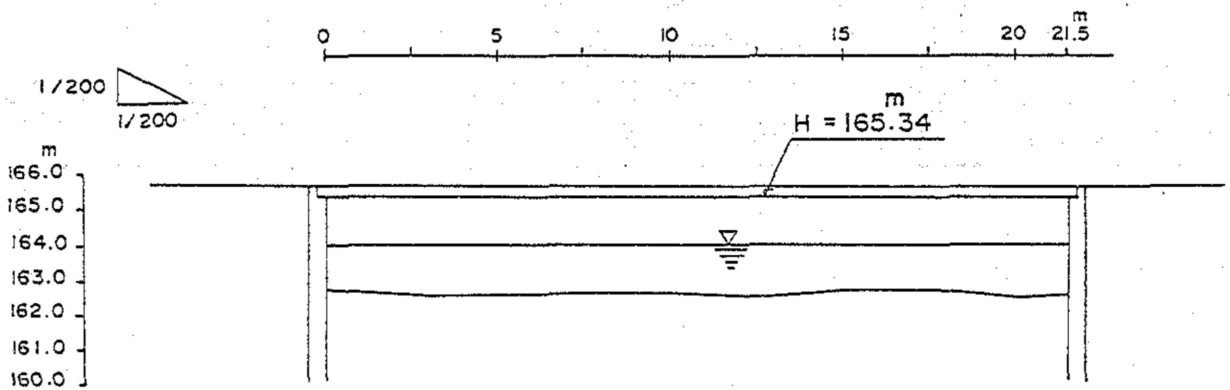


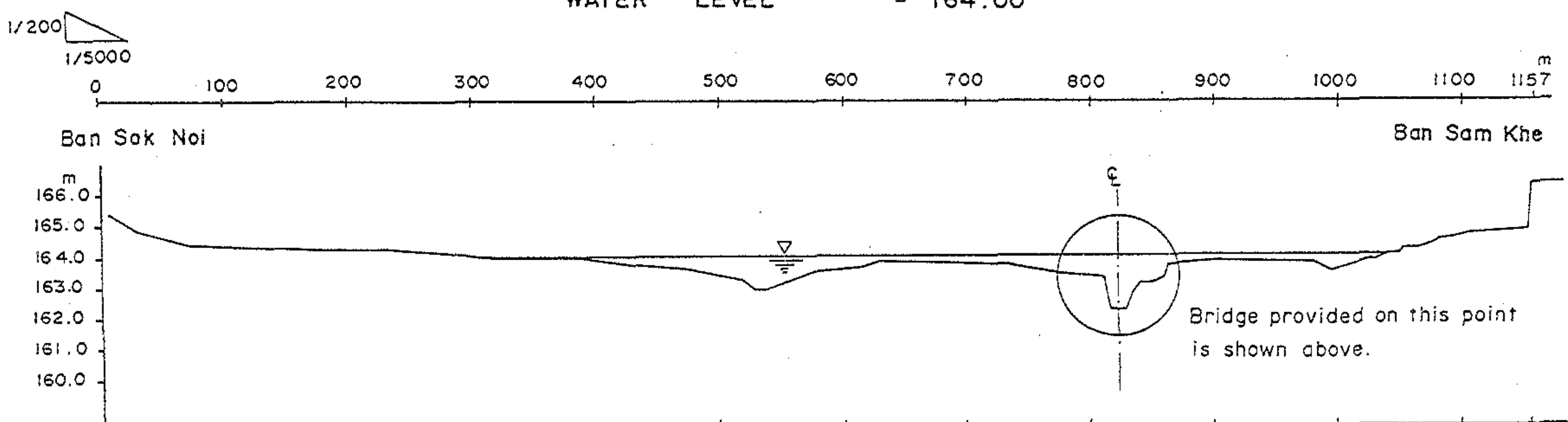
Fig. I-13 RATING CURVE AT NO.3 GAUGE (HOUA KHOUA)

NO. 1



DISTANCE (m)	0	5	10	15	20	21.5
ELEVATION (m)	162.64	162.69	162.62	162.74	162.45	162.56

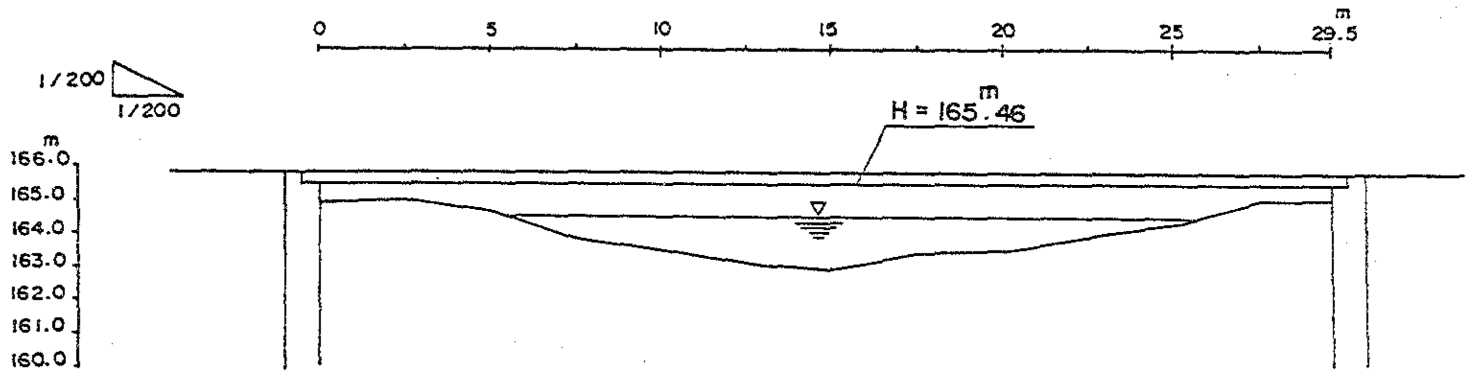
STAFF GAUGE 0 m = 162.52 m
WATER LEVEL = 164.00 m



DISTANCE(m)	0.0	100	200	300	400	500	600	700	800	900	1000	1100	1157
ELEVATION(m)	164.85	164.38	164.25	164.05	163.83	163.44	163.57	163.77	163.32	163.79	163.58	164.63	166.29

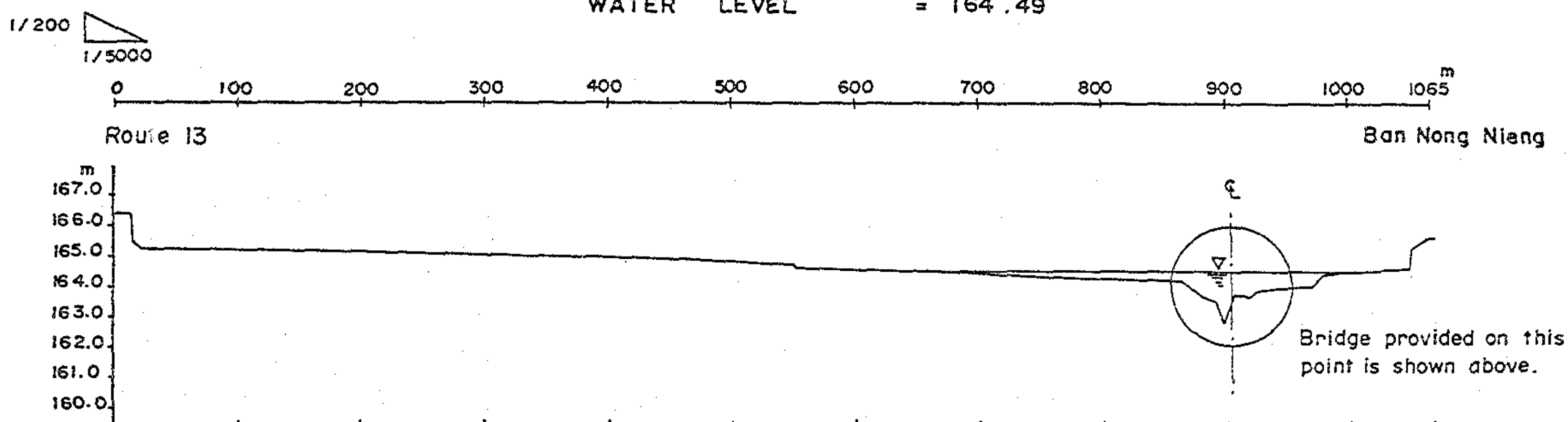
Fig. I-14 CROSS SECTION AT NO.1 GAUGE
(SAM KHE)

NO. 2



DISTANCE (m)	0	5	10	15	20	25	29.5
ELEVATION (m)	164.90	164.62	163.45	162.88	163.46	164.27	165.01

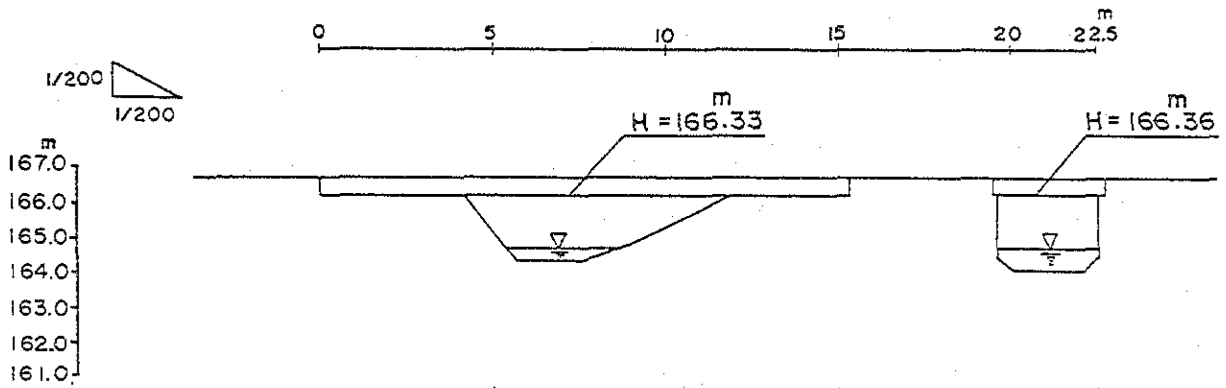
STAFF GAUGE 0 m = 163.37 m
WATER LEVEL = 164.49 m



DISTANCE (m)	00	100	200	300	400	500	600	700	800	900	1000	1065
ELEVATION (m)	166.45	165.19	165.14	165.05	164.94	164.80	164.61	164.51	164.32	163.38	164.49	165.53

Fig. I-15 CROSS SECTION AT NO.2 GAUGE
(NONG NIENG)

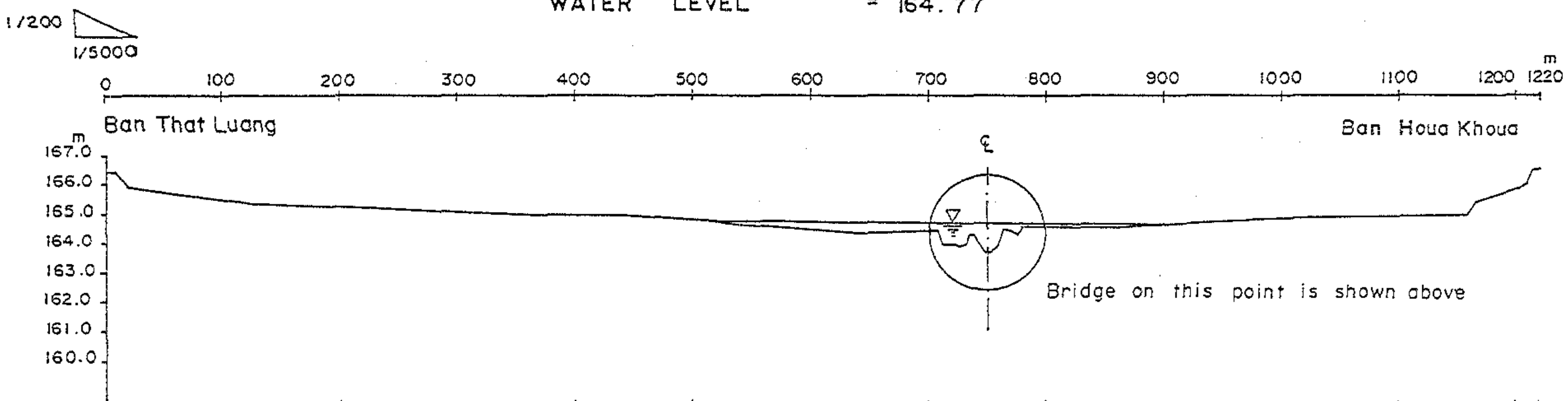
NO . 3



DISTANCE (m)	0	5	10	15	20	22.5
ELEVATION (m)	166.33	165.20	165.40	166.33	164.14	164.56

STAFF GAUGE 0m = 163.93 m

WATER LEVEL = 164.77 m



DISTANCE(m)	0.0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1220
ELEVATION(m)	166.46	165.50	165.25	165.10	165.05	164.86	164.55	164.45	164.61	164.74	164.86	164.94	165.88	166.59

Fig. I-16 CROSS SECTION AT NO.3 GAUGE
(HOUA KHOUA)

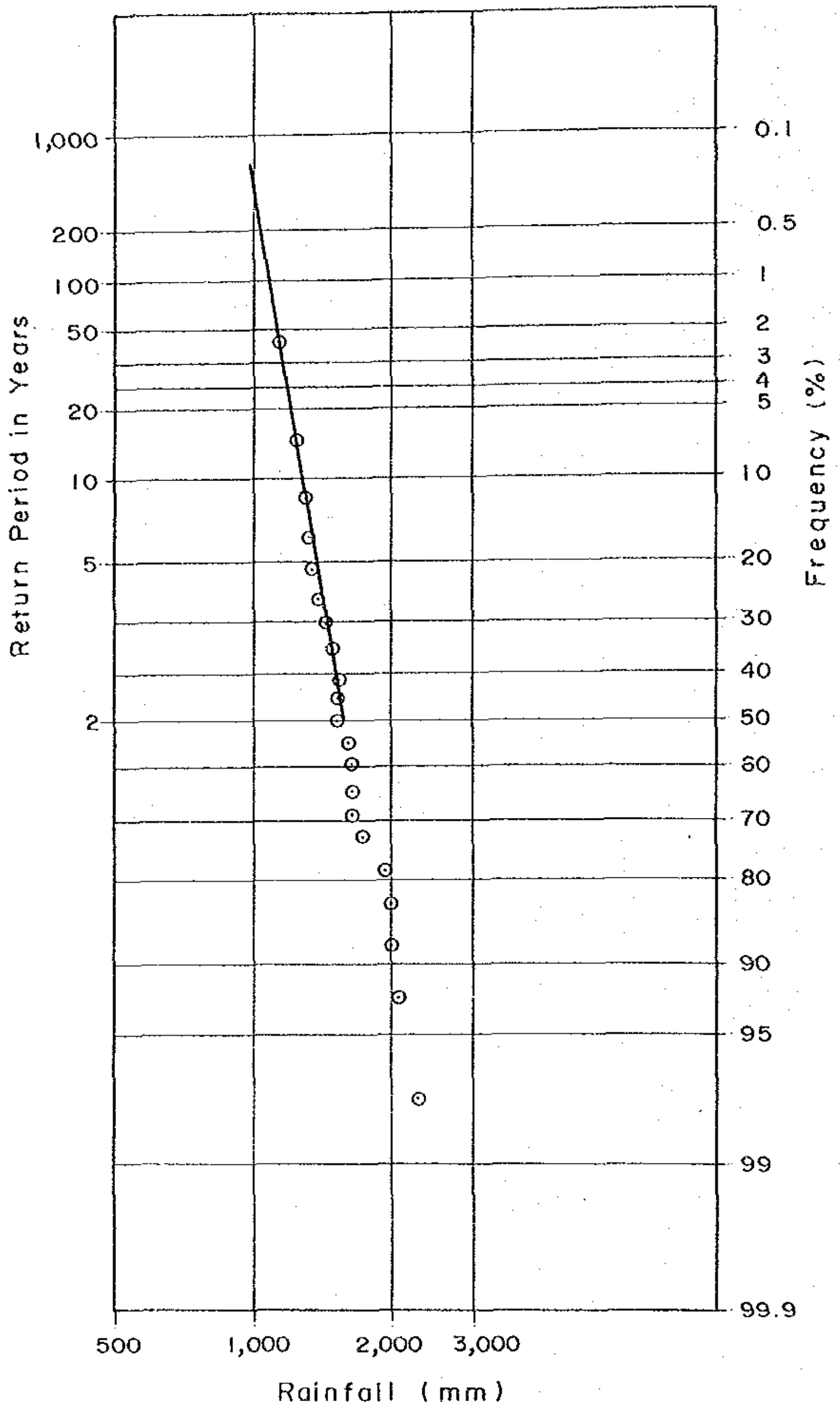


Fig. I-17 FREQUENCY OF ANNUAL RAINFALL

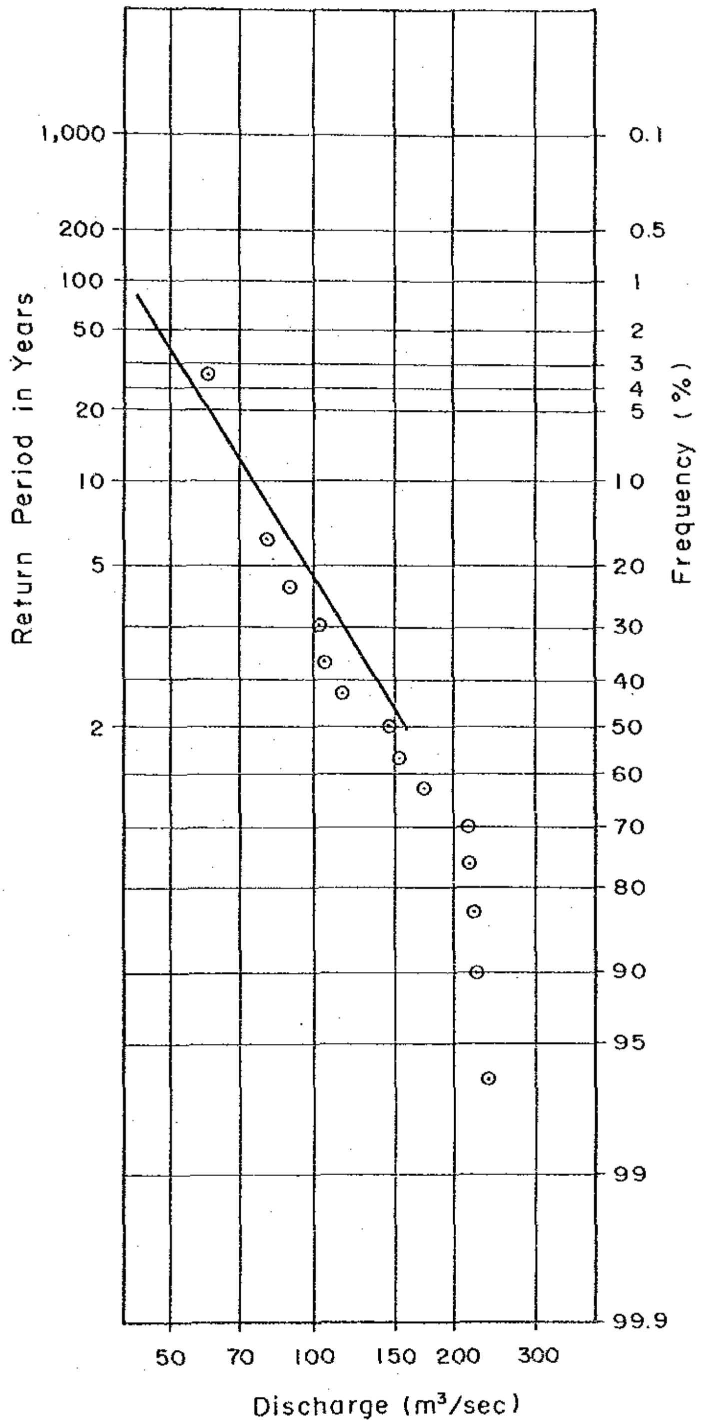


Fig. I-18 FREQUENCY OF MINIMUM MEAN DAILY DISCHARGE AT THA NGON

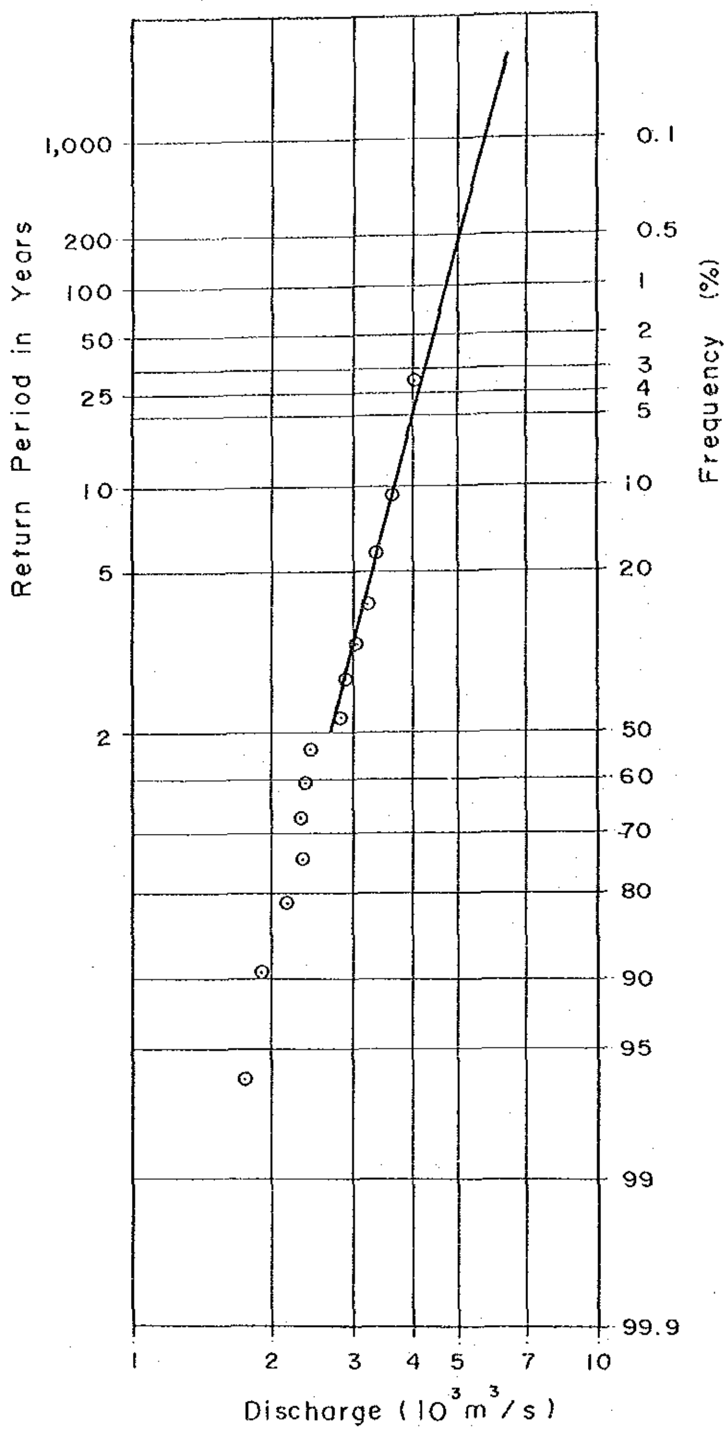
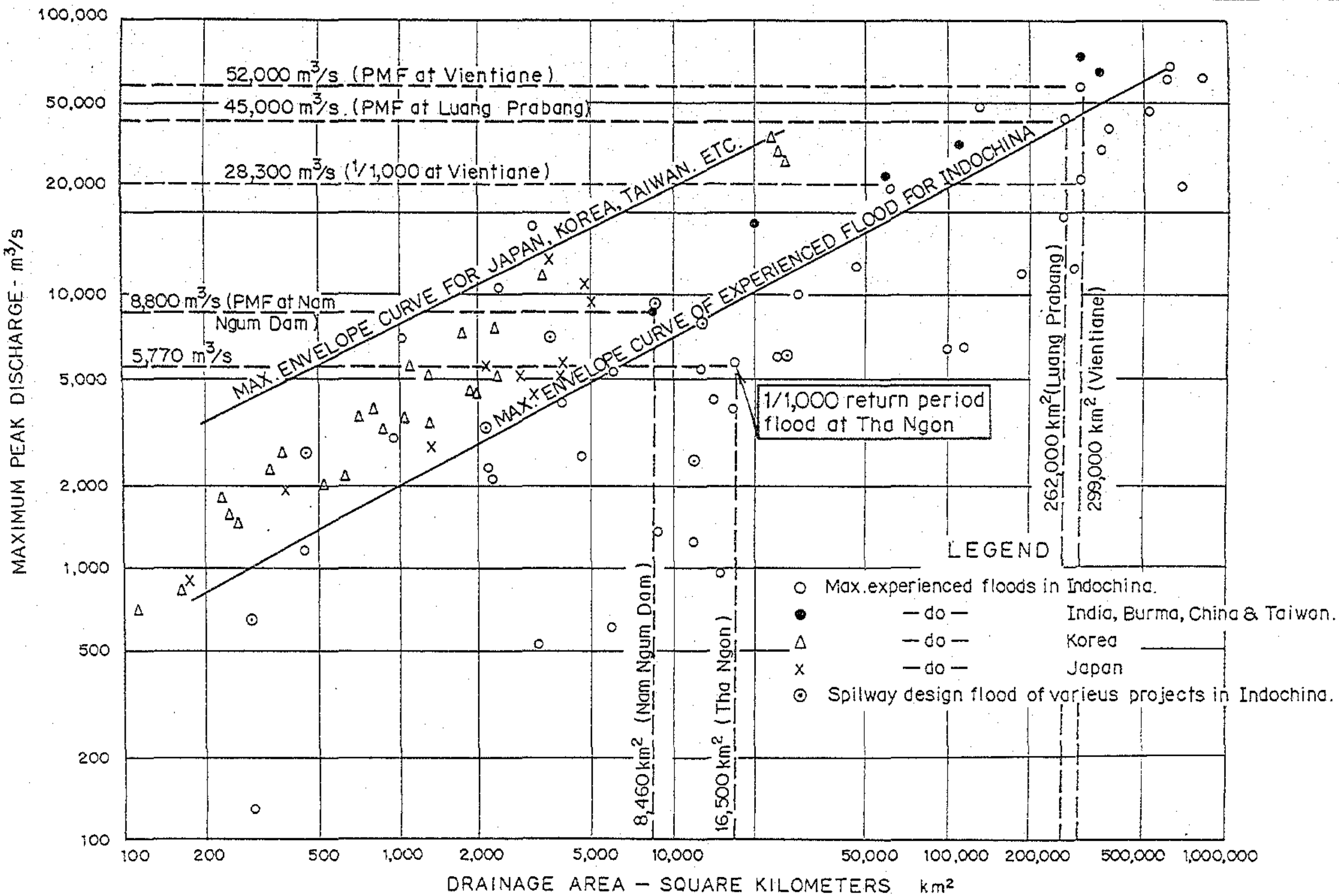


Fig. I-19 FREQUENCY OF MAXIMUM MEAN DAILY DISCHARGE AT THA NGON



(This figure is made based on the figure in the *Final Report* on Nam Ngum Hydro-electric Project First Stage)

Fig. I-20 MAXIMUM ENVELOPE CURVE FOR EXPERIENCED FLOODS OF VARIOUS RIVERS

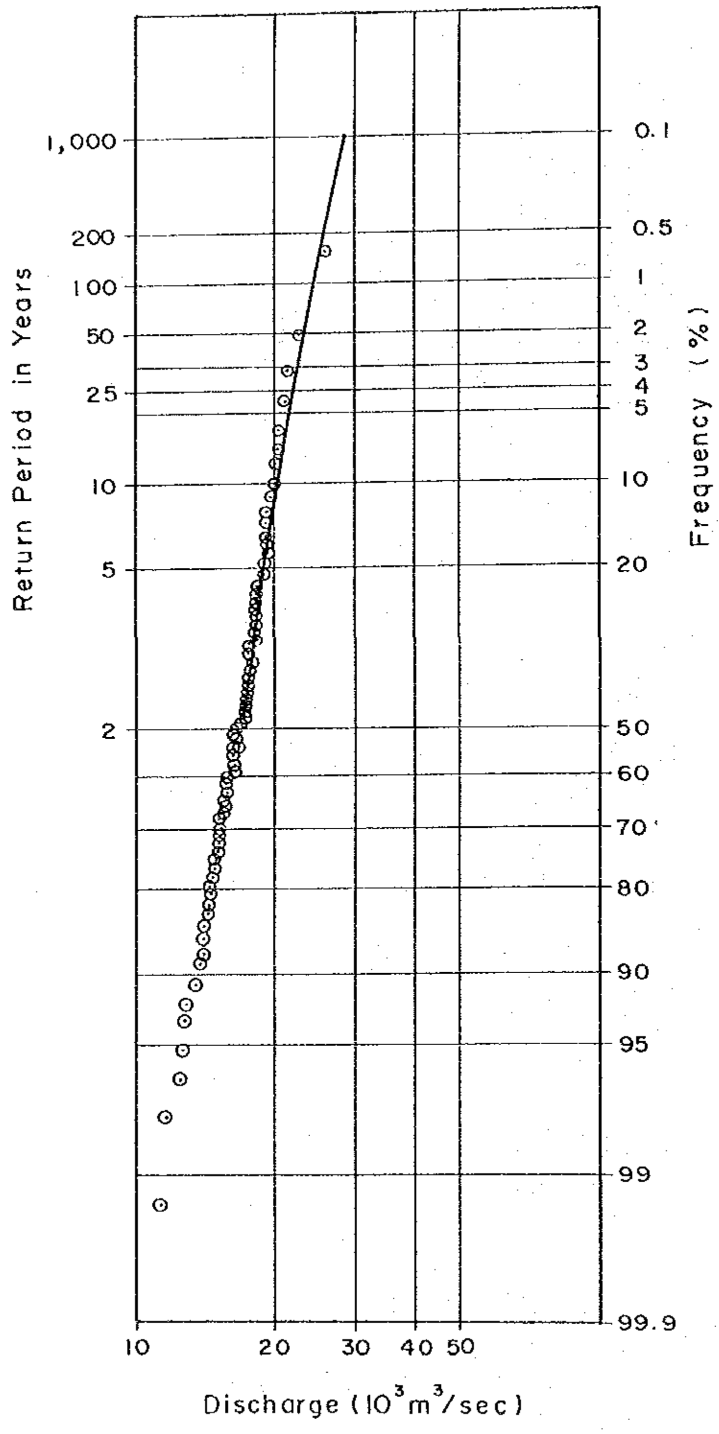


Fig. I-21 FREQUENCY OF MAXIMUM MEAN DAILY DISCHARGE IN THE MEKONG RIVER AT VIENTIANE

ANNEX II

SOILS AND LAND CLASSIFICATION

ANNEX II

SOILS AND LAND CLASSIFICATION

Table of Contents

List of Tables

List of Figures

1. General

The present soil and land classification studies aim at identifying major soil groups and their distribution in the Project area to evaluate the endowed land resources, and also examining the suitability of land for irrigation development.

Soil survey is carried out at three steps i.e. preliminary observation, field survey and soil chemical analysis. Existing topographical maps and the results of previous soil studies are fully referred to for the study. Soil classification of the Project area is made in conformity with the system of FAO/UNESCO Legend for "Soil Map of the World".

Land classification study is made in accordance with Japanese standard which is considered to be more practical than other frameworks such as FAO and USDA systems.

2. Soils

2.1 Methodology of Soil Survey

Soil survey in the Project area is carried out at three steps, i.e. preliminary observation, field survey, and chemical and physical analysis.

In the preliminary observation, topography and vegetation of the Project area is initially studied through examining the topographic map (1:10,000) and aerial photo-interpretation (1:30,000, 1981).

In the field survey, soil profile survey and sampling are made by excavating 20 exploratory pits and by boring 74 pits with hand-auger and boring stick. Location of survey sites are shown in Fig. II-1.

Chemical and physical characteristics of the samples taken by field survey are examined in the following items.

(1) Samples of profile examination pits

Samples of representative 13 pits out of 20 pits are analyzed at the soil laboratory of MAF. Methods of analysis are given in Table II-1. Items examined are: i) pH (H_2O, KCl), ii) Electric conductivity, iii) Organic matter, iv) Total nitrogen, v) Available phosphorus, vi) Total phosphorus, vii) Total potassium, viii) Exchangeable bases (Hh, Ca, Mg, Na, K), ix) % of element in sorption complex (Hh, Ca, Mg, K), and x) Soil particle size distribution and texture.

(2) Samples taken by hand-auger

74 samples taken by hand-auger are analyzed for i) pH (H_2O) and ii) Electric conductivity.

In addition, the following existing soil maps are fully referred to for the study:

- Soil map of the Vientiane Plain (1:50,000) prepared by Nippon Koei Co., Ltd. in 1961.

- Physio-agropedological land classification map (1:10,000) prepared by Mekong Committee in 1981.
- Soil Map of Saythany District (1:25,000) prepared by Lao and Vietnam Governments in 1988.

2.2 Physiography

2.2.1 Environment of soil formation

The climate in and around the Project area is characterized by distinct two seasons, namely the rainy season and the dry season. Annual mean temperature is 26.5°C with monthly mean values varying from 16.7°C in January to 34.1°C in April. Annual mean rainfall is 1,608 mm, out of which about 90% falls during the rainy season, May to September.

The Project area is geologically composed of ancient alluvial deposits, mainly consisting of sandstone and siltstone. These materials correlate with those in the upstream of the Mekong river and the Nam Ngum river, which are composed of sandstone, micaschist, gneiss and granite.

2.2.2 Topography and vegetation

The elevation of the Project area ranges from EL 164 m to EL 171 m with gentle slope from the north to the south.

The area is categorized into five relieves and vegetation of each category is as follows:

(1) Upper Pediment (EL: higher than 170 m, Topography: Terrace)

Mostly covered with wild forest. Rainfed paddy is cultivated scatteringly where water is available.

(2) Medium upper pediment (EL: 166 - 170 m, Topography: Lower terrace)

Forms rim of the flat area being extended in a shape of horseshoe. Rainfed paddy field, forest and grassland are observed. Some of the rainfed paddy field is not cultivated, showing that the area is marginally suitable for rice growing.

(3) Flat (EL: 165 - 166 m, Topography: Delta or Back swamp)

Occupies central part of the Project area. Most of this area is covered by rainfed paddy field.

(4) Medium lower pediment (EL: 164 - 165 m, Topography: Marsh)

(5) Lower pediment (EL: lower than 164 m, Topography: Marsh)

The lowest areas in the Project area, where floating rice cultivation is practiced.

2.3 Results of Field Survey and Laboratory Analysis

Soil field survey was carried out through field reconnaissance, test pit and auger borings. 20 test pits and 74 auger borings were conducted. Location of survey sites are shown in Fig. II-1. Detailed description of representative profiles are given in Table II-2.

Soil samples were taken at 13 selected test pits and 74 boring sites. Samples from test pits are analyzed at the soil laboratoty of MAF following the methods shown in Table II-1. The results are given in Table II-3. 74 samples taken by hand-auger are analyzed for their pH (H_2O) and electric conductivity. The results are given in Table II-4.

2.4 Soil Classification

The soil classification of the Project area was made in conformity with the system of "The Soil Map of the World" compiled by FAO/UNESCO in 1974. As a result of the observation on diagnostic soil characteristics and profile features, the soils in the Project area are classified into three groups. Most of the soils (97%) in the Project area belong to Acrisols. Besides that, Fluvisols are found in the southern part of the Project area and Gleysols are along the Houei Gnang River in the north of the Project area.

Soil map is prepared considering the factors of soil texture, relief conditions and soil depth as shown in Fig. II-2. Area extent of each soil unit is shown in Table II-5.

The major characteristics and distribution of each soil class are as follows:

2.4.1 Acrisols (Ferric Acrisols)

The ferric acrisols extend broadly over the Project area. Acrisols are typical soils in the humid tropical area and characterized by a base saturation of less than 50% in the B horizon at less than 120 cm depth where clay has illuviated. Acrisols develop on flats of ancient alluvial deposits which are broadly distributed on the monsoon climate areas. The mother rock is of silicate and weathered, and is leached to illuviated layer clay. They are acid and podsolized in the surface horizon and in the lower layer ferric and aluminum illuviate.

The top soils are slightly acid (pH 5.5 - 6.0) with the texture of sandy loam to clay loam. The subsoils are more acid than the top soils and the texture ranges from silty clay to clay. Soil profile shows remarkably poor soil structure with ferric characters (mottles of ferric oxides and oxidic concretion or hardened plinthite at least 25 cm thick) within 100 cm from the surface.

Clay mineral of Acrisols is mainly of kaolinite which is characterized by low cation exchange capacity (CEC), low base saturation degree, and high acidity, which are obvious in the data obtained by laboratory analysis, and especially low phosphorus content.

Generally, the soils at around EL 165 m have a depth of more than one meter, those at EL 166 - 170 m (medium upper pediment) are relatively shallow, and those at over EL 170 m (upper pediment) tend to be deeper. This difference is considered to be caused by the soil conservation effect of covering vegetation.

Acrisols extended in the Project area are classified into the following 12 sub-units by texture and effective soil depth.

(1) Sandy Loam 1 (mapping symbol $\frac{b}{I}$ in Fig. II-2)

Distribution	:	medium upper pediment, around EL 170 m		
Area extent	:	158 ha		
Soil properties	:	effective soil depth	;	more than 100 cm
		color	;	gray
		fertility	;	low
		structure	;	developed
		ground water table	;	low
		permeability	;	high

(2) Sandy Loam 2 (mapping symbol $\frac{b}{2}$)

Destribution	:	upper pediment, EL 170 m		
Area extent	:	3 ha		
Soil properties	:	effective soil depth	;	70-100 cm
		color	;	gray
		fertility	;	low
		structure	;	developed
		ground water table	;	low
		permeability	;	high

(3) Sandy Loam 3 (mapping symbol $\frac{b}{3}$)

Distribution	:	upper pediment and medium upper pediment of over EL 166 m		
Area extent	:	183 ha		
Soil properties	:	effective soil depth	;	50-70 cm
		color	;	gray
		fertility	;	low
		structure	;	developed
		ground water table	;	low
		permeability	;	high
		soil reaction	;	pH 6.0

(4) Sandy Loam 4 (mapping symbol $\frac{b}{4}$)

Distribution	:	upper pediment and medium upper pediment of over EL 160 m		
Area extent	:	322 ha		
Soil properties	:	effective soil depth	;	25-50 cm
		gravel content	;	20-50%
		color	;	gray
		fertility	;	low
		structure	;	developed
		ground water table	;	low
		permeability	;	high

soil reaction	;	pH 5.0
texture	;	relatively clayey
base saturation percentage	;	low

(5) Sandy Loam 5 (mapping symbol $\frac{b}{5}$)

Distribution	:	medium upper pediment, EL 166-170 m		
Area extent	:	292 ha		
Soil properties	:	effective soil depth	;	less than 25 cm
		gravel content	;	more than 50% (laterite)
		fertility	;	low
		soil reaction	;	pH 5.0 - 5.5

(6) Silty Loam 1 (mapping symbol $\frac{c}{1}$)

Distribution	:	throughout the Project area, EL 164-170 m		
Area extent	:	1,265 ha		
Soil properties	:	effective soil depth	;	more than 100 cm
		color	;	yellowish gray
		fertility	;	relatively high
		structure	;	moderately developed
		ground water table	;	high
		permeability	;	low
		lower layer	;	clay
		soil reaction	;	pH 5.5 - 6.0

(7) Silty Loam 2 (mapping symbol $\frac{c}{2}$)

Distribution	:	medium upper pediment and flat, EL 165-170 m		
Area extent	:	634 ha		
Soil properties	:	effective soil depth	;	70-100 cm
		color	;	yellowish gray
		fertility	;	variant
		structure	;	moderately developed
		ground water table	;	high
		permeability	;	low

	lower layer	; clay
	soil reaction	; pH 4.5 - 5.5

(8) Silty Loam 3 (mapping symbol $\frac{c}{3}$)

Distribution :	medium upper pediment, EL 166-170 m	
Soil properties :	effective soil depth	; 50-70 cm
	gravel content	; 10-20%
	structure	; moderately developed
	ground water table	; high
	permeability	; low
	lower layer	; clay
	soil reaction	; pH 5.5

(9) Silty Loam 4 (mapping symbol $\frac{c}{4}$)

Distribution :	medium upper pediment, EL 166-170 m	
Area extent :	603 ha	
Soil properties :	effective soil depth	; 25-50 cm
	gravel content	; 20-50%
	color	; brownish black (10 YR 2/2)
	fertility	; relatively high
	structure	; moderately developed
	ground water table	; high
	permeability	; low
	lower layer	; clay
	top layer	; containing humus
	soil reaction	; pH 5.0 - 5.5

(10) Silty Loam 5 (mapping symbol $\frac{c}{5}$)

Distribution :	medium upper pediment, EL 166-170 m	
Area extent :	163 ha	
Soil properties :	effective soil depth	; less than 25 cm
	gravel content	; more than 50% (laterite)

(11) Silty Clay (mapping symbol $\frac{d}{1}$)

Distribution	:	medium lower pediment, EL 164-165 m	
Area extent	:	506 ha	
Soil properties	:	effective soil depth	; more than 100 cm
		color	; grayish yellow
		structure	; poorly developed
		ground water table	; high
		permeability	; low

(12) Silty Clay (mapping symbol $\frac{d}{3}$)

Distribution	:	lower pediment, around EL 164 m	
Area extent	:	38 ha	
Soil properties	:	effective soil depth	; 50-70 cm
		color	; grayish yellow
		structure	; poorly developed
		ground water table	; high
		permeability	; low
		texture	; relatively clayey

2.4.2 Fluvisols

The soils classified into Fluvisols are distributed along the old Su-wan River (Beung Khat Khao) located in the south west boundary of the Project area on the lower pediment of EL 164 m. The area is 68 ha and cultivated mainly with floating rice.

The soils are primarily of the recent alluvium deposits on a narrow riverine depression. They are poorly drained and inundated during the rainy season and have high ground water table even in the dry season.

The profile of soil has no particular diagnostic features except for very few and weak mottling formation in the shallow depth. The typical horizon sequence is A/B/C. The A horizon is 20 cm in thickness, brownish black (5 YR 2/2) in matrix color, clay loam to clay, medium and weak sub-angular blocky structures, friable when wet and slightly hard when dry, and has gradual and smooth boundary with the B horizon.

The B horizon is 50 - 60 cm in thickness, brownish black (7.5 YR 3/2) in matrix color, clay texture, and has diffuse and smooth boundary with the C horizon.

The C horizon is dull to dark brown (7.5 YR 3/4) in matrix color, clay texture, moist condition even in the dry season, and has high organic matter content and high C/N ratio.

2.4.3 Gleysols (Humic Gleysols)

The soils of this soil unit develop rather narrowly over the depression along the Houi Gnang River in the north west of the Project area. The area is 58 ha and cultivated with rainfed paddy.

The land covered with this soil develops on the recent alluvial deposit. It is inundated during the rainy season and has high ground water table even in the dry season. Typical soil horizon sequence is A/C and the effective soil depth is shallow and limited by the ground-water which exists in only 30 - 40 cm from the ground surface even in the dry season.

The A horizon is of high moisture, grayish black color, very fine clay, massive structure, firm consistence, and has clear and smooth boundary with the C horizon.

The C horizon is grayish in color, clay to silty clay, and contains low organic carbon.

As regards physical properties, the soils have relatively high moisture holding capacity with very low permeability coefficient. This soil area is suitable for paddy cultivation but not for other crops.

3. Land Classification

3.1 Land Classification System

Land classification of the Project area is made in accordance with the land classification system formulated by National Institute of Agricultural Science, Japan.

Generally, land classification criteria to be applied to an objective area should be selected in consideration of the natural condition and socio-economic condition prevailing in the area. In this view, the systems of USDA (US Department of Agriculture), USBR (US Bureau of Reclamation) and FAO are examined in addition to Japanese one.

The USDA system is a system for assessment of land capability mainly against soil erosion, and USBR system for assessment of land productivity of arid area for upland crops. FAO system is that devised for assessment of world-wide agriculture and soils. All of them do not serve as detailed criteria for suitability for irrigated paddy cultivation and therefore are considered to be difficult to apply to the Project area. Since the Japanese system is originally devised for the purpose of accessing land capability for paddy cultivation, it is proposed to be adopted in this study.

In the Japanese system, lands are classified into 4 capability classes, i.e., I, II, III and IV. Each class is defined as follows:

- Class I ; Land has almost no limitation for crop production and/or no risk of soil conservation. It is naturally fertile and has a great potential for crop production without any improvement practices of soils.
- Class II ; Land has some limitations for crop production and/or some risks of soil conservation, and requires some soil improvement practices for normal crop production.
- Class III ; Land has many limitations for crop production and/or is likely to be subject to risks of soil conservation, and fairly intensive improvement practices are required.
- Class IV ; Land has great natural limitations than those in Class III, but can be utilized for cultivation of some specific crops under very careful management.

3.2 Factors to Decide the Capability Class

Land is classified into above four classes in each factor and finally determined at the lowest class among all classes of the factors. 13 factors shown below are evaluated for assessment of capability for production of both paddy and upland crops.

	Factor	Code
1.	Thickness of top soil	(t)
2.	Effective depth of soil	(d)
3.	Gravel content in top soil	(g)
4.	Easiness of plowing	(p)
5.	Permeability under submerged condition/1	(l)
6.	Stage of redox potential/1	(r)
7.	Wetness of land/2	(w)
8.	Inherent fertility	(f)
9.	Content of available nutrients	(n)
10.	Degree of hazard	(i)
11.	Frequency of hazard	(a)
12.	Slope/2	(s)
13.	Erosion	(e)

Note: /1 factor for paddy only
/2 factor for upland crop only

The factors of land capability class are explained as follows:

(1) Thickness of top soil (code: t)

Top soil is the first horizon where plant roots can easily penetrate, and generally corresponds to the plowed layer. The classes are grouped according to the thickness of top soils as follows (when effective depth of soil (d) is placed to class IV, this factor also is placed to class IV).

t (cm)	Class	
	Paddy	Upland
more than 25	I	I
25 - 15	I	II
less than 15	II	III

(2) Effective depth of soil (code: d)

Effective depth of soil is the depth down to bedrock, hard pan or gravel layer which plant roots can not penetrate. The classes are grouped according to the effective soil depth as follows:

d (cm)	Class	
	Paddy	Upland
more than 100	I	I
100 - 50	I	II
50 - 25	II - III	III
less than 25	IV	IV

Note: Japanese system classifies the land with a soil depth of 25-15 cm as Class III and that of 15 cm deep or less as Class IV. For the Project area, however, whole the land with a soil depth of less than 25 cm is classified as Class IV, taking into acocunt the local conditions..

(3) Gravel content in top soil (code: g)

Gravel contents in top soil are expressed by the percentage of the exposed surface area of gravel on the soil profile, and are graded into the following classes:

g (%)	Class	
	Paddy	Upland
less than 5	I	I
5 - 10	I	II
10 - 20	I - II	II - III
20 - 50	II - III	III - IV
more than 50	IV	IV

(4) Easiness of plowing (code: p)

Easiness of plowing largely depends upon the quantity and quality of clay and organic matter and moisture condition. In order to estimate the class of this factor, the following 4 sub-factors are used:

i) Soil texture of top soil;

		Content of clay	Content of sand
1.	coarse	less than 15%	more than 85%
2.	medium	less than 15%	less than 85%
3.	fine	15 - 25%	-
4.	very fine	more than 25%	

ii) Stickiness of top soil;

1. none and/or slightly sticky
2. sticky
3. very sticky

iii) Consistence when dry;

1. loose
2. hard
3. very hard

These sub-factors are combined altogether to determine capability classes as follows:

Sub-factors			Class	Criteria
i)	ii)	iii)		
1	1	(2)/1	I	Easy to slightly difficult
2	2	2	I	
2	2	2	I	
2	2	3	II	Moderately difficult
3	3	3	II	
2	2	3	III	Very difficult
3	3	3	III	

/1 : limitation by dry condition

(5) Permeability under submerged condition (code: 1)

This factor affects irrigation water requirement, soil temperature, and leaching of the nutrients or development of reduced condition of the soil. This standard factor is evaluated mainly by the combination of soil texture and the presence of compact layer within 50 cm from the surface, as sub-factors:

i) Soil texture;

			Content of clay	Content of sand
1.	very fine	:	more than 25%	-
2.	fine	:	15 - 25%	-
3.	medium	:	less than 15%	less than 85%
4.	coarse	:	less than 15%	more than 85%

ii) Compactness;

1. compact : more than 14.0 kg/cm^2 by hardness meter
2. medium : 14.0 - 1.4 kg/cm^2 by hardness meter
3. loose : less than 1.4 kg/cm^2 by hardness meter

These sub-factors are combined altogether to determine capability classes as follows:

Sub-factors		Class	Criteria
i)	ii)	Paddy	
1	1	I	Poorly to imperfectly permeable
1	2	I	
2	2	I - II	Moderately to well permeable
3	2	II	
3	3	III	Well to excessively permeable

(6) State of redox potential (code: r)

This factor indicates the risk of root damage owing to the strong reduction of soil, resulting in low rice production. The following sub-factors are used for the evaluation of this factor:

i) Content of easily decomposable organic matter in top soil;

1. low : less than 10 mg NH_4 - N/100 g
2. medium : 10 - 20 mg NH_4 - N/100 g
3. high : more than 20 mg NH_4 - N/100 g

ii) Content of free iron oxides in top soil;

1. high : more than 1.5% for dry soil
2. medium : 1.5 - 0.8%
3. low : less than 0.8%

iii) Degree of gleyzation;

1. weak : no gley horizon within 50 cm from the surface
2. medium : gley horizon exists within 50 cm
3. strong : gley horizon exists throughout profile or exists below plowing layer

These sub-factors are combined altogether to determine capability classes as follows:

Sub-factors			Class	Criteria (Risk of root damage)
i)	ii)	iii)		
1	1	2	I	Non to weak
1	3	2	I	
2	1	2	I	
1	1-2	3	II	Moderate to strong
1	3	3	II	
2	1-2	3	II	
3	1	2	II	
2	3	3	III	Very strong
3	2	2	III	
3	1	3	III	
3	3	2	III	

(7) Wetness of land (code: w; wet condition, (w); dry condition)

This factor is only applied to upland crops. This factor is used for the estimation of wet or drought injury of upland crops and trees, and is evaluated by the combination of the following 3 sub-factors:

i) Permeability;

1. high
2. medium
3. low

ii) Water holding capacity (evaluated by available moisture);

1. high : more than 20%
2. medium : 20 - 10%
3. low : less than 10%

iii) Moisture condition;

(2) dry (Limitation by dry condition)

1. slightly moist
2. moist
3. wet

These sub-factors are combined altogether to determine capability classes as follows:

Sub-factors i)	ii)	iii)	Class	Criteria (Risk of root damage)
1	3	(2) /1	(IV)	High possibility of drought
1	3	1	(III)	Possibility of drought
1	2	1	(II)	Low possibility of drought
1	1	1	I	None
2	2	2	II	Low possibility of overwetness
1-3	1	3	III	Possibility of overwetness
3	2	3	IV	High possibility of overwetness

/1 : Lmitation by dry condition

(8) Inherent fertility (code: f)

Inherent fertility is evaluated by the combination of the following 3 sub-factors:

i) Nutrient holding capacity (evaluated by CEC);

1. high : more than 20 meq/100 g
2. medium : 20 - 6 meq/100 g
3. low : less than 6 meq/100 g

ii) Nutrient fixation power (evaluated by coefficient of P_2O_5 absorption);

1. very low : less than 700 (mg P_2O_5/100 g dry soil)
2. low : 700 - 1,500 (")
3. medium : 1,500 - 2,000 (")
4. high : more than 2,000 (")

iii) Base status in soil (evaluated by base saturation degree);

1. good : more than 50%
2. medium : 50 - 30%
3. poor : less than 30%

These sub-factors are combined altogether to determine capability classes as follows:

(a) For paddy

Sub-factors i)	Sub-factors ii)	Sub-factors iii)	Class	Criteria
1	1-2	2	I	Fertile
2	1-2	1	I	
1	1-2	3	II	Medium
1	3-4	2	II	
2	1-2	2	II	
3	1	2	II	
2	3-4	3	III	Infertile
3	2	2	III	
3	3-4	3	III	

(b) For upland crops

Sub-factors i)	Sub-factors ii)	Sub-factors iii)	Class	Criteria
1	2	1	I	Fertile
2	1	2	I	
1	1	3	II	Medium
2	1	3	II	
2	1-2	2	II	
1	3	1	II	
1	3	2	II	
1	3	3	III	Infertile
2	4	2	II-III	

(9) Content of available nutrients (code: n)

Contents of available nutrients in soil are closely related to the inherent soil fertility, and evidently influence cultivation practices. The capability class is evaluated by the combination of the following sub-factors:

i) Content of exchangeable calcium;

1. high : more than 200 CaO mg/100 g
2. medium : 200 - 100 CaO mg/100 g
3. low : less than 100 CaO mg/100 g

ii) Content of exchangeable magnesium;

1. high : more than 25 MgO mg/100 g
2. medium : 25 - 10 MgO mg/100 g
3. low : less than 10 MgO mg/100 g

iii) Content of available potassium;

1. high : more than 15 K_2O mg/100 g
2. medium : 15 - 8 K_2O mg/100 g
3. low : less than 8 K_2O mg/100 g

iv) Content of available phosphate;

1. high : more than 10 P_2O_5 mg/100 g
2. medium : 10 - 2 P_2O_5 mg/100 g
3. low : less than 2 P_2O_5 mg/100 g

v) Content of available nitrogen;

1. high : more than 20 ammonia - N mg/100 g
2. medium : 20 - 10 ammonia - N mg/100 g
3. low : less than 10 ammonia - N mg/100 g

vi) Content of available silica;

1. high : more than 15 SiO_2 mg/100 g
2. medium : 15 - 5 SiO_2 mg/100 g
3. low : less than 5 SiO_2 mg/100 g

vii) Content of micro-elements (evaluated by the risk of deficiency);

1. none and/or weak
2. medium
3. serious

viii) Acidity (evaluated by pH (H_2O));

Paddy	Upland			
1	1	weak	:	more than 6.0
2	2	medium	:	6.0 - 5.0
3	3	strong	:	5.0 - 4.5
3	4	very strong	:	less than 4.5

These sub-factors are combined altogether and finally capability is classified as follows:

Class	Criteria
I	High
II	Medium
III	Low

(10) Degree of hazard (code: i)

This factor means limitation caused by the presence in excess of substances such as sulphur compounds, soluble salts, heavy metals, etc. Dependent sub-factors for this factor are as follows:

i) Presence of harmful substances;

(a) Harmful sulphur compounds

1. none
2. slightly
3. moderately
4. seriously

(b) Salts content (evaluated by chlorine content as an indicator)

1. low : less than 0.1% for dry soil
2. medium : 0.1 - 0.3%
3. high : more than 0.3%

(c) Heavy metals

1. none
2. slightly
3. moderately
4. seriously

ii) Physical hazard;

Presence of bedrock, pan, compact layer or gravel layer that disturb root development within 50 cm of the surface, and difficult of their removal:

1. none
2. slightly difficult
3. very difficult

The class of this factor is decided by the lowest grade among the dependent sub-factors:

Class	Criteria
I	Non
II	Slightly
III	Moderately
IV	Seriously

(11) Frequency of hazard (code: a)

This factor is mainly influenced by natural environmental condition. The class of this factor is determined by the combination of the following two dependent sub-factors:

i) Risk of overhead flooding inundation;

1. non and/or rarely : no risk if rainfall with high intensity occurs
2. moderately : even if inundation occurs due to high rainfall intensity, excess water is drained out in a short period
3. frequently : inundation continuous for a long period if rainfall with high intensity occurs

ii) Risk of land creep;

1. non and/or rarely
2. moderately
3. frequently

The class of this factor is determined by the lowest grade of two dependent sub-factors:

Class	Criteria
I	None to rarely
II	Moderately
III	Frequently

(12) Slope (code: s)

This factor is applied to upland crops only. The class of this factor is decided by the combination of the following sub-factors:

i) Natural slope as a main dependent sub-factors: 5 grades as shown in the following table.

ii) Direction of slope

iii) Artificial slope

Steepness of Slope (°)	(%)	Class
less than 3	less than 6	I
3 - 8	6 - 14	II
8 - 15	14 - 28	III
15 - 25	28 - 47	IV
more than 25	more than 47	IV

(13) Erosion (code: e)

The class of this factor is determined by the combination of the following sub-factors:

i) Occurrence of rill or gully;

	Occurrence of Rill	Occurrence of Gully
1. none	none	none
2. rarely	rarely	none
3. moderately	sometimes	none
4. frequently	frequently	exist

ii) Resisting power to water erosion;

1. strong
2. medium
3. weak

iii) Resisting power to wind erosion;

1. strong
2. medium
3. weak

Class	Criteria
I	None or very slightly
II	Slightly
III	Seriously
IV	Very seriously

3.3 Results of Land Classification

The land classification study for the Project area is made in accordance with the above-mentioned specification. As a result of classification, 14 groups are identified as shown in Table II-6 and their distribution is shown in Fig. II-3. Area extent of each capability class is as follows:

(Unit: ha)

Class		Originally-planned Area	Extension Area	Total
Paddy	Upland			
II	IV	2,260	1,365	3,625
III	IV	445	157	602
IV	IV	235	288	523
Total		2,940	1,810	4,750

The lands classified into classes I, II and III are regarded as suitable for agricultural development. Consequently 4,227 ha is evaluated as suitable for paddy cultivation. For cultivation of upland crops, all of the land are unsuitable under the present condition. However, after the completion of the irrigation facilities, the factor of dry condition will be improved and 344 ha (mapping unit No. 1 to 4 in Fig. II-3) will be in class II and 3,281 ha (mapping unit No. 6 to 9 in Fig. II-3) in Class III.

Table II-1 Methods of Laboratory Analysis

Items	Method
1. Texture	Particle size analysis was done by the hydrometer method using $Na_4P_2O_7$ - $10H_2O$ (Sodium pyrophosphate) as the dispersion agent. Particle size distribution was determined on particles less than 2 mm in size and calculated on a gravel and stone free basis.
2. Acidity	The soil pH was determined on a soil paste (1:2.5) in both distilled water and 1N KCl, using a glass electrode (ORSTOM-method). The hydraulic acidity was determined by the Kappen's method.
3. Organic matter and Nitrogen	The organic matter was analyzed by Tiurin method and total nitrogen by the micro-kjeldahl method; organic carbon was calculated by dividing the percentage organic matter by 1.724.
4. Available Phosphorus	Available phosphorus was extracted by sodium bicarbonate (0.5M) at pH = 8.5. The content of P was estimated colorimetrically, using ammonium molybdate for color development (Olsen's method).
5. Available Potassium	Available potassium was leached with NH_4OAc at pH = 7.0 and determined by flame photometer.
6. Element in Sorption Complex	Basic ions were extracted with NH_4OAc (pH = 7.0). Mg, Ca, were titrated with EDTA. Na, K were determined by flame photometer. CEC is the summation of basic ions and titrable acidity.

Table II-2 Detailed Description of Representative Profiles (1/3)

Profile No. 1

Date of Examination	:	16 August 1988	
Soil Name (FAO/UNESCO)	:	Acrisols (mapping Unit $\frac{b}{3}$)	
Location	:	Ban Na	
Elevation	:	EL 174 m	
Land form	:	Medium upper pediment	
Land use	:	Rainfed paddy field	
Drainage condition	:	Well drained	
Description of profile	:	A 0 ~ 20 cm	brownish black (10 YR 2/2), dry, sandy loam, structureless, no mottles, little humid, fine roots, irregular boundary, pH 6.4
		B 20 ~ 45 cm	grayish yellow brown (10 YR 5/2), moist, sandy loam, subangular blocky structures, few ferrous mottles, fine roots, irregular boundary, pH 5.5
		C 45 ~ 150 cm	dull yellow orange (10 YR 7/2), moist, clay loam, subangular blocky structures, few ferrous mottles, sticky, under 150 cm pan of laterite

Table II-2 Detailed Description of Representative Profiles (2/3)

Profile No. 9

Date of Examination	:	18 August 1988	
Soil Name (FAO/UNESCO)	:	Fluvisols (mapping Unit $\frac{d}{I}$)	
Location	:	Ban Hong Loua	
Elevation	:	EL 164 m	
Land form	:	Medium lower pediment	
Land use	:	Rainfed paddy field	
Drainage condition	:		
Profile Description	:	A 0 ~ 20 cm	brownish black (5 YR 2/2), aquic, clay loam, structureless, sticky, few ferrous mottles, frequent fine roots, wavy boundary, pH 5.6
		B 20 ~ 75 cm	brownish black (7.5 YR 3/2), aquic, clay, structureless, very sticky, many ferrous mottles, fine roots, irregular boundary, pH 6.4
		C 75 cm ~	dark brown (7.5 YR 3/4), aquic, clay, structureless, very sticky

Table II-2 Detailed Description of Representative Profiles (3/3)

Profile No. 13

Date of Examination	:	17 August 1988	
Soil Name (FAO/UNESCO)	:	Acrisols (mapping Unit $\frac{c}{I}$)	
Location	:	Ban Sok Nhai	
Elevation	:	EL 165 m	
Land form	:	Flat	
Land use	:	Rainfed paddy field	
Drainage condition	:	Poorly drained	
Description of Profile	:	A 0 ~ 20 cm	light yellowish gray (10 YR 6/4), moist, clay loam, structureless, sticky, few ferrous mottles, irregular boundary, pH 5.4
		B 20 ~ 40 cm	light yellowish gray (10 YR 6/4), moist, clay loam, structureless, sticky, ferrous mottles, fine roots, irregular boundary
		C 40 ~ 60 cm	light yellowish gray (10 YR 6/4), moist, clay, structureless, sticky, gravel (laterite) below 60 cm