III. HYDROLOGIC ANALYSIS IN LAMPUNG PROVINCE

— A REVISED EDITION —

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1. Preface

This work has been performed for the following two main subjects.

(i) To know the general hydrologic values so as not to make any big mistakes when we design new projects or rehabilitation works.

(ii) To find the proper benefited area in proportion to the run-off from the catchment area, and the effective rainfall in the benefited area.

2. Collected Data

For the above-mentioned purposes, rainfall and run-off data in Lampung province has been collected 59 and 19 stations respectively. Each of them has data for at least four years.

Rainfall data at 7 stations, however, has been rejected for the following reasons.

(i) At some stations rainfall or rainfall days, or both, are extremely small or big values compared with the ones of the near stations.

(ii) Some stations have no data for the latest years.

(iii) But both the rainfall gauge station of R. 021 and the run-off station of No.020 have been rejected only by reason of being located at the outlying place.

The numbers of both rainfall gauge and run-off stations in each river basin are shown in Table-1. This data was computed or treated by statistical methods for some hydrologic analyses. When outlying values or suspected values were found, reject tests were performed.

Table - 1 Number of Rainfall and Run-off Stations in Each River Basin

River Basin		Number of Station	
Name	Catchment Area	Rainfall	Run-off
Way Tulang Bawang	10,041 Km^2	16	8
Way Seputih	7,149	7	4
Way Sekampung	4,796	22	3
Way Semangka	1,413	3	2
Way Jepara	637	1	0
Southern Drainage	-	3	0
Total		52	17

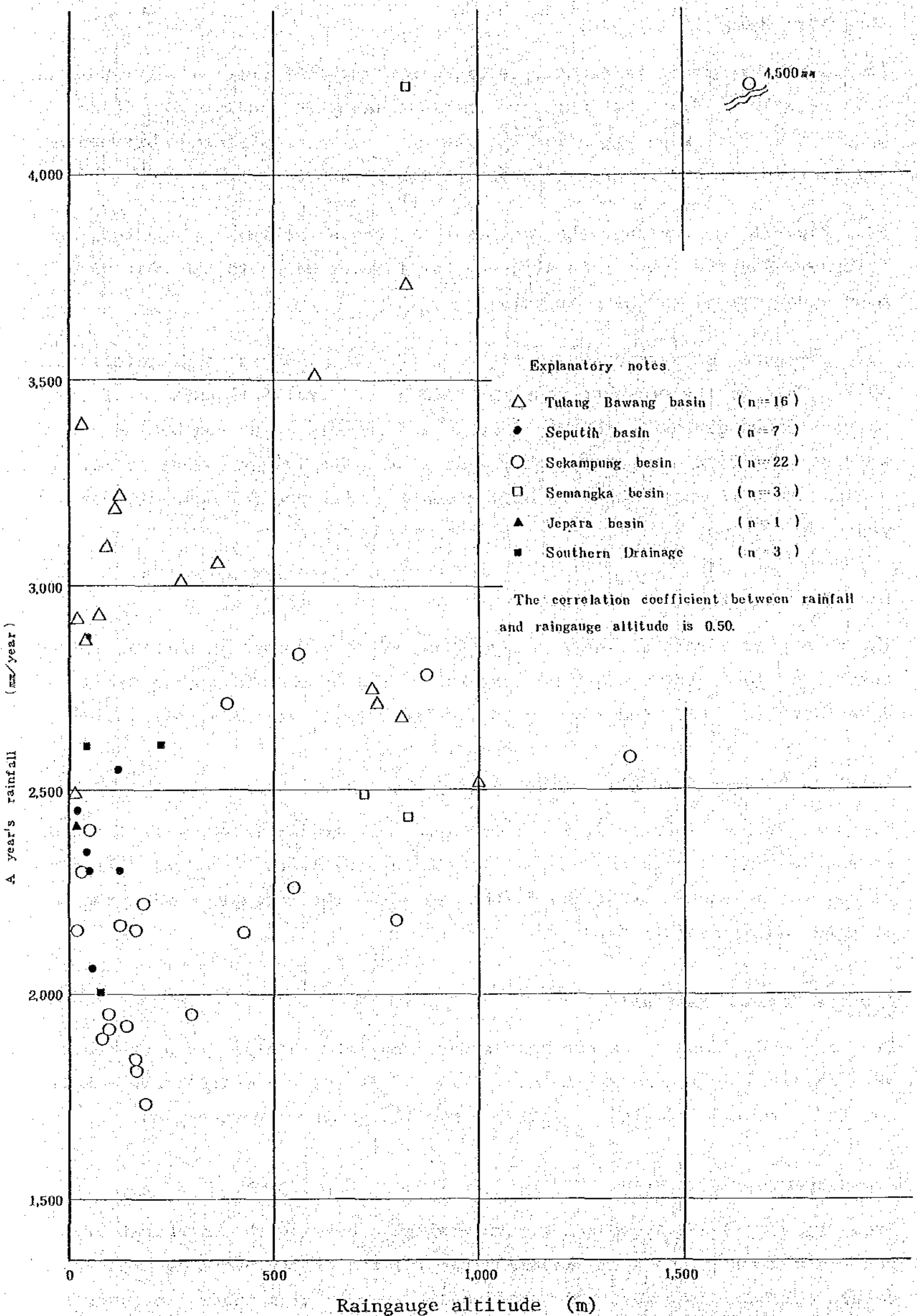


Fig - 1 Relation between a year's rainfall and raingauge altitude.

3. Long Term Rainfall Ishohyets

If a year's rainfall is closely related to a rainfall stations altitude, we will be able to draw the long term rainfall isohyets easily. For this purpose, we have made Fig - 1. But the correlation coefficient between a year's rainfall and rainfall station altitude is 0.50 only.

From Fig - A, we can know the fact that the region between Telukbetung and Pringsewu has the least rainfall, and the further we go to the west or mountainous area, the more it rains.

For reference, we have drawn up Fig-B. It is the isohyets of rainfall in 1977. This is the droughty year for rainfall and rainfall days for five years' return period in the Way Seputih and the Way Sekampung basins. But we could not find out the droughty year in the Way Tulang Bawang basin, because in this basin there is only a small difference for some five or six years past.

4. Long Term Rainfall Day Isohyets

Though a year's rainfall days change from 120 to 200 days in each area, the further we go to the west or mountainous area, the more it has rainfall days (See Fig - C). And Fig - D is the isohyets of rainfall days in 1977.

5. Relation between Rainfall and Rainfall Days

We have obtained Table - 2, which shows an average rainfall per rainfall day at each basin. Though the values distribute from 11 to 24 mm/rainfall day, we can see a tendency that the further we go to the northern basin, the more it rains on a rainfall day.

6. A Day's Maximum Rainfall

From Fig - E, F and G, we can know a day's maximum rainfall isohyets that were obtained by log-normal method. Fig - E is for ten years', Fig - F is for fifty years' and Fig - G is for a hundred years' return period.

7. Flood Specific Discharge

From Fig - 2, 3 and 4, we can see the relation between the catchment area and the maximum flood specific discharge for ten, fifty and a hundred years' return periods, that were also obtained by log-normal method. In general, it is said that the maximum specific discharge is in inverse proportion to the catchment area. We, however, could not find such a relation.

Table - 2 Average Rainfall per Rainfall Day in each River Basin

(mm/rainfall day)

No.	Tulang Bawang		Seputih		Sekampung		Semangka		Jepara		Southern Drainage	
1	A.12	14	A.23	17	A.02	13	R.054	17	R.102	18	R.009	16
2	R.205	20	R.018	15	A.03	11	R.201	13			R.010	14
3	R.206	18	R.104	20	A.22	16	R.202	24			R.064	13
4	R.208	18	R.105	17	A.26	11						
5	R.224	18	R.107	19	R.005	15						
6	R.229	24	R.130	17	R.006	16						
7	R.232	18	R.137	17	R.007	16						
8	R.233	22			R.011	13						
9	R.234	16			R.012	14						
10	R.236	17			R.013	15						
11	R.237	20			R.017	18						
12	R.239	12			R.039	15						
13	R.246	19			R.040	17						
14	R.247	21			R.049	15						
15	R.248	14			R.055	13						
16					R.057	16						
17					R.067	16						
18					R.106	17						
19					R.138	18						
$\bar{x}$		18		17		15		18		18		14

The average rainfall per rainfall day is 17 mm.

The maximum specific discharges for ten years' return period distribute between 0.20 and 2.1 $m^3/sec/km^2$, for fity years' they distribute between 0.25 and 2.4 $m^3/sec/km^2$ and for a hundred years' they are between 0.3 and 2.5 $m^3/sec/km^2$.

Fig - E and Fig - 2 will be utilized for temporary works. Fig - F and Fig - 3 will be useful for checking when we design head works. Fig - G and Fig - 4 will be instructive when we design small dams.

Each station's maximum specific discharge for ten, fifty and a hundred years' return periods is shown in Table - 3. Each position of run-off station is shown in Fig - H.

8. Monthly Rainfall, Rainfall Days and Run-off Distribution

Monthly rainfall and run-off distribution has been treated by the statistic method of ninety five confidence limits. Using this method, Fig - 5, 6 and 7 have been drawn up. Each circle shows the average value of data, on the other hand each line shows the ninety-five confidence limits of data. But we could not treat the data of the Way Semangka, the Way Jepara and the Southern Drainage by the statistic methods because these basins have only a few years' data. So data in Fig - 8, 9 and 10 are monthly average values. And also, rainfall day distribution is shown in Table - 4.

If the frequency is bigger than 8.33% (=1/12 x 100%), the month may be called a rainy month, and if it is smaller than 8.33%, it may be called a dry month. We can see the difference between a rainy month and a dry month from Fig - 5, 6, 7 and 8, and Table - 4. Those rainy and dry months in each river basin are shown in Table - 5.

That is to say, rainy months of the areas that we can divide a year into rainy and dry seasons include from December to April. Therefore we will propose that rainy season paddy should be planted between December and April. And then we had better include May in the dry season, because there is much run-off in May. So paddy in the dry season will be planted between May and September. And in both October and November, rehabilitation works of head works or canals may be performed.

Table - 3 Maximum Specific Discharge for 10, 50 and 100 Years' Return Period at each Station

($m^3/sec/km^2$)

River Basin	Station No.	Station Name	Catchment Area (km^2)	Return Period		
				10 Years'	50 Years'	100 Years'
Way Tulang Bawang	017	Way Besai-Petai Sumberjaya	389	0.25	0.28	0.30
	018	Way Besai Banjarmasin	604	0.70	0.93	1.03
	023	Way Giham Rantau Jangkung	525	0.72	0.81	0.84
	024	Way Umpu Negeribatin	559	0.80	0.96	1.03
	026	Way Rarem Pekurun	328	2.12	2.39	2.49
	032	Way Tahmi Tanjung Agung	534	0.60	0.73	0.78
	034	Way Rarem Kotabumi	913	0.32	0.38	0.40
	039	Way Umpu Rantau Temiang	203	0.88	1.40	1.65
Way Seputih	002	Way Wayah Banyuwangi	67	0.84	1.44	1.75
	025	Way Pengubuan Gedongharta	113	0.81	1.08	1.20
	027	Way Terusan Gunungbatin	543	0.23	0.28	0.30
	037	Way Tataan Sindandsari	75	0.40	0.46	0.48
Way Sekampung	001	Way Sekampung Kunyir	438	1.28	1.92	2.22
	003	Way Sekampung Pujorahayu	1,743	0.41	0.60	0.68
	021	Way Sekampung Jurak	682	0.77	0.94	1.01
Way Semangka	031	Way Semangka Srikuncoro Ferry	1,413	0.41	0.56	0.62
	035	Way Semangka Liwa Road	243	1.37	2.11	2.46

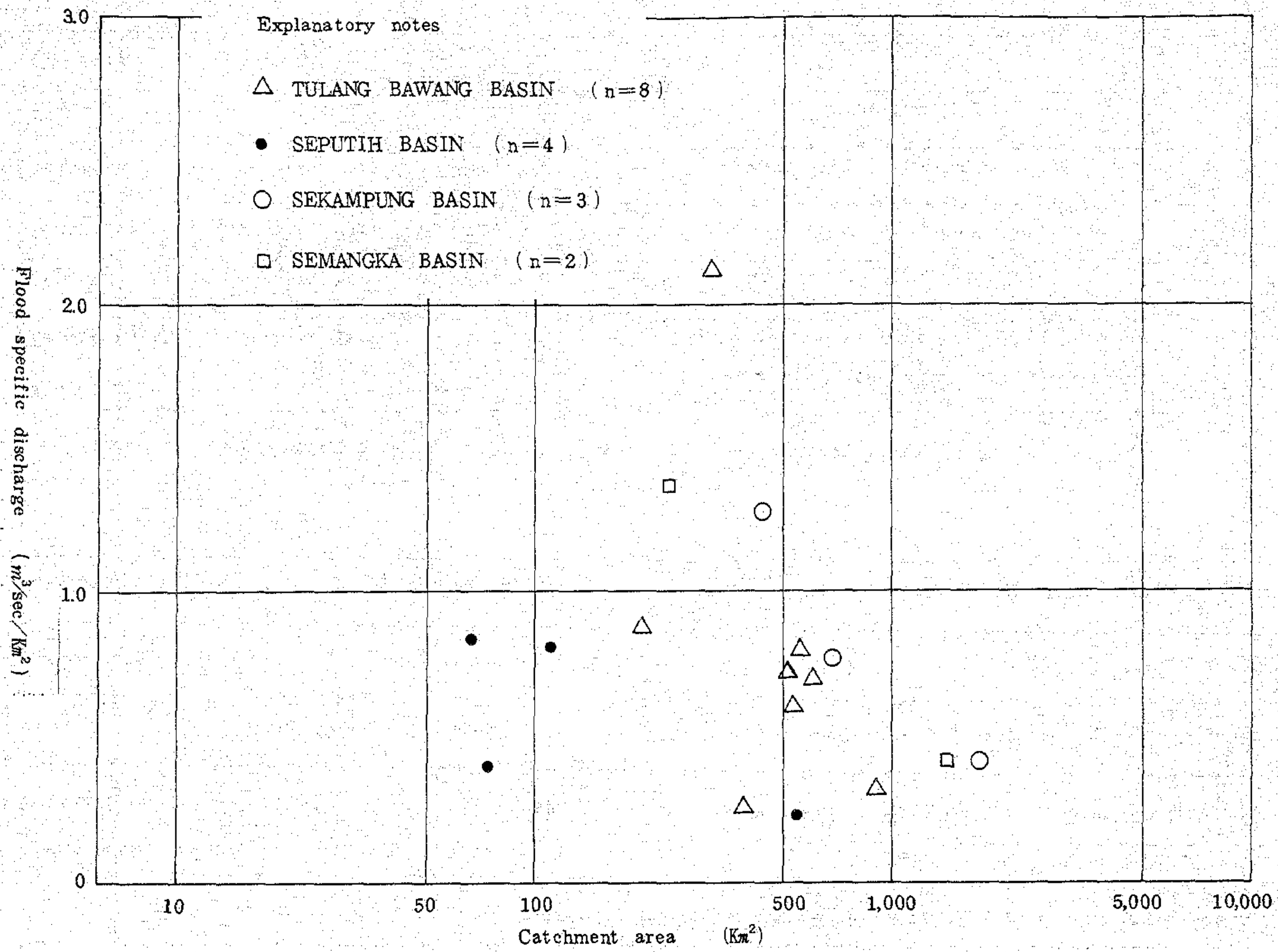
Table - 4 Ninety-five Percentage Confidence Limits of Rainfall Days in each River Basin

(days)

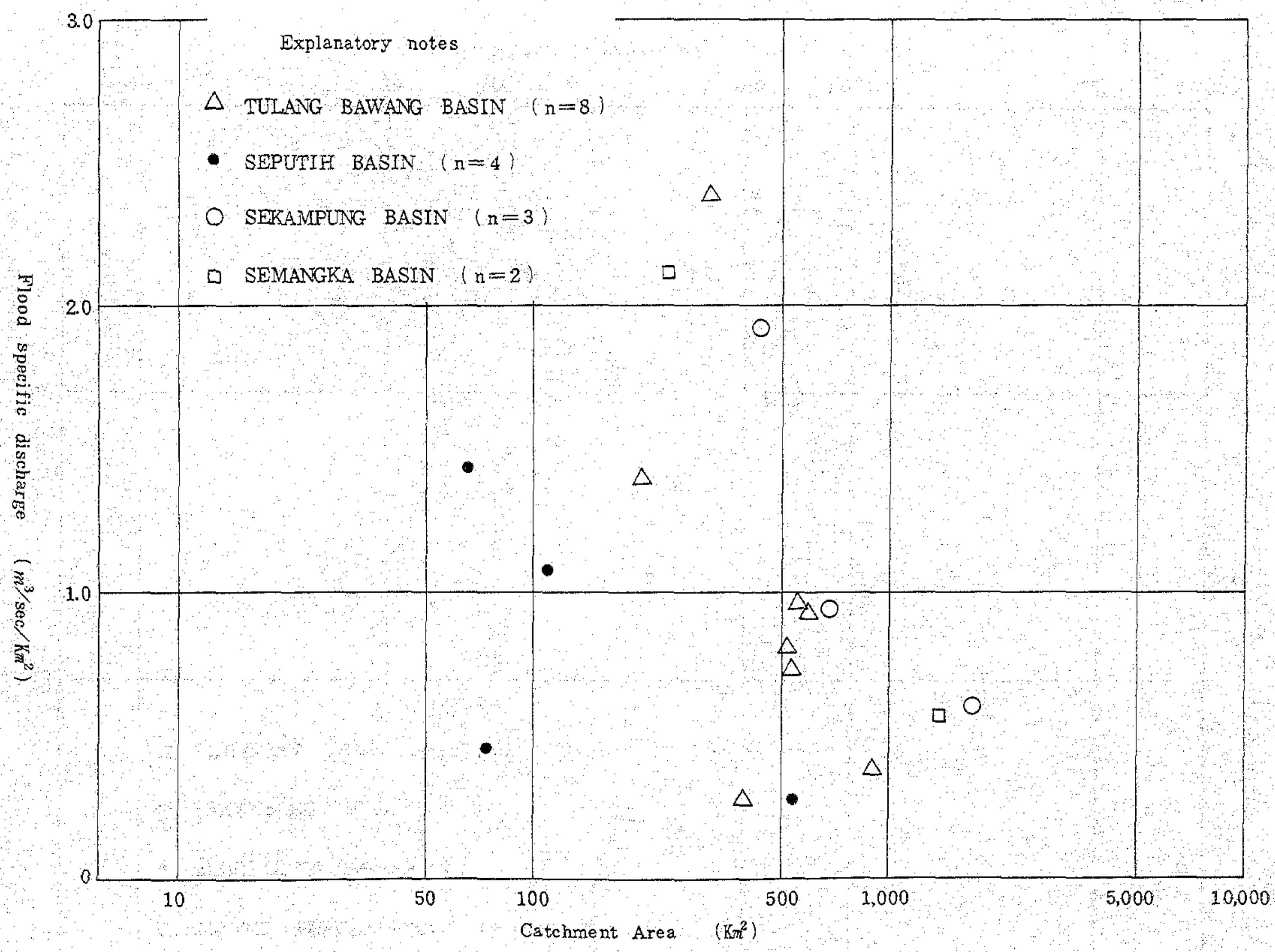
River Basin	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Tulang Bawang (n = 15)	18-20	15-18	17-19	15-17	12-14	8-11	9-11	8-10	10-13	11-15	14-17	19-20	157 - 181
Seputih (n = 7)	15-19	14-17	15-17	11-13	9-11	9-11	7-10	7- 9	7- 9	9-10	11-13	16-18	131 - 151
Sekampung (n = 18)	16-19	15-17	14-17	11-13	10-12	8- 9	8- 9	7- 9	8-10	9-11	10-12	16-18	135 - 153
Semangka (n = 3)	17-19	14-18	15-17	14-19	11-15	9-11	5-11	7-12	7-13	13-17	15-19	16-18	151 - 188

Table - 5 Distinction between Rainy Month and Dry Month in each River Basin

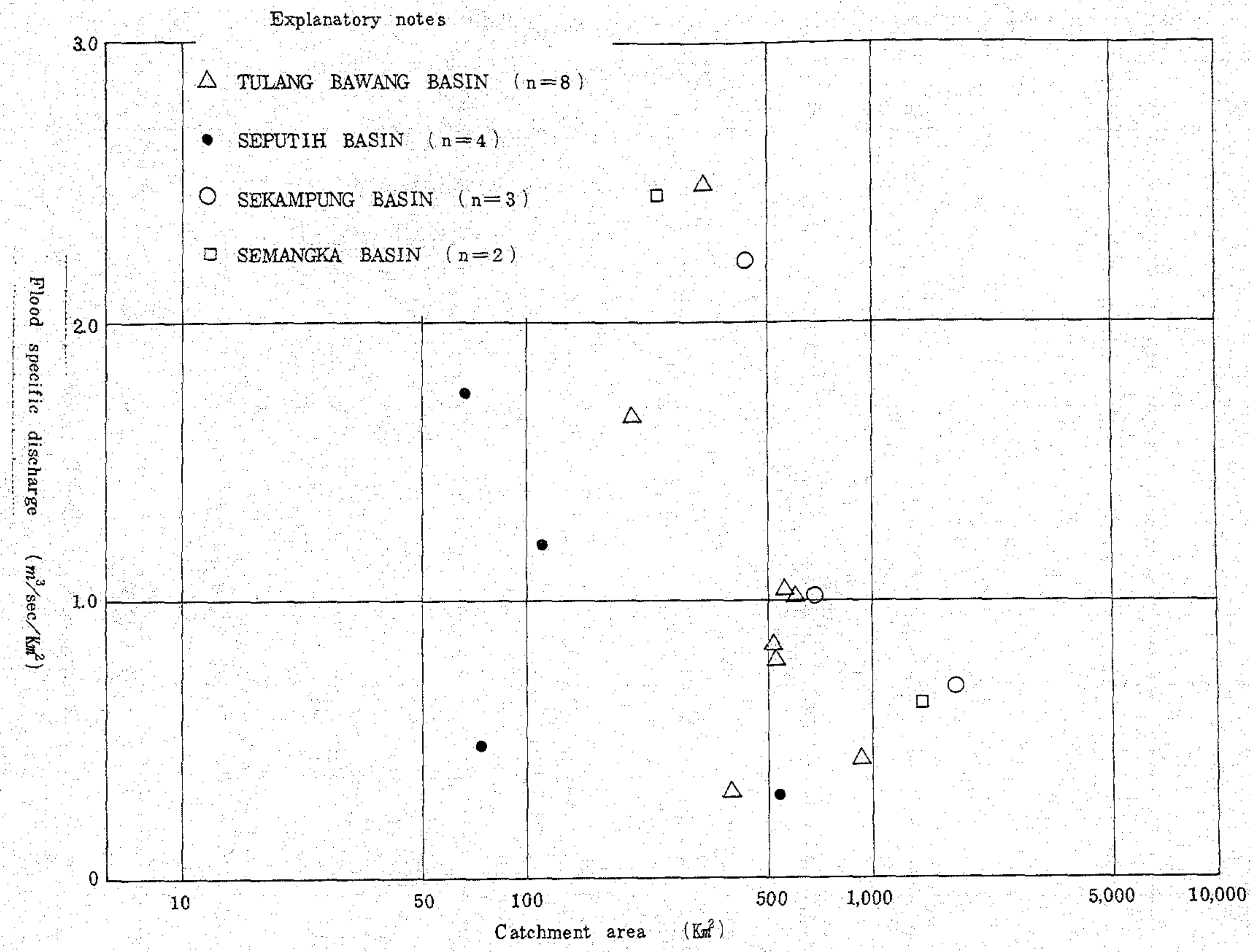
River Basin	Rainy Month	Dry Month
Tulang Bawang	Jan. Feb. Mar. Apr. Dec.	June, July, Aug. Sep. Oct.
Seputih	Jan. Feb. Mar. Apr. Dec.	June, July, Aug. Sep. Oct.
Sekampung	Jan. Feb. Mar. Apr. Dec.	June, July, Aug. Sep. Oct. Nov.
Semangka	Jan. Feb. Mar. Apr. Nov. Dec.	June, July, Aug. Sep.
Jepara	Indistinct	Indistinct
Southern Drainage	Indistinct	Indistinct



Fig—2 Relation between catchment area and flood specific discharge for ten years' return period.



Fig—3 Relation between catchment area and flood specific discharge for fifty years' return period.



Fig—4 Relation between catchment area and flood specific discharge for a hundred years' returu period.

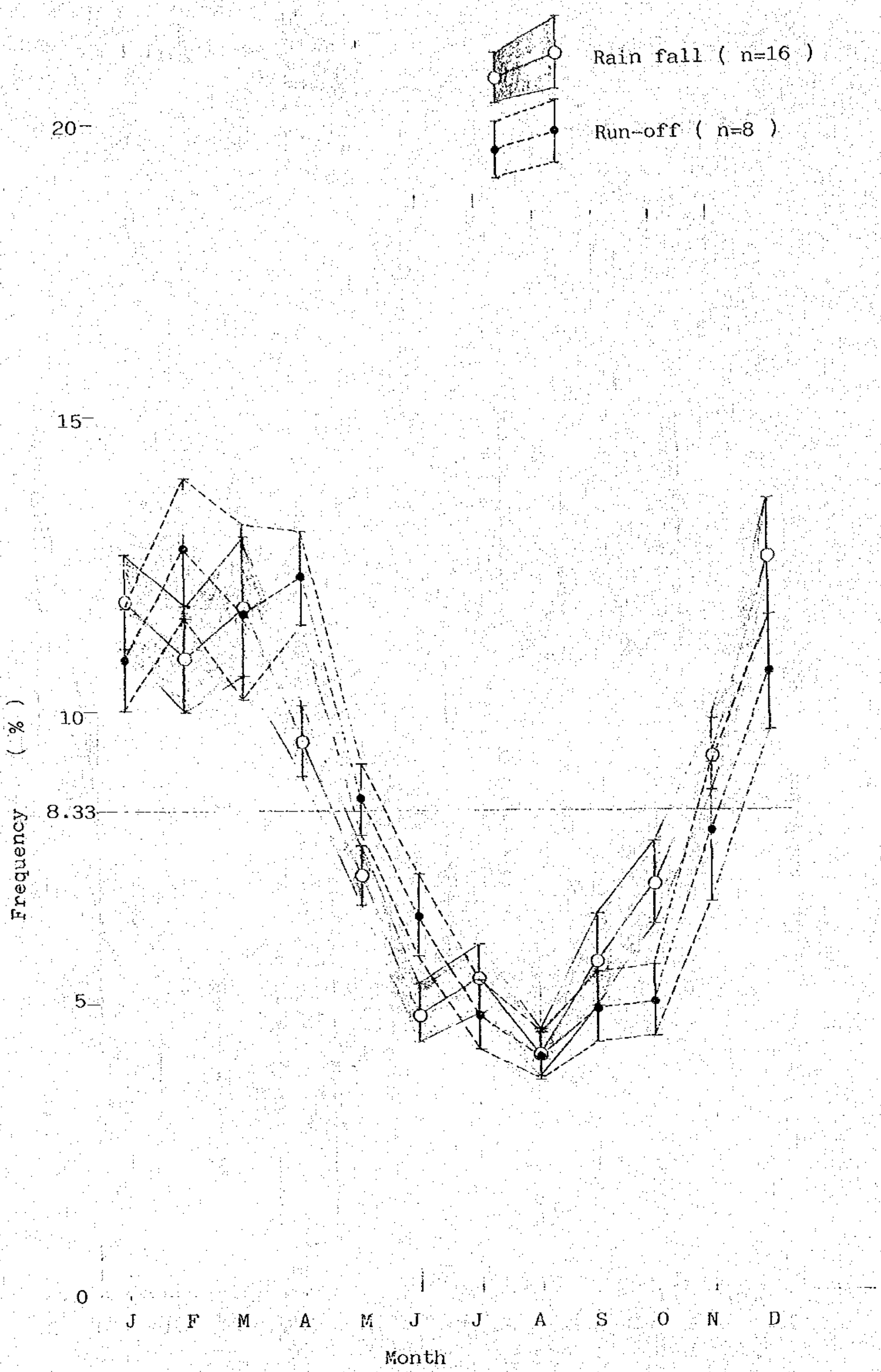


Fig-5 Distribution of both rain fall and run-off in the Way Telang Bawang basin

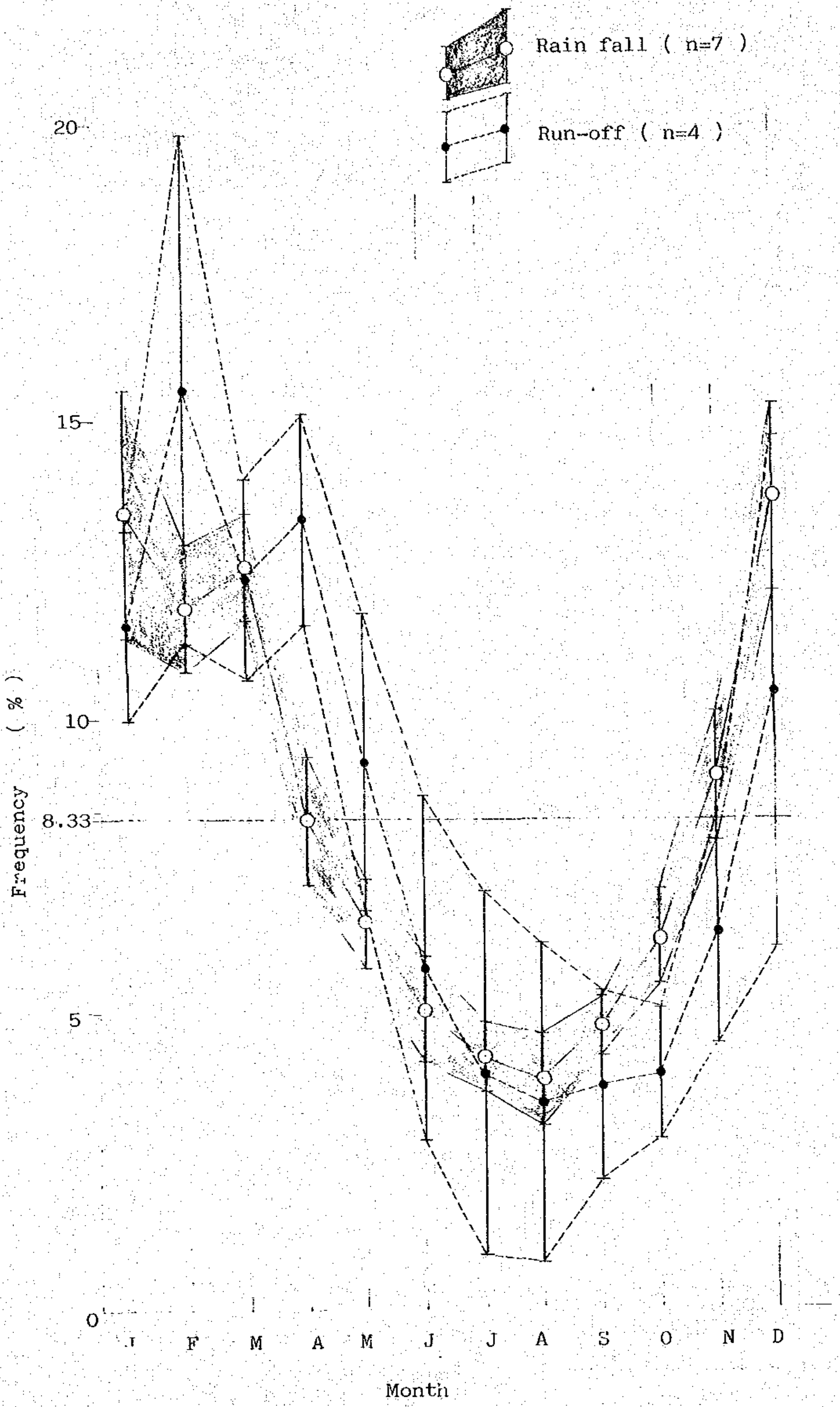


Fig-6 Distribution of both rain fall and run-off in the Way Seputih basin

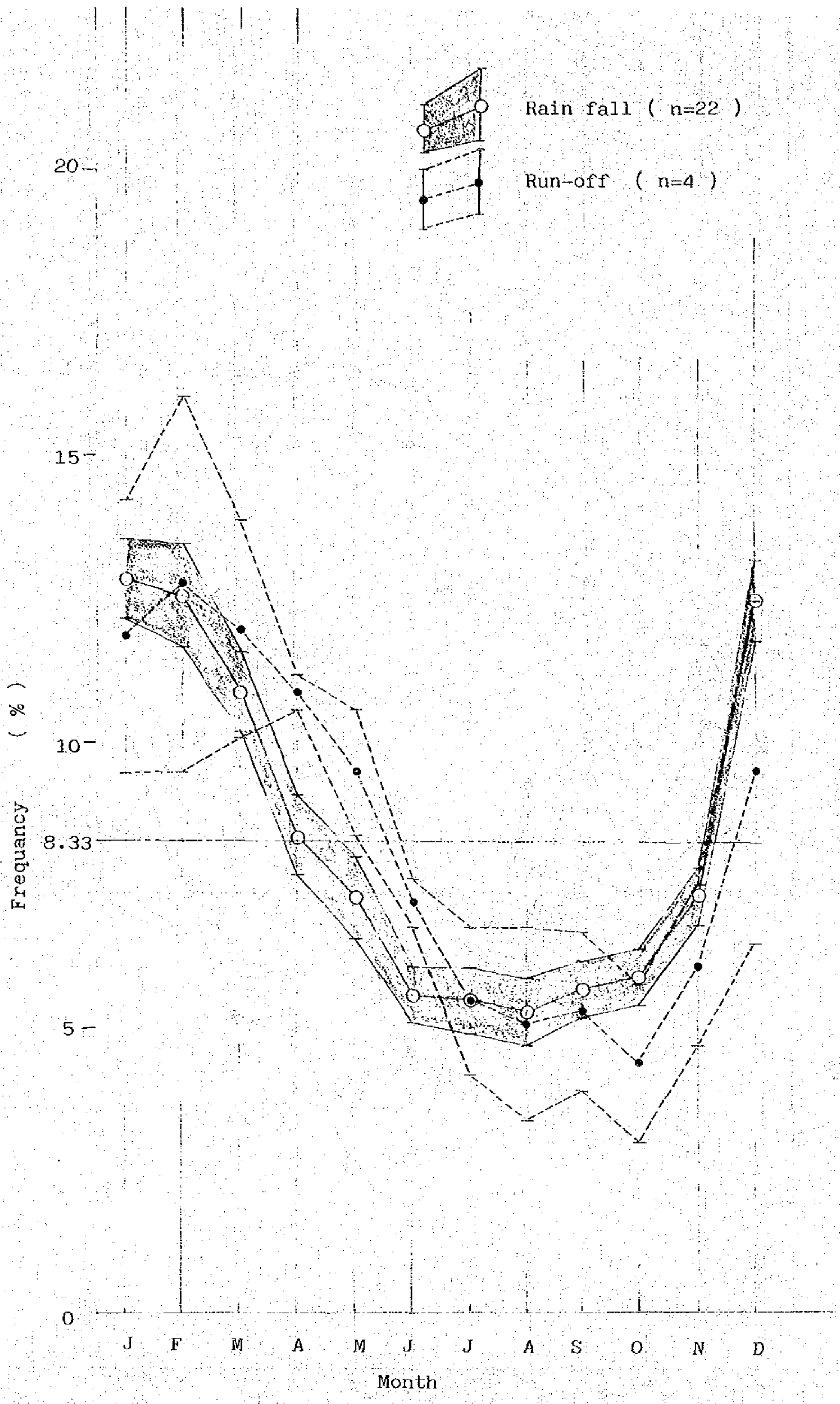


Fig-7 Distribution of both rain fall and run-off in the Way Sekampung basin

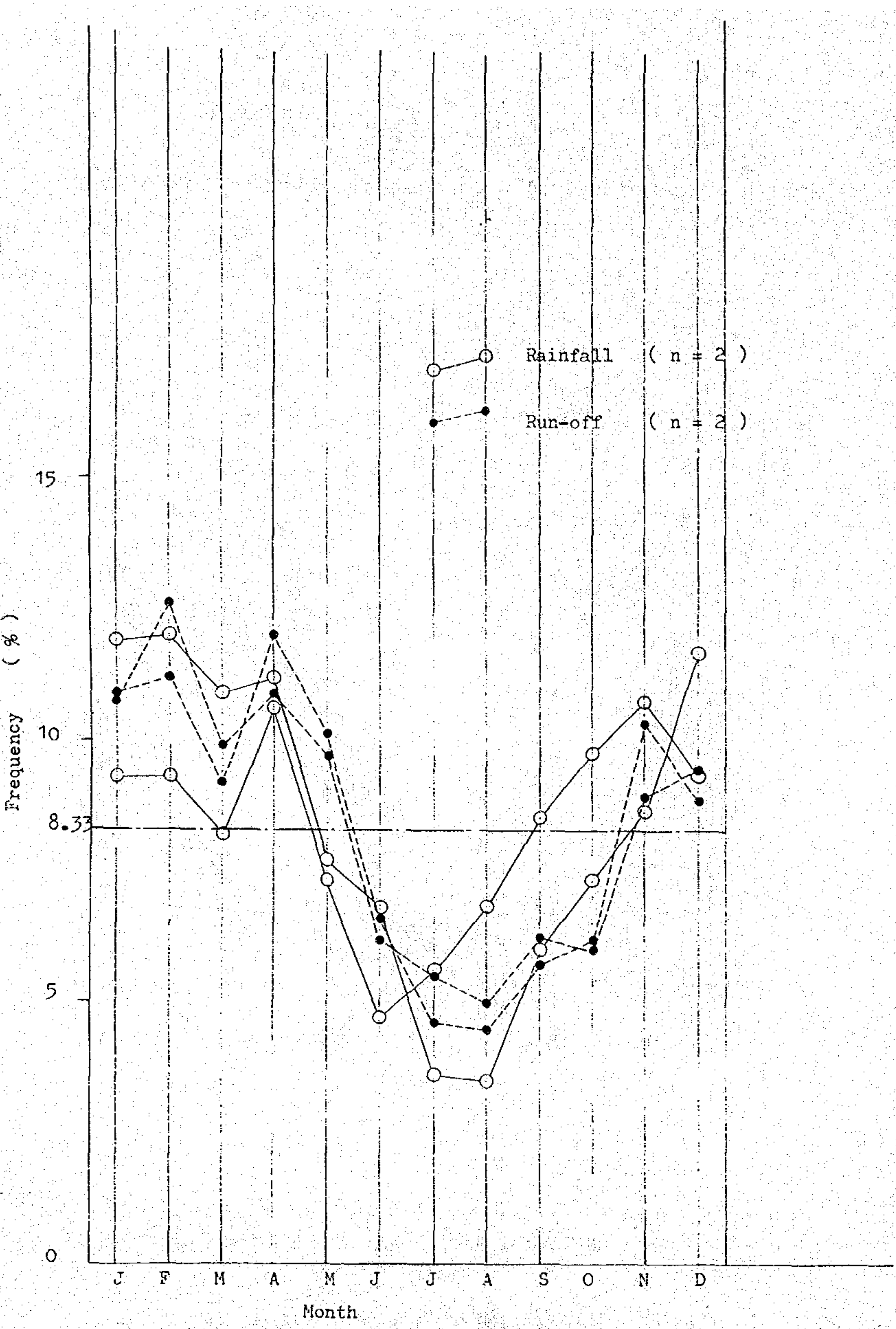


Fig - 8 Distribution of both rainfall and run-off in the Way Semangka basin.

Fig - 9 Distribution of rainfall in the Way Jepara basin.

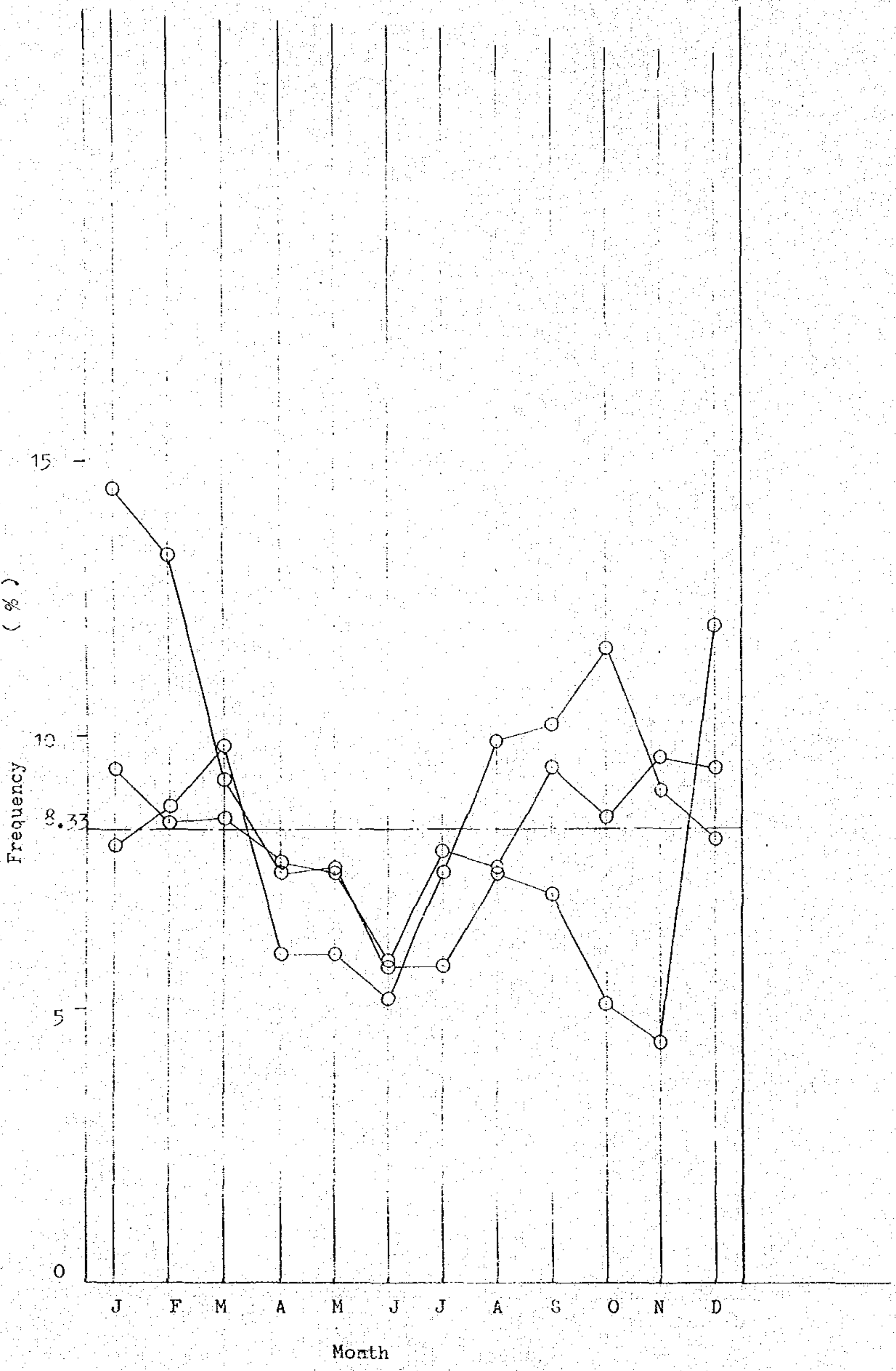


Fig - 10 Distribution of rainfall in the Southern Drainage.

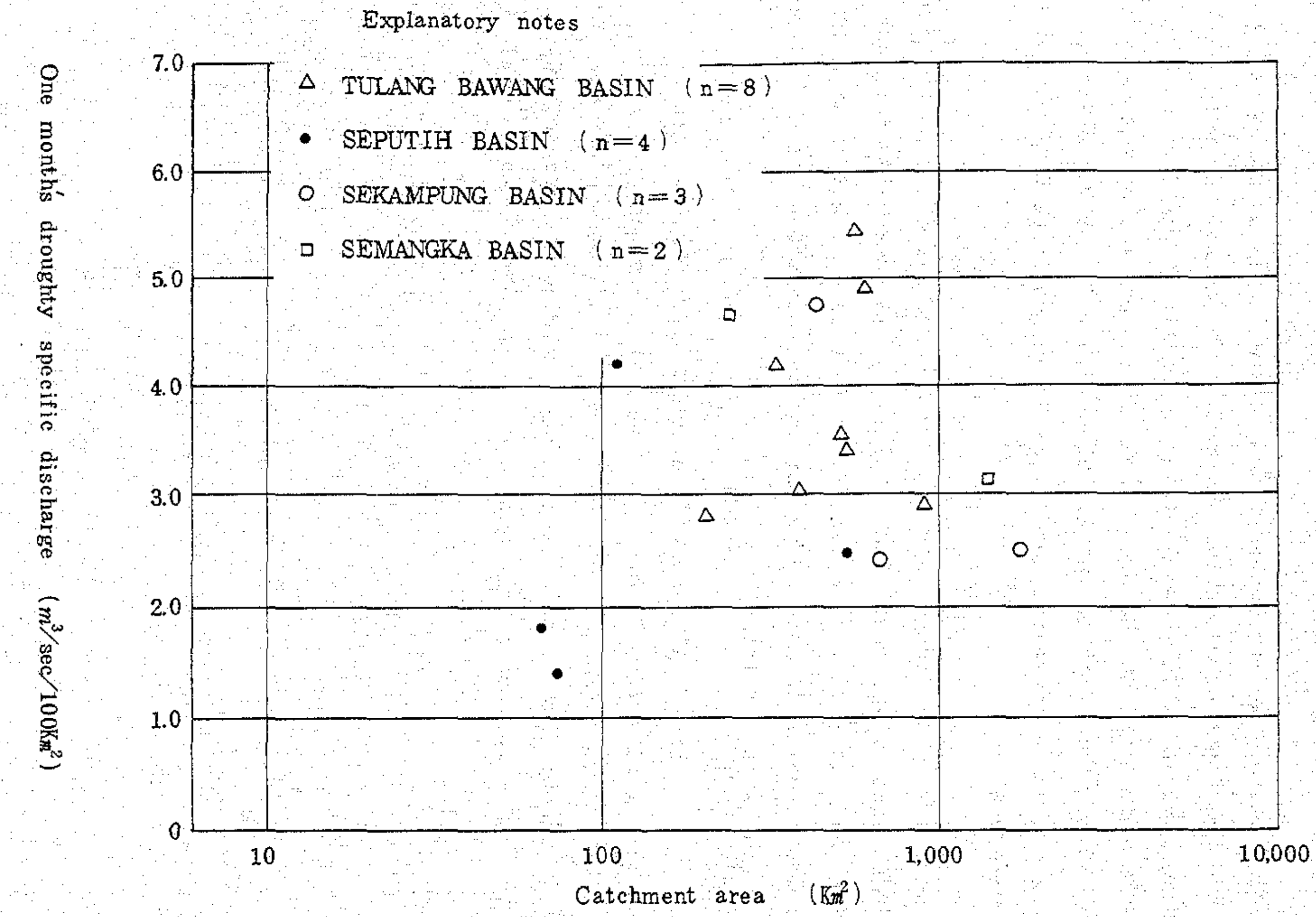
9. A Month's Droughty Rainfall and Specific Discharge

Isohyets of a month's droughty rainfall for five years' return period in the rainy season (from December to April) and in the dry season (from May to September), they were obtained by log-normal method, are shown in Fig - I and Fig - J.

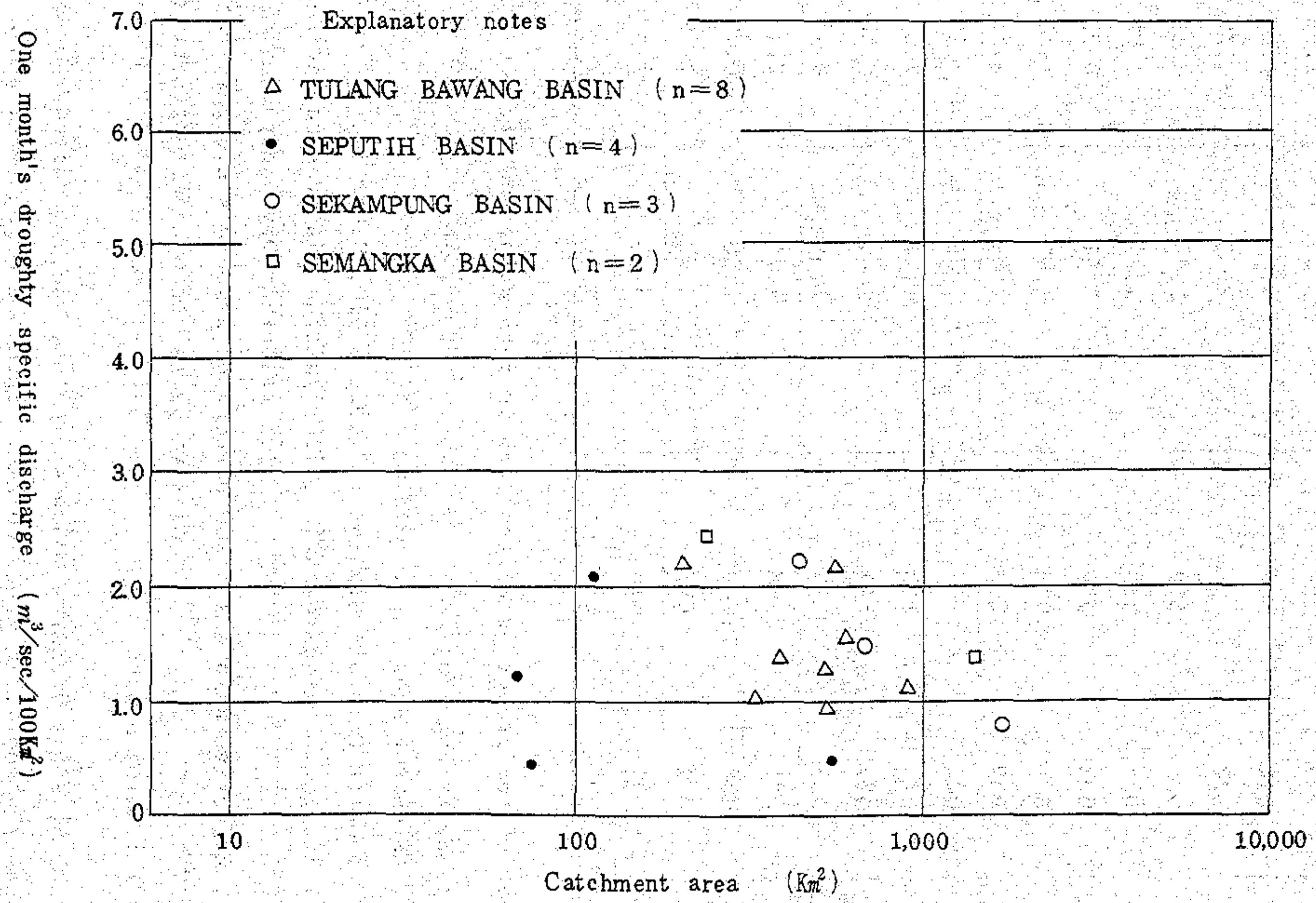
In the rainy season, we may be benefited rainfall only about 100 mm/month both in the Way Seputih and in the Way Sekampung basins. Even in the Way Tulang Bawang basin, which has plenty of rainfall, it distributes between 110 and 220 mm/month. On the other hand, in the dry season the value is less than 30 mm/month both in the Way Seputih and in the Way Sekampung basins. And also, even in the Way Tulang Bawang basin we will obtain less than 50 mm/month.

And further, a month's droughty specific discharges in the both rainy and dry paddy seasons, which were also obtained by log-normal method, are shown in Fig - 11 and Fig - 12 respectively. It is said generally that a droughty specific discharge is in inverse proportion to a catchment area, but we could not find such a relation.

From Fig - 11, we know that a month's droughty specific discharge in the rainy season for five years' return period distributes between 2.4 and 4.7 $m^3/sec/100km^2$. On the other hand in the dry season they distribute from 0.8 to 2.2 $m^3/sec/100km^2$ (Fig - 12). A month's droughty specific discharge for five years' return period at each station is shown in Table - 6.



Fig－11 Relation between catchment area and a month's droughty specific discharge in the rainy season for five years' return period.



Fig－12 Relation between catchment area and a month's droughty specific discharge in the dry season for five years' return period.

Table - 6 A Month's Droughty Specific Discharge for Five Years' Return Period at Each Station

($m^3/s/100\ km^2$)

River Basin	Station No.	Catchment Area (km^2)	A Month's Droughty Discharge	
			Rainy Season	Dry Season
Tulang Bawang	017	389	3.05	1.38
	018	604	4.89	1.57
	023	525	3.53	1.28
	024	559	5.44	2.15
	026	328	4.21	1.05
	032	534	3.41	0.93
	034	913	2.90	1.12
	039	203	2.82	2.18
Seputih	002	67	1.79	1.18
	025	113	4.22	2.09
	027	543	2.47	0.50
	037	75	1.39	0.44
Sekampung	001	438	4.74	2.19
	003	1,743	2.50	0.79
	021	682	2.42	1.49
Semangka	031	1,413	3.13	1.39
	035	243	4.65	2.41

10. Estimation of the Proper Benefited Area in Both Rainy and Dry Seasons.

Given : Way Lalaan Project

i. *Catchment Area* : *18.6* km^2

ii. Adopted Rainfall Station : T.002, R.010, R.017

iii. Irrigation Requirement : 1.0 ℓ/sec/ha (Rainy paddy season)
1.3 ℓ/sec/ha (Dry paddy season)

iv. Effective Rainfall : 100 percent of a month's droughty rainfall for five years' return period (Estimation).

Solution 1 : Rainy Season

a) We know by Fig - 9 that a month's droughty specific discharges distribute between 2.4 and 4.7 $m^3/sec/100\ km^2$. Then the effective month's run-off Q_1 *is as follows:*

$$Q_1 = (2.4\sim4.7) m^3/sec/100\ km^2 \times 18.6\ km^2$$
$$= (450\sim870)\ \ell/sec.$$

b) A month's droughty rainfall for five years' return period is known by Fig - D. Then averaged these near 3 stations, we obtained 100 mm/month. The *effective rainfall* R_1 is as follows:

R_1 = 100 mm/month
= 0.39 ℓ/sec/ha

c) Accordingly the irrigable area A_1 is as follows:

A_1 = (450~870) ℓ/sec ÷ (1.0 - 0.39)ℓ/sec/ha
≑ (740~1,430) ha

Solution 2: Dry Season

a) Q_2 = (0.8~2.2) m^3/sec/100 km^2 x 18.6 km^2
= (150~410) /sec

b) R_2 = 50 mm/month (by Fig - E)
= 0.19 ℓ/sec/ha

c) A_2 = (150~410) ℓ/sec ÷ (1.3 - 0.19) ℓ/sec/ha
≑ (140~370) ha

Accordingly we know that the irrigable area in the dry season is only one fourth of that in the rainy season.

By the way, the benefited area in the Way Lalaan project is 1,217 ha. We cannot, therefore, irrigate all of the benefited area in a droughty rainfall year.

In the same way, the relation between the estimated paddy field area and the real one at each "Sedang Kecil project" in the Way Sekampung basin is shown in Table - 7. Many real irrigated paddy fields were the same as the estimated areas in both seasons. But the Way Payung, the Way Maja, the Way Jelai, the Way Lalaan and the Way Semah projects have a small potential in the dry season compared with the real benefited area. On the other hand, the Way Gatel project has a big potential for irrigation. We should consider utilizing its river.

It is about 50 years since the paddy field had been cultivated. And further the real benefited area is nearly the same as the estimated one. But the canals of tertiary and others are in bad conditions. We hope to complete these canals as soon as possible, because by these works, or by the minimum effort and budget, we will be able to obtain the maximum effect.

Table - 7 Relation between Normal and Estimated Benefited Area in Each Project

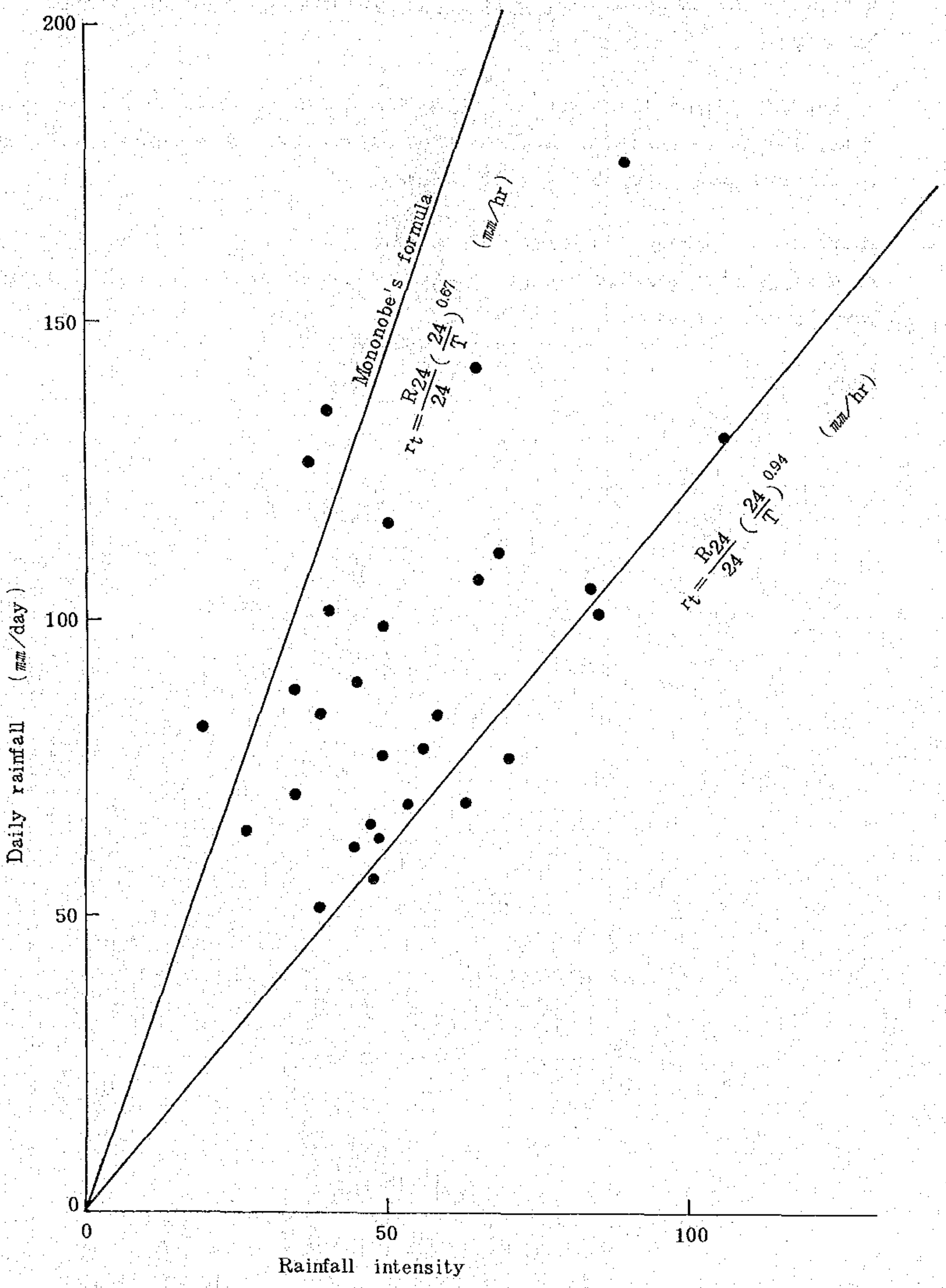
Project Name	Catchment Area (km^2)	Normal Benefited Area (ha)	Estimated Benefited Area		Real Benefited Area	
			Rainy Season (ha)	Dry Season (ha)	Rainy Season (ha)	Dry Season (ha)
Way Payung	12.1	300	480 - 930	90 - 240	300	300
Way Maja	10.5	510	410 - 810	80 - 210	410	410
Way Jelai	18.6	521	730 - 1,430	130 - 370	521	521
Way Lalaan	19.8	1,217	780 - 1,530	140 - 390	1,217	896
Way Tebu	216.0	4,214	7,100 - 13,900	1,370 - 3,770	4,214	3,055
Way Semah	17.6	510	580 - 1,130	110 - 310	510	391
Way Padangratu	37.7	874	1,240-- 2,430	240 - 660	611	559
Way Gatel	790.0	550	26,000 - 50,900	5,020 - 13,800	550	550
Way Ratai	22.4	1,158	740 - 1,440	140 - 390	750	159

11. Setting up of Recording Rain-gauge

In Fig-13, it is drawn the relation between daily rainfall and rainfall intensity for an hour. The well known Mononobe's formula indicates the least value.

By the way, flood discharge is due to the rainfall intesity for a short time, and it is said that soil erosion has a high correlation relationship to the rainfall intensity for 10 minutes.

Therefore we propose to increase recording rain-gauge. But as recording rain-gauge also sometimes went to wrong, we propose to use a daily rain-gauge simultaneously.



Fig—13 Relation between daily rainfall and rainfall intensity for an hour.

IV. REALITIES OF THE PADDY FIELD IRRIGATION AT THE WAY TEBU PROJECT

March 1982

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TABLE

FIGURE

1. Preface

In Lampung province, there are many paddy field irrigation projects, and some projects are under construction, and other projects are going to be constructed.

But we do not yet know the realities of the paddy field irrigation; cropping schedule, irrigation requirement, and so on. The plan of the paddy field irrigation has been performed not by experiment or experience but only on the table, even if it was a big project.

By the way, Lampung province has a long history of the paddy field irrigation and has data on the planted paddy field area and the irrigated water at the "Sedang Kecil Project" in South Lampung prefecture.

Therefore, at first we will study the realities of the paddy field irrigation in the tropics using this data, and then we will make some proposals.

2. Collection and Examination of Data

We have collected data on the planted paddy field area and the irrigated water. The former is a monthly record of puddling area, nursery bed area and paddy field area at each teriary sector. On the other hand, the latter is a daily record of irrigated water at each canal of main, secondary and tertiary. And also this record includes daily data on the river discharge.

Then we have examined this data by the following items.

(i) Is there a discharge apparatus at the river, or not?
(ii) Is there a staff gauge at the main or secondary canal, or not?
(iii) Is there a discharge meter (Cippoletti or Romijn gate) at each tertiary division works, or not?
(iv) Is this discharge meter measured exactly, or not?

We have confirmed each discharge meter at each project. And we have performed a discharge measurement at each canal of main and secondary. We have also checked the level, the width and the overflowing depth at each "Cippoletti", and then asked the observer his measured value.

The reliability that we have judged is shown in Table - 1.

Table - 1 Reliability of Discharge Observation at each Project

Reliability / Project Name	Main and Secondary Canal	Tertiary Canal	Reliability of Observation
	Stuff Gauge	Cippoletti	
Way Payung	×	×	×
Way Maja	×	×	×
Way Jelai	×	×	×
Way lalaan	×	×	×
Way Tebu I & II	○	○	△
Way Tebu IV	×	○	△
Way Tebu III	○	○	○
Way Padangratu	○	○	×
Way Semah	○	○	×
Way Gatel	○	×	×

We can utilize data on the Way Tebu project only. It is a primary work to take data on the paddy field irrigation for analizing irrigation realities. Therefore we hope to perfect the following matters.

(i) To equip a discharge measurement apparatus and to make a rating curve at each river every three years, because a river is changing continuously.

(ii) To equip a staff gauge and make a rating curve at each canal of main and secondary every five years.

(iii) To equip a cippoletti or a romijn gate at each tertiary division works.

(iv) And to retrain observer.

3. Outline of the Way Tebu Project

(See Fig - 1)

The Way Tebu Project is situated at the northwestern of Tanjungkarang Teluk-Betung. This project has a catchment area of 216 Km^2.

The water is taken at the Banjar Agung weir from the Way Tebu, and it flows into the main canal K.W.T. of the Way Tebu I & II project. The water at the end of the main canal K.W.T. pours into the Way Napal and it is taken again at the Way Napal weir and flows into the main canal K.T. and K.S.K. of the Way Tebu IV project. The Way Napal has a catchment area of 4.6 Km^2.

And further for the Way Tebu III project, the water at the end of the main canal K.W.T. of the Way Tebu I & II project pours into the Way Semah and it is taken again at the Gumuk Mas weir and it flows into the main canal K.S. and K.N. The Way Semah also has a catchment area of 10.0 Km^2. The benfited area is lying between the Way Tebu and the Way Sekampung.

But there are several figures for the benefited area, because there is no topographical map in this region. As topographical maps of 1 to 50,000 is the basis of our work, we hope to draw them up as soon as possible. The area is shown in Fig-2.

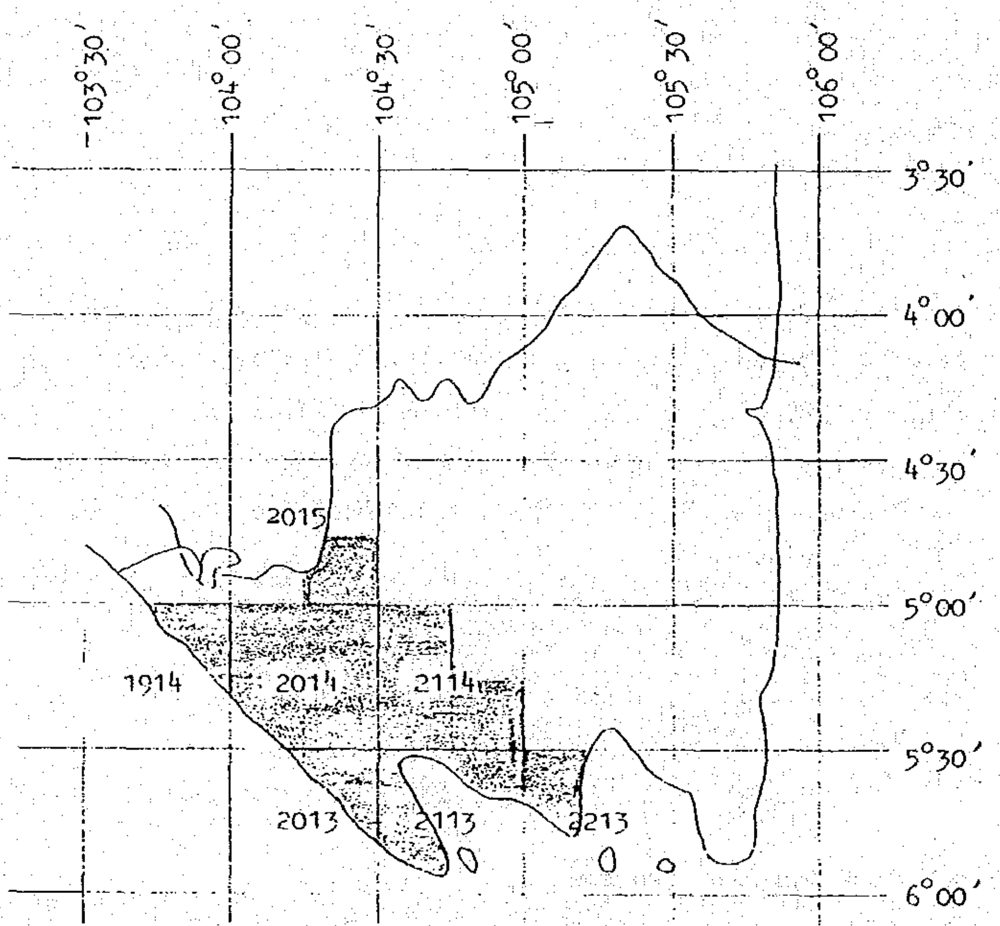


Fig - 2 Index of the undrawn topographical maps (1/50,000).

Table - 2 Several Figures of Benefited Area

Project Name	Benefited Area (ha)		
	No. 1	No. 2	No. 3
Way Tebu I & II	399	-	474
Way Tebu IV	2,124	-	1,736
Way Tebu III	2,791	-	1,999
Total	5,314	5,814	4,209
	Old "Schema"	"Data Irigasi Daerah Lampung"	"Daftar Tanaman"

In this paper, we will use the figure of No. 3, because the estimation of the planted paddy field area has been based on that.

By the report of "Hydrologic Analysis in Lampung Province, A Divised Edition, Feb. 1982", we can see this region has the least of both rainfall and rainfall days.

This project was started for transmigration people from Jawa in 1926. The main structures are drawn in Table - 3.

Table - 3 Main Structures at Each Project

Project Name / Items	Way Tebu I & II	Way Tebu IV	Way Tebu III
Supplied Water	Way Tebu	From Way Tebu I & II Project and Way Napal	From Way Tebu I & II Project and Way Semah
Name of Weir	Benjar Agung	Napal	
Main Canal	5,000 m	---	4,500 m
Secondary Canal	--	17,600 m	17,200 m

4. Paddy Field Land Consolidation

D.P.U.P. Lampung is going to construct a dense tertiary canal. The changes of the tertiary sector are shown in Fig - 3 and Fig - 4. At present, the number of the tertiary sector is 64, on the other hand in the near future it will be divided into 277. Therefore, the average of tertiary sector size will be decreased from 66 ha to 18 ha.

This means that the water flows into every tertiary sector easily. But it is also true that each paddy field requests more water. And for constructing the dense tertiary sector, maps of scale 1 to 5,000 have been drawn up.

As a result of that, the benefited area that had been only estimated has appeared as shown in Table - 4.

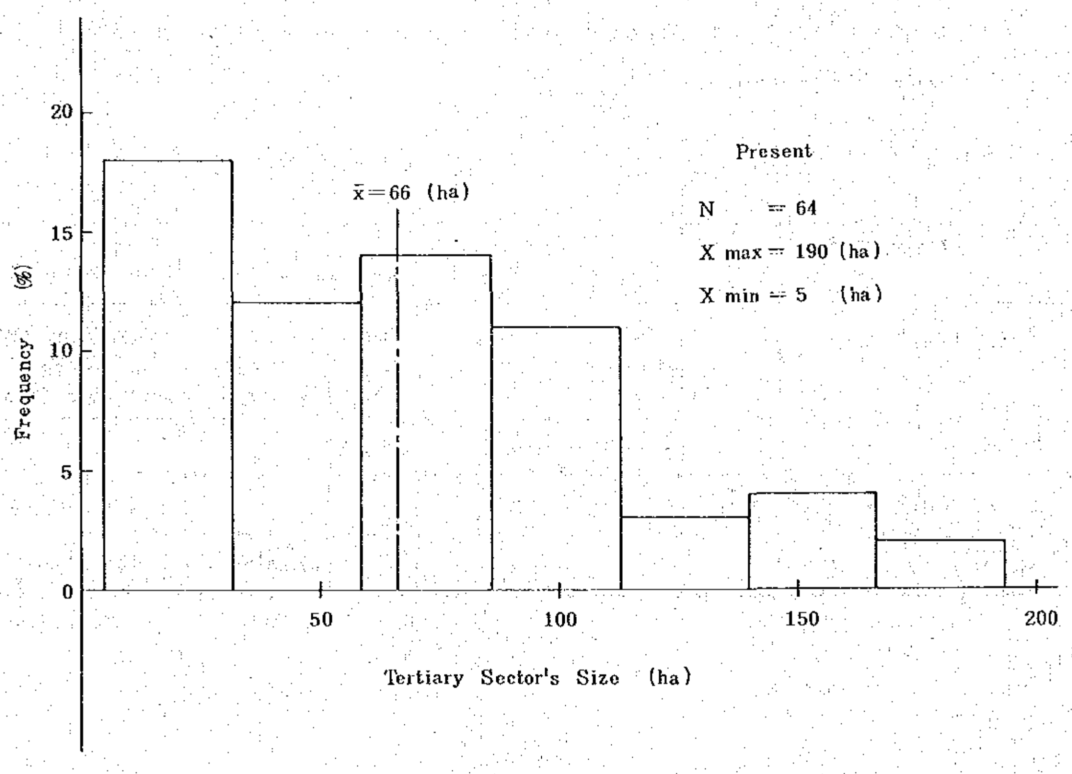


Fig - 3 Histogram of the tertiary sector's size at present.

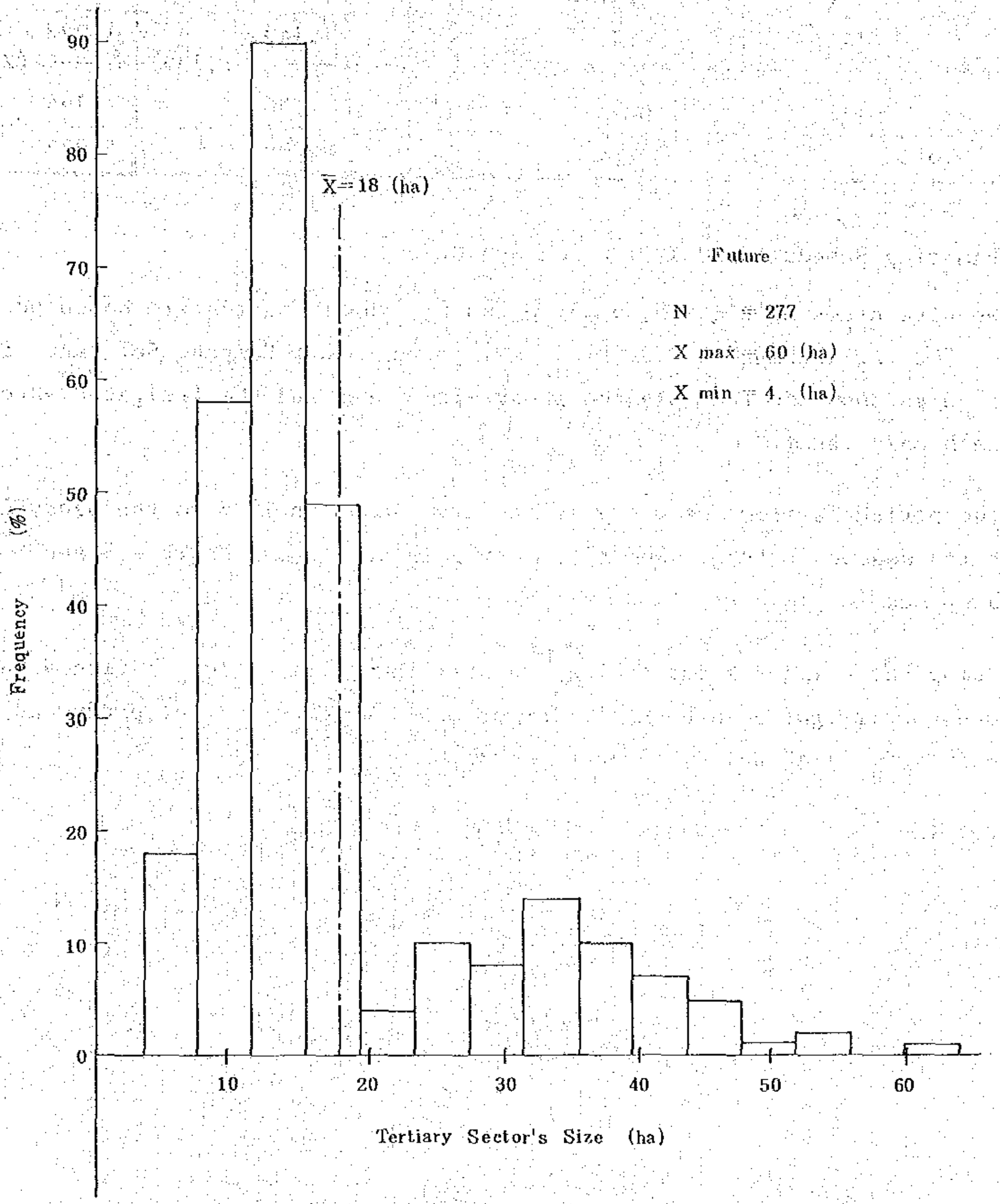


Fig - 4 Histogram of the tertiary sector's size in the future.

Table - 4 Difference of the Benefited Area

Project Name	Main Canal Name	Benefited Area (ha)			
		Present		Future	
Way Tebu I & II	K.W.T.	474		611	
IV	K.T.	1,208	(1,999)	1,459	(2,192)
IV	K.S.K.	791		733	
III	K.S.	1,140	(1,736)	1,323	(2,117)
III	K.N.	596		794	
Total		4,209		4,923	

5. Planting Schedule and Irrigation Schedule

We have drawn up Fig - 5, 6, 7, 8 and 9; these figures are based on data of "Daftar Tanaman" D.P.U. Propinsi Lampung Seksi Lampung Selatan. These figures show the real planted paddy field area and the irrigated water at each main canal.

The period is from the paddy in the dry season in 1977 to the paddy in the rainy season in 1981. And also, using these figure, Table - 5 and 6 have been made.

Using these figures and tables, we will investigate the planting schedule and the irrigation schedule. Farmers told us the kinds of paddy had been mainly "PELITA" and "IR-8" until 1980.

But they have been changed to "IR-36" since 1981.

Table - 5 Planted Period and Irrigated Period (Way Tebu I & II and IV Project)

Project	Main	Items	1977	1978		1979		1980		1981
Name	Canal		Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
I & II	K.W.T.	1. The first day of puddling.	June,15	Dec.20	July, 1	Dec.15	July, 1	Jan. 1	July, 1	Jan. 1
		2. The first day of harvest.	Nov.10	May,20	Dec.10	June, 5	Nov.30	May,31	Dec.10	May, 5
		3. The last day of harvest.	Dec.15	June,30	Jan.15	July, 5	Dec.10	June,30	Dec.30	June,15
		4. Planted period in (K.W.T.)	184	192	199	197	163	182	184	166
		5. Planted period at a field.	135	135	150	130	130	135	140	110
		6. The first day of irrigation.	June, 7	Jan. 1	July, 1	Jan. 1	June,20	Dec.25	July, 1	Dec.20
		7. The last day of irrigation.	Dec.31	June,30	Nov.30	June 5	Nov.26	June,30	Nov.19	May,31
		8. Irrigated period.	208 (199)	181 (181)	153 (153)	156 (156)	160 (160)	189 (189)	142 (142)	161 (159)
IV	K.T.	1.	June,10	Dec.20	June,15	Dec.15	June,10	Dec.20	June,15	Jan. 1
		2.	Nov.20	May, 5	Nov.30	May,25	Nov.25	Apr.30	Nov.10	Apr.30
		3.	Jan. 5	June,30	Dec.30	June,30	Dec. 5	June,30	Dec.31	June,25
		4. (K.T.)	210	193	200	203	179	194	200	176
		5.	140	140	135	140	145	135	140	125
		6.	June, 7	Jan. 1	June,21	Jan. 1	June,21	Dec.26	June, 1	Dec.20
		7.	Dec.31	May,31	Nov.30	June, 5	Nov.25	May,31	Nov.19	May,31
		8.	208	151 (128)	163 (163)	156 (156)	158 (158)	157 (157)	172 (172)	163 (161)
IV	K.S.K.	1.	June,15	Dec.15	June,20	Dec.10	June,10	Dec.20	June,20	Jan. 1
		2.	Nov.25	May,20	Dec. 5	May,25	Nov.25	Apr.30	Nov.15	Apr.25
		3.	Dec.10	June,15	Dec.25	June,30	Dec.10	July,10	Dec.15	June,10
		4. (K.S.K.)	179	183	189	203	184	204	179	161
		5.	140	140	140	145	145	135	140	115
		6.	June, 7	Jan. 1	June, 1	Jan. 7	June,21	Dec.26	June, 1	Dec.20
		7.	Dec.31	May,31	Nov.30	June, 5	Nov.25	May,31	Nov.19	May,31
		8.	208 (148)	151 (151)	183 (183)	150 (150)	158 (154)	158 (158)	172 (172)	163 (161)

Note: Figure in a parenthesis shows a sum of irrigated days.

Table - 6 Planted Period and Irrigated Period (Way Tebu III Project)

Project Name	Main Canal	Items	1977 Dry	1978 Rainy	1978 Dry	1979 Rainy	1979 Dry	1980 Rainy	1980 Dry	1981 Rainy
III	K.S.	1.	June, 1	Dec. 1	June,10	Dec.20	June,15	Jan. 1	July, 1	Jan.10
		2.	Nov.20	Apr.30	Oct.30	May,10	Nov.25	May,20	Nov.30	May,25
		3.	Jan.25	July, 5	Dec.31	June,20	Dec.31	June,30	Jan.31	June,30
		4. (K.S.)	239	217	205	183	200	182	215	172
		5.	170	145	145	140	155	145	145	135
		6.	June, 8	Jan. 1	June,20	Jan. 1	June,16	Jan. 1	July,15	Jan.16
		7.	Dec.20	June, 4	Nov.29	May,31	Nov.30	June,18	Dec.15	May,31
		8.	196 (180)	155 (155)	163(163)	151 (151)	168 (168)	170 (170)	154 (154)	136(136)
III	K.N.	1.	June, 1	Dec. 1	June,20	Dec. 5	June,10	Jan. 1	July,10	Jan. 5
		2.	Oct.20	May, 5	Oct.31	May,10	Oct.31	May,31	Nov.30	Apr.30
		3.	Dec.31	June,30	Dec.25	June,30	Jan. 5	June,30	Jan.25	July,20
		4. (K.N.)	214	212	189	208	210	182	199	197
		5.	135	140	135	145	150	150	150	140
		6.	June, 8	Jan. 1	June,20	Jan. 1	June,16	Jan. 1	July,15	Jan.16
		7.	Dec.19	June, 4	Nov.29	May,31	Nov.30	June,18	Dec.14	June, 7
		8.	195(183)	155(155)	163 (163)	151 (151)	168 (168)	170(170)	153 (153)	143(143)

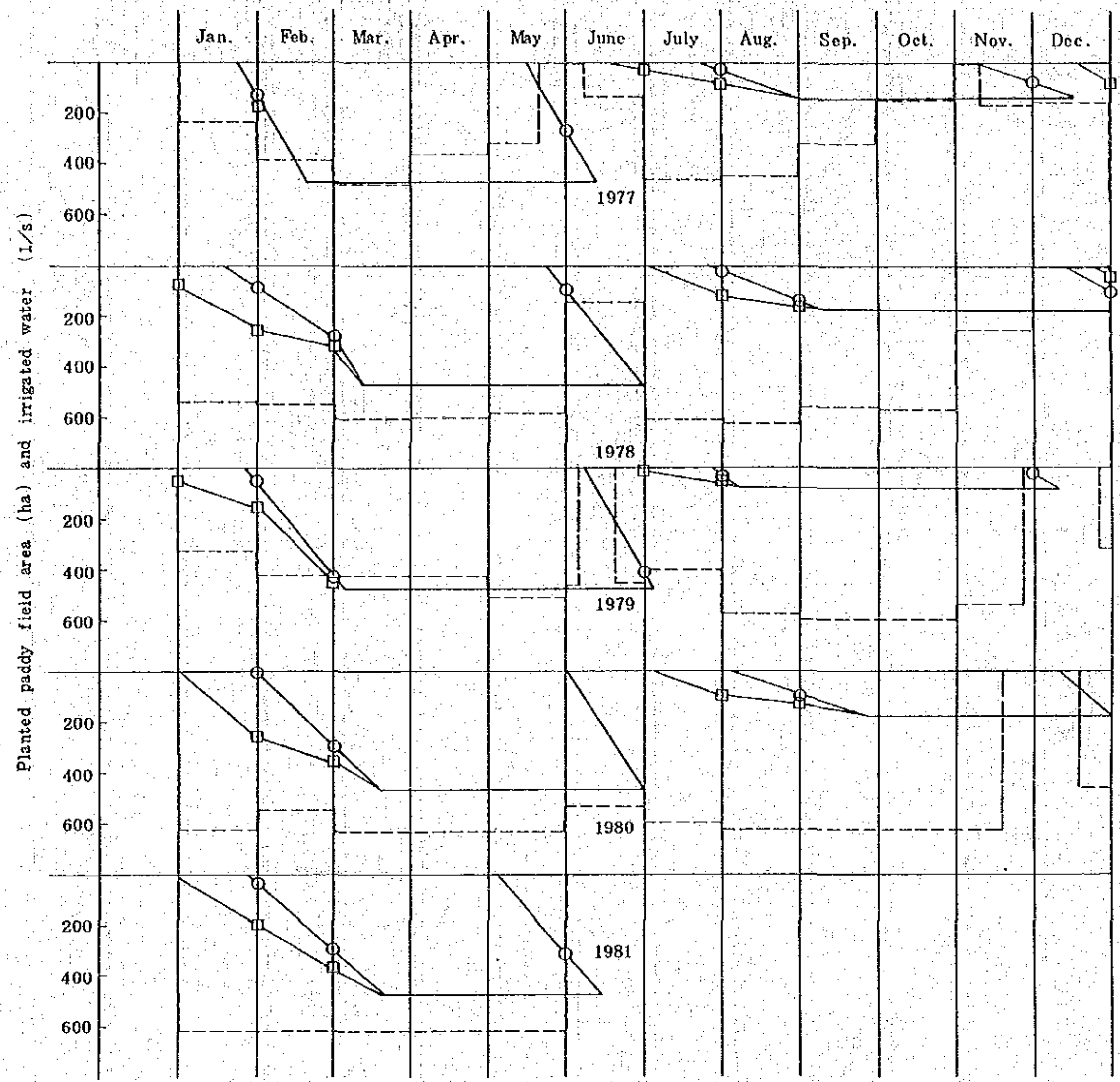
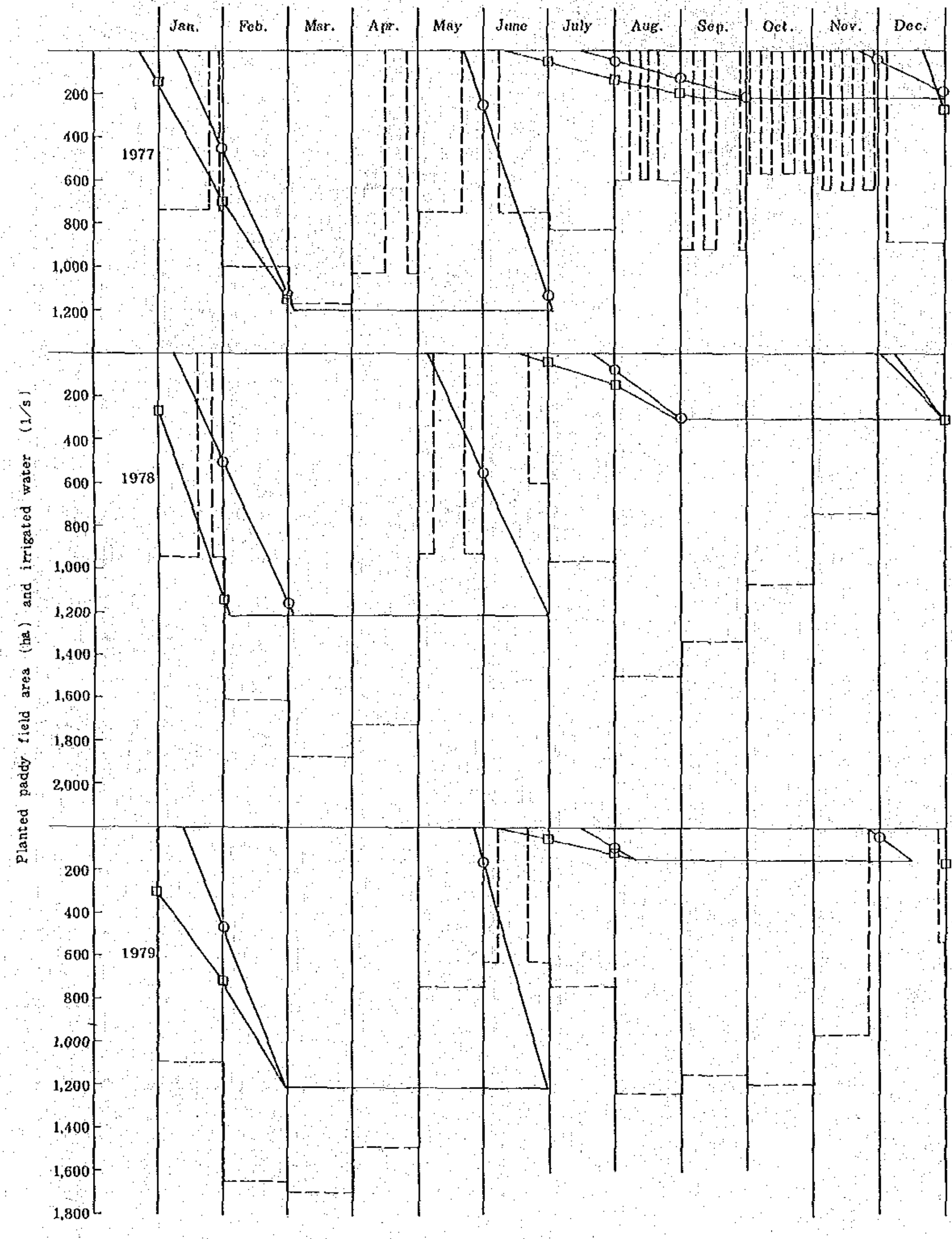
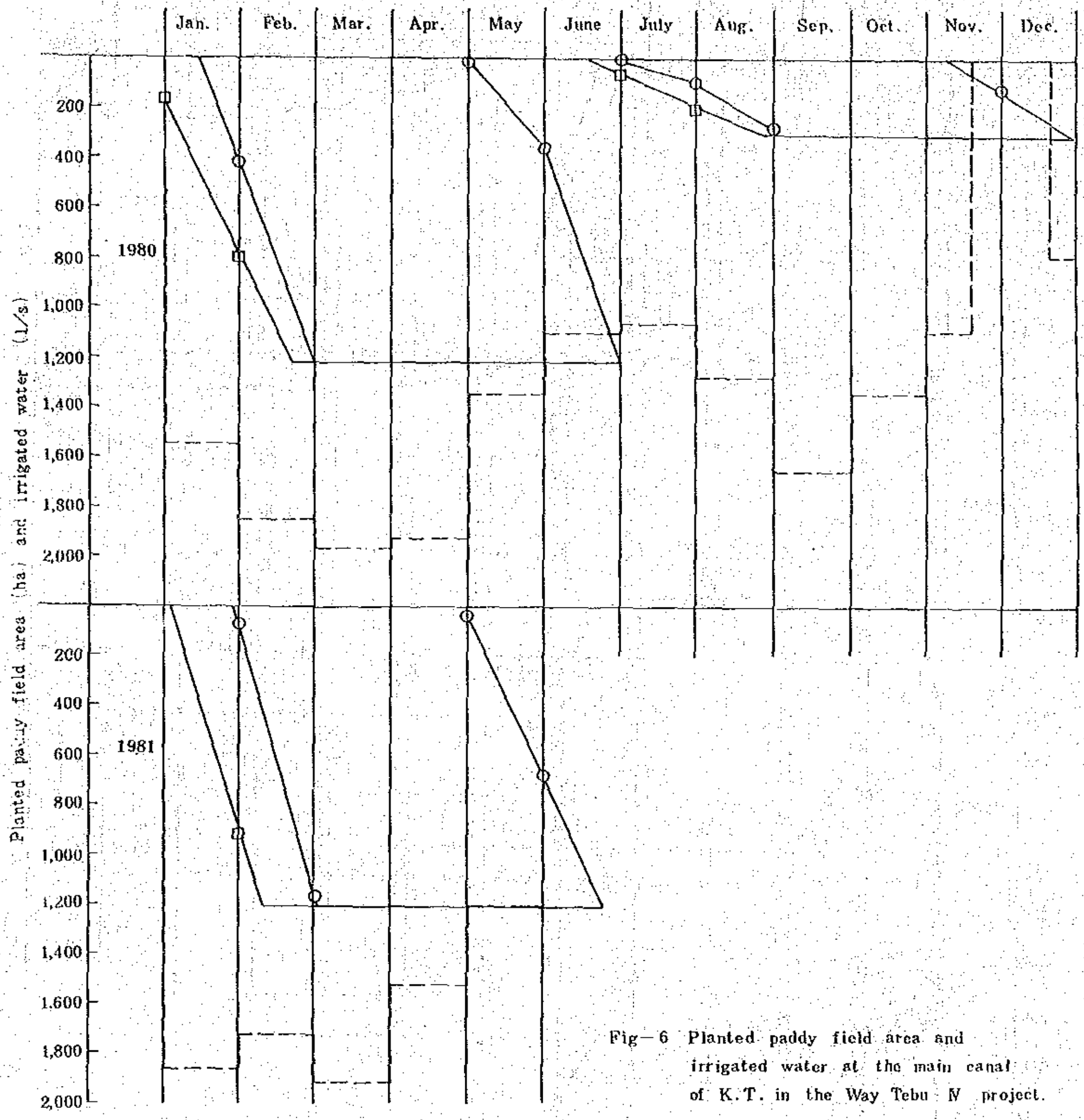


Fig - 5 Planted paddy field area and irrigated water at the main canal of K.W.T. in the Way Tebu I & II project.



Main canal of K.T. in the Way Tebu Ⅳ project.



Fig—6 Planted paddy field area and irrigated water at the main canal of K.T. in the Way Tebu Ⅳ project.

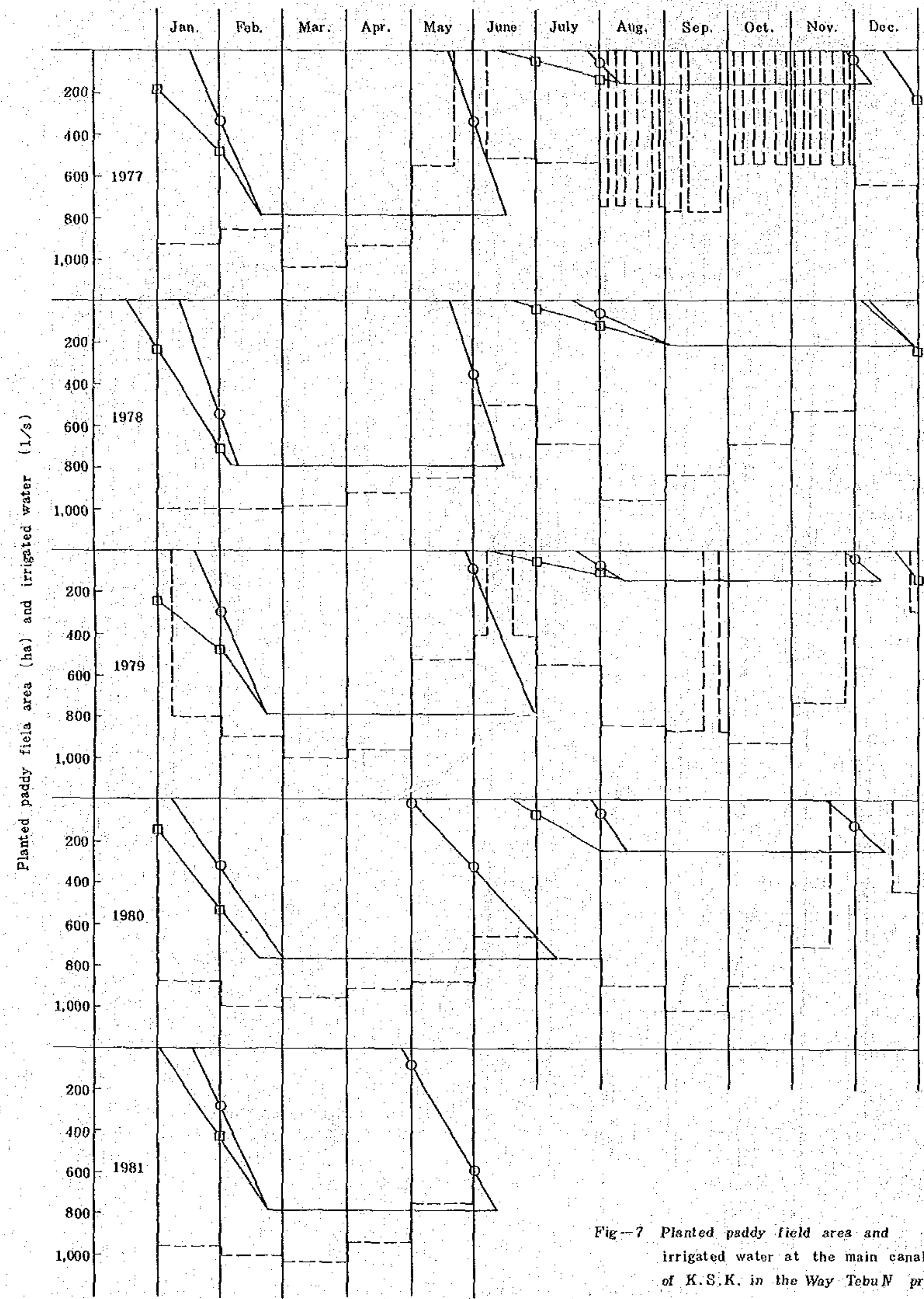
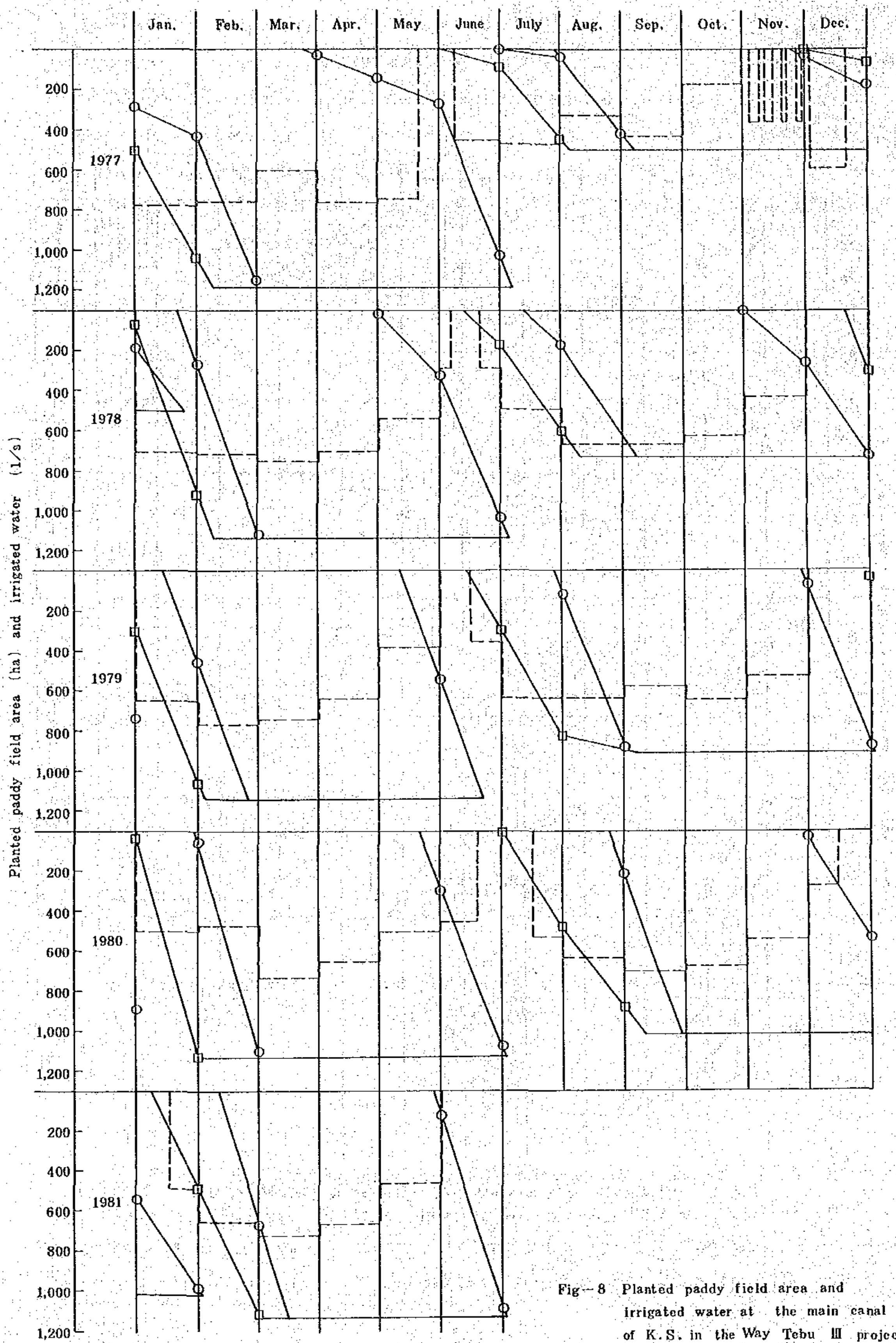
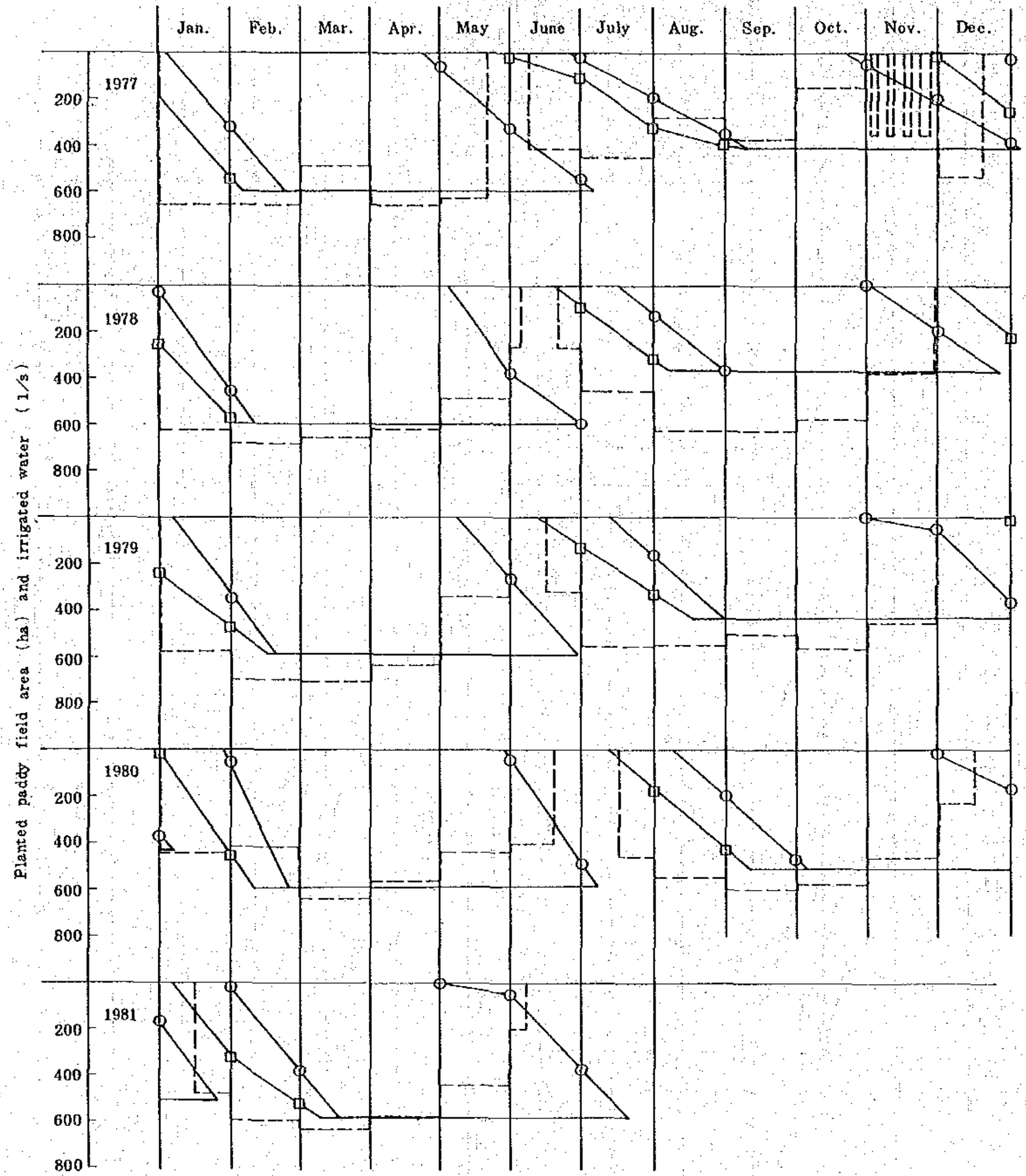


Fig-7 Planted paddy field area and irrigated water at the main canal of K.S.K. in the Way Tebu N project.



Fig—8 Planted paddy field area and irrigated water at the main canal of K.S. in the Way Tebu III project.



Fig－9 Planted paddy field area and irrigated water at the main canal of K.N. in the Way Tebu Ⅲ project.

5-1 Planted Period

Figures and tables make clear that the planted period in the rainy season at a certain paddy field of "PELITA" and "IR-8" changes from 135 to 145 days. In the case of the dry season, the period is between 140 and 150 days. And in the rainy season of "IR-36" in 1981, the period is from 120 to 130 days. So in the dry season, paddy of "IR-36" will vary from 125 and 135 days. By the way, Table - 7 and 8 were based on the talks of farmers. The periods and obtained periods by our study are almost same.

Table - 7 Planted Period of Paddy ("PELITA" and "IR-8")

Season	Rainy Season Paddy			Dry Season Paddy		
Stage	Puddling	Nursery Bed	Paddy Field	Puddling	Nursery Bed	Paddy Field
Period	15 - 20	20 - 30	100-110	20 - 30	20 - 30	100-110
Total Period	115 - 130			120 - 140		

Table - 8 Planted Period of Paddy ("IR-36")

Season	Rainy Season Paddy			Dry Season Paddy		
Stage	Puddling	Nursery Bed	Paddy Field	Puddling	Nursery Bed	Paddy Field
Period	15 - 20	18 - 22	90-100	20 - 30	18 - 22	90-100
Total Period	105 - 120			110 - 130		

On the other hand, planted period in a main canal sector was about 200 days in the case of "PELITA" and "IR-8". And the period of "IR-36" was about 175 days.

5-2 First Day of Planting.

The first day of the puddling and harvest was estimated as shown in Table - 5 and 6. That is to say, the planting in the rainy season was started on between December 1st and January 10th, on the other hand that of the dry season was planted on from May 20th to July 10th.

We will examine the propriety.

Fig - 10 shows the monthly distribution on both rainfall at R.006 for 11 years from 1970 to 1980 and run-off at the Banjar Agung weir in the Way Tebu of 4 years from 1977 until 1980.

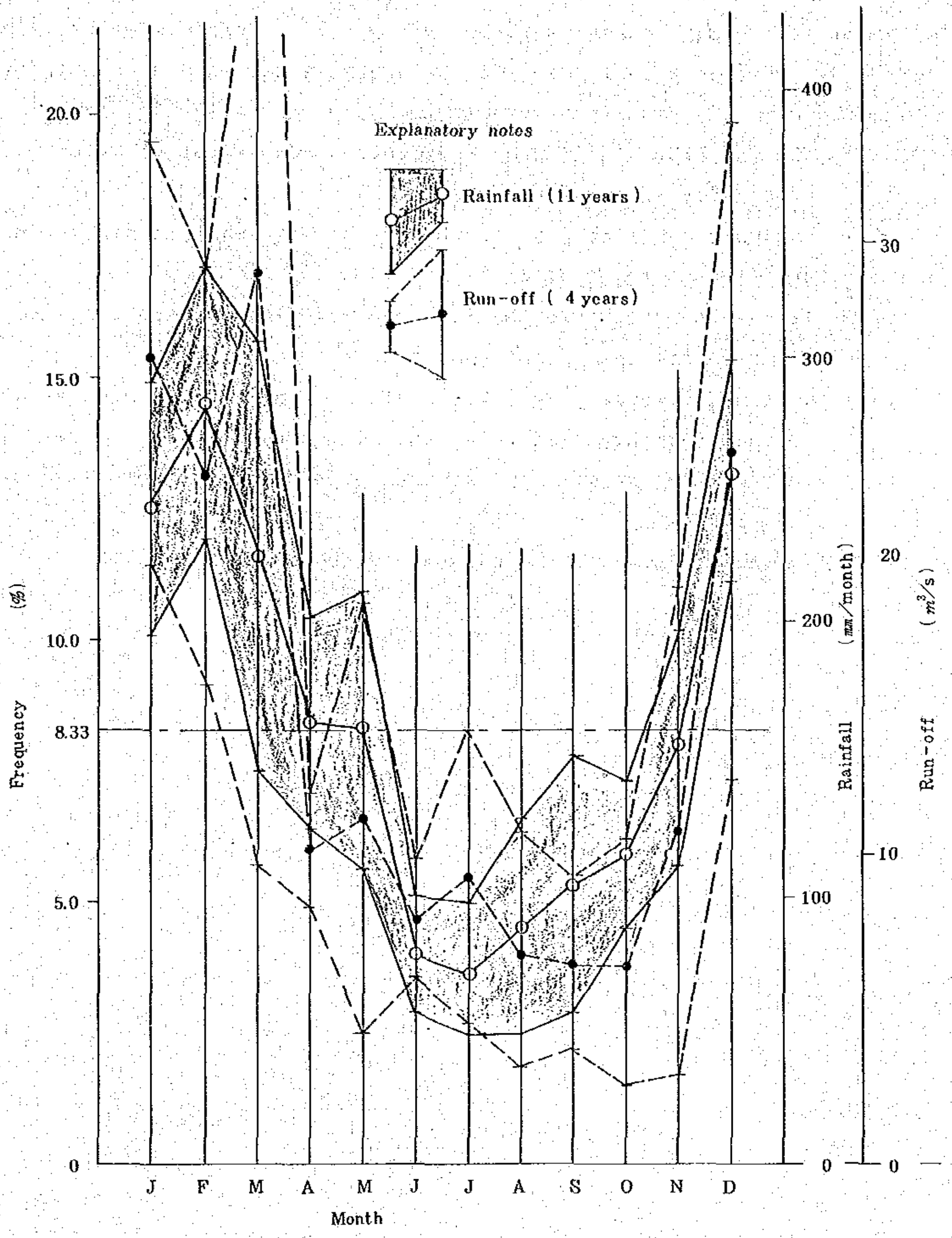
We can call the rainy season from December to March; but in the whole Way Sekampung basin it is from December to April (See: "Hydrologic Analysis in Lampung Province, Feb. 1982). Therefore it is proper to start planting of the paddy in the rainy season from December. But after harvesting it, planting was suspended for one month or one and a half months.

From Fig - 10, it appears that more rainfall and run-off are expected in May than those in June or in July. Therefore we propose that we had no sooner harvested the paddy in the rainy season than we should plant it for the dry season. If we start cultivation on December 10th we will be able to harvest the paddy in the middle of April. And then we should plant the paddy for the dry season on the 1st May.

And as it takes about one month from the first puddling to the last one, we will be able to finish the last puddling in the first of June.

5-3 Irrigation Period

The first day of irrigation was not always the same day as the first day of puddling. Sometimes farmers started puddling without irrigation water. We propose to irrigate one week before puddling. The last day of irrigation was on the day after one month from the first day of harvest and one month before the last day of harvest.



Fig—10 Ninety-five confidence limits of both rainfall and run-off.

6. Unit Duty of Water and Total Duty of Water

Fig - 11 shows real average unit duty of water for four years' plant of paddy field in the rainy season.

The value in the dry season is shown in Fig - 12. And then we have obtained Table - 9. That is a real total of the flowed water into each main canal. Though these values distribute widely, we know the following facts.

(i) The Way Tebu I & II and IV projects use plenty of water, especially in the dry season.

(ii) The main canal of K.S. sector of the Way Tebu III project uses a small quantity of water.

(iii) Irrigated water into the K.N. sector of the Way Tebu III project takes an average in both seasons.

(iv) We find a tendency that the smaller a paddy field area at a certain tertiary sector is, the bigger unit duty of water becomes.

(v) In the rainy season, the average unit duty of water is about 1.1 l/s/ha.

(iv) In the dry season, the average is about 1.3 l/s/ha.

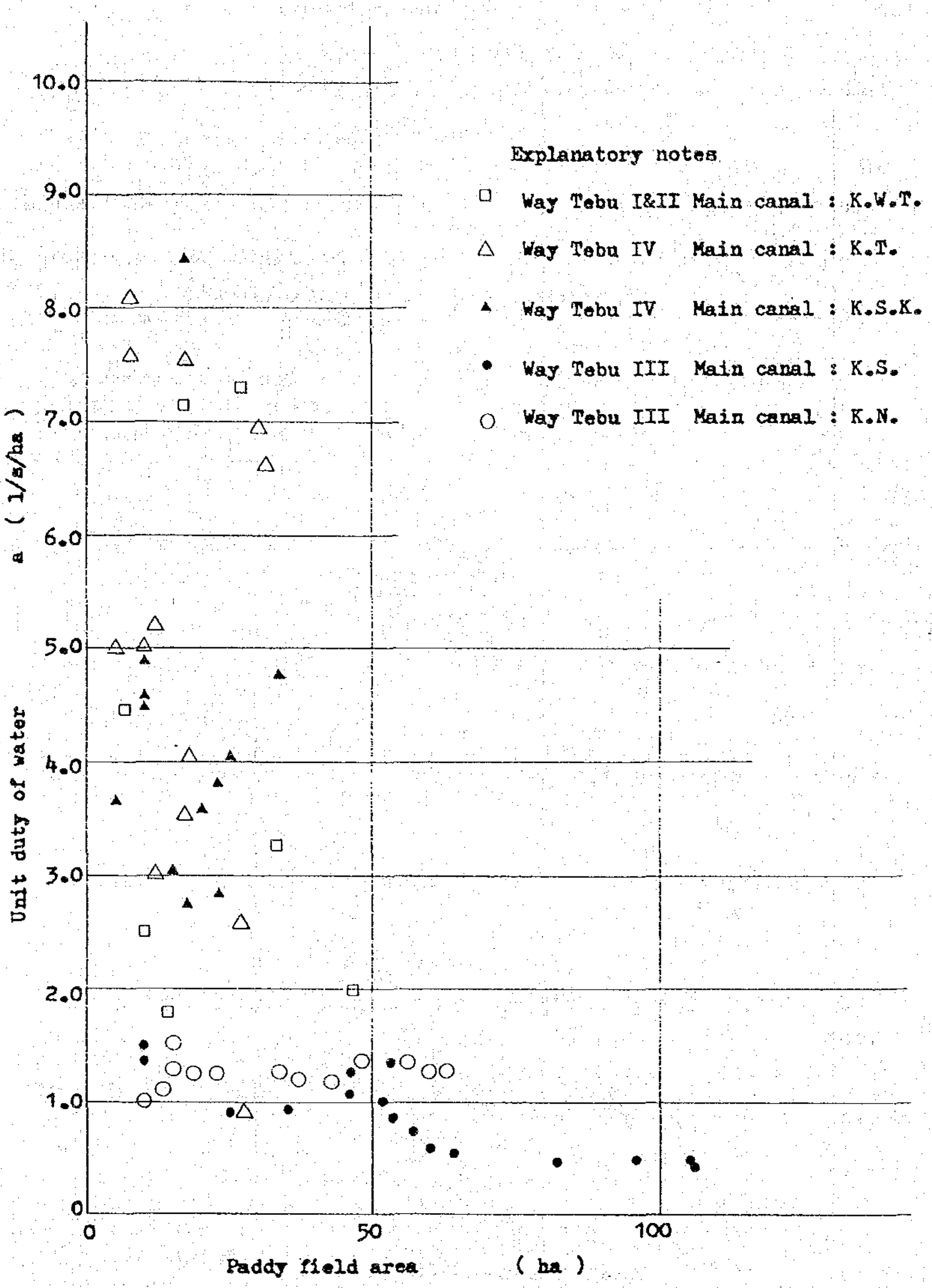
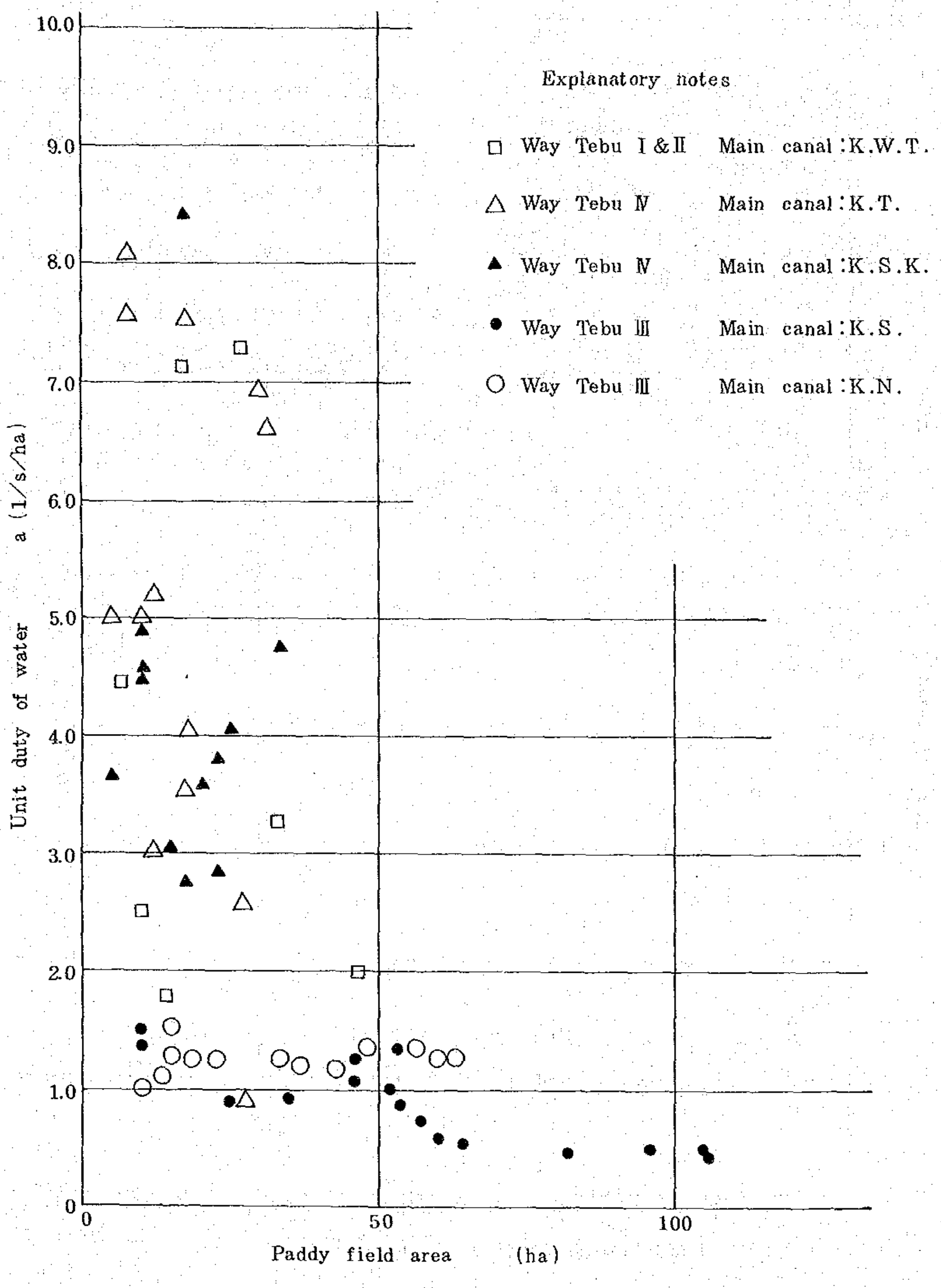


Fig - 11 Unit duty of water in the dry paddy season (Plot-to-plot irrigation).



Fig－12 Unit duty of water in the dry paddy season (Plot－to－plot irrigation).

7. Supplied Water and Irrigation Requirement

It is important to know how much a paddy field uses irrigated water and how much the paddy field utilizes rainfall effectively. But as there is no data on them, it is impossible to know the effective ratios. So we calculated the ratio of irrigation requirement to water supplied in the paddy field.

Table - 10 and 11 show the total water which was supplied in the paddy field by the main canal of K.N. sector in both seasons.

Table - 10 Supplied Water in the Paddy Field at the Main Canal of K.N. Sector (Rainy Season)

(mm)

Items	1978	1979	1980	1981
Total Irrigated Water	1,354	1,281	1,225	1,125
- ditto - Period	Jan. 1 - June,4	Jan. 1 - May,31	Jan. 1 - June,18	Jan.16 - June,7
Total Rainfall	1,375	1,250	1,298	1,374
- ditto - Period	Dec.1 - May,5	Dec.5 - May,10	Jan.1 - May,31	Jan.5 - May,31
Total Supplied Water	2,726	2,531	2,523	2,499

Table - 11 Supplied Water in the Paddy Field at the Main Canal of K.N. Sector (Dry Season)

(mm)

Items	1977	1978	1979	1980
Total Irrigated Water	1,364	1,934	1,710	1,308
- ditto - Period	June,8 - Dec.19	June,20 - Nov.29	June,16 - Nov.30	July,15 - Dec.14
Total Rainfall	215	419	354	636
- ditto - Period	June,1 - Oct.20	June,20 - Oct.31	June,10 - Oct.31	July,10 - Nov.30
Total Supplied Water	1,579	2,353	2,064	1,944

The total irrigated water is the amount of irrigated water in a certain irrigation period. And the total rainfall is the total of rainfall that rained at R.006 in a period between the first day of puddling and the first day of harvest.

As a result of this, we recognize the total supplied water is nearly the same amount every year. In the rainy season it is about 2,500 mm, and in the dry season it is about 2,000 mm.

By the way, we can get the following numerical values;

Evapotranspiration	: 5 mm/day	1)
Percolation	: 2 - 3 mm/day	2)
Irrigation period	: 130 days	3)

Therefore, irrigation requirement will be about 1,000 mm.

It means that only 40% of the supplied water is utilized in the rainy season, and 50% of that in the dry season.

Note 1) By data at B.J.T.IV of the Way Jepara (T. Nakamura; Field Study of Irrigation Requirement of the Way Jepara Project Area, Nov. 1979).

2) Observed values at the Way Tebu Project

K.W.T. - 1, K	: 3.4 mm/day
K.T. - V, Kn	: 2.3 mm/day
K.T. - VI, Ki	: 2.0 mm/day

3) See Capter 5 - 1

Table - 12 Planted Paddy Field Area at Each Main Canal Sector

(ha)

Project	Main Canal \ Season \ Year	1977		1978		1979		1980		1981		Average	Ratio
		Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy		(Dry) ÷ (Rainy) %
I & II	K.W.T.	140	474	180	474	99	474	180	474	150	474		32
IV	K.T.	215	1,208	302	1,208	150	1,208	310	1,229	244	1,213		20
IV	K.S.K.	160	791	220	791	155	771	250	791	196	786		25
III	K.S.	502	1,140	737	1,140	910	1,137	1,021	1,137	793	1,139		70
III	K.N.	410	592	375	594	430	587	513	584	432	589		73

8. Irrigable Area in Both Rainy and Dry Seasons

Table - 12 shows real planted paddy field areas at each main canal sector in each year.

By Table - 12 and Fig - 5, 6, 7, 8 and 9, we know that the total planted area in the dry season at the Way Tebu I & II and the Way Tebu IV projects is only one third of that in the rainy season, though the water in the dry season is irrigated as much as in the rainy season.

On the other hand, by the same irrigation condition, the planted ratio in the dry season was over 70% of that in the rainy season in the Way Tebu III project.

Before investigating irrigable area, we will perform some hydrologic analysis in this project.

In the benefited area at the Way Tebu project, there are 6 rainfall stations, namely, R.005 R.006, R.007, R.011, R.012, and R.013.

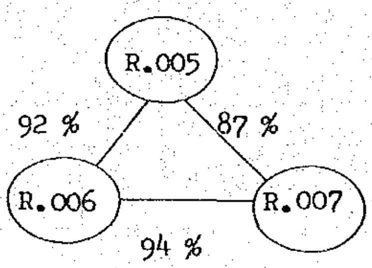
We have selected rainfall data at R.006, because this station has data for 11 years from 1970 to 1980. And we have calculated correlation coefficient of both rainfall and rainfall days among R.005, R.006 and R.007 during 8 years, because both R.005 and R.007 have rainfall data for 8 years from 1973 to 1980 (See Table - 13).

Table - 13 Rainfall (R) and Rainfall Days (D) at R.005, R.006 and R.007

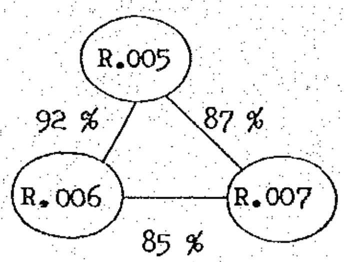
i	Year	R.005		R.006		R.007	
		R (mm)	D (days)	R (mm)	D (days)	R (mm)	D (days)
1	1980	2,090	129	2,514	139	2,355	123
2	1979	1,704	108	1,761	108	1,699	98
3	1978	2,529	157	2,513	159	2,322	134
4	1977	1,765	177	1,662	119	1,536	111
5	1976	1,413	103	1,318	106	1,230	113
6	1975	1,814	135	2,036	135	1,728	126
7	1974	1,525	123	1,706	117	1,971	109
8	1973	2,288	141	2,659	127	2,519	129
9	1972	-	-	1,576	89	-	-
10	1971	-	-	2,076	128	-	-
11	1970	-	-	1,613	114	-	-

The correlation coefficients are as follows.

Rainfall



Rainfall Days



Accordingly, we can put reliance on data of R.005, R.006 and R.007. And then, putting the minimum rainfall and rainfall days at each year on the log normal curve paper, we have found out a droughty rainfall and rainfall days for five years' return period.

As shown in Fig - 13, a yearly rainfall in a droughty year for five years' return period is 1,600 mm, and rainfall days are 107 days from Fig - 14.

By the way, in 1970 the rainfall is 1,613 mm and the rainfall days are 114 days. And then in 1977, the former is 1,662 mm and the latter are 119 days. So we know the droughty year for five years' return period is 1970 (See. Table - 13).

By data at the Banjar Agung weir, we know a month's drought run-off for five years' return period at the Way Tebu in both rainy and dry seasons (See Fig - 15).

The value is $7.4\ m^3/s$ ($=3.43\ m^3/s/100\ km^2$; $= 7.4\ m^3/s \div 216\ km^2 \times 100\ km^2$) in the rainy season and it is $2.7\ m^3/s$ ($= 1.25\ m^3/s/100\ km^2$; $= 2.7\ m^3/s \div 216\ km^2 \times 100\ km^2$) in the dry season.

These values have been plotted on Fig - 16 and 17, and then they show the relation between catchment area and a month's droughty specific discharge for five years' return period in both rainy and dry seasons respectively.

We know these values are also reliable.

i	X_i mm	Year
1	1,318	1976
2	1,576	1972
3	1,613	1970
4	1,662	1977
5	1,706	1974
6	1,761	1979
7	2,036	1975
8	2,076	1971
9	2,513	1978
10	2,514	1980
11	2,659	1973

$$\log_{10} X_0 = \frac{\log_{10} X_0}{N}$$

$$= \frac{36.0748}{11}$$

$$= 3.2795$$

$$X_0 = 1{,}903 \text{ (mm)}$$

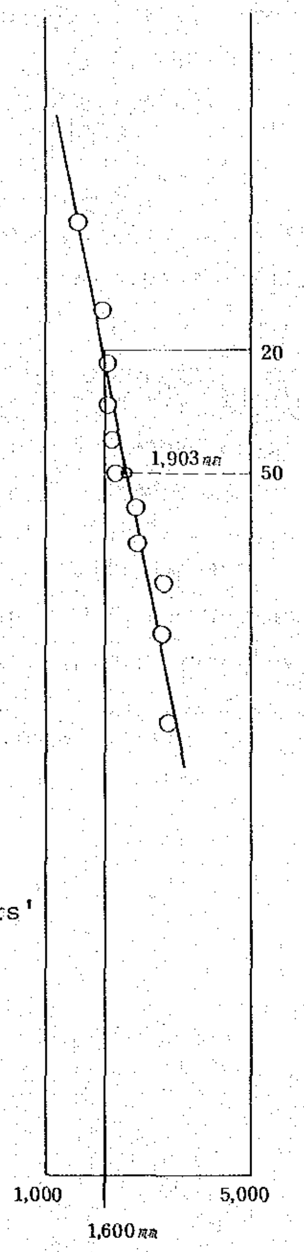


Fig - 13 Droughty rainfall for five years' return period at R.006.

i	X_i days	Year
1	89	1972
2	106	1976
3	108	1979
4	114	1970
5	117	1974
6	119	1977
7	127	1973
8	128	1971
9	135	1975
10	139	1980
11	159	1978

$$\log_{10} X_0 = \frac{\log_{10} X_i}{N}$$

$$= \frac{22.8945}{11}$$

$$= 2.0813$$

$$X_0 = 121 \text{ (days)}$$

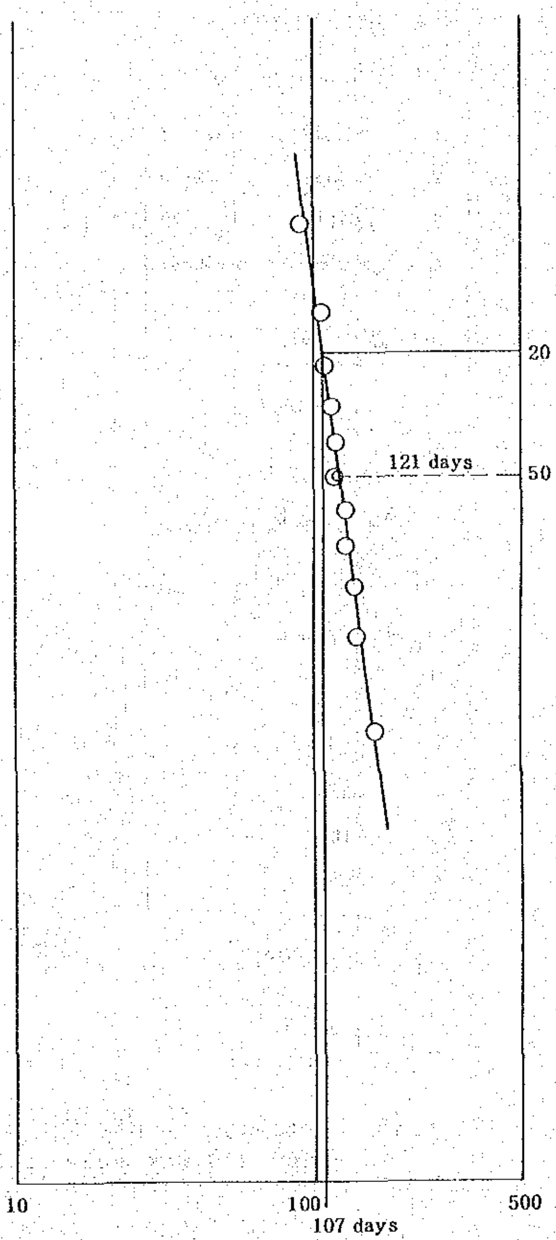


Fig - 14 Droughty rainfall days for five years' return period at R.006.

Rainy paddy season

i	X_i (l/s)	Year
1	6,920	1977-78
2	9,333	1979-80
3	13,414	1978-79
4	21,086	1980-81

$$\log_{10} X_0 = \frac{\log_{10} X_i}{N}$$

$$= \frac{16,2617}{4}$$

$$= 4.065$$

$$X_0 = 11,626 \text{ (l/s)}$$

Dry paddy season

i	X_i (l/s)	Year
1	1,700	1977
2	4,576	1979
3	5,108	1980
4	8,962	1978

$$\log_{10} X_0 = \frac{14,5516}{4}$$

$$= 3.636$$

$$X_0 = 4,344 \text{ (l/s)}$$

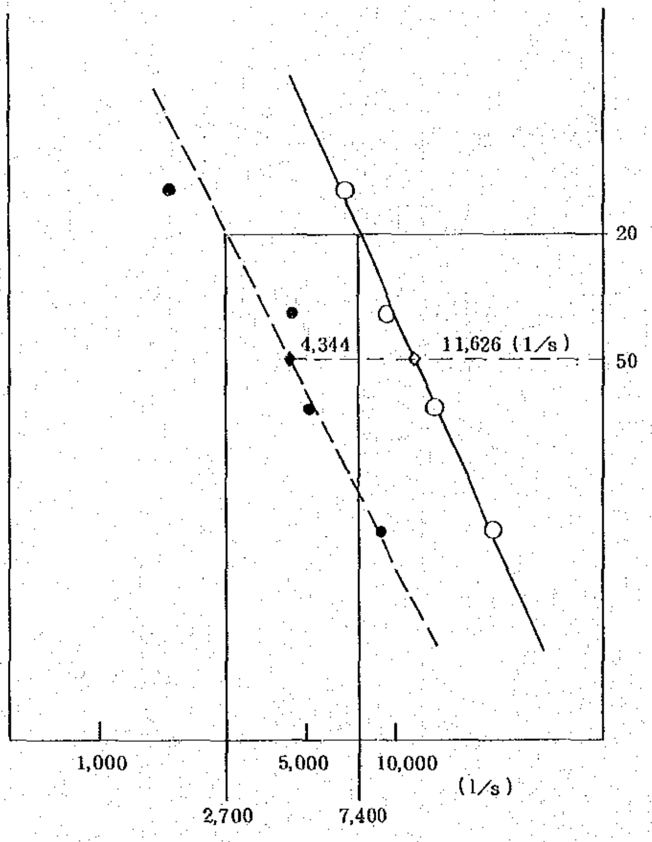


Fig - 15 Droughty run-off for five years' return period in both rainy and dry seasons at the Banjar Agung weir.

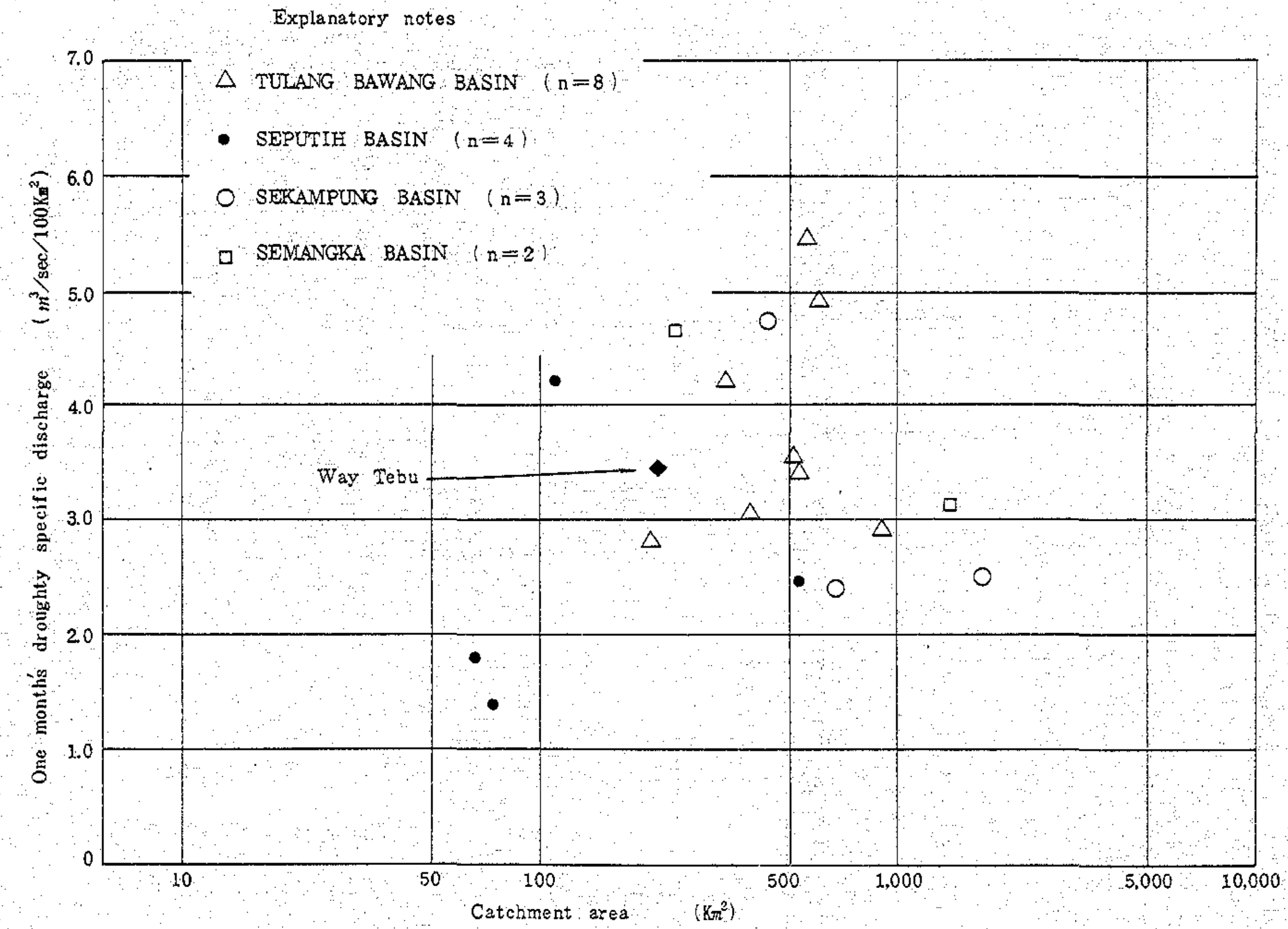


Fig - 16 Relation between catchment area and a month's droughty specific discharge in the rainy season for five years' return period.

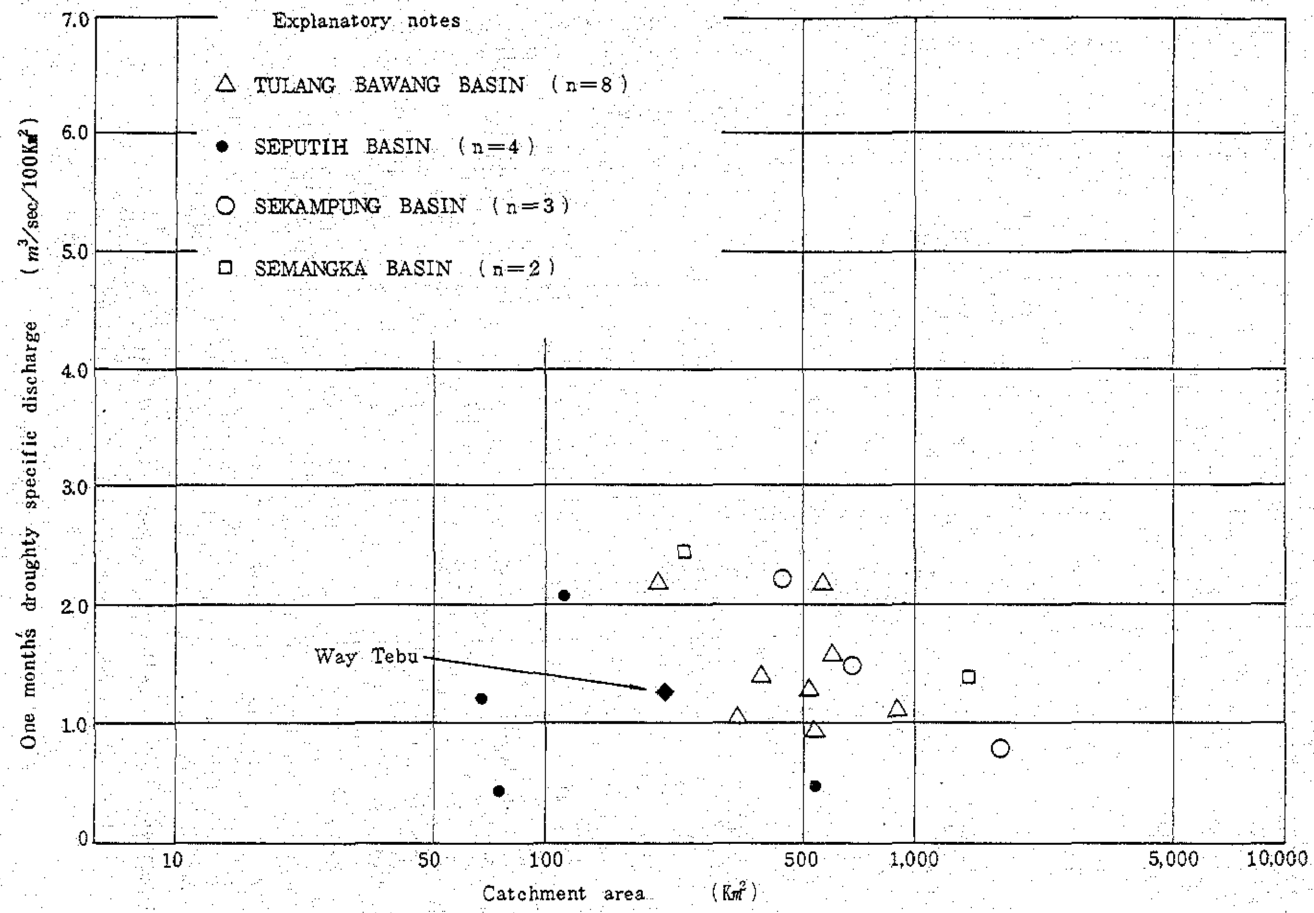


Fig - 17 Relation between catchment area and a month's droughty specific discharge in the dry season for five years' return period.

By the way, as mentioned in chapter 7, the total supplied water was nearly 2,500 mm in the rainy season and it was 2,000 mm in the dry season. If we plant the paddy for the rainy season from December to April, the total rainfall is 1,174 mm on average (see Table - 14). So the water to be irrigated in the paddy field is as follows.

$$(2{,}500\ mm - 1{,}174\ mm) \div 130\ days = 10.2\ mm/day$$
$$= 1.18\ l/s/ha$$

Accordingly, we will be able to irrigate the following area in a normal year.

$$11{,}626\ l/s \times 0.9 \times 0.8 \div 1.18\ l/s/ha = 7{,}100\ ha$$

where,

0.9 : we think we can use 90% of the river discharge

0.8 : we think water loss of the main canal is 20%

In the droughty year for five years' return period in 1970, it is as follows.

$$(2{,}500\ mm - 927\ mm) \div 130\ days = 12.1\ mm/day$$
$$= 1.40\ l/s/ha$$

Therefore the irrigable area is as follows,

$$7{,}400\ l/s \times 0.9 \times 0.8 \div 1.40\ l/s/ha = 3{,}800\ ha$$

That is to say, even if it is a droughty year, we can irrigate almost all the benefited area.

On the other hand, in the dry season they are as follows.

Normal year.

$$(2{,}000 - 504) \div 130 = 11.5\ mm/day$$
$$= 1.33\ l/s/ha$$
$$4{,}344 \times 0.9 \times 0.8 \div 1.33 = 2{,}350\ ha$$

Droughty year (1970)

$$(2{,}000 - 394) \div 130 = 12.4\ mm/day$$
$$= 1.43\ l/s/ha$$
$$2{,}700 \times 0.9 \times 0.8 \div 1.43 = 1{,}360\ ha$$