RAINFALL DATA GENERATION

PEMALI-COMAL IRRIGATION AREA

JAVA - I N D O N E S I A

by

SUSENO DARSONO

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ABSTRACT

The main content of this report deals with the methodology of daily rainfall generation by statistical modeling. Rainfall data for this study were taken from the record of the Pemali- Comal Irrigation Project in Central Java.

In water resources planning, rainfall is an important variable; it is used in determining water balance, in management of surface water resources and in river flow forcasting. Many studies of generating daily rainfall have been done successfully in other parts of the world. However, no such study rainfall generation has been done for Central Java.

The writer hopes that this study will contribute to hydrological science in Indonesia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

1.1 BACKGROUND OF THE STUDY.

Long records of rainfall and flow data are required in water resources planning. For example, flow and rainfall data are needed to prepare an efficient plan for irrigation operations in the study area on Central Java.

Synthetic flow data are required to extend the available data, because the existing records are too short. Two types of model are commonly used to obtain synthetic flow data. These are statistical models such as the Thomas Fiering Model that can generate rainfall or flow data directly, and deterministic rainfall - runoff models such as the Tank Model or the Stanford Watershed Model, that can be used to convert rainfall data into stream flow data. Synthetic daily rainfall data are needed as an input to the rainfall-runoff model. The rainfall data is also needed to model water management in the irrigation area.

The available record of daily rainfall stations in the area of the Pemali Comal Irrigation Project is more than 20 years. However it is still not long enough for longterm water resources planning, because we have to take into account the frequency of occurrence of droughts. Also several parts of this area have not enough rainfall data, because there is a new or no rainfall gauging station. Based on the requirements of rainfall data, this rainfall study describes two major activities :

- The first activity is extending the rainfall record using Markov Chain Simulation Model.
- The second activity is estimating the rainfall for areas without a rainfall station or areas that only have a short period of rainfall record.

1.2. THE OBJECTIVE AND THE PROGRAM OF THE STUDY :

1.2.1. The objective of the study.

The main objective of the study is generating the daily point rainfall, for input into planning of an irrigation operation or as input into a rainfall - runoff model. It can be stated as follows :

a. To extend daily rainfall data record at gaged site.

b. To estimate daily rainfall at ungaged site, using data from surrounding stations.

1.2.2. The program of the study.

The program of generating rainfall data, using a Markov Chain Model consist of the several steps:

a. The first step is determining the rainfall occurrence on the first day of generation.

b. The second step is generating the daily rainfall occurrence base on the Markov Chain transition matrix.

c. The third step is generating the daily rainfall depth.

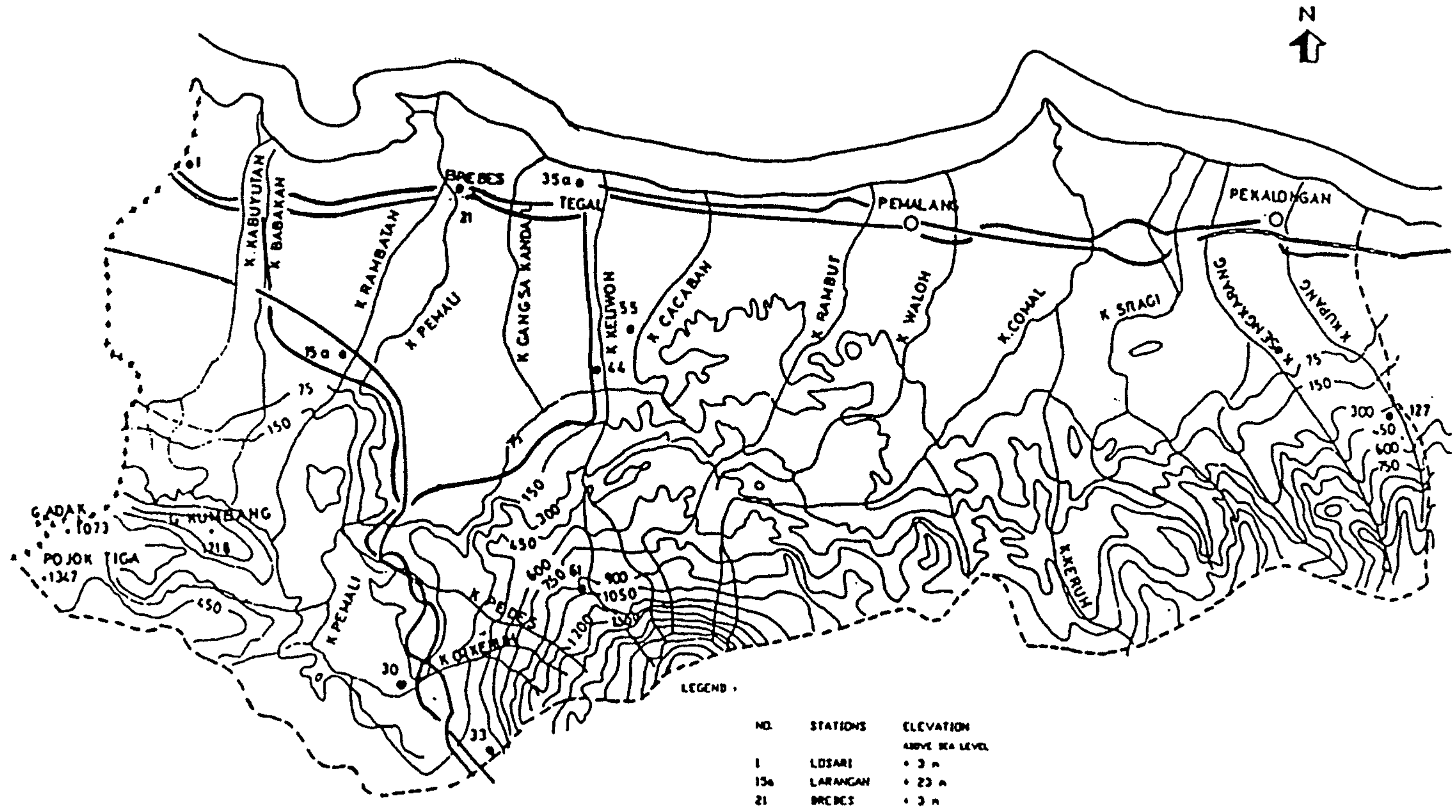
d. The last step is performing the necessary statistical tests.

1.3. GENERAL DESCRIPTION OF THE STUDY AREA.

The study area is the Pemali - Comal Irrigation Project area. It is located in the North West part of Central Java. The study area lies between 6.7^{o} and 7.3^{o} south latitude and 109^{o} to 110^{o} east longitude. Due to the time available for the study, only 10 stations from more than 100 stations were chosen for this study. To represent the rainfall pattern in the study area adequately, the stations were chosen to include stations in mountainous areas, stations at intermediate levels and station in the coastal plains. The location of the 10 stations are shown in Figure 1 and the list of the stations are listed in Table I.1.

1.4. DATA SOURCES.

The rainfall data for the study are taken from the record of Pemali - Comal Irrigation Project. The daily rainfall data has about 25 to 27 years of observations, and they are measured at daily gauging stations. The locations of



LEGEND :

NO.	STATIONS	ELEVATION ABOVE SEA LEVEL
1	LOSARI	+ 3 m
15a	LARANGAN	+ 23 m
21	BREBES	+ 3 m
30	BUMIAYU	+ 152 m
33	PETUGURAN	+ 345 m
35a	TEGAL	+ 3 m
44	PROCOT	+ 40 m
55	PANGKAH	+ 36 m
61	BUMIJAVA	+ 946 m
127	BANDAR	+ 408 m

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PEMALI - COMAL

IRRIGATION PROJECT

LOCATION OF THE 10 STATIONS

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MARCH 1987 | FIGURE 1

all available gauging stations are shown on Figure 2. It was taken from the Pemali-Comal Irrigation Project. The topographic map is shown in Figure 3 with a scale of 1 : 1,000,000. It was obtained from the Central Java Irrigation Design Unit. Only one meteorological station is located in the study area, that is the Tegal meteorological station.

Table I.1

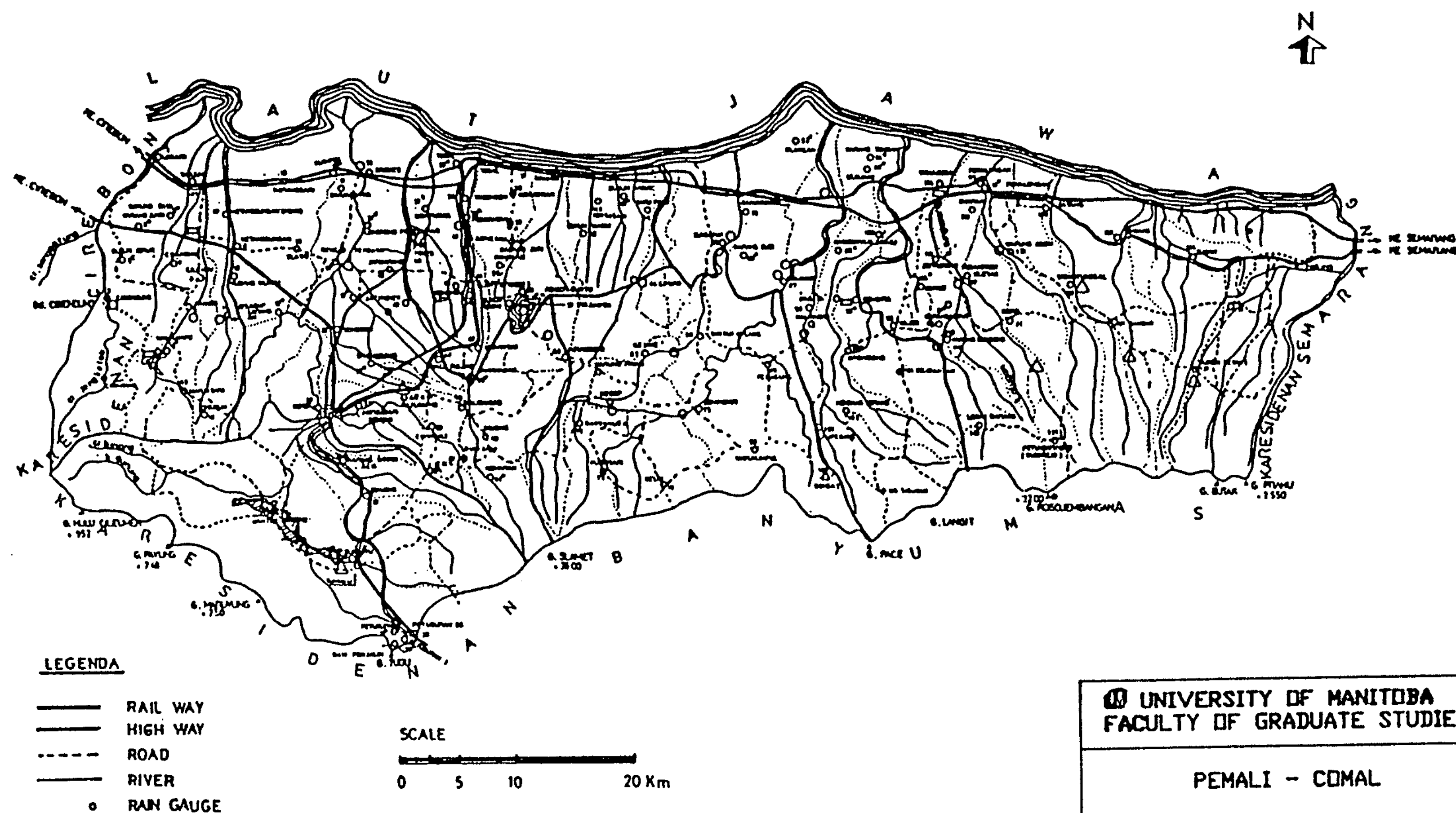
RAIN GAUGE ELEVATIONS

NO.	STATION	ELEVATION (above sea level) (m)	MEAN ANNUAL RAINFALL (mm)
01	LOSARI	+ 3	1551
02	LARANGAN	+ 23	2084
03	BREBES	+ 3	1689
04	TEGAL	+ 25	1588
05	PANGKAH	+ 36	2094
06	PROCOT	+ 40	1893
07	BUMIJAWA	+ 946	4253
08	BUMIAYU	+ 152	2624
09	PETUGURAN	+ 243	4250
10	BANDAR	+ 408	4276

1.5. GEOGRAPHICAL AND METEOROLOGICAL DESCRIPTION.

The approximate total surface area of the study area is about 4,600 Km^2 and it is located in the north west of

Central Java. The climate of the study area is classified as tropical monsoon. The dry season occurs during April - October and the wet season occurs during November - March. The mean annual rainfall is 1,750 mm and the mean annual temperature is around 30 ^{o}C in the coastal plain, and between 10 ^{o} - 20 ^{o}C in the mountainous areas.



SOURCE : PEMALI-COMAL IRRIGATION PROJECT

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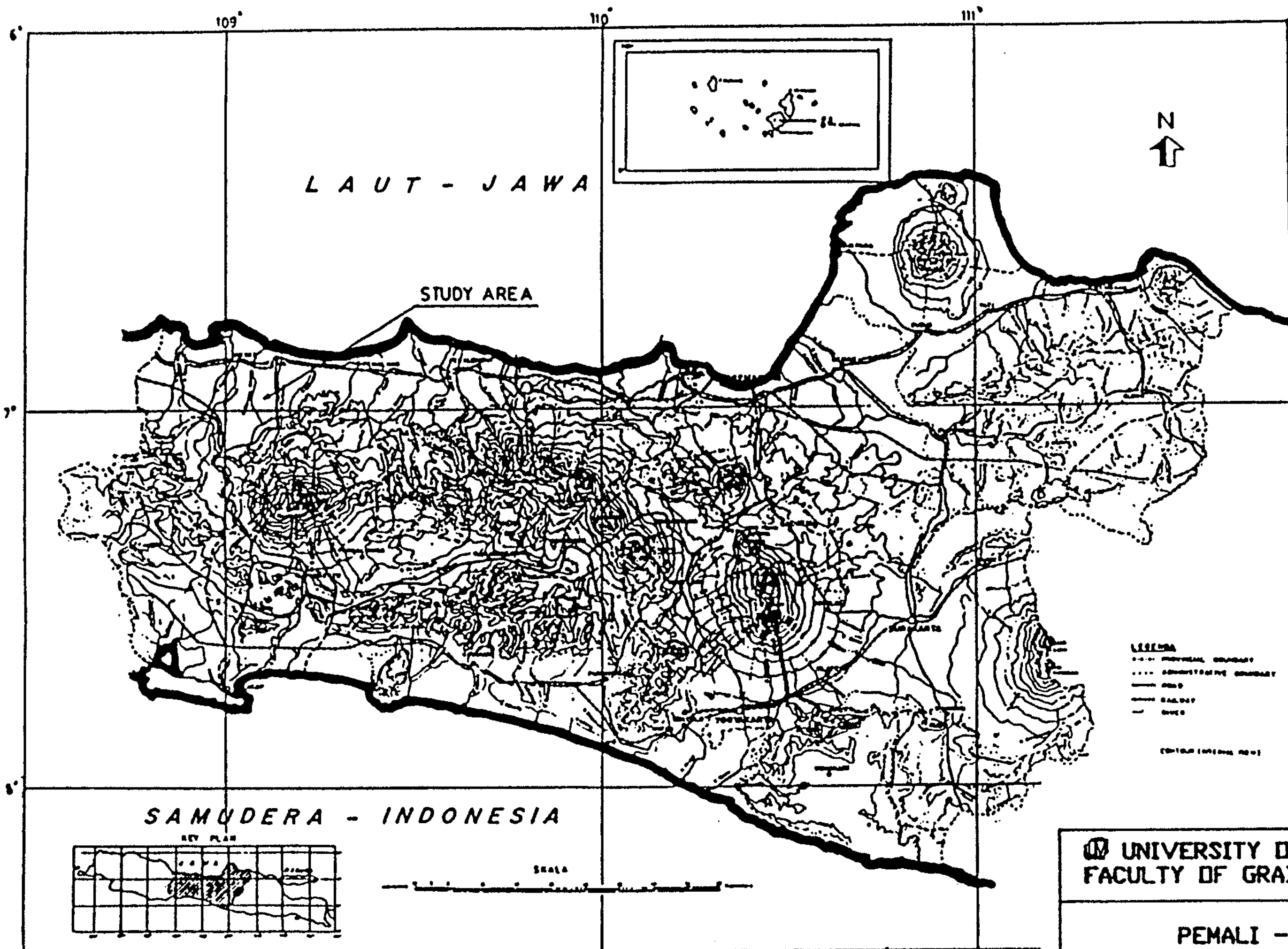
PEMALI - COMAL
IRRIGATION PROJECT
LOCATION OF GAUGING STATIONS

PREPARED BY : SUSENO DARSONO

MARCH 1987	FIGURE 2



SOURCE : CENTRAL JAVA IRRIGATION DESIGN UNIT.

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PEMALI - COMAL IRRIGATION PROJECT CENTRAL JAVA TOPOGRAPHICAL MAP	
PREPARED BY : SUSENO DARSONO	
MARCH 1987	FIGURE 3

CHAPTER II

METHODOLOGY OF GENERATING DAILY RAINFALL DATA

CHAPTER II

METHODOLOGY OF GENERATING DAILY RAINFALL DATA

2.1. RAINFALL OCCURRENCE.

There are two steps in the generation of daily rainfall data. The first step generates the daily rainfall occurrence. This is followed by the generation of the rainfall depth. This section describes the simulation of rainfall occurrence. A Markov Chain simulation model that has been widely used to simulate daily rainfall occurrence is adopted. Studies of daily rainfall occurrence at Tel Aviv by K.R. Gabriel and J.Newmann, (1952) and Markov Chain Model of daily rainfall by C.T. Haan, D.M. Allen and J.O. Street (1976) found that the Markov Chain Simulation Model gave good results for estimating daily rainfall occurrence.

2.1.1. Description of the Markov Chain Model.

The basic assumption of the Markov Chain Model is that the probability of rainfall on any day depends only on whether or not it rained on the preceding days (Chin,1977).

In the first order Markov Chain Model, the probability of rainfall is only dependent upon the previous day. For the second order or higher order of Markov Chains Model, the probability of rainfall occurrence is also influenced or dependent upon the condition of the previous two days or more. The Markov Chain Model is a simple model for the analysis of the probability of rainfall occurrence but we have to choose a proper order of the model which fits the characteristics of observed rainfall. Recorded rainfall data for each station were divided into twelve month sequences, because the characteristics of the data,in each month are different.

In the Markov Chain Model the conditional probabilities can be arranged as a transition matrix shown below.

The matrix :

X-wet	X-dry
Y-wet	Y-dry

Where :

- X-wet is the probability of a wet day occurring when the previous day is a wet day.
- X-dry is the probability of a dry day occurring when the previous day is a wet day.
  X-dry = 1 - (X-wet).
- Y-wet is the probability of a wet day occuring when the previous day is a dry day.

- Y-dry is the probability of a dry dry occurring when the previous day is a dry day.
  Y-dry = 1 - (Y-wet).

2.1.2. Probability of rainfall occurrence on the initial day

Before the procedure of generating wet days and dry days can be started, the condition on the initial day of the series should be determined. To provide the possibility of generating discontinuous series the probability of a rainfall occurrence on the first day of each month was determined. This was based on the observed number of rainy days within a particular range of time for which was chosen a period of six days around the first of the month. The probability that it will rain on the first day of the month is equal to the total number of rainy days in the range devided by total days within this range. For example, the probability of rainfall occurrence for the first February is, total rainy days between January 29, to February 3 divided by number of days from January 29, to February 3 (6 days).

2.2. RAINFALL DEPTH GENERATION.

The depth of rainfall on a wet day can be generated, after the daily occurrence has been established. The distribution and the relationship of the rainfall depth data are checked, before the process of generation can be conducted. The data were transformed into a normal distribution using a logarithmic transformation. It was found from the Anderson's test and the scatter diagrams that the transformed rainfall depth data on successive days are serially independent. A simple Monte Carlo Technique can be used when the data is normally distributed and serially independent.

2.2.1. Normalizing Transformations.

The logarithmic transformation is one of the common transformation methods. It transforms a Lognormal Distribution into a Normal Distribution. The transformation formula is :

$$Y_i = \text{Log}\ (X_i).$$

Another commonly used transformation is the power transformation;

$$Y_i = X_i^a$$

Power transformations used for rainfall data are the square root and the cube root transformations. If the distribution of data is a gamma distribution, the square root will produce a normal distribution.

The transformation formula as follow :

$$Y_i = (X_i)^{0.5}$$

Rainfall study by Buishand (1978) and the n^{th} root distribution of prepicipitations done by C.K. Stidd (1970) are two examples of the applications of the cube root transformation for normalizing daily rainfall data. For this study, the logarithmic was chosen, and it is explained in Chapter III.

2.2.2. Generation Procedure.

Since transformed rainfall data are serially independent and normally distributed, a simple generation algorithm is used in this study. The general formulation of this technique is as follows (Haan, 1986):

$$Y_i = \mu_y + \sigma_y * Rn$$

where :

- Y_i is rainfall depth = log (X_i)
- μ_y is mean of rainfall depth data.
- σ_y is standard deviation of rainfall depth data.
- Rn is normal random number, with mean = 0 and standard deviation = 1.

CHAPTER III

GENERATION MODEL

CHAPTER III

GENERATION MODEL

Components of the generation models must be estimated from observed data. The following steps are required .

1. Obtain the transition matrix of probabilities that is to be used to generate rainfall occurrences.
2. Determine the probability of rainfall on the initial day of generation.
3. Determine the degree of correlation of rainfall depths on successive days.
4. Determine the probability distribution of the rainfall depth.
5. Determine the parameters of the transformed rainfall depth distribution.

All of these will be explained in the following section.

3.1. THE ESTIMATION OF TRANSITION MATRIX.

Several levels of the Markov Chain Model can be used in the rainfall study, but for this study only first order and second order Markov Chain Models were considered. The first and the second order transition matrices are calculated and explained in this Chapter. But, for the rainfall generation the first order transition matrix was chosen, because the second order matrix did not give a significant improvement as will be explained in 3.1.3.

3.1.1. First - order transition matrix.

As mentioned before, each station has twelve transition matrices, one for each month. To calculate the conditional probabilities in that matrices, the number of wet and dry days following wet or dry days has been counted for the period of record for each station. The general procedure of calculating the conditional probability matrix is as follow :

- Prob.(wet/wet) = N (wet/wet) :{(N (wet/wet) + N (wet/dry)}
- Prob.(wet/dry) = N (wet/dry) : {(N (wet/wet) + N (wet/dry)}
- Prob.(dry/wet) = N (dry/wet) : {(N (dry/wet) + N (dry/dry)}
- Prob.(dry/dry) = N (dry/dry) : {(N (dry/dry) + N (dry/dry)}

Where :

- Probability (wet/wet) = a probability of wet day will be followed by a wet day.
- Probability (wet/dry) = a probability of wet day will be followed by a dry day.
- Probability (dry/wet) = a probability of dry day will be followed by a wet day.

- Probability (dry/dry) = a probability of dry day will be followed by a dry day.
- N (wet/wet) = Total number of wet days followed by a wet day.
- N (wet/dry) = Total number of wet days followed by a dry day.
- N (dry/wet) = Total number of dry days followed by a wet day.
- N (dry/dry) = Total number of dry days followed by a dry day.

Station Procot was chosen as an example of the calculation of the transition matrix. The matrix of the numbers of rainfall occurrences for the first - order Markov Chain is shown in Table III.1 and the conditional probabilities of rainfall occurrences can be seen in Table III.2. The result for other stations are attached in Appendix B.

3.1.2. Second - order transition matrix.

The procedure of calculation is similar to the calculation of the first - order Markov Chain Model. Rainfall occurrence in the second - order Markov Chain is not only dependent upon the previous day but also dependent upon the condition of the day before. The results for the station Procot are shown in Table III.3 and Table III.4. Each column in tables represent a sequences of occurrence e.g. 1 = wet/wet/wet. A list of the numbering is found in Table III.5.

Table III.1

RAINFALL OCCURRENCES FOR THE FIRST - ORDER MARKOV CHAIN.

	WET/WET (DAYS)	WET/DRY (DAYS)	DRY/WET (DAYS)	DRY/DRY (DAYS)
<u>PROCOT</u>				
January	262	157	151	210
February	254	140	137	178
March	174	152	146	308
April	101	128	129	396
May	61	113	112	494
June	19	78	73	584
July	21	56	54	649
August	28	37	40	675
September	23	46	45	640
October	31	73	79	597
November	90	136	134	452
December	183	127	131	309

Table III.2.

TRANSITION MATRIX OF RAIN PROBABILITY

FOR FIRST - ORDER MARKOV CHAIN.

	WET/WET	WET/DRY	DRY/WET	DRY/DRY
PROCOT				
January	0.62530	0.37470	0.41828	0.58172
February	0.64467	0.35533	0.43492	0.56508
March	0.53374	0.46626	0.32159	0.67841
April	0.44105	0.55895	0.24571	0.75429
May	0.35057	0.64943	0.18482	0.81518
June	0.19588	0.80412	0.11111	0.88889
July	0.27273	0.72727	0.07681	0.92319
August	0.43077	0.56923	0.05594	0.94406
September	0.33333	0.66667	0.06569	0.93431
October	0.29808	0.70192	0.11686	0.88314
November	0.39823	0.60177	0.22867	0.77133
December	0.59032	0.40968	0.29773	0.70227

Table III.3

RAINFALL OCCURRENCE USING SECOND - ORDER MARKOV CHAIN

	1 *)	2	3	4	5	6	7	8
PROCOT								
January	173	84	73	79	80	67	75	123
February	164	85	70	61	79	52	59	111
March	98	75	55	89	70	73	83	211
April	49	48	41	83	51	74	82	300
May	21	39	28	81	38	69	82	396
June	4	15	16	59	14	57	55	508
July	5	15	12	43	15	38	40	586
August	13	14	5	31	14	22	30	625
September	12	11	7	37	11	32	37	581
October	10	18	17	54	21	54	60	520
November	34	49	43	87	54	80	89	348
December	116	61	45	77	64	62	84	216

Table III.4.

TRANSITION MATRIX OF RAIN PROBABILITY

FOR SECOND - ORDER MARKOV CHAIN

PROCOT	1 *)	2	3	4	5	6	7	8
January	0.673	0.326	0.480	0.519	0.544	0.455	0.378	0.621
February	0.658	0.341	0.534	0.465	0.603	0.396	0.347	0.652
March	0.566	0.433	0.381	0.618	0.498	0.510	0.282	0.717
April	0.505	0.494	0.330	0.669	0.408	0.592	0.290	0,709
May	0.350	0.650	0.256	0.743	0.493	0.506	0.171	0.828
June	0.210	0.789	0.213	0.786	0.197	0.802	0.097	0.902
July	0.250	0.750	0.218	0.781	0.283	0.716	0.063	0.936
August	0.481	0.518	0.138	0.861	0.388	0.611	0.045	0.954
September	0.521	0.478	0.159	0.840	0.255	0.744	0.059	0.940
October	0.357	0.642	0.239	0.760	0.280	0.720	0.103	0.896
November	0.409	0.590	0.330	0.669	0.402	0.597	0.203	0.796
December	0.655	0.344	0.368	0.631	0.507	0.492	0.280	0.720

*) see Table III.5

Table III.5

NUMBER	SEQUENCE OF OCCURRENCE
1	wet / wet / wet.
2	wet / wet / dry.
3	wet / dry / wet.
4	wet / dry / dry.
5	dry / wet / wet.
6	dry / wet / dry.
7	dry / dry / wet.
8	dry / dry / dry.

3.1.3. Selection of the order of the Markov Chain Model.

A statistical test was used to choose which order of Markov Chain will be used in this study. The results of the test can be seen in Table III.6a and Table III.6b. In this test the null hypothesis is that the probability of rain is not influenced by the condition of the day before the previous day. This hypothesis is tested with a confidence level of 0.95. , and the hypothesis is accepted.

3.2. PROBABILITY OF RAINFALL OCCURRENCE ON THE INITIAL DAY.

The method for obtaining probability of rain occurring on the first day of the month , has been explained in the Chapter II. A six days range is used for calculating the frequency of rainfall occurrence from the record, that is three days in the previous month and three days in the month itself. Since the probability of rainfall maybe assumed constant over this period, the probability of rain is equal to the number of rainy days divided by six days. The probabilities of rainfall occurrence in the first day for stations Bandar, Procot and Bumijawa are listed in Table III.7.

Table III.6 a

THE DATA FOR SELECTION MARKOV CHAIN ORDER

(WET/WET/WET)

STATION : P R O C O T

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WET/WET/WET	173	164	98	49	21	4	5	13	12	10	34	116
DRY/WET/WET	80	79	70	51	38	14	15	14	11	21	54	64
SUB. TOTAL	253	243	168	100	59	18	20	27	23	31	88	180
WET/WET/DRY	84	85	75	48	39	15	15	14	11	18	49	61
DRY/WET/DRY	67	52	73	74	39	57	38	22	32	54	80	62
SUB. TOTAL	151	137	148	122	78	72	53	36	43	72	129	123
T O T A L	404	380	316	222	137	90	73	63	66	103	217	303
PROB.(WET/WET)	0.626	0.639	0.532	0.45	0.431	0.2	0.274	0.429	0.348	0.301	0.406	0.594
PROB.(WET/DRY)	0.374	0.361	0.468	0.55	0.569	0.8	0.726	0.571	0.652	0.699	0.594	0.406
WET/WET/WET	173	164	98	49	21	4	5	13	12	10	34	116
WET/WET/DRY	84	85	75	48	39	15	15	14	11	18	49	61
T O T A L	257	249	173	97	60	19	20	27	23	28	83	177
PROB.(WET/WET)	0.673	0.659	0.566	0.505	0.35	0.211	0.25	0.481	0.522	0.357	0.41	0.655
PROB.(WET/DRY)	0.327	0.341	0.434	0.495	0.65	0.789	0.75	0.519	0.478	0.643	0.59	0.345
IF P (WET/WET)	0.626	0.639	0.532	0.45	0.431	0.2	0.274	0.429	0.348	0.301	0.406	0.594
NUMBER OF TRIALS	257	249	173	97	60	19	20	27	23	28	83	177
MEAN	160.9	159.2	91.97	43.69	25.84	3.8	5.48	11.57	8.02	8.43	33.66	105.1
VARIANCE	60.15	57.41	43.08	24.01	14.7[illegible]	3.04	3.98	6.61	5.22	5.89	20.01	42.68
STD. DEVIATION	7.76	7.58	6.56	4.9	3.84	1.74	1.99	2.57	2.29	2.43	4.47	6.53
LIMIT VALUE	174	172	103	52	32	7	9	16	12	12	41	116

Table III.6 b

THE DATA FOR SELECTION MARKOV CHAIN ORDER

(DRY/DRY/DRY)

STATION : P R O C O T

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DRY/DRY/DRY	123	111	211	200	396	508	586	625	581	520	348	216
WET/DRY/DRY	79	61	89	83	81	59	43	31	37	54	87	77
SUB. TOTAL	202	172	300	283	477	567	629	656	618	574	435	293
DRY/DRY/WET	75	59	83	82	82	55	40	30	34	60	89	84
WET/DRY/WET	73	70	55	41	28	16	12	5	7	17	43	45
SUB. TOTAL	148	129	138	123	110	71	52	35	44	77	132	129
T O T A L	350	301	438	406	587	638	681	691	662	651	567	422
PROB.(DRY/DRY)	0.577	0.571	0.685	0.697	0.813	0.889	0.924	0.949	0.934	0.882	0.767	0.694
PROB.(WET/DRY)	0.423	0.429	0.315	0.303	0.187	0.111	0.076	0.051	0.066	0.118	0.233	0.306
DRY/DRY/DRY	123	111	211	200	396	508	586	625	581	520	348	216
DRY/DRY/WET	75	59	83	82	82	55	40	30	37	60	89	84
T O T A L	198	170	294	282	478	563	626	655	618	580	437	300
PROB.(DRY/DRY)	0.621	0.653	0.718	0.709	0.828	0.902	0.936	0.954	0.94	0.897	0.796	0.72
PROB.(WET/DRY)	0.379	0.347	0.282	0.291	0.172	0.098	0.064	0.046	0.06	0.103	0.204	0.28
IF P (DRY/DRY)	0.577	0.571	0.685	0.697	0.813	0.889	0.924	0.949	0.934	0.882	0.767	0.694
NUMBER OF TRIALS	198	170	294	282	478	563	626	655	618	580	473	300
MEAN	144.2	97.14	201.4	196.6	388.4	500.3	578.2	621.8	576.9	511.4	335.3	206.3
VARIANCE	48.32	41.63	63.45	59.55	72.79	55.66	44.15	31.5	38.35	60.49	78.05	63.67
STD. DEVIATION	6.95	6.45	7.97	7.72	8.53	7.46	6.64	5.61	6.19	7.78	8.83	7.98
LIMIT VALUE	126	108	214	209	402	513	589	631	587	524	350	221

3.3. THE RELATIONSHIP OF THE RAINFALL DEPTH IN SUCCESSIVE DAYS.

The relationship between rainfall depths on successive days was analyzed using coefficient correlation, and applying Anderson's test of significance for the serial correlation coefficient (C.T. Haan,1986). The relations are graphically presented as scatter diagram. The following relationship were analyzed :

a. The relationship between the rainfall depth on the first day and the second day for any two days of rain or more of successive rain days.
b. The relationship between the rainfall depths on the first day and the second day for any three days or more successive rain days.
c. The relationship between the rainfall depth on the second day and the third day for any three days or more successive rain days.

It was concluded, that at the 95 % confidence level, the correlation coefficients are not significantly different from Zero. Therefore,the rainfall depths are treated as independent events. Table III.8, Table III.9 and Table III.10 show that the values of correlation coefficient for stations Bandar, Procot and Bumijawa are very small. The scatter diagrams also support this conclusion, because the data are scattered at random on the graph. The result of the dependency test are shown in Table III.11 and the scatter diagrams for station Procot can be seen in Appendix C.

3.4. MODEL FOR GENERATING RAINFALL DEPTHS.

Since the rainfall depths are independent , a simple random number generation can be used to generate the rainfall depth once the distribution type and its parameters have been determined (Zekaisen, 1978). It was found that the rainfall depths are not normally distributed, thus it is preferable to transform the data. So as to achieve normality ,the Logarithmic, the square root and the cube root transformation were tried to transform the data record. The Kolmogorov - Smirnov's and the coefficient of skewness were used to test the normality of transformed data, and it was found that the lognormal transformation is the best. The explanation of the adequacy test is found in Appendix D.

3.5. PARAMETERS FOR RAINFALL DEPTH MODEL.

From the previous test, is shown that the transformed variables are independent and normally distributed. Therefore, the required parameters for rainfall depth model are the mean and the standard deviation of the transformed variable data from record. These data are shown in Table III.12.

Table III.7

THE PROBABILITY OF RAINFALL OCCURRENCE IN THE FIRST DAY.

M O N T H	S T A T I O N		
	B A N D A R	P R O C O T	B U M I J A W A
JANUARY	0.764	0.422	0.654
FEBRUARY	0.814	0.500	0.882
MARCH	0.827	0.473	0.771
APRIL	0.647	0.333	0.747
MAY	0.571	0.267	0.599
JUNE	0.327	0.200	0.432
JULY	0.314	0.100	0.321
AUGUST	0.218	0.100	0.185
SEPTEMBER	0.250	0.080	0.272
OCTOBER	0.313	0.080	0.290
NOVEMBER	0.480	0.210	0.617
DECEMBER	0.593	0.341	0.641

Table III.8

CORRELATION COEFFICIENT BETWEEN FIRST AND SECOND DAY RAINFALL FROM TWO-DAY RAINFALLS OR LONGER

MONTH	STATION		
	BANDAR	PROCOT	BUMIJAWA
JANUARY	0.078619	0.024103	0.058464
FEBRUARY	0.007365	0.028290	0.000917
MARCH	0.018526	0.1183290	0.002217
APRIL	0.016823	0.038798	0.010033
MAY	0.002414	- *)	0.014412
JUNE	0.000350	- *)	0.000065
JULY	0.027460	0.104265	0.000152
AUGUST	0.170104	- *)	0.155816
SEPTEMBER	0.103235	0.023567	0.000028
OCTOBER	0.087521	0.041310	0.016532
NOVEMBER	0.002123	0.004451	0.000043
DECEMBER	0.004524	0.008326	0.002323

*) Insufficient data.

Table III.9

CORRELATION COEFFICIENT BETWEEN FIRST AND SECOND DAY RAINFALL FROM THE THREE-DAY RAINFALLS OR LONGER

M O N T H	S T A T I O N		
	B A N D A R	P R O C O T	B U M I J A W A
JANUARY	0.119251	0.030154	0.058563
FEBRUARY	0.007511	0.024921	0.000025
MARCH	0.047287	0.135113	0.009993
APRIL	0.106247	0.068862	0.013376
MAY	0.009874	0.438831	0.003206
JUNE	0.123405	- *)	0.000006
JULY	0.000045	- *)	0.002424
AUGUST	0.060177	- *)	0.309125
SEPTEMBER	0.243996	- *)	0.000000
OCTOBER	0.034771	- *)	0.009948
NOVEMBER	0.046505	0.015296	0.011444
DECEMBER	0.005111	0.020295	0.009850

*) Insufficient data.

Table III.10

CORRELATION COEFFICIENT BETWEEN SECOND AND THIRD DAY RAINFALL FROM THE THREE-DAY RAINFALLS OR LONGER

MONTH	STATION		
	BANDAR	PROCOT	BUMIJAWA
JANUARY	0.162589	0.002248	0.003892
FEBRUARY	0.006316	0.066275	0.001644
MARCH	0.003739	0.069378	0.059177
APRIL	0.225837	0.003112	0.008408
MAY	0.022128	0.024570	0.000254
JUNE	0.008957	- *)	0.055591
JULY	0.132939	- *)	0.002347
AUGUST	0.059449	- *)	0.051366
SEPTEMBER	0.225961	- *)	0.000393
OCTOBER	0.008271	- *)	0.000313
NOVEMBER	0.131872	0.003390	0.005402
DECEMBER	0.008399	0.004946	0.000921

*) Insufficient data.

Table III.11

ACCEPTANCE LIMITS FOR THE HYPOTHESIS OF INDEPENDENCY

MONTH	THREE-DAY RAINFALLS			
	r FIRST & SECOND DAY	r SECOND & THIRD DAY	LOWER LIMIT	UPPER LIMIT
PROCOT				
January	0.030154	0.002248	- 0.20050	0.243690
February	0.024921	0.066275	- 0.27237	0.237890
March	0.135113	0.058278	- 0.32262	0.275002
April	0.068862	0.003112	- 0.44318	0.356226
May	0.438831	0.024570	- 0.62504	0.458382
June	-	-	-	-
July	-	-	-	-
August	-	-	-	-
September	-	-	-	-
October	-	-	-	-
November	0.015296	0.006690	- 0.49029	0.385030
December	0.020295	0.004946	- 0.33544	0.274160
BANDAR				
January	0.119251	0.162589	- 0.28840	0.249946
February	0.007511	0.006316	- 0.24326	0.125489
March	0.047287	0.003739	- 0.24873	0.219747
April	0.106247	0.225837	- 0.23981	0.212787
May	0.009874	0.022128	- 0.29440	0.254400
June	0.123405	0.008957	- 0.43332	0.349992
July	0.000045	0.132939	- 0.42407	0.344079
August	0.060177	0.059449	- 0.65436	0.427551
September	0.243996	0.225960	- 0.39944	0.328016
October	0.034771	0.008271	- 0.34486	0.290810
November	0.046505	0.131872	- 0.28275	0.245722
December	0.005111	0.008399	- 0.23981	0.212797

MONTH	THREE-DAY RAINFALLS			
	r FIRST & SECOND DAY	r SECOND & THIRD DAY	LOWER LIMIT	UPPER LIMIT
BUMIJAWA				
January	0.058563	0.003892	- 0.25870	0.227453
February	0.000025	0.002644	- 0.28840	0.249946
March	0.009993	0.059177	- 0.24504	0.216880
April	0.012276	0.008408	- 0.25063	0.221224
May	0.003206	0.000254	- 0.29135	0.252142
June	0.000006	0.055591	- 0.39944	0.328016
July	0.002424	0.002347	- 0.47717	0.377172
August	0.319125	0.051366	- 0.52000	0.402352
September	0.000000	0.000393	- 0.47717	0.377172
October	0.009948	0.000313	- 0.34005	0.287426
November	0.011444	0.005402	- 0.24678	0.218299
December	0.009850	0.000921	- 0.25457	0.224273

MONTH	TWO-DAY RAINFALLS		
	r FIRST & SECOND DAY	LOWER LIMIT	UPPER LIMIT
PROCOT			
January	0.024103	- 0.22041	0.197428
February	0.028290	- 0.21410	0.192360
March	0.118353	- 0.23650	0.210185
April	0.038798	- 0.28840	0.249946
May	-	-	-
June	-	-	-
July	0.104265	- 0.55557	0.422243
August	-	-	-
September	0.023567	- 0.68800	0.488000
October	0.041310	- 0.47717	0.377172
November	0.004451	- 0.28275	0.245722
December	0.008326	- 0.25870	0.227453

MONTH	TWO-DAY RAINFALLS r FIRST & SECOND DAY	LOWER LIMIT	UPPER LIMIT
<u>BANDAR</u>			
January	0.078619	- 0.24152	0.214125
February	0.007365	- 0.22877	0.204083
March	0.108526	- 0.21532	0.193342
April	0.016823	- 0.19330	0.175445
May	0.002414	- 0.22041	0.197428
June	0.000250	- 0.29135	0.256142
July	0.027460	- 0.29135	0.252142
August	0.170104	- 0.44318	0.356226
September	0.103235	- 0.28840	0.249946
October	0.087521	- 0.26528	0.232493
November	0.002123	- 0.20396	0.184158
December	0.004524	- 0.20718	0.186673
<u>BUMIJAWA</u>			
January	0.058464	- 0.23331	0.207678
February	0.000917	- 0.25258	0.222733
March	0.002217	- 0.21055	0.189504
April	0.010033	- 0.20941	0.188580
May	0.014412	- 0.21782	0.195353
June	0.000065	- 0.82871	0.542999
July	0.000152	- 0.32262	0.275002
August	0.155816	- 0.39211	0.323149
September	0.000028	- 0.22544	0.284160
October	0.016532	- 0.24326	0.215489
November	0.000043	- 0.21055	0.189504
December	0.002323	- 0.22310	0.199572

Table III.12

PARAMETERS OF THE DAILY RAINFALL MODEL

FOR STATION PROCOT

MONTH	OBSERVED	
	MEAN *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.6306	1.0961
FEBRUARY	2.6523	1.0093
MARCH	2.5258	1.1109
APRIL	2.2374	1.0848
MAY	2.1853	0.9916
JUNE	2.3840	1.0348
JULY	2.2223	1.0491
AUGUST	2.6166	1.0858
SEPTEMBER	2.1022	0.9795
OCTOBER	2.2034	1.0533
NOVEMBER	2.2877	1.0471
DECEMBER	2.4736	1.0412

*) The mean and the standard deviation from transformed rainfall depth data .

CHAPTER IV

PROCESS OF GENERATING DAILY RAINFALL

CHAPTER IV

PROCESS OF GENERATING DAILY RAINFALL

The process of generating of daily rainfall data will be explained in this chapter. As mentioned before, the initial step of the process is generating the rainfall occurrence for the first day of the month. The next step is determining for each day in the series whether there is rainfall or not, using the appropriate transition matrix. The third step is the rainfall depth calculation for each rainy day. Finally the total rainfall for each month is calculated. This is the synthetic monthly rainfall.

4.1. RAINFALL OCCURRENCE FOR THE FIRST DAY OF GENERATION.

The process of the first step of daily rainfall generation is as follows :

a. Generate a uniformly distributed random number between 0 and 1.

b. Compare this number to the probability of a rainfall occurrence on that day. This probability value is obtained from the table of probabilities rainfall occurrence.

c. If it is higher than the value of probability of rainfall, then the result of the generation is a dry day.

d. If the number is less than the value of the probability of rainfall then the result of the generation is a wet day.

4.2. DAILY RAINFALL OCCURRENCE.

The second step is generating rainfall occurrences for the entire period. The Transition Matrix is used in this process, and the generating procedure is similar as the generating process for the first day rainfall occurrence.

The procedure is as follow :

1. Generate the uniformly distributed random number, between 0 and 1.
2. Check whether the previous day is wet or dry :
   a. If the previous day is wet, then the prob.(wet/wet) and prob.(wet/dry) are used.
   b. If the previous day is dry, then the prob.(dry/wet) and Prob.(dry/dry) are used.
3. When the previous day is wet, and;
   a. The random number is higher than the prob.(wet/wet), this day is dry.
   b. The random number is less than the prob.(wet/wet), this day is wet.
4. When the previous day is dry, and;
   a. The random number is higher than the prob.(dry/wet), this day is dry.
   b. The random number is less than the prob.(dry/wet), this day is wet.

To make clear the generation process, the flow chart of generation process of daily rainfall occurrence is shown in Figure 4.

4.3. THE PROCESS OF GENERATING RAINFALL DEPTH.

The last step in generating daily rainfall is the generation of rainfall depth.

The procedure of generating is as follows :

a. Generate a normally distribution random number (RN), with mean = 0 and standard deviation = 1.

b. Determine the rainfall depth using this formulation :

$$X_i = \bar{X} + S * RN_i$$

Where :

X_i : Transformed rainfall variable.

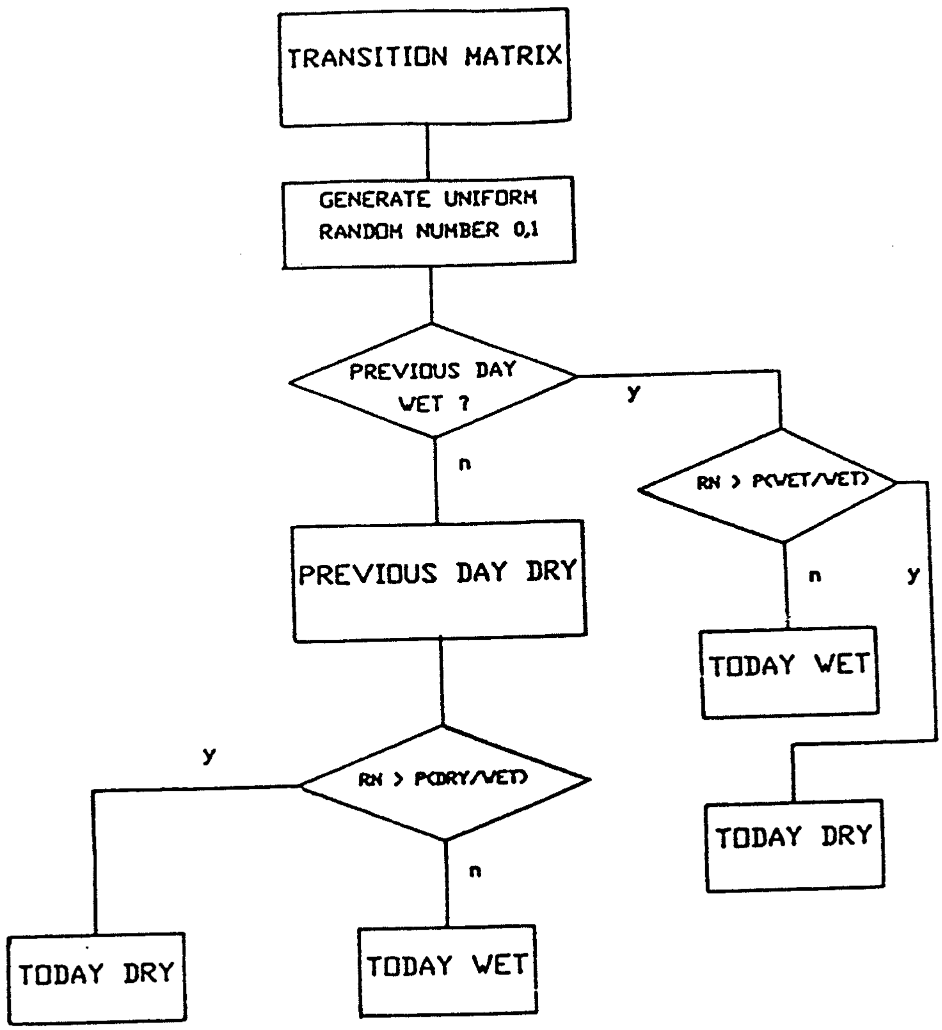
$\bar{X}$: The mean of rainfall variable, obtained from the record.

S : The standard deviation of daily rainfall depth from the record.

RN_i : The normal variate.

c. Then the synthetic daily rainfall is found by transforming back the result of the generation.

d. The synthetic monthly rainfall is calculated as the total of the synthetic daily rainfalls.



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PEMALI - COMAL
IRRIGATION PROJECT

THE GENERATION PROCEDURE
OF RAINFALL OCCURRENCE

PREPARED By : SUSENO DARSONO

MARCH 1987 | FIGURE 4

CHAPTER V

THE ADEQUACY OF THE MODEL

CHAPTER V

THE ADEQUACY OF THE MODEL

The adequacy of the model has tested by comparing the rainfall occurrence and parameters of observed data with the rainfall occurrence and parameters of synthetic data.

5.1. THE COMPARISON OF DAILY RAINFALL OCCURRENCE

The comparison between the synthetic and observed rainfall occurrence is used to prove the adequacy of the model. In the Table V.1 can be seen that the synthetic daily rainfall occurrence for station Procot is very close as the observed rainfall occurrences. Thus, the Markov Chain Order One appears to be an adequate model for the Pemali Comal Irrigation area.

5.2. THE COMPARISON BETWEEN SYNTHETIC AND OBSERVED RAINFALL DEPTH.

50 sequences of generation were done for each station, thus we have 50 data of the means and the standard deviations. The mean of the mean, the mean of the standard deviation and also the standard deviation of the mean, the standard deviation of the standard deviation are calculated based on these data. Then the confidence interval of the mean and the standard deviation can be calculated using

the chi-square test and Student t test. But, these tests can be approximated by the normal distribution test, because we have 50 data. And the following formula is used for calculation the confidence interval.(Salas et al. 1985)

$$(\bar{U}_{syn.} \pm C * S_{syn.})$$

Where :

C = the standard normal variate of a given significant level (95% level = 1.96)

$U_{syn.}$ = the mean of the synthetic parameters.

S_{syn} = the standard deviation of the synthetic parameters.

The confidence intervals for station Procot are shown in Table V.2, and the confidence interval for the others station are listed in the Appendix E. The mean and the standard deviation are still in logarithmic value, because the distribution of rainfall depth is lognormal distribution.

As mentioned before, the monthly rainfall is calculated from the total of daily rainfall depth for each month. Thus, we have (25 or 27 * 50) of monthly rainfall data. From these data, the mean and standard deviations of synthetic data was calculated using similar procedure as the daily rainfall . The comparison for station Procot is listed in Table V.3 and for the other stations are listed in the Appendix E. It can be seen from Table V.3 and Appendix E that all parameters lie within the confidence limit, thus the model can be used for extending monthly rainfall data.

Table V.1

COMPARISON OF DAILY RAINFALL OCCURRENCE

FOR STATION : PROCOT.

M O N T H	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	253	262	154	157	155	151	217	210
February	247	254	139	140	140	137	182	178
March	170	174	151	152	149	146	310	308
April	101	101	130	128	130	129	393	396
May	61	61	115	113	113	112	491	494
June	19	19	75	78	73	73	587	584
July	21	21	54	56	54	54	651	649
August	30	28	39	37	39	40	672	675
September	23	23	45	46	45	45	641	640
October	32	31	76	73	78	79	594	597
November	81	90	124	136	126	134	422	452
December	182	183	130	127	131	131	307	309

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table V.2.

SUMMARY OF DAILY RAINFALL FOR STATION PROCOT

MONTH	HISTORICAL		SYNTHETIC		ST. DEVIATION OF		CONFIDENCE LIMIT OF THE MEAN		CONFIDENCE LIMIT OF ST. DEVIATION	
	MEAN	ST.DEV.	MEAN	ST.DEV.	MEAN	ST.DEV.	U.B	L.B	U.B	L.B
JANUARY	2.6306	1.0961	2.6212	1.0868	0.0535	0.049	2.7261	2.5163	1.1828	0.9908
FEBRUARY	2.6523	1.0093	2.6437	1.0143	0.045464	0.04022	2.7508	2.5366	1.0931	0.9355
MARCH	2.5258	1.1109	2.5155	1.0944	0.0613	0.042	2.6356	2.3954	1.1747	1.0121
APRIL	2.2374	1.0848	2.224	1.0303	0.073	0.0541	2.3671	2.0809	1.1363	0.9243
MAY	2.1853	0.9916	2.1723	1.0339	0.0696	0.0459	2.3087	2.0359	1.1631	0.9047
JUNE	2.384	1.0348	2.386	0.9609	0.0937	0.0857	2.5697	2.2023	1.2189	0.7929
JULY	2.2223	1.0491	2.2305	1.0877	0.102	0.1058	2.4304	2.0306	1.2950	0.8803
AUGUST	2.6166	1.0858	2.6287	1.143	0.1141	0.1067	2.8523	2.4051	1.3521	0.9339
SEPTEMBER	2.022	0.9795	2.1114	0.9037	0.1941	0.092	2.2958	1.927	1.0840	0.7234
OCTOBER	2.2034	1.0533	2.2061	1.0833	0.102	0.0844	2.404	2.0062	1.2487	0.9179
NOVEMBER	2.2877	1.0471	2.2729	1.01	0.0698	0.0559	2.4897	2.1361	1.1196	0.9004
DECEMBER	2.4734	1.0412	2.4628	0.9812	0.0587	0.0455	2.5779	2.3499	1.1596	0.9812

note : STD. DEV. = STANDARD DEVIATION.
U.B. = UPPER BOUND
L.B. = LOWER BOUND

Table V.3

SUMMARY OF MONTHLY RAINFALL FOR STATION PROCOT

MONTH	HISTORICAL		SYNTHETIC		ST. DEVIATION OF		CONFIDENCE LIMIT OF THE MEAN		CONFIDENCE LIMIT OF ST. DEVIATION	
	MEAN	ST.DEV.	MEAN	ST.DEV.	MEAN	ST.DEV.	U.B	L.B	U.B	L.B
JANUARY	370.8	145.2	403.8	169.1	35.6	31.3	473.5	333.9	230.50	107.80
FEBRUARY	343.8	150.2	359.7	130.6	25.1	28.75	408.9	310.5	186.98	74.29
MARCH	270.8	129.7	290.9	142.3	25.1	29.6	340.1	241.7	198.40	86.20
APRIL	148.2	91.4	152.4	85.07	15.1	20.3	182	122.8	124.30	45.30
MAY	103.2	78.1	99.9	62.17	12	15.1	123.4	76.4	91.80	32.60
JUNE	67.8	54.8	68.8	58.92	10.9	17.9	90.16	47.4	94.00	23.80
JULY	47	52.8	48.3	49	9.8	14.21	67.5	29.1	76.90	21.20
AUGUST	63.1	50.8	68.6	80.9	15.5	24.81	98.98	38.22	129.50	32.30
SEPTEMBER	37.8	55.3	36.3	39	7.6	12	51.2	21.4	62.50	15.48
OCTOBER	65.9	64.3	68.2	58.08	11.8	17.1	91.3	45.1	91.60	24.60
NOVEMBER	145.6	80.4	137	77.6	15.4	19.7	167.2	106.8	116.20	38.90
DECEMBER	259.4	107.8	258.4	118.6	23.8	24.1	305.5	211.8	165.80	71.40

note : STD. DEV. = STANDARD DEVIATION.
U.B. = UPPER BOUND
L.B. = LOWER BOUND

CHAPTER VI

MODEL FOR UNGAGED SITES

CHAPTER VI

MODEL FOR UNGAGED SITES

This Chapter will explain the second activity of the study, that is point rainfall generation for ungaged site. From the previous activity, we have a model for synthetic point daily rainfall generation, this model only can be used for a gaged site, because the parameters of the model were calculated from recorded data. The parameters are :

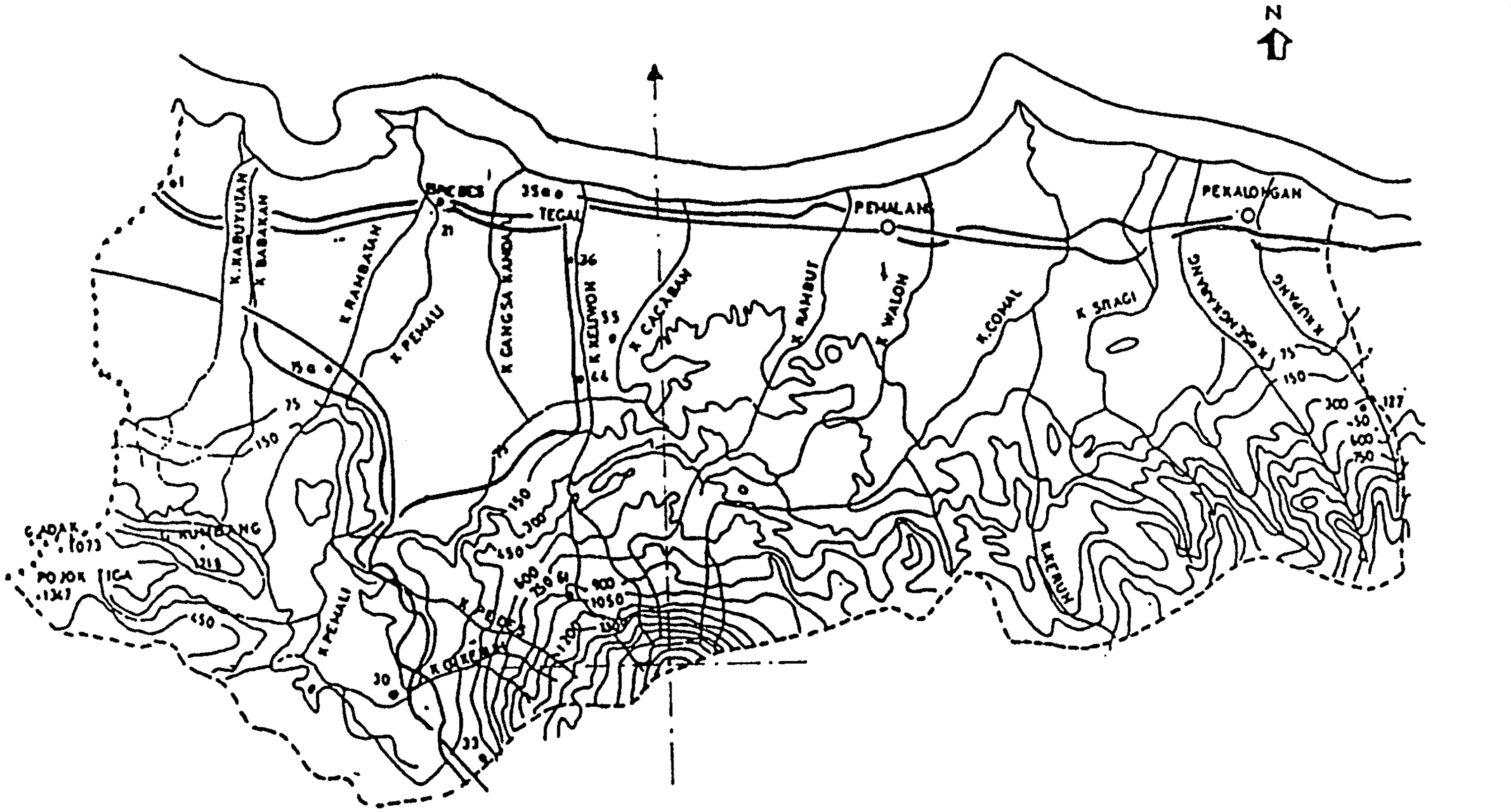
a. The transition matrices of probabilities used in the Markov Chain Order 1 model.

b. The mean and the standard deviation from the transformed record of rainfall depths.

These parameters also will be required for ungaged site model. A regression analysis was used to estimate the model parameters at an ungaged site. Station Pagongan is chosen as ungaged site in this study, and the recorded data from this station were used for comparison only. The location of Pagongan Station and the other surrounding stations is shown in Figure 5.

1. Dependent variables.

   Dependent variables are the values in the transition matrices, the mean and the standard deviation of the



LEGEND :

NO.	STATIONS	ELEVATION	AZIMUTH
1.	LOSARI	+ 3 m.	315
15a.	LARANGAN	+ 23 m.	312
21	BREBES	+ 3 m.	335
30	BUMIAYU	+ 152 m.	266
33	PETUGURAN	+ 345 m.	246
35a.	TEGAL	+ 3 m.	348
44	PROCOT	+ 40 m.	344
55	PANGKAH	+ 36 m.	351
61	BUMIJAWA	+ 946 m.	308
26	PAGONGAN	+ 4.5 m.	348

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LOCATION OF UNGAGED SITE

PREPARED BY : SUSENO DARSONO

MARCH 1987 | FIGURE 5

rainfall depths for 12 month in the stations used in the analysis.

2. Independent variables.

The type of precipitation in the study area is the tropical monsoon which is influenced by the mountainous, (orographic precipitation). Therefore the factors that may affect the rainfall occurrence and depth are :

a. The elevation of the rainfall stations.
b. The distance from the sea, this is reflected in the location of the station.
c. The location of the stations which respect to the windward side of the dominating mountain e.g. North side.

The distance from the sea was omitted because it is highly correlated with the elevation of stations. Therefore, only two independent variables are considered, that are elevation of the surrounding stations and location of the stations (azimuth). Table VI.1 is the list of elevations and azimuth of stations which have been used in the analysis.

There are two steps in the generation of point daily rainfall for the ungaged site. The first step is parameter estimation using a regression model. The second step is the rainfall generation using Markov Chain Model.

This step has been fully explained in the first section of the study. Now we only deal with parameters estimation.

Table VI.1

RAIN GAUGE AZIMUTH AND ELEVATIONS

NO.	S T A T I O N	ELEVATION (above sea level) (m)	A Z I M U T H (Degree)
01	LOSARI	+ 3	315
02	LARANGAN	+ 23	312
03	BREBES	+ 3	335
04	TEGAL	+ 25	348
05	PANGKAH	+ 36	351
06	PROCOT	+ 40	344
07	BUMIJAWA	+ 946	308
08	BUMIAYU	+ 152	152
09	PETUGURAN	+ 243	345
10	PAGONGAN	+ 4.5	348

6.1. ESTIMATION OF THE PROBABILITY RAINFALL.

Because of the few data and the magnitude of the scatter, a linear model was chosen for the regression analysis.

The general formula of the model is :

$$Y = B_0 + B_1 X_1 + B_2 X_2$$

Where :

Y are dependent variabels

- The conditional probability of rainfall occurrence.
- The mean of transformed rainfall depth.
- The standard deviation of transformed rainfall depth.

X_1, X_2 are independent variables

- X_1 is the elevation of station.
- X_2 is the azimuth of station.

The result of the entire analysis is shown in the Appendix F.1. An example calculation as follow :

month : JANUARY

The appropriate model for the prob.(wet/wet) is

$$Y_1 = 0.59698862 + 0.000289 X_1$$

a. If independent variables X_1 and X_2

Coefficient of multiple determination (R^2) = 0.9196

F^* (from calculation) = 16.439

F (0.95 ; 2,6) = 2.6

t_1 = 5.06874

t_2 = -0.63249

t (0.05 ; 6) = 2.447

F test is used to test whether or not there is a relationship between the dependent variable and independent variables. From the test, it is found that the relationship between variables are significant. But, from the result of t test is known that there is no statistically significant relationships between azimuth with the other variables.

b. If independent variable X_1

Coefficient of determination (R^2) = 0.9140

F^* (from calculation) = 35.523

F (0.95 ; 1, 7) = 3.590

t_1 = 5.96012

t (0.05 ; 7) = 1.895

MONTH : JANUARY

	R	F*	t(7)	b0 and b1
Prob.wet/wet	0.9140	35.523	5.96012	b0= 0.596988620 b1= 0.000289
Prob.wet/dry	0.9140	35.510	- 5.96153	b0= 0.403055313 b1= -0.000289
Prob.dry/wet	0.9035	31.509	5.57756	b0= 0.446398886 b1= 0.000238
Prob.dry/dry	0.9035	31.109	- 5.57756	b0= 0.55360 b1= -0.000238

The regression equations are :

1. $Y_1 = 0.59698862 + 0.000289 X_1$

2. $Y_2 = 0.403055313 - 0.000289 X_1$

   or $Y_2 = 1 - Y_1$

3. $Y_3 = 0.446398886 + 0.000238 X_1$

4. $Y_4 = 0.55360000 - 0.000238 X_1$

   or $Y_4 = 1 - Y_3$

Where : X_1 = the elevation of station.

Y_1 = prob. (wet/wet).

Y_2 = prob. (wet/dry).

Y_3 = prob. (dry/wet).

Y_4 = prob. (dry/dry).

From these equations, the estimated values of the probabilities of rainfall together with the 95 % confidence limits, are shown in Table VI.2. The results are good because all estimated and observed values are close and they lie within the limits.

6.2. ESTIMATION OF MEAN RAINFALL AT STATION PAGONGAN.

The regression formulation was also used for estimating the mean of the rainfall depth. The summary of best fit regression equation is attached in the Appendix F.2,. But, from May up to December the relationship between elevation, azimuth and the mean of rainfall is very small.

Thus, the mean of rainfall for these month are estimated from the average of the mean values from surrounding stations.

Table VI.2

COMPARISON BETWEEN ESTIMATED VALUES AND OBSERVED PROBABILITY OF RAIN FOR STATION PAGONGAN

PROB.	OBSERVED	PREDICTION	UPPER LIMIT	LOWER LIMIT
WET/WET				
January	0.5667506	0.5982891	0.705669	0.490908
February	0.6302083	0.598630	0.706011	0.491249
March	0.5545171	0.544197	0.651578	0.436817
April	0.3640776	0.451089	0.702920	0.199259
May	0.3390800	0.364272	0.534056	0.194488
June	0.2626262	0.303963	0.518724	0.089201
July	0.3297872	0.305680	0.475464	0.135896
August	0.3529411	0.284631	0.558400	0.010863
September	0.3055555	0.252240	0.510772	0
October	0.2444400	0.240906	0.248701	0.233111
November	0.3783783	0.381401	0.491639	0.271162
December	0.4964028	0.585693	0.693074	0.478312
WET/DRY				
January	0.4332493	0.4018549	0.509135	0.294373
February	0.3697917	0.398659	0.506040	0.291278
March	0.4454829	0.455802	0.563182	0.348421
April	0.6359224	0.548910	0.800740	0.297079
May	0.6609196	0.638814	0.808598	0.469030
June	0.7373738	0.696030	0.910798	0.481275
July	0.6702128	0.694319	0.864103	0.524535
August	0.6470589	0.715367	0.989136	0.441599
September	0.6944445	0.747856	1	0.489324
October	0.7555556	0.759093	0.766888	0.751298
November	0.6216217	0.618598	0.728837	0.508360
December	0.5035972	0.414305	0.521680	0.306925

PROB.	OBSERVED	PREDICTION	UPPER LIMIT	LOWER LIMIT
DRY/WET				
January	0.4412532	0.4571080	0.523399	0.371540
February	0.4461538	0.4216648	0.529029	0.314267
March	0.3050180	0.354451	0.485965	0.222936
April	0.2359014	0.284571	0.436431	0.132712
May	0.1782178	0.205314	0.281244	0.129384
June	0.1160305	0.196070	0.143618	0.095596
July	0.0932944	0.087075	0.094668	0.079482
August	0.0548696	0.058060	0.065653	0.050467
September	0.0703812	0.067584	0.075892	0.060302
October	0.1202898	0.127099	0.134894	0.119304
November	0.2038664	0.214128	0.390392	0.041787
December	0.3044397	0.295727	0.427241	0.164213
DRY/DRY				
January	0.5587467	0.543250	0.618820	0.466961
February	0.5538462	0.577020	0.684401	0.469639
March	0.6949892	0.648284	0.779799	0.516770
April	0.7645986	0.717812	0.869672	0.565953
May	0.8217822	0.794683	0.870614	0.718755
June	0.8839695	0.880392	0.881151	0.879633
July	0.9067056	0.912924	0.920517	0.905331
August	0.9451304	0.941113	0.948706	0.335200
September	0.9296188	0.931902	0.939697	0.924107
October	0.8794710	0.863086	0.870880	0.855491
November	0.7966133	0.783909	0.958212	0.609607
December	0.6955603	0.704272	0.835787	0.572758

An example of the calculation for January is as follow .

MONTH : JANUARY

The regression analysis for the mean rainfall.

Model : $Y = B_0 + B_1 X_1 + B_2 X_2$

Dependent Variable (Y) = the mean of the transformed rainfall depth.

Independent variables (X_1) = the elevation of station.

(X_2) = the azimuth of station.

a. If independent variables X_1 and X_2

Coefficient of multiple determination (R^2) = 0.8234.

F^* (from calculation) = 6.317

F (0.95 ; 2, 6) = 5.14

t_1 = 3.49963

t_2 = 0.79618

t (0.05 ; 7) = 2.447

There is significant relationship between variables of the model, it can be seen from the result of F test. But, it is found from t test that there is no relation ships between azimuth and the other variables.

b. If independent variable X_1

Coefficient of determination (R^2) = 0.8025

F^* (from calculation) = 12.663

F (0.95 ; 1, 7) = 3.59

t_1 = 3.55853

t (0.05 ; 7) = 1.895

Hence, the appropriate model is :

$$Y = 2.424423469 + 0.00479 X_1$$

From this equations, the estimated values of probability rainfall with confidence level 0.95, are shown in Table VI.3. The result are good, because all estimated values and observed are close and they lie within the confidence limit.

6.3. ESTIMATION OF THE STANDARD DEVIATION OF RAINFALL FOR STATION PAGONGAN.

The regression formulations have been tried for estimating the standard deviation of the rainfall depth. However, it was found no relationship between the standard deviations, elevation of the stations and the azimuth. Confirmed by Table VI.4 which shown that the observed standard deviation are within 95 % confidence limit,if the true value is assumed from the average of standard deviation tranformed rainfall depth surrounding stations. The predictions are shown in Table VI.4 and the statistical test of the estimation of the standard deviation is attached in Appendix F.3.

Table VI.3

PREDICTION OF THE MEAN RAINFALL

FOR STATION PAGONGAN

MONTH	OBSERVED	PREDICTION	UPPER LIMIT	LOWER LIMIT
January	2.647211	2.426578	2.738607	2.114550
February	2.609219	2.604513	2.916541	2.292484
March	2.638995	2.358005	2.670034	2.045977
April	2.364087	2.179857	2.491886	1.867829
May	2.286115	2.237840	-	-
June	2.336055	2.234744	-	-
July	2.188375	2.138633	-	-
August	2.389680	2.315230	-	-
September	2.103052	2.119511	-	-
October	2.264422	2.244000	-	-
November	2.354212	2.342980	-	-
December	2.598185	2.451530	-	-

Table VI.4

PREDICTION OF THE STANDARD DEVIATION

FOR STATION PAGONGAN

M O N T H	OBSERVED	MEAN OF OBSERVED
January	1.0759960	1.1398
February	1.0696350	1.1042
March	1.0105580	1.1217
April	1.0275510	1.1459
May	1.1078410	1.1380
June	1.2012610	1.1487
July	1.0433780	1.1731
August	1.0987090	1.1866
September	1.0269170	1.0560
October	0.9295019	1.1189
November	0.9486325	1.1017
December	0.9674738	1.1374

After the estimation of the transition probability matrices, mean and standard deviation are finished, the next step is the procedure of generation rainfall it self. It can follow the procedure explained previously.

CHAPTER VII

CONCLUSION AND RECOMMENDATION

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CONCLUSION AND RECOMMENDATION

7.1. CONCLUSIONS OF THE STUDY.

In general, the conclusion of the study is that the synthetic daily and monthly rainfall have similar characteristic as the observed. In detail, several conclusions can be drawn as follows :

1. The first order Markov Chain was applied in this study and the result is good.
2. The first and the second order transition matrix of Markov Chains were compared, that the second order matrix does provide a significant improvement .
3. The rainfall depths on rainy days are serially independent and lognormally distributed.
4. The synthetic daily and monthly rainfall have a similar statistical characteristic as the observed rainfall. Therefore, the sum of daily rainfall can also be used to calculate the weekly rainfalls for irrigation management purposes.
5. Regression analysis can be used to estimate the model parameters at an ungaged site. Station Pagongan has used as ungaged site and the prediction parameters for station Pagongan are reasonably close to the observed ones.

6. The last conclusion is that the rainfall generation is very useful for planning a water resources management.

7.2. RECOMMENDATION

There are two recommendations for further study.

1. To prove the validity of result from this study it is better to conduct similar study for other stations.
2. Further studies on the application of the result from the study, such as :
   - the study on rainfall and runoff relationship.
   - the study on water management planning.

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REFERENCES

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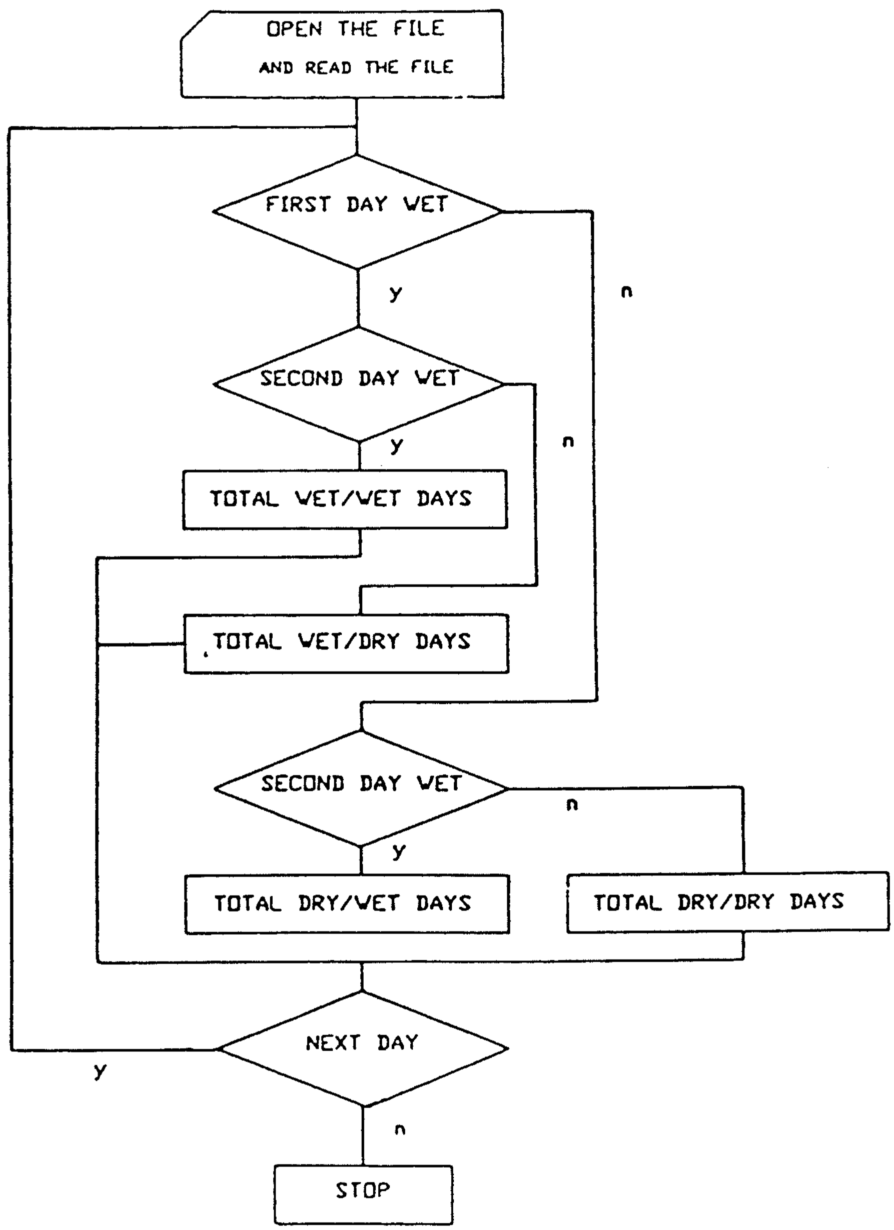
APPENDIX A
COMPUTER PROGRAMS

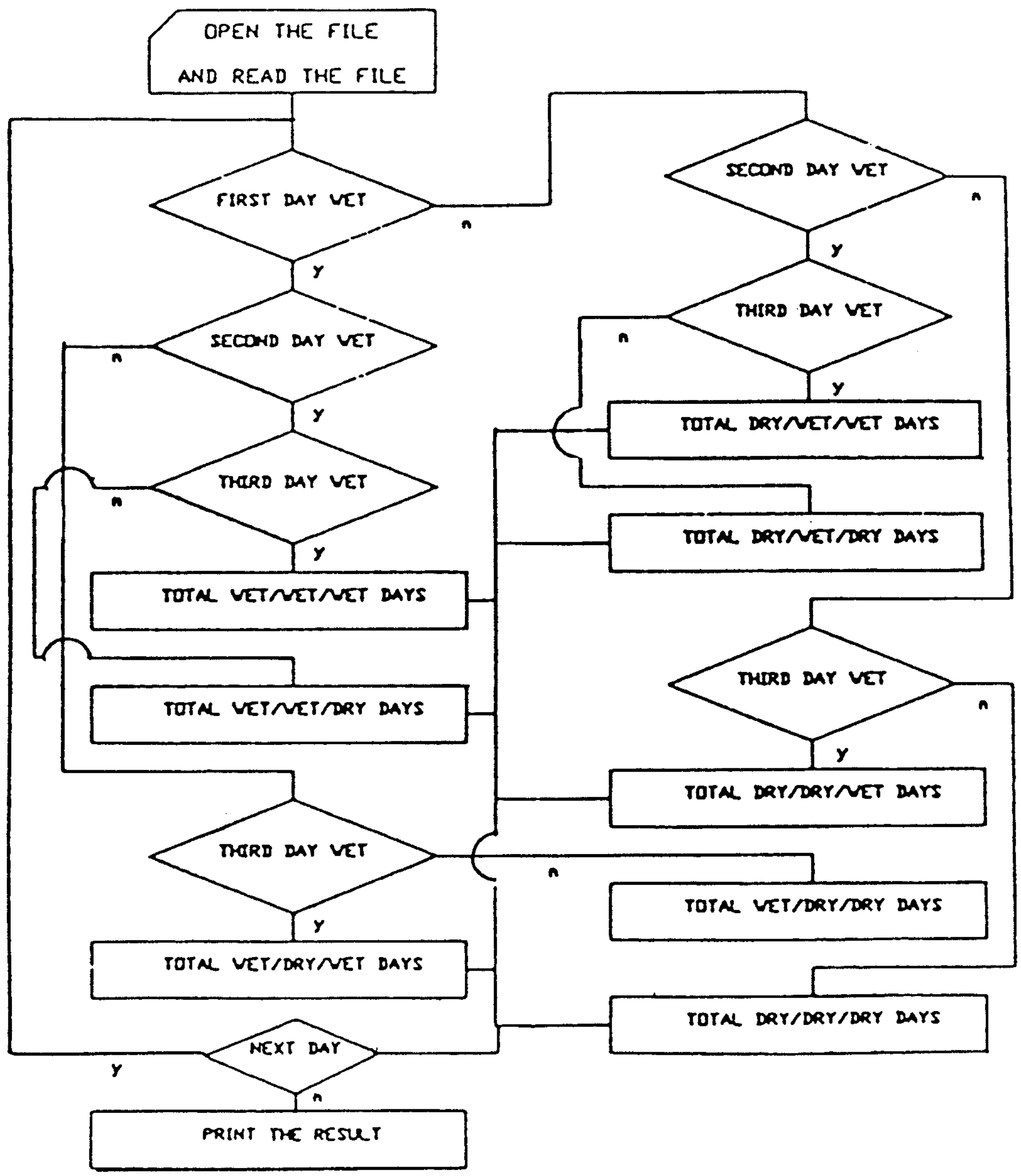
FIG. A.1. FLOWCHART OF FIRST ORDER MARKOV CHAIN.
NUMBER OF DAYS RAINFALL OCCURRENCE



```
10 CLS
20 REM
30 REM  ****************************************
40 REM  *                                      *
50 REM  *      PROGRAM TRANSITION MATRIX       *
60 REM  *       FIRST ORDER MARKOV CHAIN       *
70 REM  *                                      *
80 REM  ****************************************
90 REM
100 DIM Q(4000)
110 S = 0
120 REM
130 REM INPUTING DATA (OPEN FILE)
140 REM
150 INPUT " ENTER FILE NAME "; F$
160 OPEN F$ FOR INPUT AS #1
170 INPUT #1,X
180 S = S + 1
190 Q(S) = X
200 IF EOF(1) THEN 250
210 GOTO 170
220 REM
230 REM DATA FOR EACH MONTH
240 REM
250 INPUT " NUMBER OF DAYS IN THIS MONTH ";MD
260 TM = S / MD
270 DIM P(50,50)
280 FOR J = 1 TO TM
290 FOR I = 1 TO MD
300 BT = ( J - 1) * MD
310 P(J,I) = Q (I + BT)
320 NEXT I
330 NEXT J
340 AA = 0 : AB = 0
350 AC = 0 : AD = 0
360 DIM A (30), B (30), C (30), D (30)
370 REM
380 REM THE CALCULATION.
390 REM
400 FOR J = 1 TO TM
```

```
410 A (J) = 0
420 B (J) = 0
430 C (J) = 0
440 D (J) = 0
450 DM = MD - 1
460 FOR I = 1 TO DM
470 REM
480 REM CHECK , THE FIRST DAY WET OR DRY
490 REM
500 IF P (J,I) = 0 THEN 590
510 REM
520 REM CHECK , THE SECOND DAY WET OR DRY
530 REM
540 IF P (J, I + 1) = 0 THEN 570
550 A (J) = A (J) + 1
560 GOTO 630
570 B (J) = B (J) + 1
580 GOTO 630
590 IF P (J, I+1) = 0 THEN 620
600 C (J) = C (J) + 1
610 GOTO 630
620 D (J) = D (J) + 1
630 NEXT I
640 AA = AA + A (J)
650 AB = AB + B (J)
660 AC = AC + C(J)
670 AD = AD + D (J)
680 NEXT J
690 PRINT "GRANDTOTAL WET/WET"; AA
700 PRINT "GRANDTOTAL WET/DRY"; AB
710 PRINT "GRANDTOTAL DRY/WET"; AC
720 PRINT "GRANDTOTAL DRY/DRY"; AD
730 END
```

FIG. A. 2. FLOWCHART OF SECOND ORDER MARKOV CHAIN
NUMBER OF DAYS RAINFALL OCCURRENCE

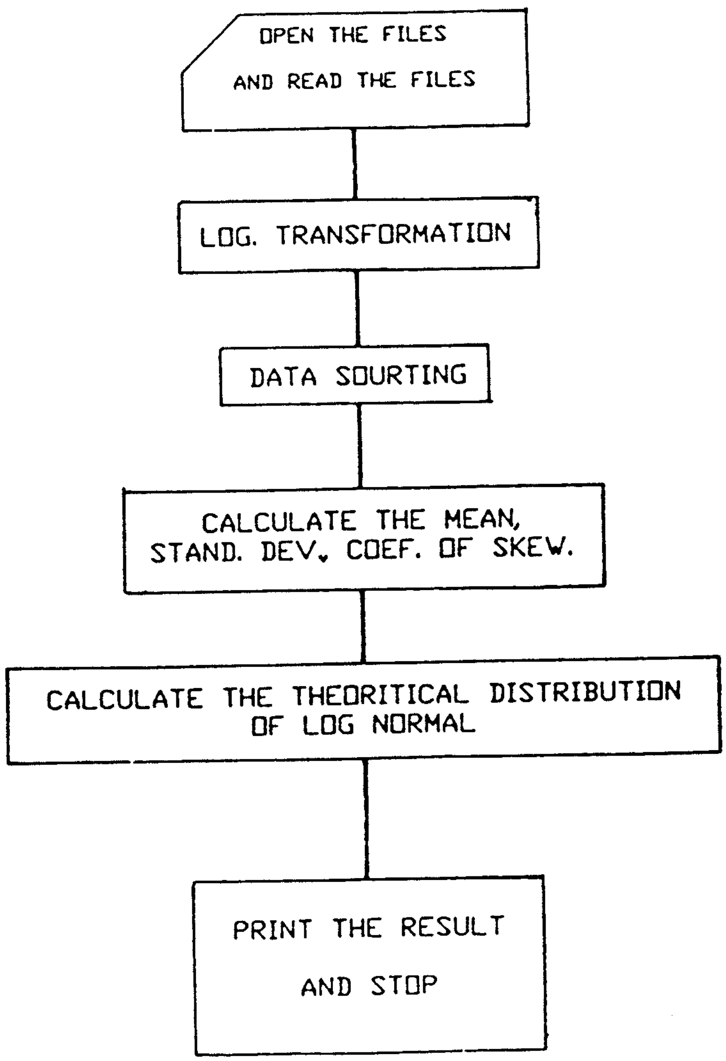


```
10 CLS
20 REM
30 REM *********************************************
40 REM *                                           *
50 REM *     PROGRAM SECOND ORDER MARKOV CHAIN     *
60 REM *           TRANSITION  MATRIX              *
70 REM *                                           *
80 REM *********************************************
90 REM
100 DIM Q(4000)
110 REM
120 REM INPUTING DATA FROM DATA FILE
130 REM
140 S=0
150 INPUT "ENTER FILE NAME "; F$
160 OPEN F$ FOR INPUT AS #1
170 INPUT #1,X
180 S=S+1
190 Q(S)=X
200 IF EOF (1) THEN 220
210 GOTO 170
220 INPUT " NUMBER OF DAYS IN THIS MONTH =";MD
230 TM = S/MD
240 DIM P(50,50)
250 FOR J= 1 TO TM
260 FOR I= 1 TO MD
270 BT=(J-1)*MD
280 P(J,I)= Q(I+BT)
290 NEXT I
300 NEXT J
310 AA=0:AB=0:AC=0:AD=0
320 AE=0:AF=0:AG=0:AH=0
330 DIM A(50),B(50),C(50),D(50),E(50),F(50),G(50),H(50)
340 FOR J= 1 TO TM
350 A(J)=0
360 B(J)=0
370 C(J)=0
380 D(J)=0
390 E(J)=0
400 F(J)=0
```

```
410 G(J)=0
420 H(J)=0
430 DM = MD-2
440 REM
450 REM THE CALCULATION
460 REM
470 FOR I = 1 TO DM
480 REM
490 REM THE FIRST DAY WET OR DRY.
500 REM
510 IF P(J,I)=0 THEN 690
520 REM
530 REM THE SECOND DAY WET OR DRY
540 REM
550 IF P(J,I+1)=0 THEN 640
560 REM
570 THE THIRD DAY WET OR DRY.
580 REM
590 IF P(J,I+2)=0 THEN 620
600 A(J)=A(J)+1
610 GOTO 790
620 B(J)=B(J)+1
630 GOTO 790
640 IF P(J,I+2)=0 THEN 670
650 C(J)=C(J)+1
660 GOTO 790
670 D(J)=D(J)+1
680 GOTO 790
690 IF P(J,I+1)=0 THEN 750
700 IF P(J,I+2)=0 THEN 730
710 E(J)=E(J)+1
720 GOTO 790
730 F(J)=F(J)+1
740 GOTO 790
750 IF P(J,I+2)=0 THEN 780
760 G(J)=G(J)+1
770 GOTO 790
780 H(J)=H(J)+1
790 NEXT I
800 AA=AA+A(J)
```

```
810 AB=AB+B(J)
820 AC=AC+C(J)
830 AD=AD+D(J)
840 AE=AE+E(J)
850 AF=AF+F(J)
860 AG=AG+G(J)
870 AH=AH+H(J)
880 NEXT J
890 FOR J= 1 TO TM
900 PRINT "TOTAL WET/WET/WET";J;"=";A(J)
910 PRINT "TOTAL WET/WET/DRY";J;"=";B(J)
920 PRINT "TOTAL WET/DRY/WET";J;"=";C(J)
930 PRINT "TOTAL WET/DRY/DRY";J;"=";D(J)
940 PRINT "TOTAL DRY/WET/WET";J;"=";E(J)
950 PRINT "TOTAL DRY/WET/DRY";J;"=";F(J)
960 PRINT "TOTAL DRY/DRY/WET";J;"=";G(J)
970 PRINT "TOTAL DRY/DRY/DRY";J;"=";H(J)
980 NEXT J
990 PRINT :PRINT
1000 PRINT "GRAND TOTAL WET/WET/WET";AA
1010 PRINT "GRAND TOTAL WET/WET/DRY";AB
1020 PRINT "GRAND TOTAL WET/DRY/WET";AC
1030 PRINT "GRAND TOTAL WET/DRY/DRY";AD
1040 PRINT "GRAND TOTAL DRY/WET/WET";AE
1050 PRINT "GRAND TOTAL DRY/WET/DRY";AF
1060 PRINT "GRAND TOTAL DRY/DRY/WET";AG
1070 PRINT "GRAND TOTAL DRY/DRY/DRY";AH
1080 END
```

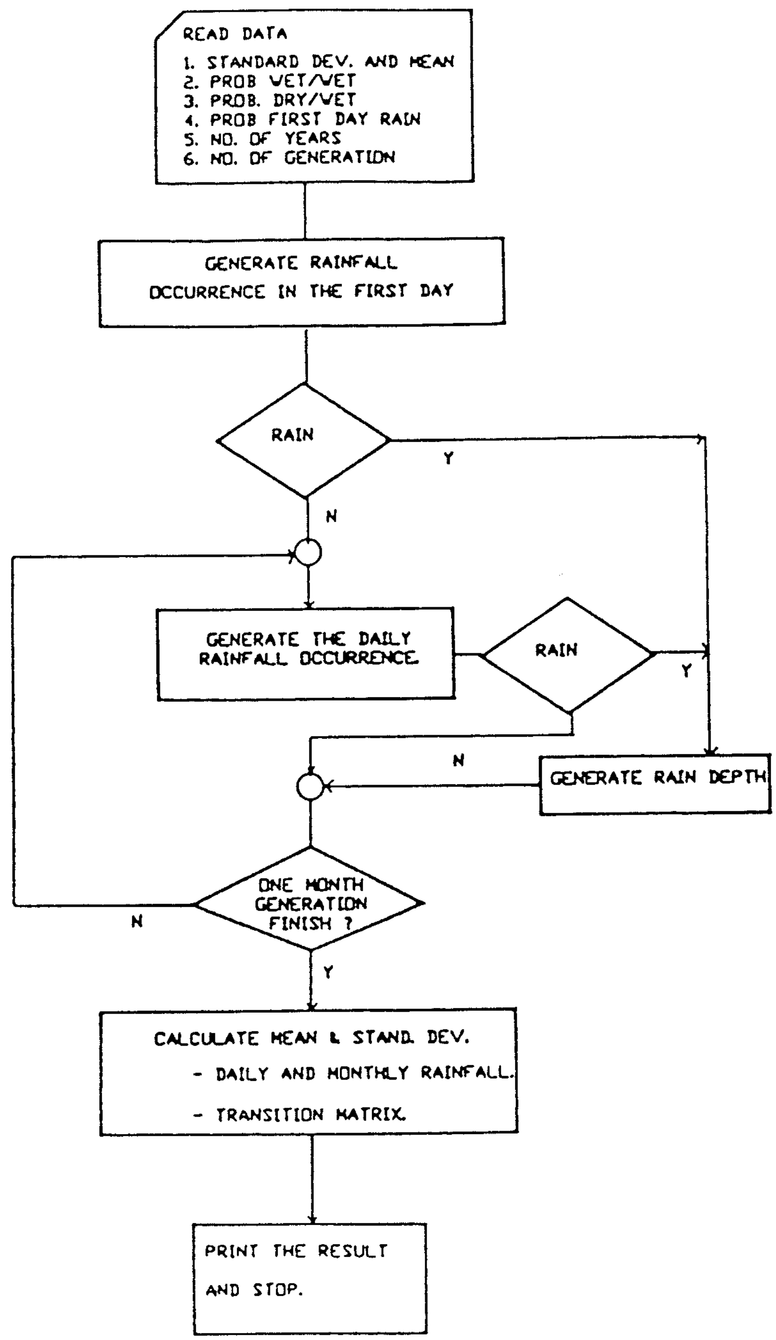
FIG. A. 3. FLOWCHART PROGRAM OF THEORITICAL DISTRIBUTION



```
10 CLS
20 DIM D(1000)
30 REM
40 REM **************************************
50 REM *                                    *
60 REM *    LOGNORMAL DISTRIBUTION TEST     *
70 REM *                                    *
80 REM **************************************
90 REM
100 PI=3.141593
110 REM
120 REM INPUTING DATAFILE
130 REM
140 INPUT " ENTER FILE NAME :";F$
150 OPEN F$ FOR INPUT AS #1
160 INPUT #1,X
170 IF X=0 THEN 220
180 S = S +1
190 TP =0
200 D(S)=X
210 PRINT D(S),S,X
220 IF EOF(1) THEN 240
230 GOTO 160
240 DIM P(1000)
250 REM
260 REM LOG. TRANSFORMATION.
270 REM
280 FOR I= 1 TO S
290 P(I)=LOG(D(I))
300 TP = TP + P(I)
310 NEXT I
320 FOR O = 2 TO S
330 REM
340 REM SOURTING PROCES
350 REM
360 K=O
370 IF P(K)>= P(K-1) THEN 430
380 C= P(K)
390 P(K) = P(K-1)
400 P(K-1) =C
```

```
410 K = K-1
420 IF K >=2 THEN 370
430 NEXT O
440 REM
450 REM CALCULATE THE MEAN, STANDARD DEV. AND COEF. OF SKEWNESS
460 REM
470 AP= TP/S
480 FOR I = 1 TO S
490 VP = VP +((P(I)-AP)^2)
500 NP = NP + ((P(I)-AP)^3)
510 NEXT I
520 SP = (VP/(S-1))^.5
530 GS = (S)/((S-1)*(S-2))
540 CP = (NP*GS)/(SP^3)
550 DIM PP(1000)
560 FOR I = 1 TO S
570 XP = (P(I)-AP)/SP
580 IF XP <> 0 THEN 610
590 L=0
600 GOTO 660
610 AJ = -(XP^2)/2
620 ZP = EXP (AJ)
630 ZP = ZP/((2*PI)^.5)
640 IF XP>0 THEN 680
650 L = 1/(1-(.33267*XP))
660 PP(I) = ZP *((.4361836*L)-(.12016*(L^2))+(.937298*(L^3 )))
670 GOTO 700
680 L = 1/(1+(.33267*XP))
690 PP(I) = 1 - (ZP*((.4361836*L)-(.12016*(L^2))+(.937298*(L^3))))
700 NEXT I
710 FOR I = 1 TO S
720 PP(I)= PP(I) *100
730 PRINT I,PP(I)
740 NEXT I
750 PRINT "AVERAGE=";AP
760 PRINT "DEV. STANDARD = ";SP
770 INPUT "ENTER FILE NAME ";D$
780 OPEN D$ FOR OUTPUT AS#2
790 FOR I = 1 TO S
800 PRINT #2,P(I),PP(I)
810 NEXT I
820 PRINT #2,AP
830 PRINT #2,SP
840 PRINT #2,CP
850 CLOSE (2)
860 END
```

FIG. A. 4. FLOWCHART OF RAINFALL GENERATION.



```
************************************************************
  THIS PROGRAM GENERATES SYNTHETIC RAINFALL SEQUENCES USING
  MARKOV CHAINS AND LOG-NORMAL DISTRIBUTION
************************************************************


      REAL P(50,50,50),TM(50,35),TY(50),MEAN(50),STD(50)
      DIMENSION DAA(12),DAB(12),DAC(12),DAD(12),DAE(12),DAF(12)
      DIMENSION DAG(12)
      REAL RSD(50),LSD(50),RSTD(50),LSTD(50),LMEAN(50)
      DIMENSION DP(50,50,50),TLM(50,35),TRY(50),RMEAN(50),TLY(50)
       DIMENSION TSD(50),AVM(50),STM(50),TRM(50,35),SKEW(50),FMD(50)
       REAL MOM,MTSD,LMOM,LMEA,MLSD,LOSD,MRSD
       DIMENSION TWW(50),TWD(50),TDW(50),TDD(50)
      DOUBLE PRECISION DSEED,DSEED2
      DSEED = 234564.DO
      DSEED2 = 130013.DO
      DO 10 N = 1,11
      READ(5,*)DAA(N),DAB(N),DAC(N),DAD(N),DAE(N),DAF(N),DAG(N)
10    CONTINUE
      DO 20 N = 1,11
      SD = DAA(N)
      AV = DAB(N)
      WE = DAC(N)
      DR = DAD(N)
      MD = DAE(N)
      PFDR = DAF(N)
      IY   = DAG(N)
      WRITE(6,*)SD,AV,WE,DR,MD,PFDR,IY
      NG=50
*************************************************************

VARIABLE DEVINITION   :

      SD = STANDARD DEVIATION
      AV = MEAN
      WE = PROB. TODAY WET AND THE NEXT DAY IS WET
      DR = PROB. TODAY DRY AND THE NEXT DAY IS WET
      P(K,I,J) = RAINFALL DEPTH   ( IN MM)
      MD = MONTH DAYS
      IY = NUMBER OF YEARS WILL BE GENERATED.
      NG = NUMBER OF GENERATION
      PFDR = PROB. FIRST DAY RAIN

*************************************************************

      DO 700 K = 1,NG
      DO 600 I = 1,IY
      DO 500 J = 1,MD
      X = 0

      CALL UNIFORM RANDOM NUMBER (1,0) FROM SUBROUTINE FUNCTION

      X = GGUBFS(DSEED)
```

```
      IF (J.GT.1) GO TO 100
C     IF THE RANDOM NUMBER GREATER THAN 0.5 THE FIRST DAY IS WET
      IF (X.GT.PFDR) GO TO 400
      P(K,I,J) = 0
      DP(K,I,J)= 0
      GOTO 500
  100 R = 0
      R = J - 1
C     CHECK , IS THE DAY BEFORE WET ?
      IF (P(K,I,R).EQ.0) GO TO 200
C     IF THE DAY BEFORE IS WET AND THE RND <= WE THAN TODAY IS WET
      IF (X.LE.WE) GO TO 400
      P(K,I,J) = 0
      DP(K,I,J)= 0
      GO TO 500
C     IF THE DAY BEFORE IS DRY AND THE RND <= DR THEN TODAY IS WET
  200 IF (X.LE.DR) GO TO 400
      P(K,I,J) = 0
      DP(K,I,J) = 0
      GO TO 500
C    IF TO DAY IS WET THEN GO TO SUBROUTINE AND GENERATE A RAINFALL
 400  P(K,I,J) = 0
      DP(K,I,J) = 0
      P(K,I,J) = AV + (GGNQF(DSEED2) * SD)
      DP(K,I,J) = P(K,I,J)
      P(K,I,J) = EXP(P(K,I,J))
 500  CONTINUE
 600  CONTINUE
 700   CONTINUE

*************************************************************

      CALCULATE MEAN AND MEAN OF THE MEAN

**************************************************************


      TAV = 0
      TAL = 0
      TAR =0
      DO 1010 K = 1,NG
      TD = 0
      TLD = 0
      SUM24=0
      SUM23=0
      SUM2 = 0
      DO 1020 I = 1,IY
      ND = 0
      LND = 0
      SUM21 = 0
      SUM22 = 0
      SUM1 = 0
      DO 1030 J = 1,MD
      SUM1=SUM1+ P(K,I,J)
      ND = ND + 1
      TDP = P(K,I,J)
      IF (TDP.LE.0) GO TO 1030
      SUM22 = SUM22 + P(K,I,J)
      SUM21 = SUM21 + DP(K,I,J)
      LND = LND +1
      CONTINUE
      TM(K,I) = SUM1
      TLM(K,I) = SUM21
      TRM(K,I) = SUM 22
```

```
      SUM23 = SUM23 + TLM(K,I)
      SUM24 = SUM24 + TRM(K,I)
      TLD = TLD + LND
      SUM2 = SUM2 + TM(K,I)
      TD = TD + ND
1020  CONTINUE
      TY(K) = SUM2
      TLY(K) = SUM23
      TRY(K) = SUM24
      RMEAN(K) = TRY(K)/TLD
      LMEAN(K) = TLY(K)/TLD
      TAR = TAR + RMEAN(K)
      TAL = TAL + LMEAN(K)
      MEAN(K) = TY(K)/TD
      TAV= TAV + MEAN(K)
1010  CONTINUE
      MOM = TAV / NG
      LMOM = TAL / NG
      RMOM = TAR / NG

*******************************************************************

      CALCULATE STANDARD DEVIATION AND MEAN OF STANDARD DEV.

*******************************************************************

      GTSD = 0
      SUM35=0
      GRSD = 0
      GLSD = 0
      DO 1040 K = 1,NG
      SUM31 = 0
      SUM32 = 0
      SUM33 = 0
      SUM3 =0
      DO 1050 I = 1,IY
      DO 1060 J = 1,MD
      SUM3 = SUM3 + ( P(K,I,J)-MEAN(K))**2
      TDP = P(K,I,J)
      IF (TDP.LE.0) GO TO 1060
      SUM31 = SUM31 + (P(K,I,J) - RMEAN(K))**2
      SUM32 = SUM32 + (DP(K,I,J) - LMEAN(K))**2
      SUM33 = SUM33 + (DP(K,I,J) - LMEAN(K))**3
1060  CONTINUE
1050  CONTINUE
      TSD(K) = SUM3
      RSD(K) = SUM31
      LSD(K) = SUM32
      RSTD(K) = SQRT(RSD(K)/(TLD-1))
      LSTD(K) = SQRT(LSD(K)/(TLD-1))
      SKEW(K) = (TLD/((TLD-1)*(TLD-2))*(SUM33/((LSTD(K))**3)))
      SUM35 = SUM35 +SKEW(K)
      GRSD = GRSD + RSTD(K)
      GLSD = GLSD + LSTD(K)
      STD(K) = SQRT(TSD(K)/(TD-1))
      GTSD = GTSD + STD(K)
1040  CONTINUE
      ASKEW = SUM35/NG
      MTSD = GTSD/NG
      MRSD = GRSD/NG
      MLSD = GLSD/NG
      WRITE(6,1041)(RMEAN(K),K=1,NG)
      WRITE(6,1042)(LMEAN(K),K=1,NG)
      WRITE(6,1043)(RSTD(K),K=1,NG)
```

```
      WRITE(6,1044)(LSTD(K),K=1,NG)
      WRITE(6,1045)(SKEW(K),K=1,NG)
 1041 FORMAT(/,4X,'RAINFALL MEAN =',5(3X,F10.5))
 1042 FORMAT(/,4X,'LOG MEAN =',10(3X,F8.5))
 1043 FORMAT(/,4X,'RAINFALL STD.=',5(3X,F10.5))
 1044 FORMAT(/,4X,'LOG STD. =',10(3X,F8.5))
 1045 FORMAT(/,4X,'COEF. SKEW.=',10(3X,F8.5))
      WRITE (6,1070)(MEAN(K),K=1,NG)
 1070 FORMAT (/,4X,'MEAN =',10(3X,F7.1))
      WRITE (6,1080)(STD(K),K=1,NG)
 1080 FORMAT (/,4X,'STD. =',10(3X,F7.1))
C
C
C*************************************************************
C
C      CALCULATE STANDARD DEVIATION OF THE MEAN AND OF THE STD.
C
C*************************************************************
C
C
       SUM4 = 0
       SUM41 = 0
       SUM42 =0
       SUM5 = 0
       SUM51 = 0
       SUM52 = 0
       DO 1090 K = 1,NG
       SUM4 = SUM4 + (MEAN(K) - MOM)**2
       SUM5 = SUM5 + (STD(K) - MTSD)**2
       SUM41 = SUM41 + (RMEAN(K) - RMOM)**2
       SUM42 = SUM42 + (LMEAN(K) - LMOM)**2
       SUM51 = SUM51 + (RSTD(K) - MRSD)**2
       SUM52 = SUM52 + (LSTD(K) - MLSD)**2
 1090  CONTINUE
       SMEA = SQRT(SUM4/(NG-1))
       RMEA = SQRT(SUM41/(NG-1))
       LMEA = SQRT(SUM42/(NG-1))
       SOSD1 = SQRT(SUM5/(NG-1))
       ROSD  = SQRT(SUM51/(NG-1))
       LOSD  = SQRT(SUM52/(NG-1))
       WRITE(6,1100) MOM,SMEA
       WRITE(6,1110) MTSD,SOSD1
 1100  FORMAT (/,4X,'MEAN OF THE MEAN=',F10.5,2X,'STD OF MEAN=',F10.5)
 1110  FORMAT (/,4X,'MEAN OF THE STD=',F10.5,2X,'STD OF STD =',F10.5)
       WRITE(6,1111)LMOM,LMEA
       WRITE(6,1112)RMOM,RMEA
       WRITE(6,1113)MLSD,LOSD
       WRITE(6,1114)MRSD,ROSD
       WRITE(6,1115)ASKEW
 1111  FORMAT(/,4X,'MEAN OF THE MEAN(LOG)=',F8.5,2X,
     $ 'STD OF MEAN(LOG)=',F8.5)
 1112  FORMAT(/,4X,'MEAN OF THE MEAN(RAINFALL)=',F7.1,2X,
     $ 'STD OF MEAN(RAINDAYS)=',F7.1)
 1113  FORMAT(/,4X,'MEAN OF STD (LOG)=',F8.5,2X,
     $ 'STD OF STD=',F8.5)
 1114  FORMAT(/,4X,'MEAN OF STD(RAINDAYS)=',F7.1,2X,
     $ 'STD OF STD=',F7.1)
 1115  FORMAT(/,4X,'MEAN OF COEFF. SKEW. =',F8.5)
```

```
      ****************************************************************

            CALCULATE MEAN & STD. OF MONTHLY RAINFALL

      ****************************************************************

            SUM8 = 0
            SUM9 = 0
            DO 1125 K = 1,NG
            SUM6 = 0
            DO 1130 I = 1,IY
            SUM6 = SUM6 + TM(K,I)
      1130  CONTINUE
            AVM(K) = SUM6/IY
            SUM7 = 0
            DO 1140 I = 1,IY
            SUM7 = SUM7 + (TM(K,I) - AVM(K))**2
      1140  CONTINUE
            STM(K) = SQRT(SUM7/(IY-1))
            SUM8 = SUM8 + AVM(K)
            SUM9 = SUM9 + STM(K)
      1125  CONTINUE
            TAVM = SUM8/NG
            TASD = SUM9/NG
            SUM10 = 0
            SUM11 = 0
            DO 1135 K = 1,NG
            SUM10 = SUM10 + (AVM(K)-TAVM)**2
            SUM11 = SUM11 + (STM(K) - TASD)**2
      1135  CONTINUE
            SOMM = SQRT(SUM10/(NG-1))
            SOSD = SQRT(SUM11/(NG-1))
            WRITE(6,1145) (AVM(K), K=1,NG)
            WRITE(6,1155) (STM(K), K=1,NG)
            WRITE(6,1165) SOMM,SOSD
            WRITE(6,1175) TAVM,TASD
      1145  FORMAT(/,4X,'AVERAGE MONTHLY =',5(3X,F10.5))
      1155  FORMAT(/,4X,'STD. MONTHLY =',5(3X,F10.5))
      1165  FORMAT(/,4X,'STD. OF MEAN=',2X,F10.5,2X,'STD.=',2X,F10.5)
      1175  FORMAT(/,4X,'MEAN OF MEAN=',2X,F10.5,2X,'STD =',2X,F10.5)

      ****************************************************************

        THE CALCULATION OF TRANSITION MATRIX.

      ****************************************************************

            SUM65=0
            SUM66=0
            SUM67=0
            SUM68=0
            DO 2020 K=1,NG
            SUM61=0
            SUM62=0
            SUM63=0
            SUM64=0
            DO 2030 I=1,IY
            NMD=MD-1
            DO 2040 J= 1,NMD
            IF (P(K,I,J).LE.0) GO TO 2060
            LS = J+ 1
            IF (P(K,I,LS).LE.0) GO TO 2050
            SUM61 = SUM61 + 1
            GO TO 2040
      2050  SUM62 = SUM62 + 1
            GO TO 2040
      2060  LS = J + 1
            IF (P(K,I,LS).LE.0) GO TO 2070
```

```
      SUM63 = SUM63 + 1
      GO TO 2040
2070  SUM64 = SUM64 + 1
2040  CONTINUE
2030  CONTINUE
      TWW(K) = SUM61
      TWD(K) = SUM62
      TDW(K) = SUM63
      TDD(K) = SUM64
      SUM65 = SUM65 + TWW(K)
      SUM66 = SUM66 + TWD(K)
      SUM67 = SUM67 + TDW(K)
      SUM68 = SUM68 + TDD(K)
2020  CONTINUE
      AWW = SUM65/NG
      AWD = SUM66/NG
      ADW = SUM67/NG
      ADD = SUM68/NG
      WRITE(6,2300)(TWW(K),K=1,NG)
      WRITE(6,2310)(TWD(K),K=1,NG)
      WRITE(6,2320)(TDW(K),K=1,NG)
      WRITE(6,2330)(TDD(K),K=1,NG)
2300  FORMAT(/,4X,'NO.OF DAYS WET/WET =',5(3X,F8.2))
2310  FORMAT(/,4X,'NO.OF DAYS WET/DRY =',5(3X,F8.2))
2320  FORMAT(/,4X,'NO.OF DAYS DRY/WET =',5(3X,F8.2))
2330  FORMAT(/,4X,'NO. OF DAYS DRY/DRY =',5(3X,F8.2))
      WRITE (6,2340) AWW
      WRITE (6,2350)AWD
      WRITE(6,2360)ADW
      WRITE(6,2370)ADD
2340  FORMAT(/,4X,' MEAN OF NO. OF DAYS WET/WET =',F8.2)
2350  FORMAT(/,4X,' MEAN OF NO. OF DAYS WET/DRY =',F8.2)
2360  FORMAT(/,4X,' MEAN OF NO. OF DAYS DRY/WET =',F8.2)
2370  FORMAT(/,4X,' MEAN OFONO. OF DAYS DRY/DRY =',F8.2)
  20  CONTINUE
      STOP
      END
```

APPENDIX B
TRANSITION MATRICES

Table B.1

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : PROCOT

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	253	262	154	157	155	151	217	210
February	247	254	139	140	140	137	182	178
March	170	174	151	152	149	146	310	308
April	101	101	130	128	130	129	393	396
May	61	61	115	113	113	112	491	494
June	19	19	75	78	73	73	587	584
July	21	21	54	56	54	54	651	649
August	30	28	39	37	39	40	672	675
September	23	23	45	46	45	45	641	640
October	32	31	76	73	78	79	594	597
November	81	90	124	136	126	134	422	452
December	182	183	130	127	131	131	307	309

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.2

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : LOSARI

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	223	229	166	168	165	162	256	251
February	210	215	138	137	140	139	221	210
March	166	170	159	162	156	154	329	324
April	90	88	134	137	133	135	426	423
May	57	61	129	114	129	113	496	522
June	33	34	70	69	68	67	662	613
July	18	20	45	46	45	46	702	698
August	10	9	25	23	23	24	753	754
September	6	6	43	43	43	43	691	691
October	21	20	65	62	67	67	627	631
November	71	67	107	105	110	110	495	501
December	155	154	138	135	141	141	346	350

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.3

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : BREBES

M O N T H	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	260	261	177	174	175	175	198	200
February	218	222	149	148	150	148	219	218
March	218	218	157	158	156	155	279	279
April	99	98	154	158	154	154	376	373
May	72	70	138	137	139	137	461	466
June	46	44	91	87	90	88	557	564
July	18	18	66	65	65	66	661	661
August	12	12	48	46	47	47	702	705
September	22	21	61	62	60	61	639	639
October	38	34	87	80	90	90	596	606
November	83	80	125	123	126	128	449	452
December	224	224	149	148	151	150	286	288

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.4

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION :BUMIAYU

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	322	320	160	160	160	161	168	169
February	164	264	156	156	156	158	164	167
March	258	262	173	173	172	170	207	205
April	254	191	683	169	170	168	191	255
May	103	102	136	136	134	131	438	441
June	53	54	88	87	86	84	555	558
July	33	36	68	70	66	67	643	637
August	12	11	54	52	54	54	690	693
September	65	66	68	68	69	68	581	581
October	97	93	108	102	111	114	463	471
November	169	166	126	126	125	125	334	337
December	249	243	144	140	142	145	249	252

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.5

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : PETUGURAN

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	377	379	152	154	152	149	129	128
February	290	299	138	138	136	132	173	167
March	375	369	145	146	148	151	141	144
April	187	342	127	131	131	124	188	196
May	223	216	140	138	138	136	309	324
June	142	138	110	109	108	109	422	427
July	93	90	100	95	98	97	518	528
August	75	73	73	69	73	74	589	594
September	159	157	83	80	82	79	460	467
October	278	268	105	98	110	108	318	306
November	357	358	125	127	127	127	146	142
December	368	372	145	142	145	143	123	123

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.6

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : TEGAL

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	1 *)	2 *)	1	2	1	2	1	2
January	181	182	177	176	178	178	244	244
February	171	138	164	130	164	132	213	173
March	123	127	147	151	143	141	368	361
April	48	146	113	113	112	112	482	483
May	41	39	113	113	112	111	514	518
June	22	22	72	71	70	69	590	592
July	21	22	63	66	62	64	633	628
August	7	7	37	38	37	37	698	698
September	13	14	45	47	45	45	650	648
October	18	17	71	67	71	70	621	626
November	53	51	199	100	100	99	502	504
December	125	130	117	121	120	125	388	404

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.7

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : BANDAR

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	551	547	89	89	89	92	48	52
February	487	490	87	87	87	85	48	47
March	473	480	110	112	107	103	90	85
April	288	295	159	162	158	153	149	144
May	205	208	147	145	142	141	285	286
June	93	95	103	102	101	101	456	456
July	95	94	104	103	101	102	498	481
August	50	49	88	87	86	88	556	556
September	123	122	97	93	98	98	437	441
October	167	166	124	120	125	125	334	339
November	257	258	159	158	162	162	147	147
December	398	397	128	129	130	132	93	92

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.8

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : LARANGAN

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	276	279	177	176	175	173	182	182
February	295	260	162	141	164	138	115	197
March	230	232	166	169	166	164	247	245
April	140	137	153	155	154	155	337	336
May	100	97	132	129	132	130	446	454
June	38	37	93	89	91	89	561	568
July	34	35	67	66	66	67	643	642
August	36	36	60	58	60	60	654	565
September	25	23	54	52	53	53	651	655
October	529	59	113	110	110	113	559	528
November	129	127	145	145	146	147	363	364
December	242	241	152	151	152	152	263	266

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.9

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : PANGKAH

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	*) 1	*) 2	1	2	1	2	1	2
January	307	310	159	159	160	158	155	153
February	257	261	151	150	152	150	149	148
March	203	207	150	152	147	143	280	278
April	119	115	148	148	149	149	339	342
May	82	81	126	138	124	123	448	448
June	34	33	82	79	81	79	557	563
July	37	37	56	55	55	56	632	632
August	16	15	35	34	34	34	694	697
September	33	34	56	57	56	56	609	607
October	35	34	98	96	98	97	550	553
November	117	114	144	144	146	147	347	349
December	223	212	137	129	140	135	280	274

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.10

COMPARISON OF DAILY RAINFALL OCCURRENCE

STATION : BUMIJAWA

MONTH	WET/WET		WET/DRY		DRY/WET		DRY/DRY	
	1 *)	2 *)	1	2	1	2	1	2
January	571	569	93	94	96	98	50	49
February	544	529	79	77	78	71	35	32
March	502	502	117	119	116	116	75	73
April	351	352	149	150	147	146	136	135
May	241	241	138	136	133	133	297	300
June	112	112	129	128	126	126	416	417
July	88	90	88	89	84	84	550	547
August	72	71	75	73	75	75	588	591
September	121	122	78	76	78	79	505	506
October	372	199	125	129	126	140	160	342
November	204	373	135	125	138	126	332	159
December	421	399	115	112	115	109	159	160

*) 1. Number of days (Synthetic data).

2. Number of days (Observed data).

Table B.11

TRANSITION MATRIX OF PROBABILITY RAINFALL OCCURRENCE

FOR FIRST - ORDER MARKOV CHAINS.

LOSARI	WET / WET	WET / DRY	DRY / WET	DRY / DRY
January	0.57683	0.42317	0.39225	0.60775
February	0.61080	0.38920	0.39828	0.60172
March	0.51205	0.48795	0.32218	0.67782
April	0.39111	0.60889	0.24194	0.75806
May	0.34857	0.65143	0.17795	0.82205
June	0.33010	0.66990	0.09853	0.90147
July	0.30303	0.69697	0.06183	0.93817
August	0.28125	0.71875	0.03085	0.96915
September	0.12245	0.87755	0.05858	0.94142
October	0.24390	0.75610	0.09599	0.90401
November	0.38953	0.61047	0.18003	0.81997
December	0.53287	0.46713	0.28717	0.71283

BREBES.	WET / WET	WET / DRY	DRY / WET	DRY / DRY
January	0.60000	0.40000	0.46667	0.53333
February	0.60000	0.40000	0.40437	0.59563
March	0.57979	0.42021	0.35714	0.64286
April	0.38281	0.61719	0.29222	0.70778
May	0.33816	0.66184	0.22720	0.77280
June	0.33588	0.66412	0.13497	0.86503
July	0.21687	0.78313	0.09078	0.90922
August	0.20690	0.79310	0.06250	0.93750
September	0.25301	0.74699	0.08714	0.91286
October	0.29825	0.70175	0.12931	0.87069
November	0.39409	0.60591	0.22069	0.77931
December	0.60215	0.39785	0.34247	0.65753

	WET / WET	WET / DRY	DRY / WET	DRY / DRY
LARANGAN				
January	0.61319	0.38681	0.48732	0.51268
February	0.64838	0.35162	0.41194	0.58806
March	0.57855	0.42145	0.40098	0.59902
April	0.46918	0.53082	0.31568	0.68432
May	0.42920	0.57080	0.22260	0.77740
June	0.29365	0.70635	0.13546	0.86454
July	0.34653	0.65347	0.09450	0.90550
August	0.38298	0.61702	0.08380	0.91620
September	0.30667	0.69333	0.07486	0.92514
October	0.34911	0.65089	0.17629	0.82371
November	0.46691	0.53309	0.28767	0.71233
December	0.61480	0.38520	0.36364	0.63636

	WET / WET	WET / DRY	DRY / WET	DRY / DRY
PANGKAH				
January	0.66098	0.33902	0.50804	0.49196
February	0.63504	0.36496	0.50336	0.49664
March	0.57660	0.42340	0.33967	0.66033
April	0.43726	0.56274	0.30346	0.69654
May	0.38756	0.61244	0.21541	0.78459
June	0.29464	0.70536	0.12305	0.87695
July	0.40217	0.59783	0.08140	0.91860
August	0.30612	0.69388	0.04651	0.95349
September	0.37363	0.62637	0.08446	0.91554
October	0.26154	0.73846	0.14923	0.85077
November	0.44186	0.55814	0.29637	0.70363
December	0.62170	0.37830	0.33007	0.66993

TEGAL.	WET / WET	WET / DRY	DRY / WET	DRY / DRY
January	0.50838	0.49162	0.42180	0.57820
February	0.51493	0.48507	0.43279	0.56721
March	0.45683	0.54317	0.28088	0.71912
April	0.28931	0.71069	0.18824	0.81176
May	0.25828	0.74172	0.17647	0.82353
June	0.23656	0.76344	0.10439	0.89561
July	0.25000	0.75000	0.09249	0.90751
August	0.15556	0.84444	0.05034	0.94966
September	0.22951	0.77049	0.06494	0.93506
October	0.20238	0.79762	0.10057	0.89943
November	0.33775	0.66225	0.16418	0.83582
December	0.51793	0.48207	0.23629	0.76371

BANDAR	WET / WET	WET / DRY	DRY / WET	DRY / DRY
January	0.86006	0.13994	0.63889	0.36111
February	0.84922	0.15078	0.64394	0.35606
March	0.81081	0.18919	0.54787	0.45213
April	0.64551	0.35449	0.51515	0.48485
May	0.58924	0.41076	0.33021	0.66979
June	0.48223	0.51777	0.18133	0.81867
July	0.47716	0.52284	0.17496	0.82504
August	0.36029	0.63971	0.13665	0.86335
September	0.56744	0.43256	0.18182	0.81818
October	0.58042	0.41958	0.26940	0.73060
November	0.62019	0.37981	0.52427	0.47573
December	0.75475	0.24525	0.58929	0.41071

	WET / WET	WET / DRY	DRY / WET	DRY / DRY
BUMIAYU				
January	0.66667	0.33333	0.48788	0.51212
February	0.62857	0.37143	0.48615	0.51385
March	0.60230	0.39770	0.45333	0.54667
April	0.53056	0.46944	0.39716	0.60284
May	0.42857	0.57143	0.22902	0.77098
June	0.38298	0.61702	0.13084	0.86916
July	0.33962	0.66038	0.09517	0.90483
August	0.17460	0.82540	0.07229	0.92771
September	0.49254	0.50746	0.10478	0.89522
October	0.47692	0.52308	0.19487	0.80513
November	0.56849	0.43151	0.27056	0.72944
December	0.63446	0.36554	0.36524	0.63476

	WET / WET	WET / DRY	DRY / WET	DRY / DRY
PETUGURAN				
January	0.71107	0.28893	0.53791	0.46209
February	0.68421	0.31579	0.44147	0.55853
March	0.71650	0.28350	0.51186	0.48814
April	0.72304	0.27696	0.38750	0.61250
May	0.61017	0.38983	0.29565	0.70435
June	0.55870	0.44130	0.20336	0.79664
July	0.48649	0.51351	0.15520	0.84480
August	0.51408	0.48592	0.11078	0.88922
September	0.66245	0.33755	0.14469	0.85531
October	0.73224	0.26776	0.26087	0.73913
November	0.73814	0.26186	0.47212	0.52788
December	0.72374	0.27626	0.53759	0.46241

	WET / WET	WET / DRY	DRY / WET	DRY / DRY
BUMIJAWA				
January	0.85822	0.14178	0.66667	0.33333
February	0.87294	0.12706	0.68932	0.31068
March	0.80837	0.19163	0.61376	0.38624
April	0.70120	0.29880	0.51957	0.48043
May	0.63926	0.36074	0.30716	0.69284
June	0.46667	0.53333	0.23204	0.76796
July	0.50279	0.49721	0.13312	0.86688
August	0.49306	0.50694	0.11261	0.88739
September	0.61616	0.38384	0.13504	0.86496
October	0.60671	0.39329	0.29046	0.70954
November	0.74900	0.25100	0.44211	0.55789
December	0.78082	0.21918	0.40520	0.59480

Table B.12

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : PROCOT

MONTH	OBSERVED	
	MEAN *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.6306	1.0961
FEBRUARY	2.6523	1.0093
MARCH	2.5258	1.1109
APRIL	2.2374	1.0848
MAY	2.1853	0.9916
JUNE	2.3840	1.0348
JULY	2.2223	1.0491
AUGUST	2.6166	1.0858
SEPTEMBER	2.1022	0.9795
OCTOBER	2.2034	1.0533
NOVEMBER	2.2877	1.0471
DECEMBER	2.4736	1.0412

*) The mean and the standard deviation from transformed rainfall depth data .

Table B.13

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : LOSARI

M O N T H	O B S E R V E D	
	M E A N *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.4475	1.0351
FEBRUARY	2.3611	1.0587
MARCH	2.4179	1.0656
APRIL	2.2329	1.1100
MAY	2.2124	1.2353
JUNE	2.1979	1.0531
JULY	2.2682	1.0535
AUGUST	2.0181	1.1501
SEPTEMBER	2.2038	0.9724
OCTOBER	2.1567	1.1094
NOVEMBER	2.2638	0.1032
DECEMBER	2.4374	1.0926

*) the mean and the standard deviation from transformed rainfall depth data.

Table B.14

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : BREBES

MONTH	OBSERVED	
	MEAN *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.3197	1.2668
FEBRUARY	2.3869	1.1820
MARCH	2.2049	1.1875
APRIL	2.0103	1.1861
MAY	1.9418	1.2057
JUNE	2.1322	1.1510
JULY	1.9163	1.2080
AUGUST	2.0318	1.2792
SEPTEMBER	1.8082	1.1897
OCTOBER	1.8684	1.1542
NOVEMBER	2.0858	1.1039
DECEMBER	2.2532	1.1837

*) The mean and the standard deviation from transformed rainfall depth data

Table B.15

PARAMETERS OF THE DAILY RAINFALL

STATION : BUMIAYU

MONTH	OBSERVED	
	MEAN *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.5319	1.1221
FEBRUARY	2.6756	1.0908
MARCH	2.6116	1.1235
APRIL	2.4078	1.1324
MAY	2.3051	1.1869
JUNE	2.3725	1.2234
JULY	2.0270	1.3946
AUGUST	2.3958	1.4066
SEPTEMBER	2.0911	1.0491
OCTOBER	2.3074	1.6923
NOVEMBER	2.3694	1.2177
DECEMBER	2.4078	1.3243

*) The mean and the standard deviation from transformed rainfall depth data.

Table B.16

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : PETUGURAN

M O N T H	O B S E R V E D	
	M E A N *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.5300	1.0780
FEBRUARY	2.6080	1.0700
MARCH	2.5901	1.1010
APRIL	2.6451	1.1044
MAY	2.6158	1.1420
JUNE	2.4140	1.1470
JULY	2.3000	1.2540
AUGUST	2.3820	1.2050
SEPTEMBER	2.6760	1.2210
OCTOBER	2.9380	1.1820
NOVEMBER	2.9382	1.0558
DECEMBER	2.6322	1.0919

*) The mean and the standard deviation from transformed rainfall depth data.

Table B.17

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : TEGAL

M O N T H	O B S E R V E D	
	M E A N *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.5318	1.1633
FEBRUARY	2.5606	1.1288
MARCH	2.8913	1.1678
APRIL	2.3272	1.4578
MAY	2.1947	1.1966
JUNE	2.2831	1.1859
JULY	2.0107	1.2235
AUGUST	2.4559	1.1856
SEPTEMBER	1.9993	1.0672
OCTOBER	2.1391	1.0604
NOVEMBER	2.2995	1.0493
DECEMBER	2.4852	1.0236

*) The mean and the standard deviation from transformed rainfall depth data.

Table B.18

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : BANDAR

MONTH	OBSERVED	
	MEAN *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	3.0032	1.9255
FEBRUARY	2.8024	1.2247
MARCH	2.5736	1.2495
APRIL	2.3437	1.2399
MAY	2.1962	1.2384
JUNE	2.1450	1.3010
JULY	2.1001	1.3576
AUGUST	2.0995	1.2205
SEPTEMBER	1.9891	1.1746
OCTOBER	2.0642	1.1802
NOVEMBER	2.2333	1.2678
DECEMBER	2.3877	1.1501

*) The mean and the standard deviation from transformed rainfall depth data.

Table B.19

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : LARANGAN

M O N T H	O B S E R V E D	
	M E A N *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.4284	1.2056
FEBRUARY	2.5003	1.1320
MARCH	2.3555	1.1470
APRIL	2.2482	1.0863
MAY	2.1500	1.0922
JUNE	1.8179	1.2322
JULY	2.0818	1.2414
AUGUST	2.2312	1.1743
SEPTEMBER	2.0784	1.0831
OCTOBER	2.1554	1.0489
NOVEMBER	2.3921	1.0623
DECEMBER	2.4347	1.1412

*) The mean and the standard deviation from transformed rainfall depth data.

Table B.20

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : PANGKAH

MONTH	OBSERVED	
	MEAN *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.5953	1.0791
FEBRUARY	2.6500	1.0479
MARCH	2.4871	1.0172
APRIL	2.3123	1.0438
MAY	2.1914	1.0407
JUNE	2.2441	1.0956
JULY	2.3060	1.0652
AUGUST	2.5266	1.0672
SEPTEMBER	2.0589	0.9202
OCTOBER	2.3021	1.0023
NOVEMBER	2.1970	1.0846
DECEMBER	2.4319	1.0381

*) The mean and the standard deviation from transformed rainfall depth data.

Table B.21

PARAMETERS OF THE DAILY RAINFALL MODEL

STATION : BUMIJAWA

M O N T H	O B S E R V E D	
	M E A N *) (log. mm)	STANDARD DEVIATION *) (log. mm)
JANUARY	2.8903	1.2120
FEBRUARY	2.7343	1.2181
MARCH	2.7188	1.1747
APRIL	2.3777	1.1077
MAY	2.3441	1.1456
JUNE	2.2670	1.1086
JULY	2.1154	1.1172
AUGUST	2.1791	1.1092
SEPTEMBER	2.0577	1.0609
OCTOBER	2.1255	0.9937
NOVEMBER	2.2623	1.1550
DECEMBER	2.5078	1.1997

*) The mean and the standard deviation from transformed rainfall depth data.

APPENDIX C
SCATTER DIAGRAMS

FIG. C. 1 THE FIRST THREE DAYS RAINFALL.

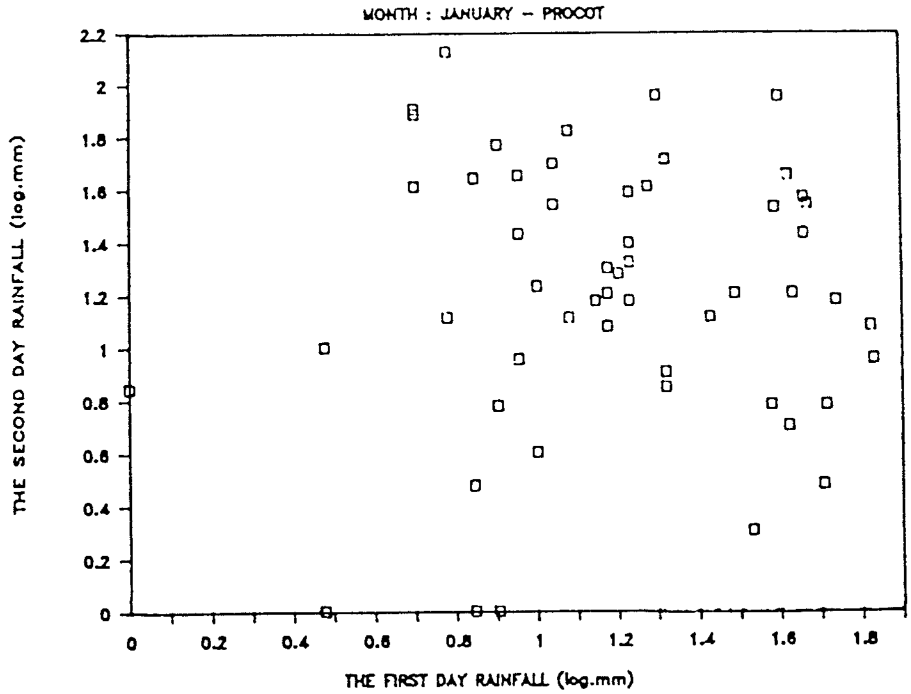


FIG. C. 2. THE FIRST THREE DAYS RAINFALL.

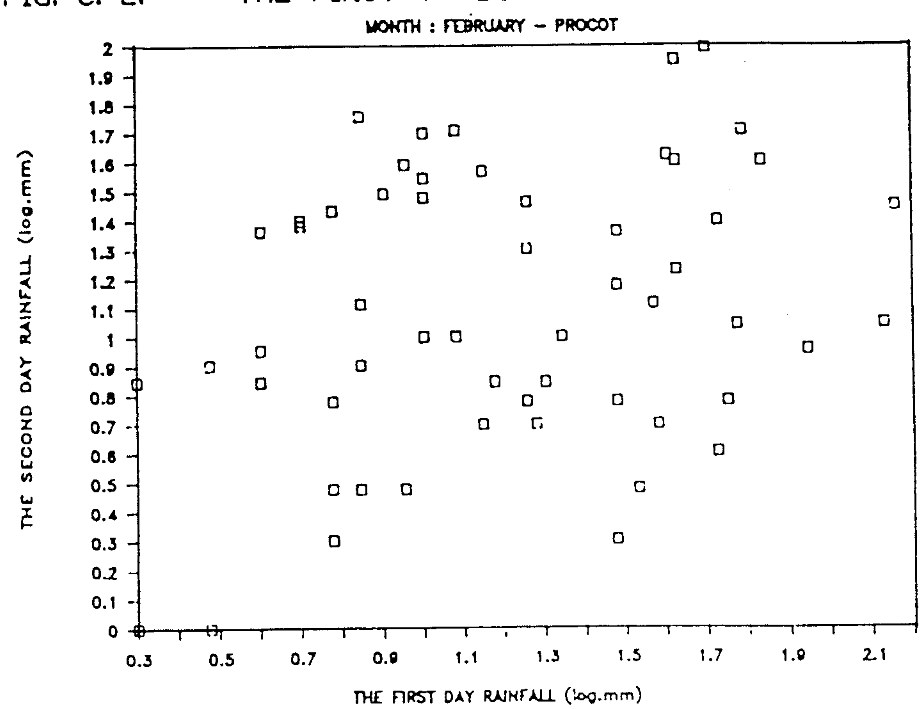


FIG. C. 3. THE FIRST THREE DAYS RAINFALL.

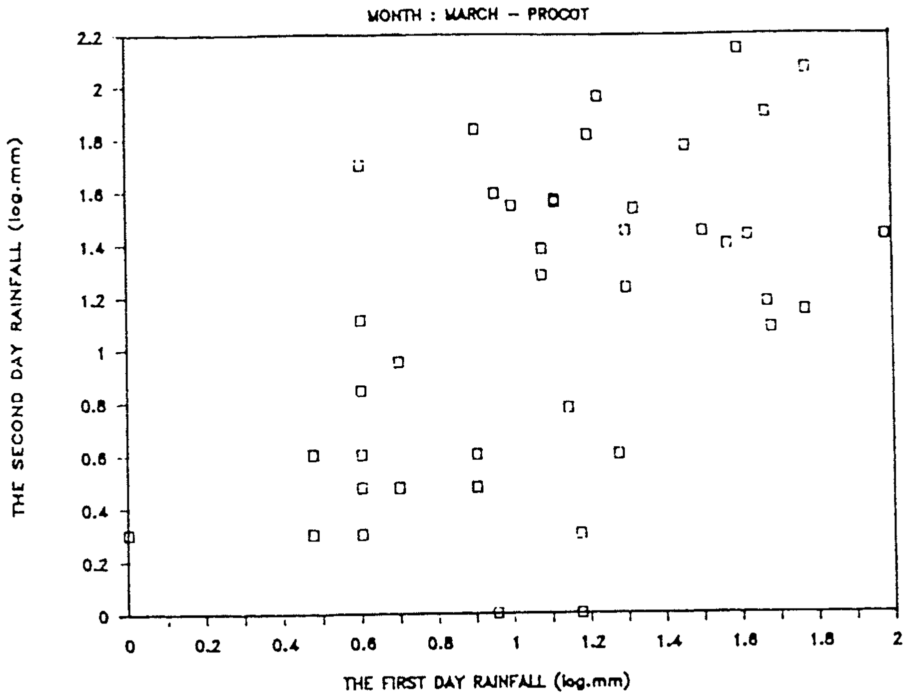


FIG. C. 4. THE FIRST THREE DAYS RAINFALL.

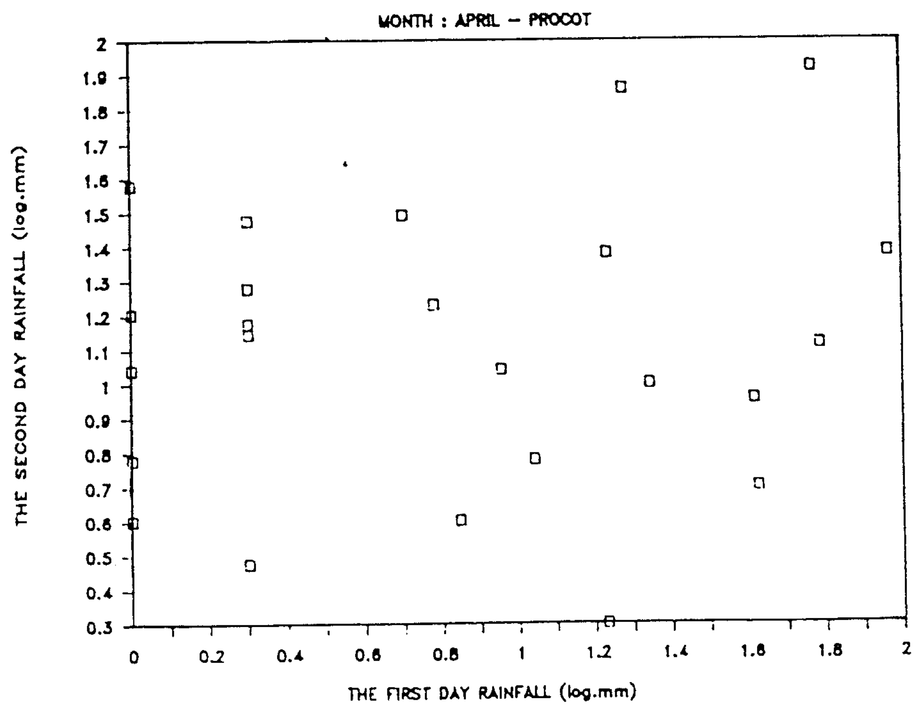


FIG. C. 5. THE FIRST THREE DAYS RAINFALL.

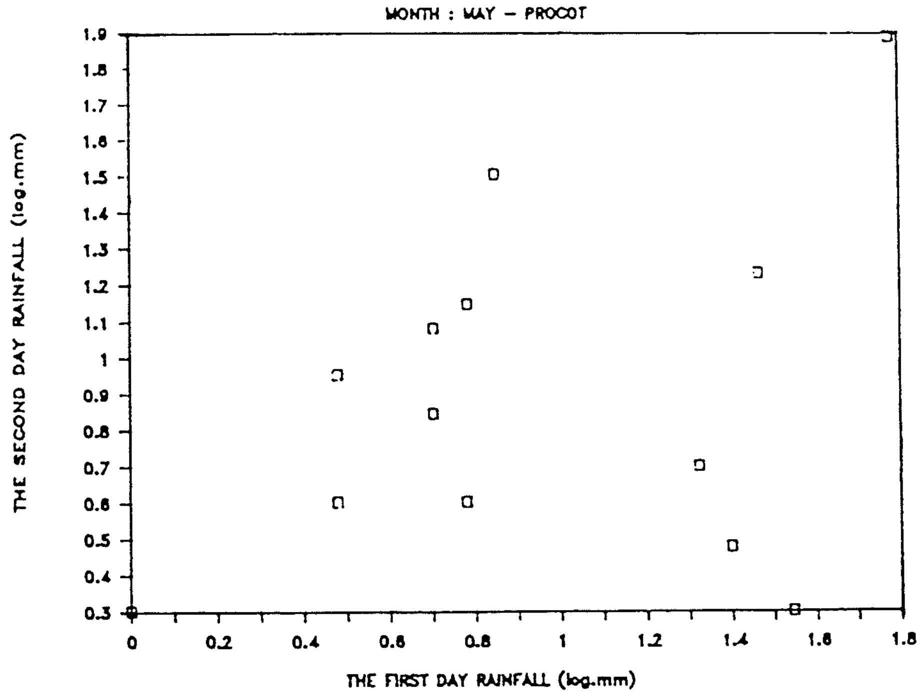


FIG. C. 6. THE FIRST THREE DAYS RAINFALL.

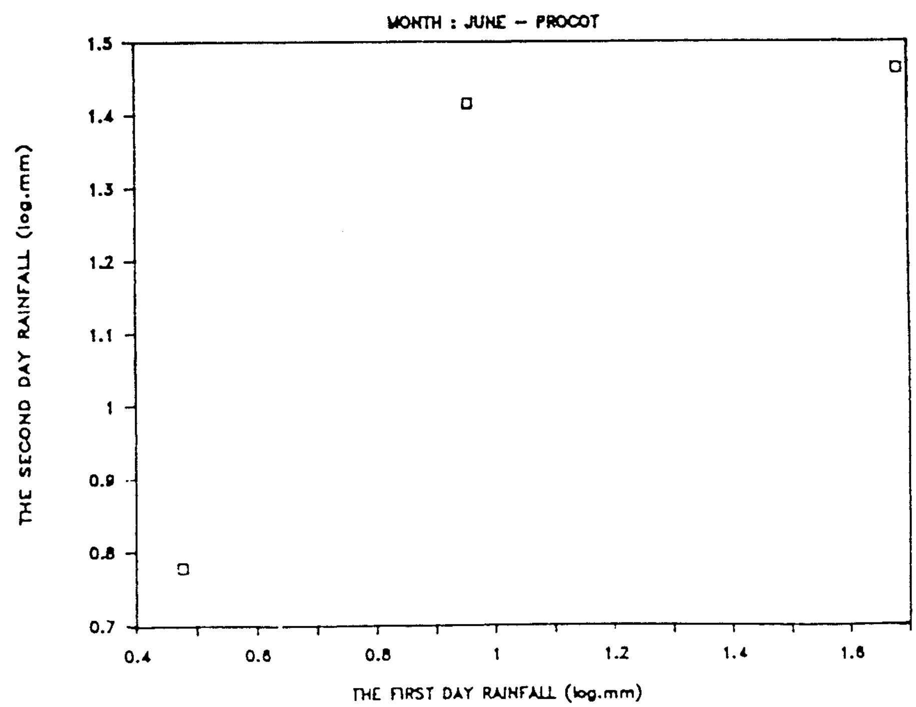


FIG. C. 7. THE FIRST THREE DAYS RAINFALL.

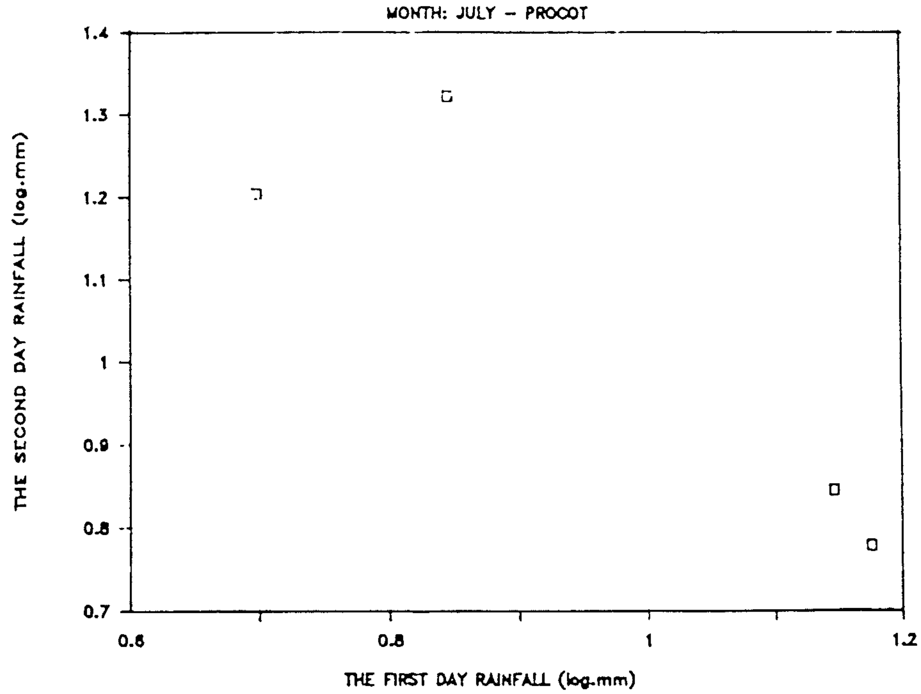


FIG. C. 8. THE FIRST THREE DAYS RAINFALL

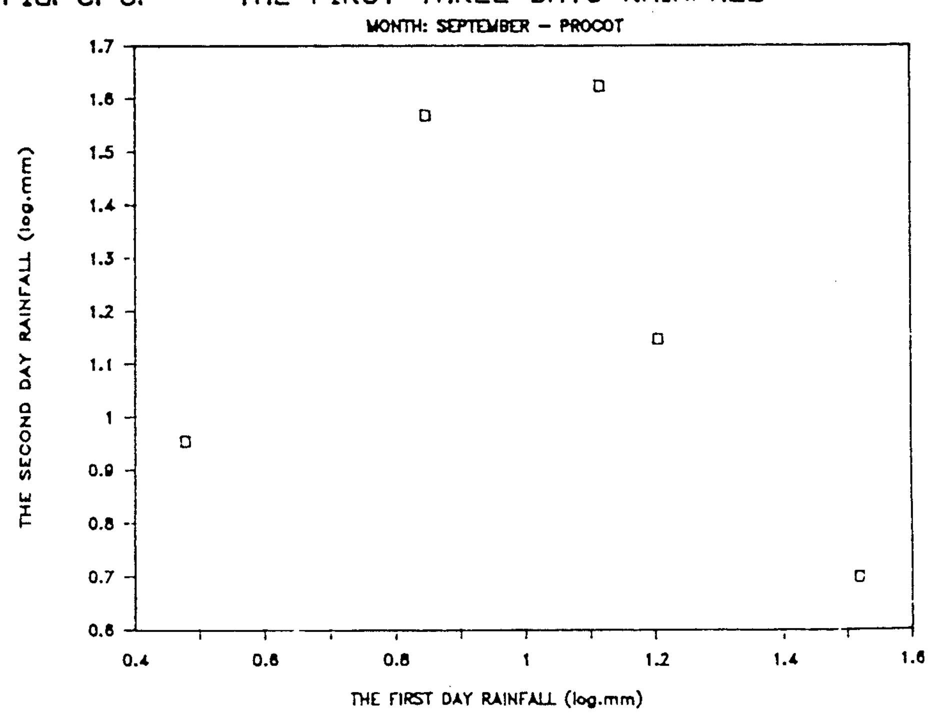


FIG. C. 9. THE FIRST THREE DAYS RAINFALL.

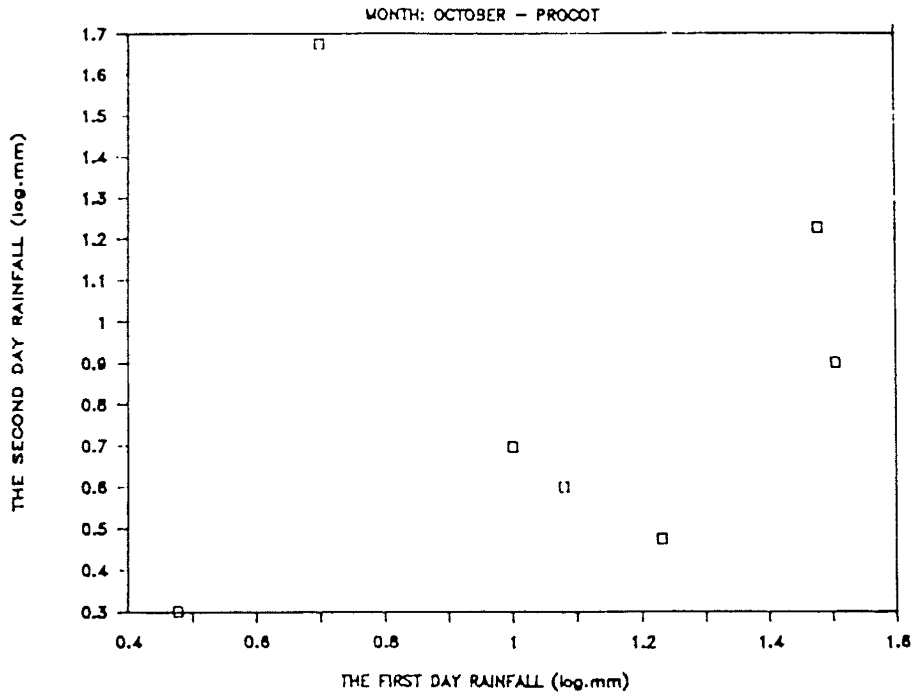


FIG. C. 10. THE FIRST THREE DAYS RAINFALL.

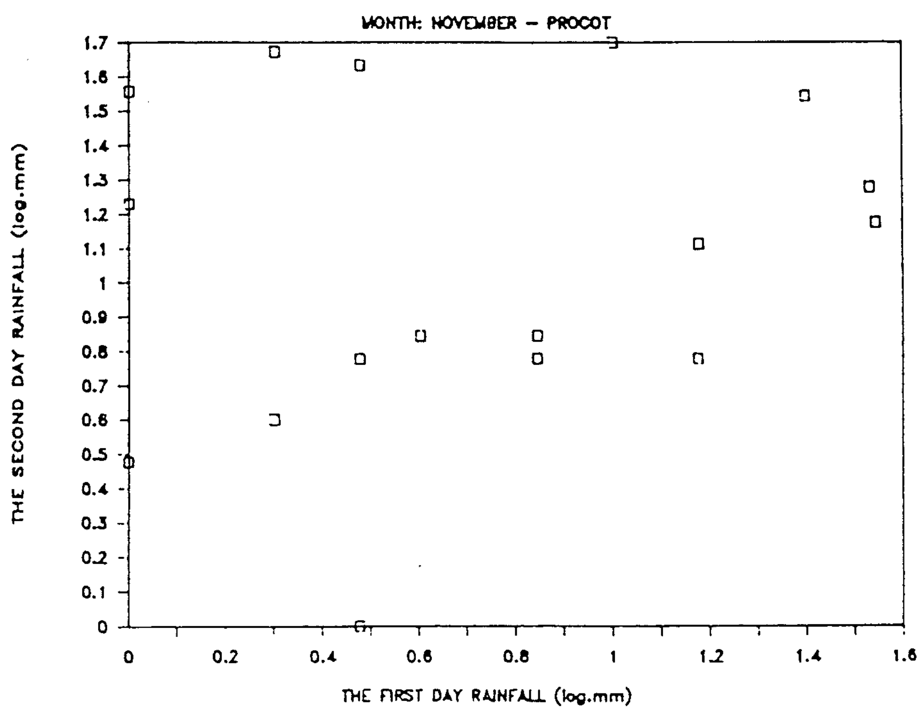


FIG. C. 11. THE FIRST THREE DAYS RAINFALL.

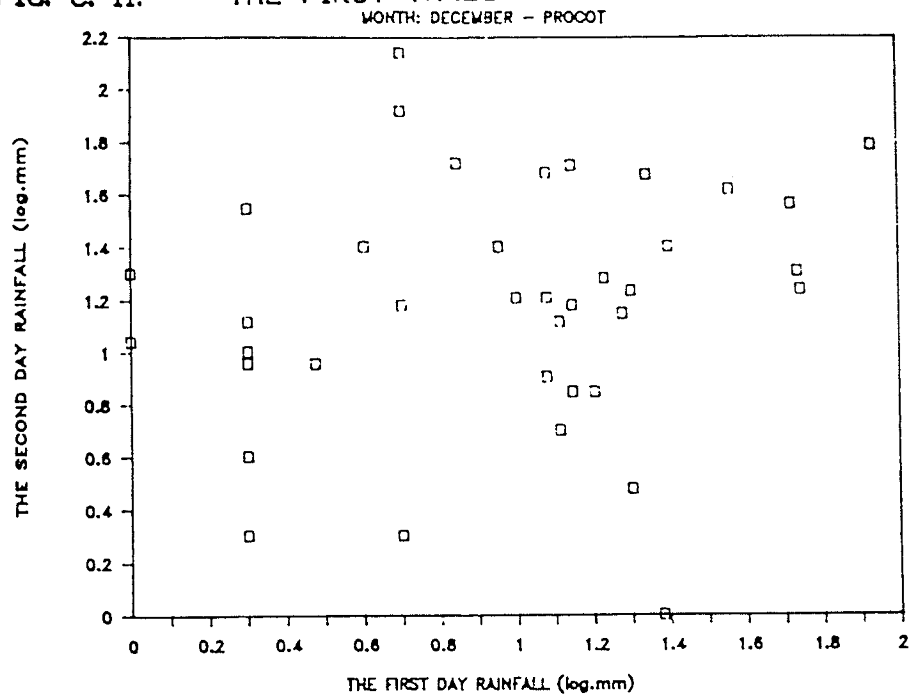


FIG. C. 12. THE FIRST THREE DAYS RAINFALL.

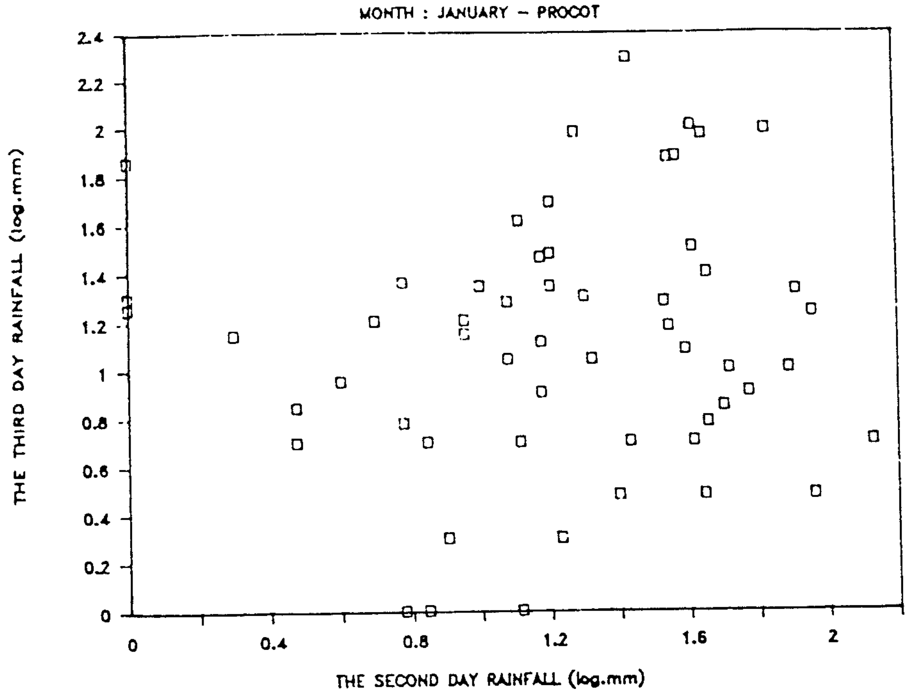


FIG. C. 13. THE FIRST THREE DAYS RAINFALL.

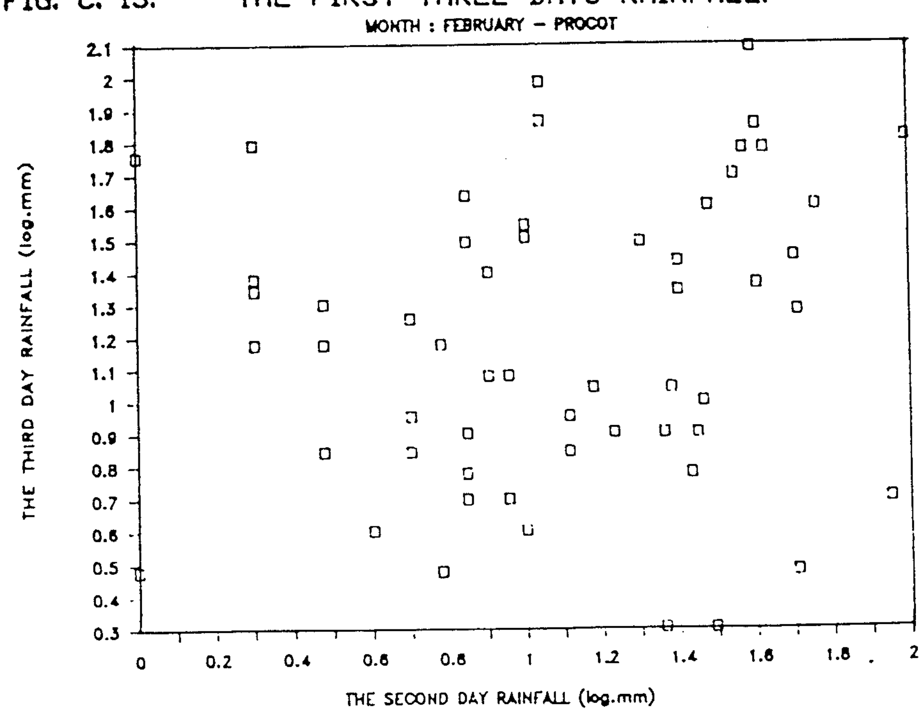


FIG. C. 14. THE FIRST THREE DAYS RAINFALL.

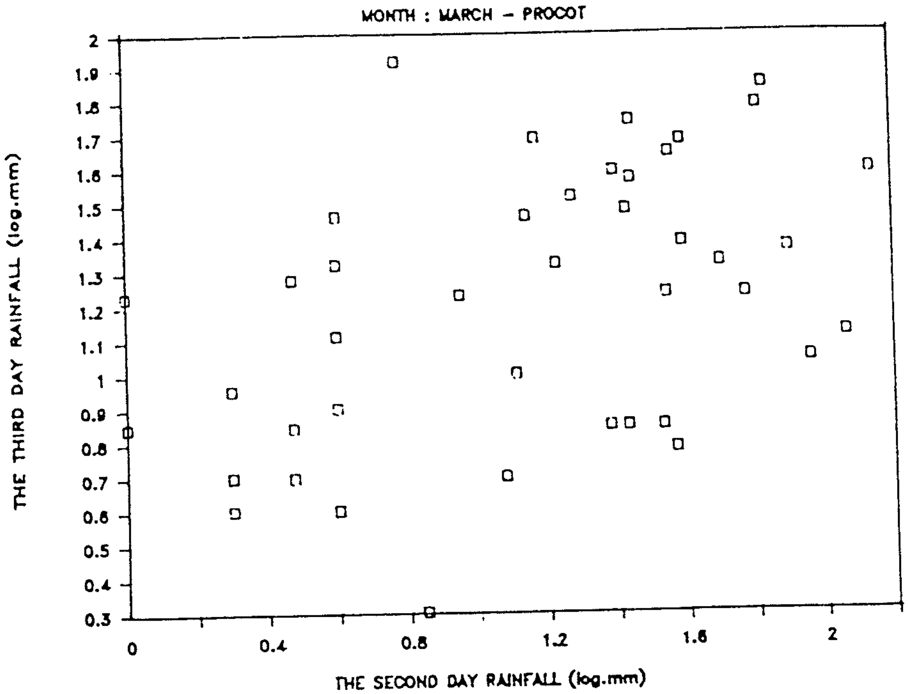


FIG. C. 15. THE FIRST THREE DAYS RAINFALL.

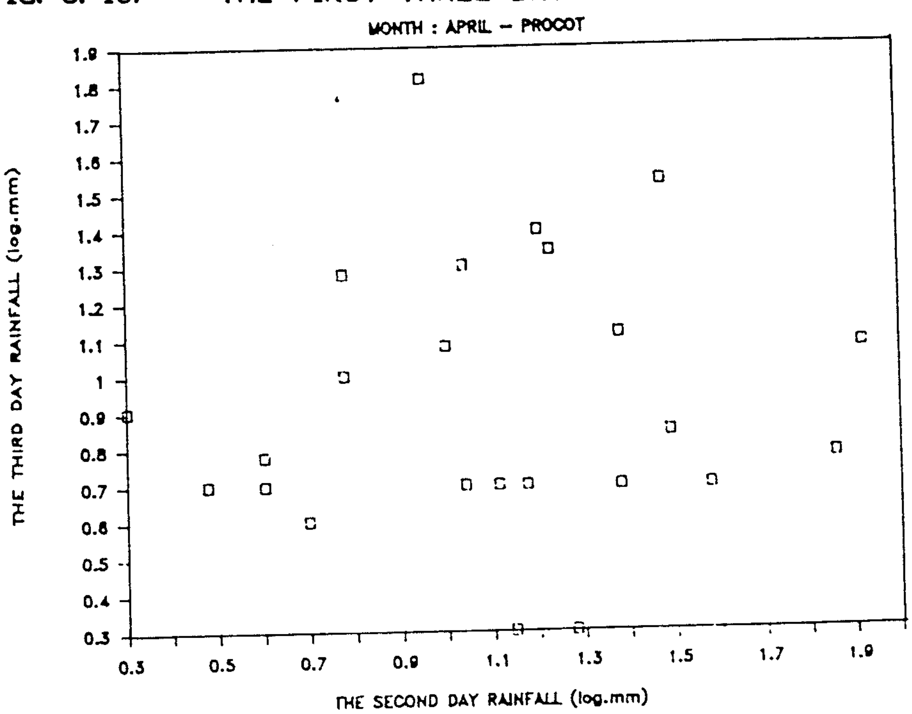


FIG. C. 16. THE FIRST THREE DAYS RAINFALL.

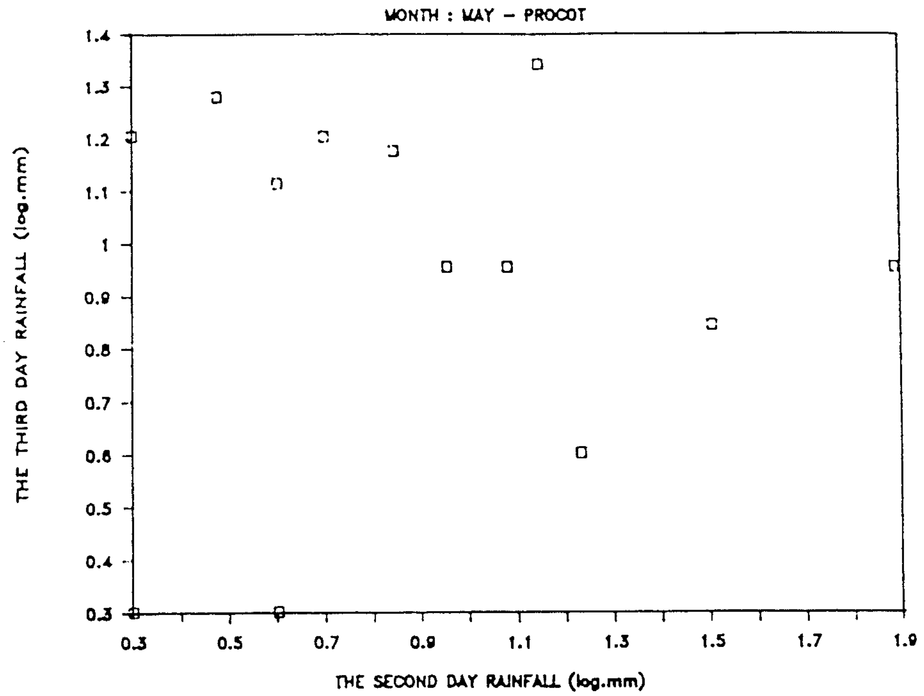


FIG. C. 17. THE FIRST THREE DAYS RAINFALL.

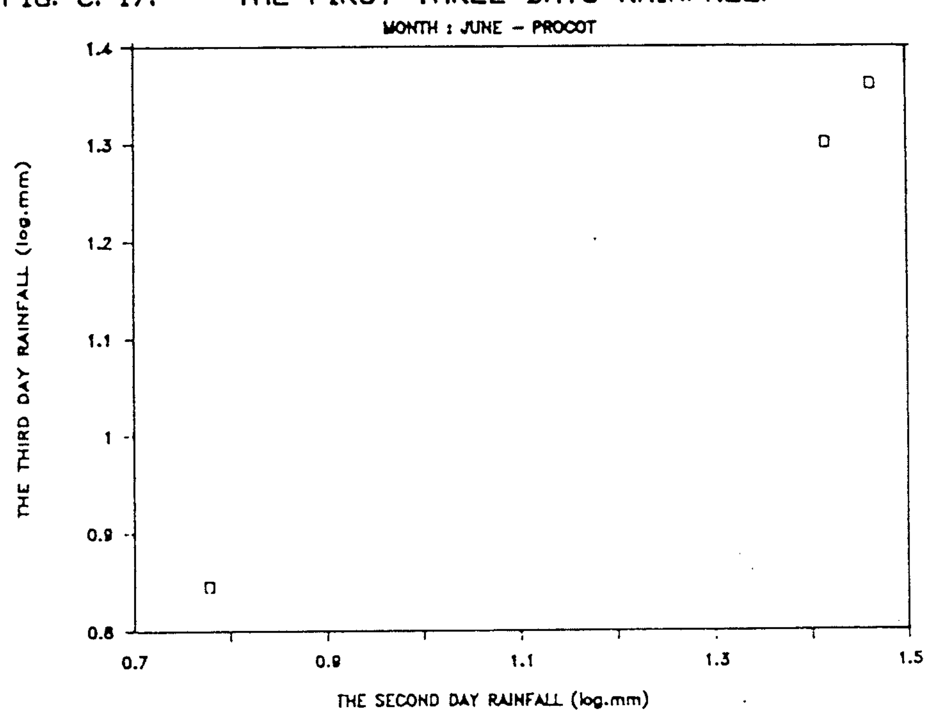


FIG. C. 18. THE FIRST THREE DAYS RAINFALL.

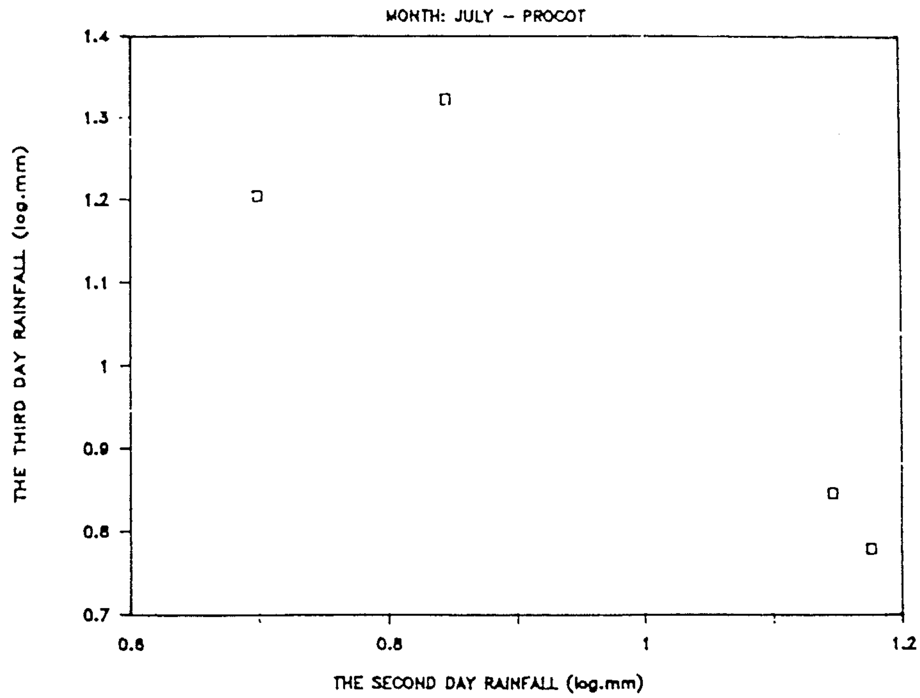


FIG. C. 19. THE FIRST THREE DAYS RAINFALL.

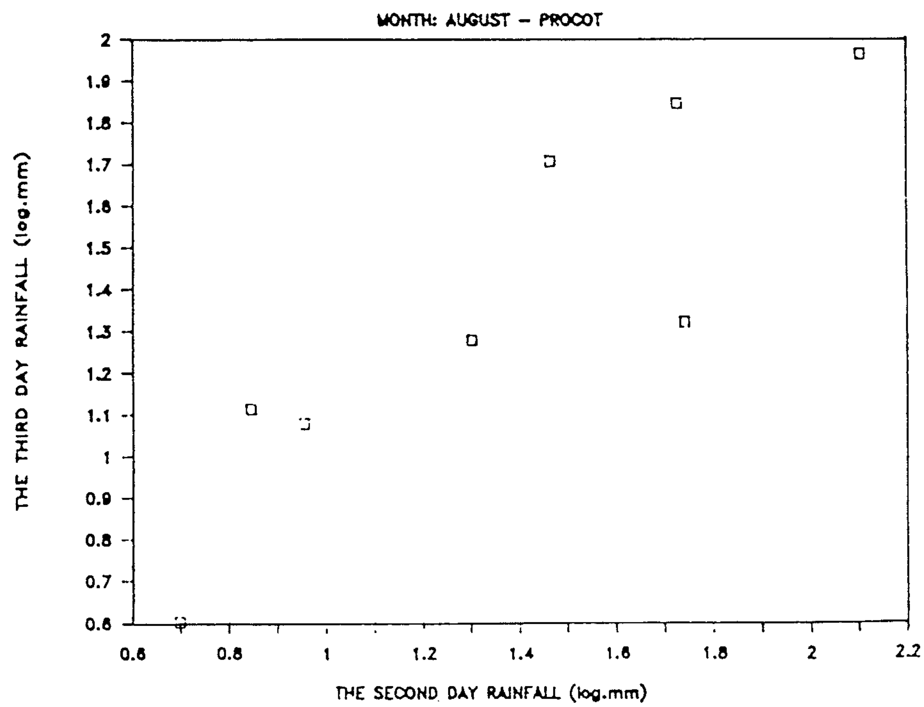


FIG. C. 20. THE FIRST THREE DAYS RAINFALL.

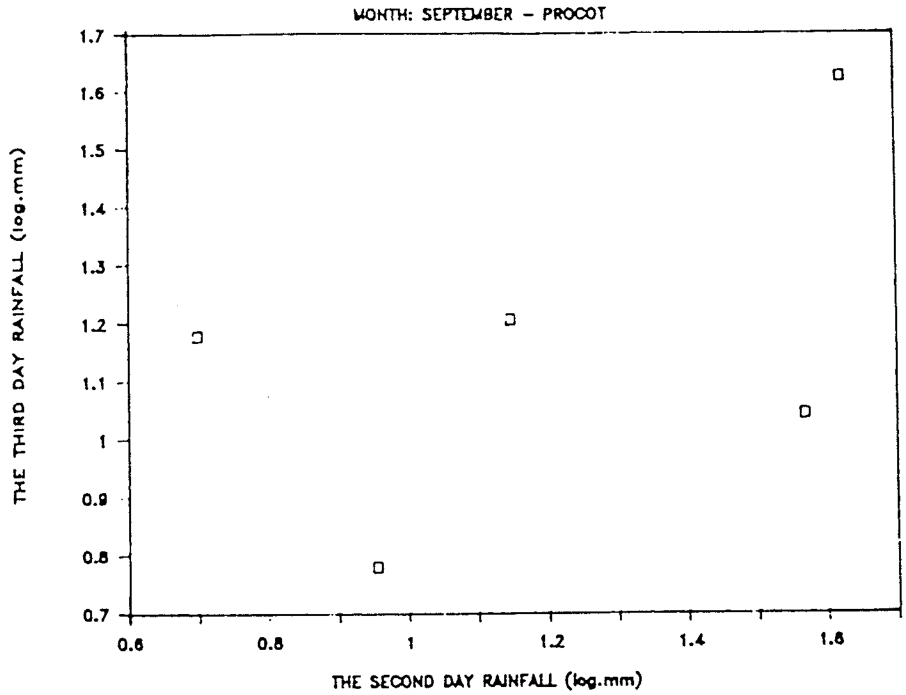


FIG. C. 21. THE FIRST THREE DAYS RAINFALL.

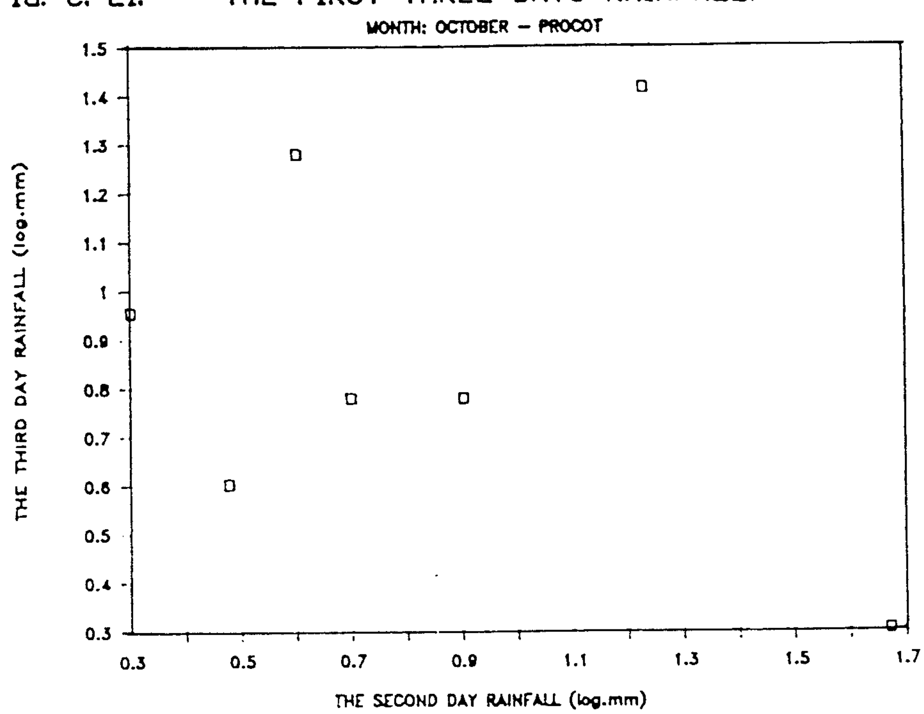


FIG. C. 22. THE FIRST THREE DAYS RAINFALL.

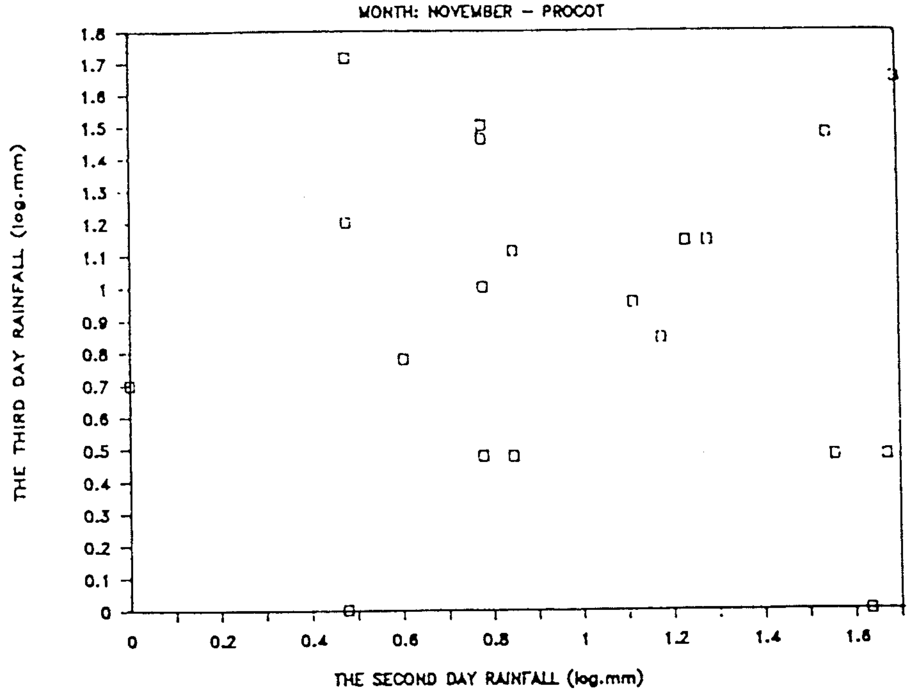


FIG. C. 23. THE FIRST THREE DAYS RAINFALL.

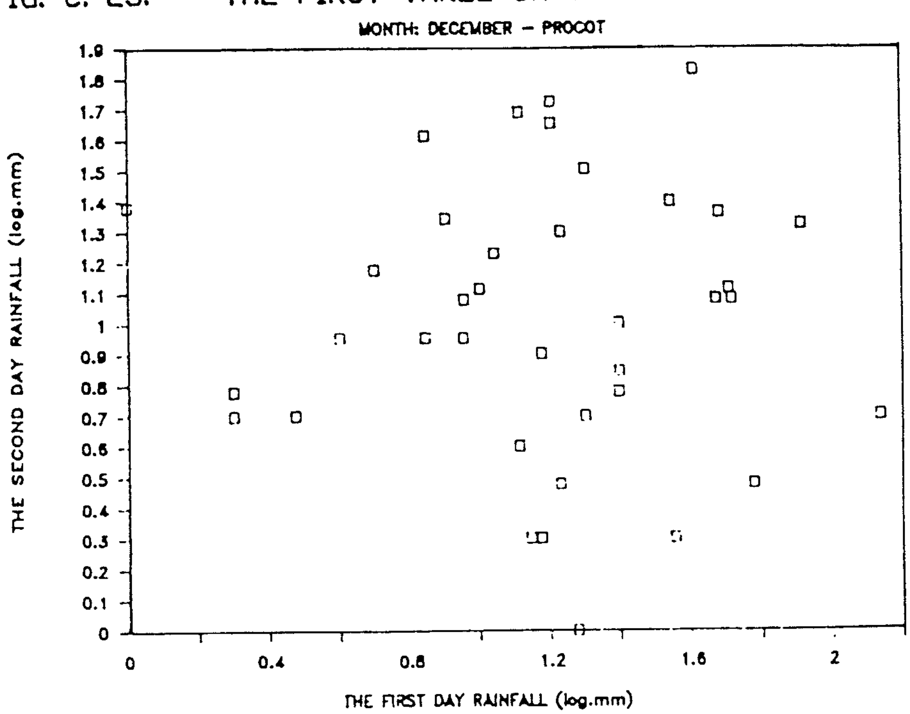


FIG. C.24. THE FIRST TWO DAYS RAINFALL.

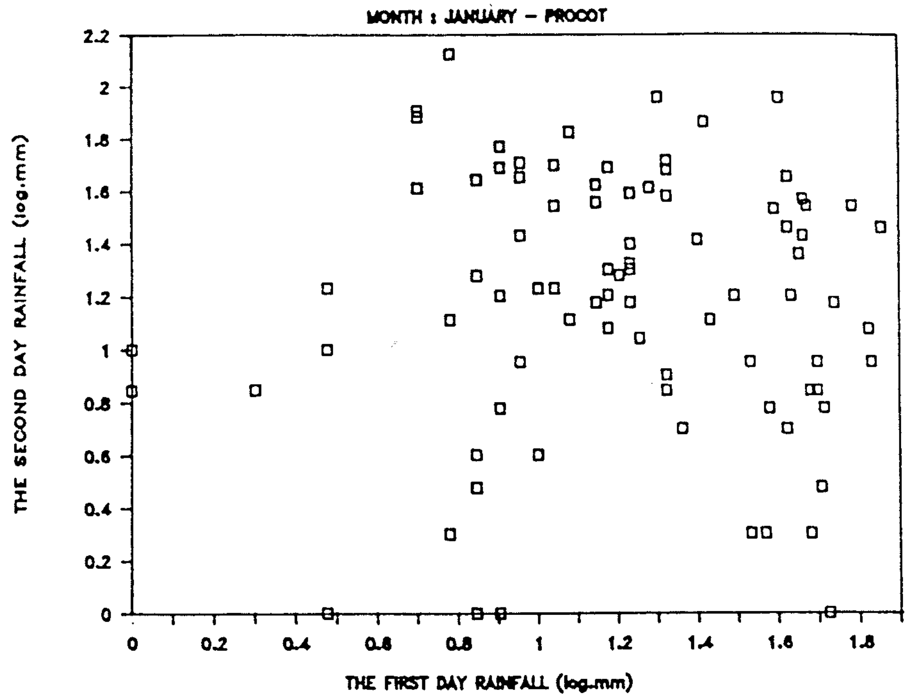


FIG. C.25. THE FIRST TWO DAYS RAINFALL.

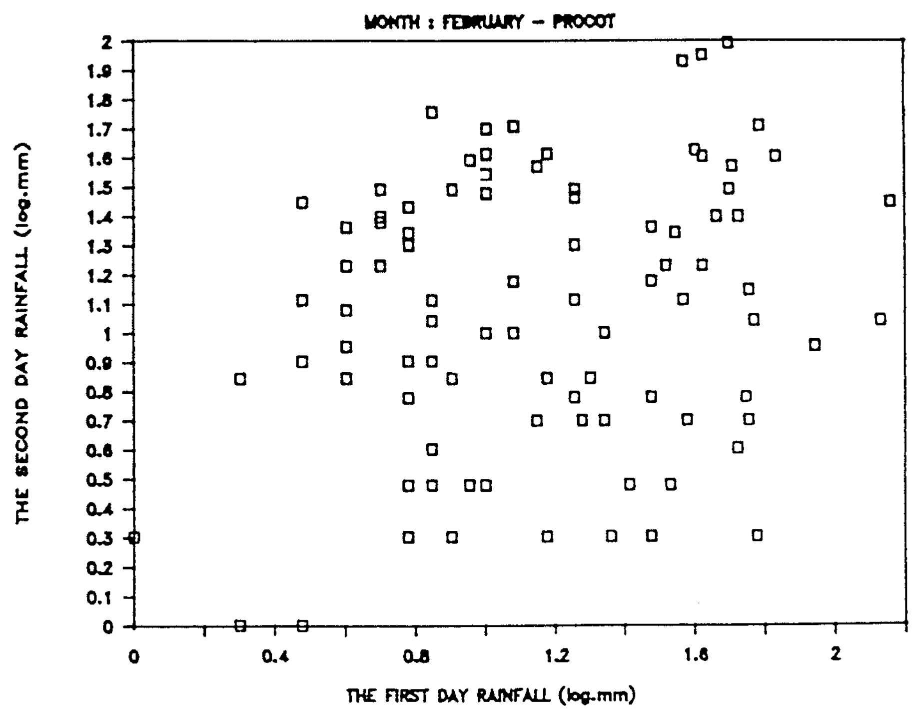


FIG. C.26. THE FIRST TWO DAYS RAINFALL.

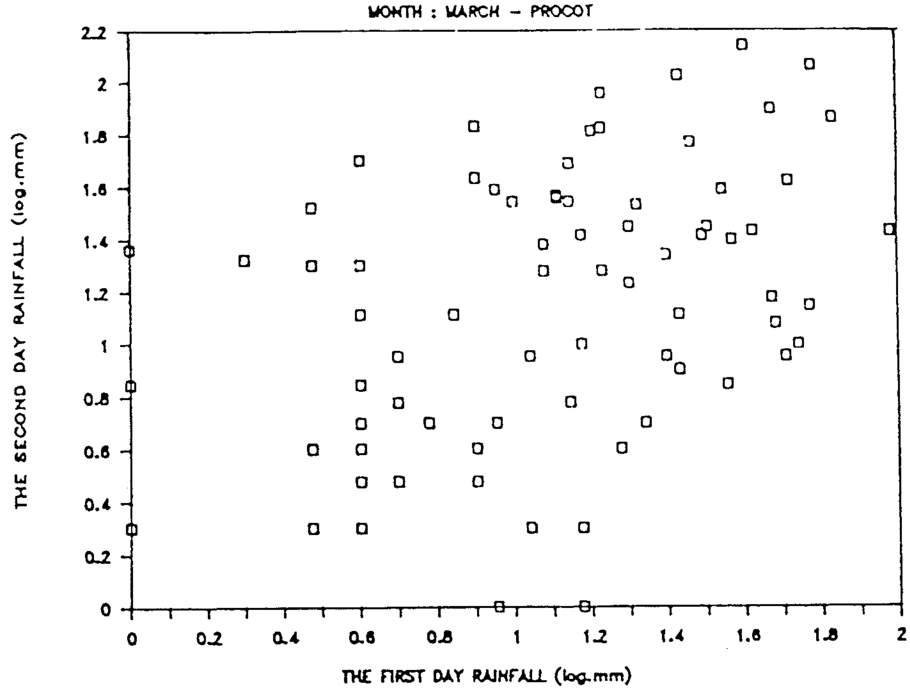


FIG. C.27. THE FIRST TWO DAYS RAINFALL.

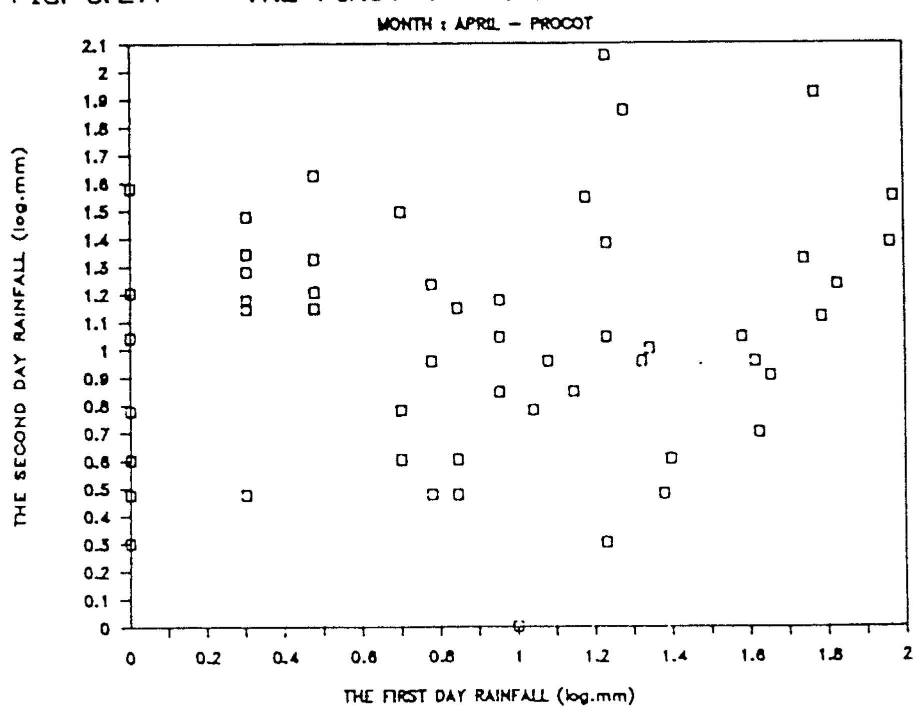


FIG. C.28. THE FIRST TWO DAYS RAINFALL.

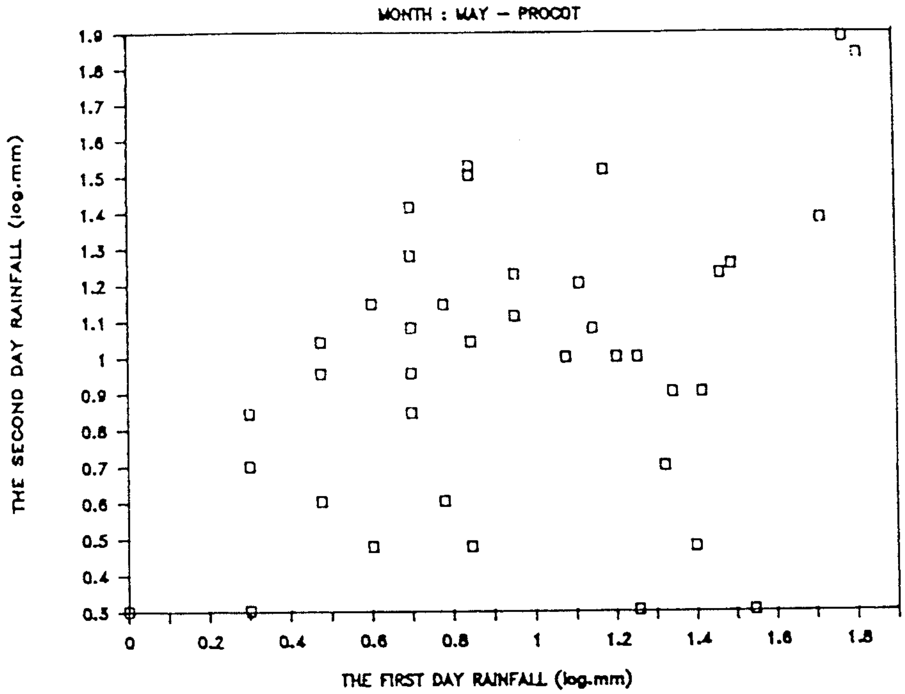


FIG. C.29. THE FIRST TWO DAYS RAINFALL.

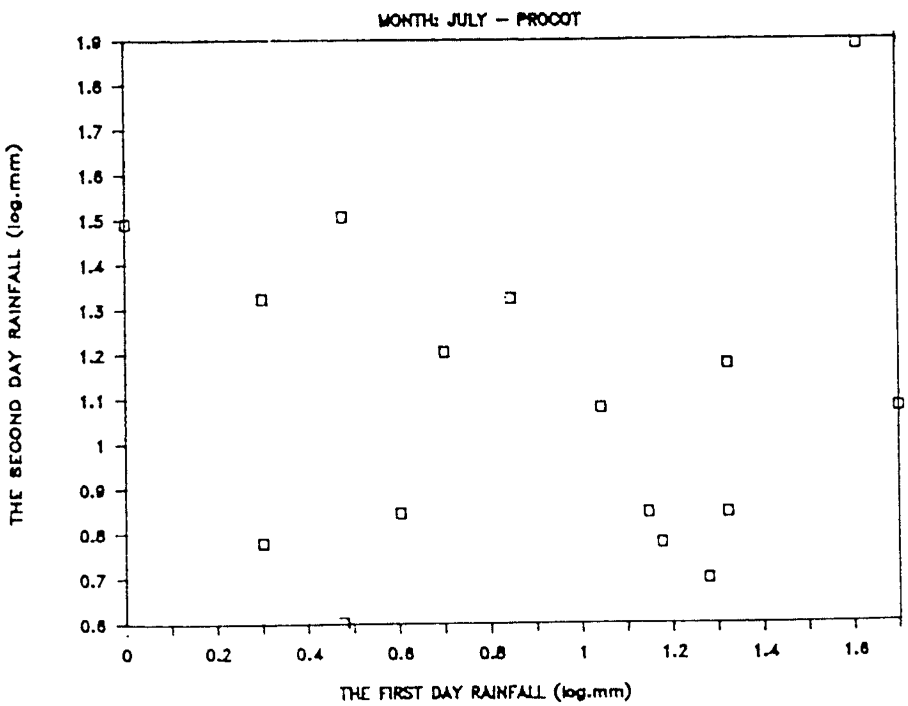


FIG. C. 30. THE FIRST TWO DAYS RAINFALL.

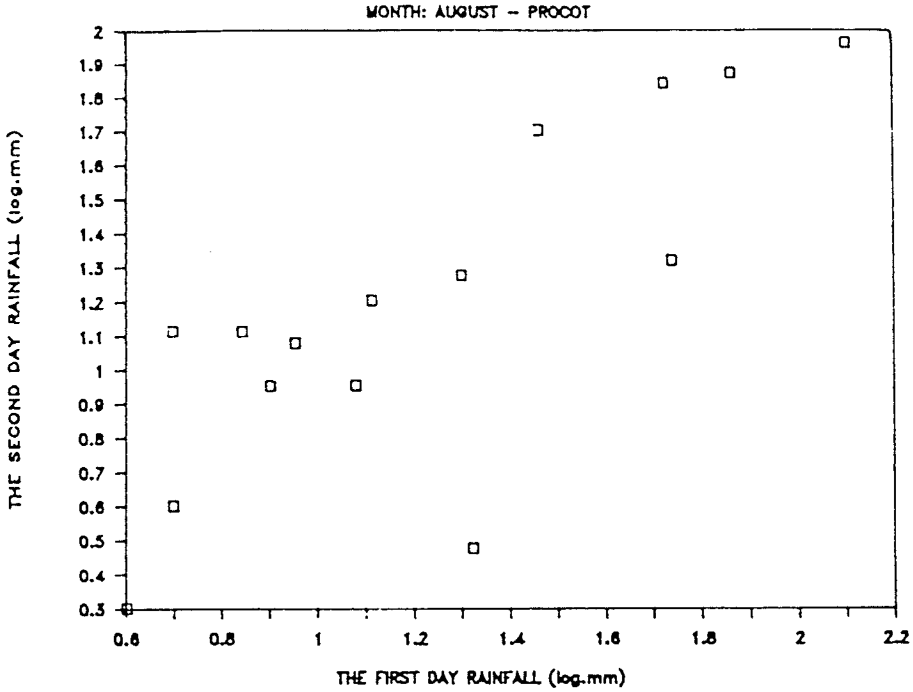


FIG. C.31. THE FIRST TWO DAYS RAINFALL.

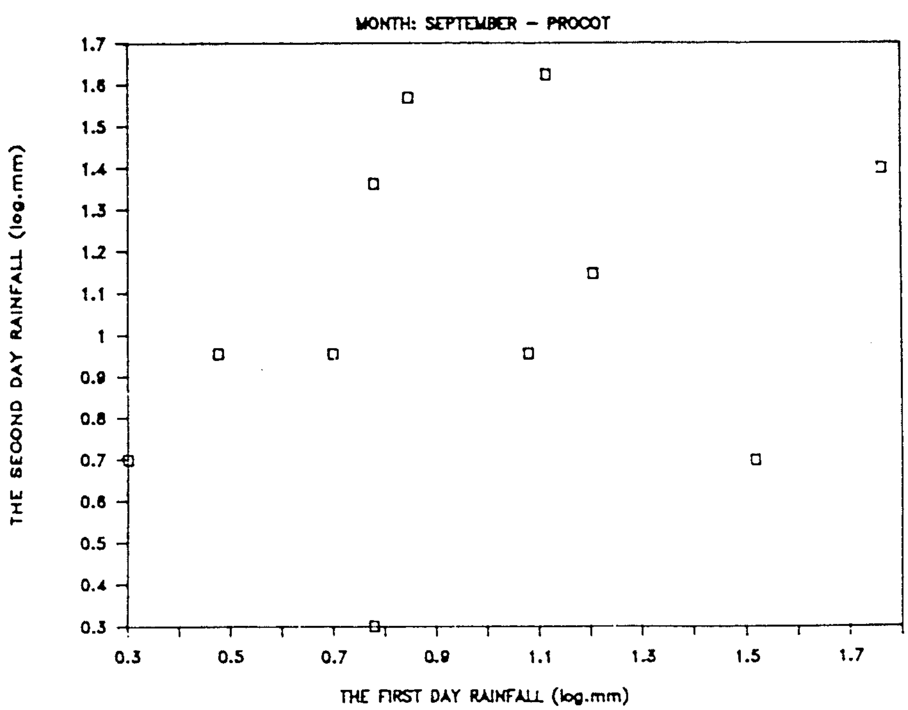


FIG. C.32. THE FIRST TWO DAYS RAINFALL.

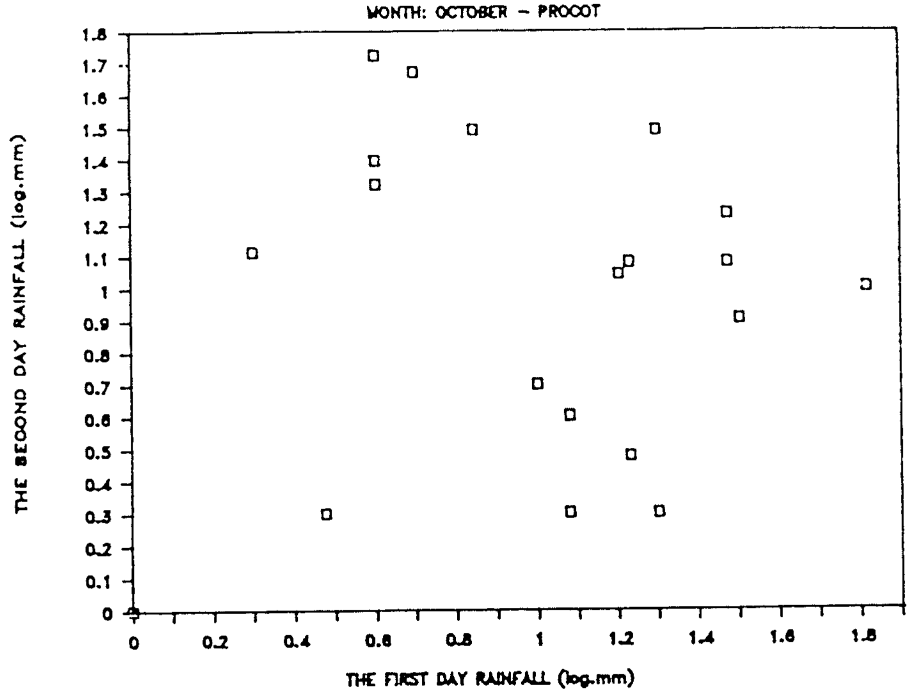


FIG. C.33. THE FIRST TWO DAYS RAINFALL.

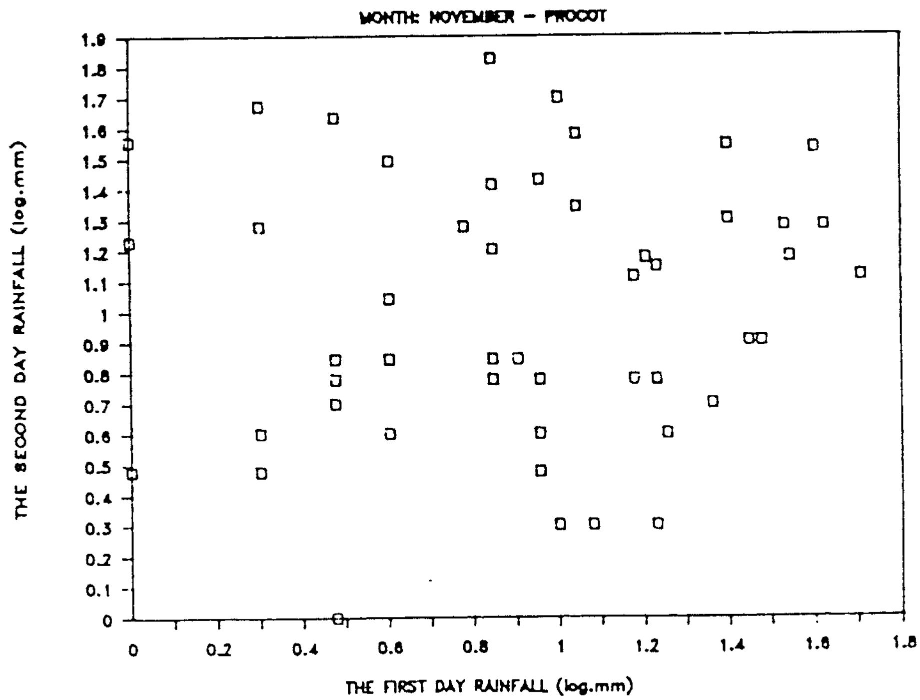
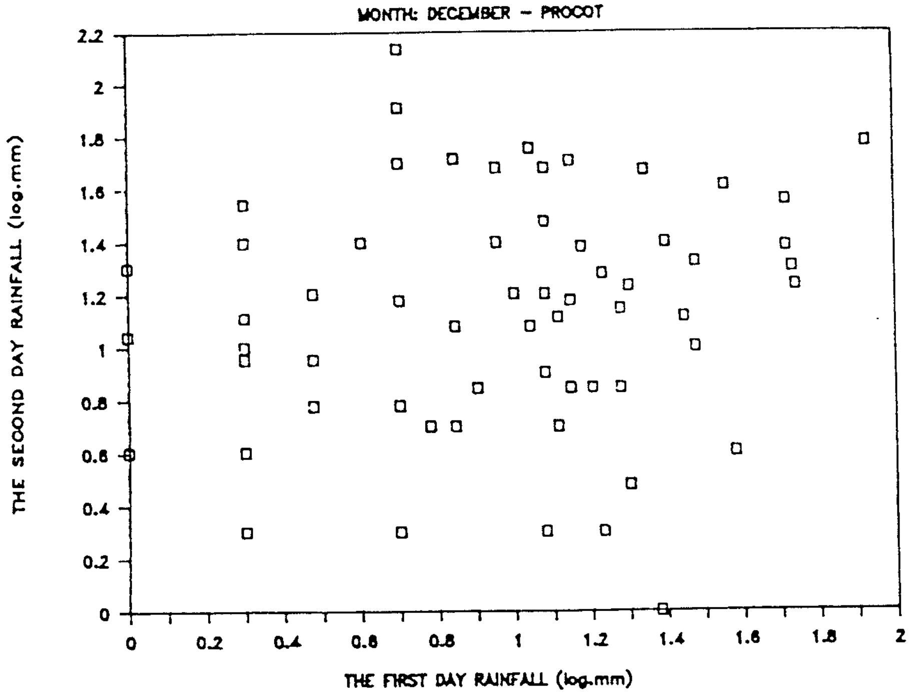


FIG. C.34. THE FIRST TWO DAYS RAINFALL.



APPENDIX D

METHODS OF NORMALITY TEST

APPENDIX D

METHOD OF THE NORMALITY TEST

D.1. The plotting of rainfall record.

Usually, plotting the data in normal probability paper is used to test the normality. In this study the plotting position is not done in the normal probability paper, but using graph lotus 123. Therefore, the theoretical probability for each datum is required for plotting the theoritical value of normal curve and it only can be calculated using Polynomial and Rational Approximation. The polynomial formula is taken from Hand Book of Statistic as follow :

$$P(x) = 1 - Z(x)\,(a_1 t_1 + a_2 t_2 + a_3 t_3 + e(X)$$

$$= |\,e(X)\,| < 1 * 10^{-5}$$

where :

$$t = \frac{1}{1 + px}$$

$$Z(x) = \frac{1}{(2)\text{\^{}}0.5}\ \mathrm{Exp}\,(-x^2/2)$$

$$p = 0.33267$$

$$a_1 = 0.4361836$$

a_2 = - 0.1201676

a_3 = 0.9372980

The data are plotted in this graph using Weibull formula (Mc.Cuen, 1986):

$$Pp = \frac{i}{n + 1}$$

where: - i = the rank number.

- Pp = the estimate plotting position.
- n = the sample size.

The plotting data of station Procot shown in figure D.1 to D.12.

D.2. The test of skewness.

The skewness test of normality is also used for normalizing test, because the skewness coefficient for a normal distribution is zero. An approximation unbiased estimate of skewness coefficient (Cs) is determined by (Salas, Delleur, Yevjevich and Lane. 1985).

$$Cs = \frac{N \sum_{t=1}^{N} (X_t - X)^3}{(N-1)(N-2)S^3}$$

where :

- $$S^2 = \frac{1}{(N-1)} \sum_{t=1}^{N} (X_t - X)^2$$

- $$X = \frac{1}{N} \sum_{t=1}^{N} X_t$$

- Cs = Coefficient of skewness.
- X = Mean of the sample.
- S^2 = Variance of the sample.

Then if Cs falls within the limit of

$$\pm U_{(1-\alpha/2)} * (6/N)^{0.5}$$

the hypothesis of normality is accepted (Snedecor and Cochran).

Where :

- N = Numbers of sample.
- U (1 - α/2) = The quantile of the standard normal distribution.

The result of skewness are shown in table D.1 to D.10.

D.3. The Kolmogorov - Smirnov test.

Kolmogorov - Smirnov is used to test this plotting data. The objective of the Kolmogorov - Simirnov one sample test is to test the null hypothesis that the cumulative distribution of some specified probability function (Mc.Cuen, 1985). The computation of the Kolmogorov - Smirnov test is a simple calculation, the following general steps are required :

- The test statistic, D max., is the maximum absolute difference between the cumulative function of the sample and the cumulative particular theoretical distribution.
- The value of 0.05 and 0.01 usually is used as the level of significant.
- The critical value, D critic , of the test statistic should be obtained from table or formulation.
- Then if the computed value D max. is greater than D critic, the null hypothesis should be rejected.

The result of Kolmogorov - Smirnov test are shown in table D.11 to D.20.

P A N G K A H

Table D.1. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED)	:	-0.2242	-0.1583	-0.1106	0.0353	0.0784	-0.1410	-0.3041	0.3617	-0.2201	-0.0183	-0.1970	-0.2735
SYNTHETIC	:	-0.0261	-0.0229	0.0910	-0.0219	-0.0255	-0.0070	-0.0179	-0.0432	0.0166	0.0441	-0.0032	0.0259
UPPER BOUND	:	0.2185	0.2329	0.2506	0.2922	0.3290	0.4477	0.4926	0.6723	0.4978	0.4132	0.2927	0.2552
LOWER BOUND	:	-0.2185	-0.2329	0.2506	-0.2922	-0.3290	-0.4477	-0.4926	-0.6723	-0.4978	-0.4132	-0.2927	-0.2552

L A R A N G A N

Table D.2. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED)	:	-0.1315	-0.2013	-0.2421	-0.2040	0.0650	0.3234	0.2418	-0.1305	-0.1223	-0.1455	-0.2990	-0.1830
SYNTHETIC	:	-0.0234	-0.0266	0.0109	-0.0224	-0.0311	0.0274	-0.0379	0.0758	0.0340	-0.0028	0.0193	-0.0098
UPPER BOUND	:	0.2215	0.2337	0.2368	0.2772	0.3132	0.4195	0.4708	0.4801	0.5402	0.3640	0.2849	0.2377
LOWER BOUND	:	-0.2215	-0.2337	-0.2368	-0.2772	-0.3132	-0.4195	-0.4708	-0.4801	-0.5402	-0.3640	-0.2849	-0.2377

T E G A L

Table D.3. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED)	:	-0.4446	-0.3752	-0.3091	-0.1584	-0.0572	0.0179	-0.0245	0.0136	-0.1190	0.0782	-0.1103	-0.3433
SYNTHETIC	:	-0.0311	-0.0280	0.0004	0.0009	0.0149	-0.0125	-0.0133	-0.0216	0.0008	-0.0326	0.0011	0.0107
UPPER BOUND	:	0.2503	0.2527	0.2869	0.3738	0.3856	0.4930	0.5005	0.7003	0.6049	0.5118	0.3844	0.2977
LOWER BOUND	:	-0.2503	-0.2527	-0.2869	-0.3738	-0.3856	-0.4900	-0.5005	-0.7003	-0.6049	-0.5118	-0.3844	-0.2977

P R O C O T — Table D.4. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED)	:	-0.2973	-0.2180	-0.2103	-0.0768	-0.0196	-0.2142	-0.2073	0.0055	-0.1497	-0.1493	-0.2211	-0.2453
SYNTHETIC	:	-0.0284	-0.0235	-0.0229	-0.0319	-0.0282	-0.0083	0.0341	0.0297	0.0304	-0.0062	-0.0441	-0.0297
UPPER BOUND	:	0.2321	0.2392	0.2643	0.3119	0.3578	0.4825	0.5402	0.5738	0.4801	0.4557	0.3145	0.2680
LOWER BOUND	:	-0.2321	-0.2392	-0.2643	-0.3119	-0.3578	-0.4825	-0.5402	-0.5738	-0.4801	-0.4557	-0.3145	-0.2680

B R E B E S — Table D.5. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED)	:	-0.2414	-0.1856	-0.1018	-0.0913	0.1604	-0.1519	0.0744	0.3145	0.0655	0.1159	-0.2534	-0.2370
SYNTHETIC	:	-0.0230	-0.0257	0.0088	-0.0170	-0.0149	-0.0047	-0.0079	-0.0315	0.0200	0.0579	-0.0113	0.0326
UPPER BOUND	:	0.2261	0.2463	0.2450	0.2972	0.3259	0.4087	0.4875	0.6147	0.5238	0.4294	0.3290	0.2440
LOWER BOUND	:	-0.2261	-0.2463	-0.2450	-0.2972	-0.3259	-0.4087	-0.4875	-0.6147	-0.5238	-0.4294	-0.3290	-0.2440

B U M I A Y U — Table D.6. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED)	:	-0.3647	-0.4112	-0.2218	-0.3247	-0.1321	-0.0469	-0.0306	0.1077	-0.2442	-0.1418	-0.2713	-0.3247
SYNTHETIC	:	-0.0261	-0.0200	0.0071	-0.0215	-0.0018	-0.0084	0.0525	0.0557	-0.0439	0.0026	0.0163	-0.0163
UPPER BOUND	:	0.2158	0.2294	0.2273	0.2486	0.3074	0.3946	0.4620	0.5910	0.4087	0.3321	0.2772	0.2486
LOWER BOUND	:	-0.2158	-0.2294	-0.2273	-0.2486	-0.3074	-0.3946	-0.4620	-0.5910	-0.4087	-0.3321	-0.2772	-0.2486

LOSARI

Table D.7. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED) :	-0.2420	-0.2081	-0.2830	-0.1955	-0.1903	-0.2535	0.1626	-0.0664	-0.2582	2.6915	-0.1108	-0.0537
SYNTHETIC :	-0.0239	-0.0300	0.0016	-0.0057	-0.0242	-0.0050	-0.1450	-0.0369	-0.0888	0.0426	-0.0140	0.0328
UPPER BOUND :	0.2392	0.2510	0.2623	0.3139	0.3578	0.4685	0.5780	0.8115	0.6658	0.5147	0.3588	0.2763
LOWER BOUND :	-0.2392	-0.2510	-0.2623	-0.3139	-0.3578	-0.4685	-0.5780	-0.8115	-0.6658	-0.5147	-0.3588	-0.2763

PETUGURAN

Table D.8. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED) :	-0.2486	-0.2222	-0.2925	-0.3441	-0.2717	-0.0394	-0.1254	-0.3123	-0.1560	-0.3763	-0.3219	-0.4597
SYNTHETIC :	-0.0225	-0.0213	-0.0014	-0.0170	0.0383	-0.0363	0.0402	0.0011	-0.0139	-0.0097	-0.0148	-0.0107
UPPER BOUND :	0.2051	0.2236	0.2074	0.2178	0.2513	0.2989	0.3465	0.3907	0.3093	0.2453	0.2147	0.2097
LOWER BOUND :	-0.2051	-0.2236	-0.2074	-0.2178	-0.2513	-0.2989	-0.3465	-0.3907	-0.3093	-0.2453	-0.2147	-0.2097

BANDAR

Table D.9. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED) :	-0.4887	-0.4414	-0.3395	-0.1776	-0.1765	-0.1987	0.0454	-0.1438	0.0121	-0.0729	-0.1116	-0.1931
SYNTHETIC :	-0.0178	-0.0233	-0.0244	-0.0243	-0.0276	-0.0343	-0.0356	-0.0209	-0.0417	-0.0296	-0.0213	-0.0214
UPPER BOUND :	0.1872	0.1965	0.1950	0.2217	0.2523	0.3345	0.3361	0.4043	0.3194	0.2781	0.2315	0.2057
LOWER BOUND :	-0.1872	-0.1965	-0.1950	-0.2217	-0.2523	-0.3345	-0.3361	-0.4043	-0.3194	-0.2781	-0.2315	-0.2057

B U M I J A W A

Table D.10. SUMMARY OF COEFFICIENT SKEWNESS RAINFALL

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED)	:	-0.2934	-0.2836	-0.2279	-0.2975	-0.1621	-0.1778	-0.0104	-0.0068	-0.0973	-0.2267	-0.1005	-0.2014
SYNTHETIC	:	-0.0159	-0.0181	-0.0203	-0.0201	-0.0300	-0.0322	-0.0296	-0.0234	-0.0372	-0.0327	-0.0192	-0.0257
UPPER BOUND	:	0.1834	0.1085	0.1899	0.2114	0.2431	0.3036	0.3539	0.3907	0.3329	0.2585	0.2114	0.2089
LOWER BOUND	:	-0.1834	-0.1085	-0.1899	-0.2114	-0.2431	-0.3036	-0.3539	-0.3907	-0.3329	-0.2585	-0.2114	-0.2089

Table D.11

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : PROCOT

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	6.574	4.797	-	-
FEBRUARY	6.775	3.739	-	-
MARCH	7.487	5.142	-	-
APRIL	8.834	4.931	-	-
MAY	10.137	5.479	-	-
JUNE	13.669	10.504	-	-
JULY	15.301	7.937	-	-
AUGUST	16.225	7.806	-	-
SEPTEMBER	16.140	7.504	-	-
OCTOBER	12.909	7.734	-	-
NOVEMBER	8.910	6.636	-	-
DECEMBER	7.591	6.196	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.12

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : PANGKAH

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	6.188	5.392	-	-
FEBRUARY	6.597	5.754	-	-
MARCH	7.099	5.352	-	-
APRIL	8.277	7.925	-	-
MAY	9.319	7.818	-	-
JUNE	12.682	9.580	-	-
JULY	13.956	7.292	-	-
AUGUST	19.004	11.878	-	-
SEPTEMBER	14.103	7.383	-	-
OCTOBER	11.705	6.635	-	-
NOVEMBER	8.292	6.276	-	-
DECEMBER	7.228	4.557	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.13

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : LOSARI

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	6.775	4.466	-	-
FEBRUARY	7.109	4.626	-	-
MARCH	7.430	4.774	-	-
APRIL	8.891	5.189	-	-
MAY	10.137	6.843	-	-
JUNE	13.272	7.480	-	-
JULY	16.372	7.409	-	-
AUGUST	22.988	7.463	-	-
SEPTEMBER	18.860	10.512	-	-
OCTOBER	14.581	9.346	-	-
NOVEMBER	10.165	6.981	-	-
DECEMBER	7.826	5.438	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.14

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : TEGAL

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	7.089	6.842	-	-
FEBRUARY	7.158	6.332	-	-
MARCH	8.128	5.473	-	-
APRIL	10.588	5.642	-	-
MAY	10.924	6.824	-	-
JUNE	13.880	10.859	-	-
JULY	14.179	8.034	-	-
AUGUST	19.838	7.727	-	-
SEPTEMBER	17.134	7.999	-	-
OCTOBER	14.498	6.405	-	-
NOVEMBER	10.889	5.870	-	-
DECEMBER	8.434	7.478	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.15

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : BREBES

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	6.404	7.118	10.547	9.027
FEBRUARY	6.977	6.190	-	-
MARCH	6.940	5.993	-	-
APRIL	8.418	8.503	11.250	9.807
MAY	9.232	7.578	-	-
JUNE	11.557	6.222	-	-
JULY	19.581	8.574	-	-
AUGUST	17.413	11.735	-	-
SEPTEMBER	18.839	10.204	-	-
OCTOBER	12.164	9.537	-	-
NOVEMBER	9.313	7.082	-	-
DECEMBER	6.913	6.962	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.16

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : BUMIAYU

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	6.113	6.361	7.764	5.872
FEBRUARY	6.498	5.740	-	-
MARCH	6.440	5.671	-	-
APRIL	7.042	5.929	-	-
MAY	8.707	5.927	-	-
JUNE	11.179	6.695	-	-
JULY	13.087	7.017	-	-
AUGUST	16.740	10.318	-	-
SEPTEMBER	11.577	6.810	-	-
OCTOBER	9.407	7.878	-	-
NOVEMBER	7.852	5.578	-	-
DECEMBER	7.042	5.929	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.17

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : LARANGAN

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	6.273	5.902	-	-
FEBRUARY	6.620	6.876	10.220	8.921
MARCH	6.708	6.508	10.140	7.783
APRIL	7.852	6.054	-	-
MAY	8.872	7.469	-	-
JUNE	11.882	10.962	-	-
JULY	13.336	9.696	-	-
AUGUST	13.600	4.777	-	-
SEPTEMBER	15.301	9.566	-	-
OCTOBER	10.310	5.007	-	-
NOVEMBER	8.070	6.111	-	-
DECEMBER	6.733	5.195	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.18

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : PETUGURAN

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	5.810	5.714	-	-
FEBRUARY	6.334	5.316	-	-
MARCH	5.874	6.374	7.868	6.866
APRIL	6.169	7.389	8.765	7.304
MAY	7.119	5.747	-	-
JUNE	8.467	3.403	-	-
JULY	9.815	7.198	-	-
AUGUST	11.068	7.659	-	-
SEPTEMBER	8.653	4.860	-	-
OCTOBER	6.949	7.005	7.819	6.211
NOVEMBER	6.082	4.173	-	-
DECEMBER	5.913	7.456	8.248	5.634

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.19

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : BANDAR

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	5.302	7.381	8.185	5.488
FEBRUARY	5.566	6.377	8.285	6.475
MARCH	5.525	7.122	9.092	6.296
APRIL	6.280	5.985	-	-
MAY	7.148	7.267	-	-
JUNE	9.478	9.107	-	-
JULY	9.522	10.000	14.578	11.801
AUGUST	11.453	9.091	-	-
SEPTEMBER	9.047	8.631	-	-
OCTOBER	7.878	8.539	11.217	6.211
NOVEMBER	6.559	7.384	11.599	8.616
DECEMBER	5.826	4.763	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

Table D.20

THE RESULT OF KOLMOGOROV - SMIRNOV TEST

STATION : BUMIJAWA

MONTH	D. critic	D. maximum		
		LOGNORMAL	SQUARE TRANS.	CUBE TRANS.
JANUARY	5.196	5.209	-	-
FEBRUARY	5.338	4.588	-	-
MARCH	5.380	4.585	-	-
APRIL	5.987	7.848	8.095	5.949
MAY	6.887	5.129	-	-
JUNE	8.601	5.016	-	-
JULY	10.026	6.322	-	-
AUGUST	11.068	6.908	-	-
SEPTEMBER	9.430	6.052	-	-
OCTOBER	7.322	6.215	-	-
NOVEMBER	5.987	6.690	9.654	8.757
DECEMBER	5.919	5.412	-	-

NOTE :

- Square Trans = Square Transformation.
- Cube Trans = Cube Transformation.

FIG. D. 1. STATION : PROCOT

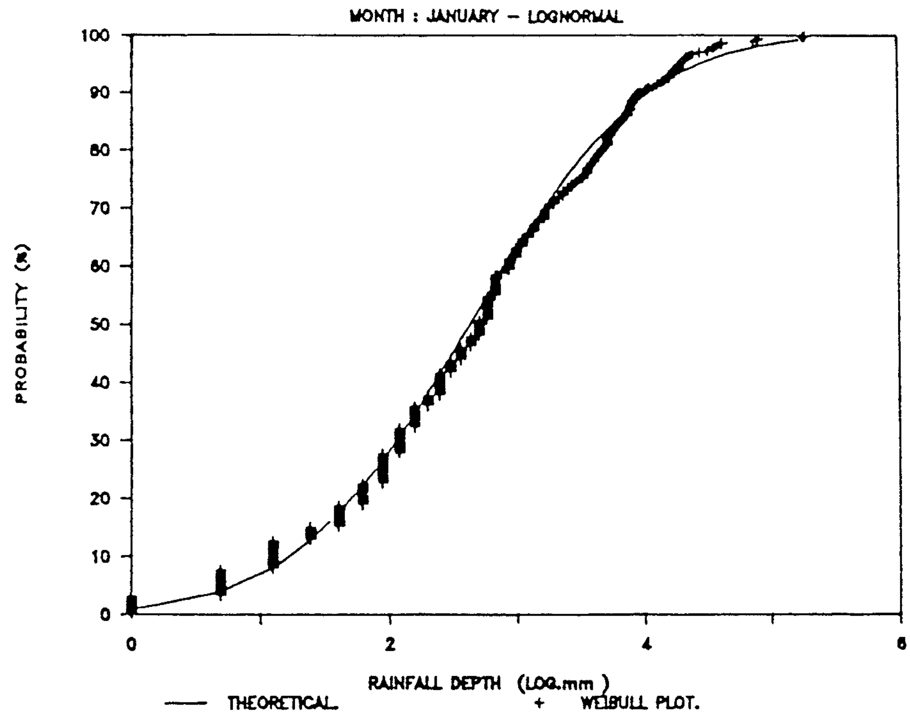


FIG. D. 2. STATION : PROCOT

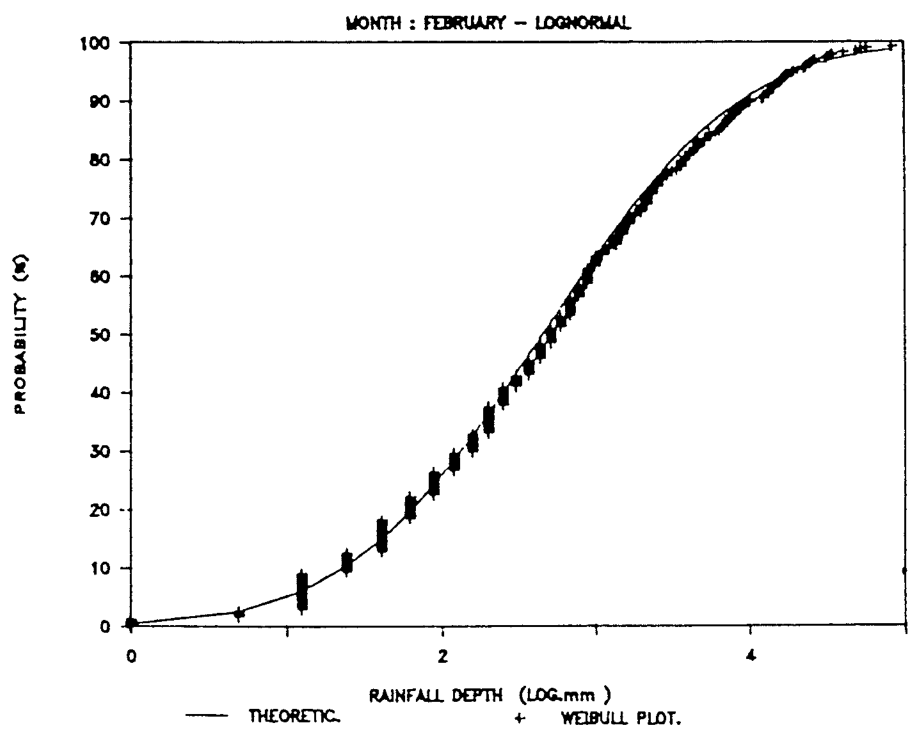


FIG. D. 3. STATION : PROCOT

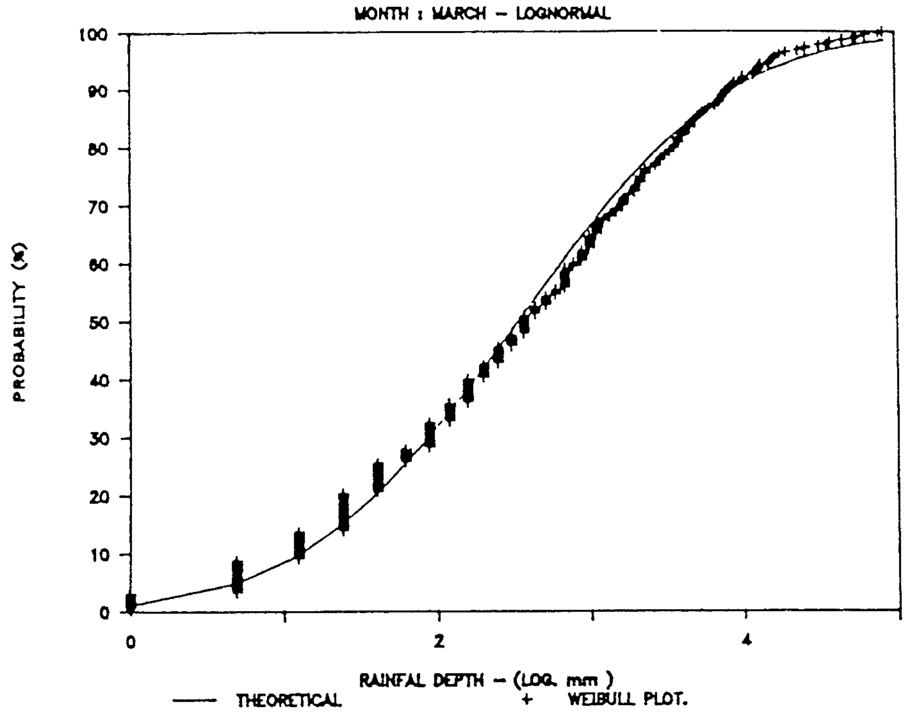


FIG. D. 4. STATION : PROCOT

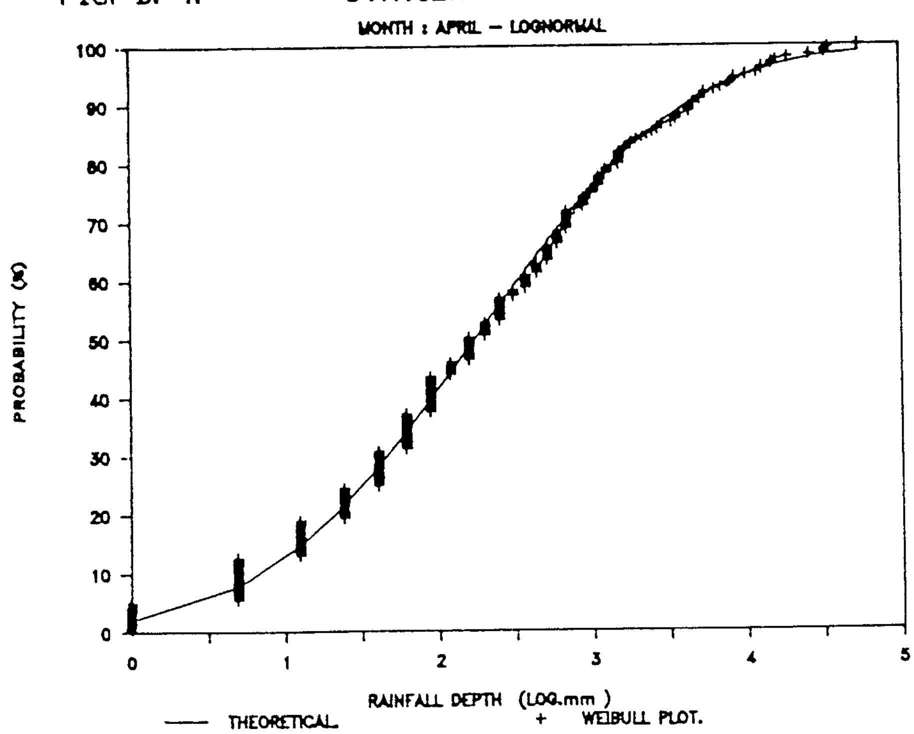


FIG. D. 5 STATION : PROCOT

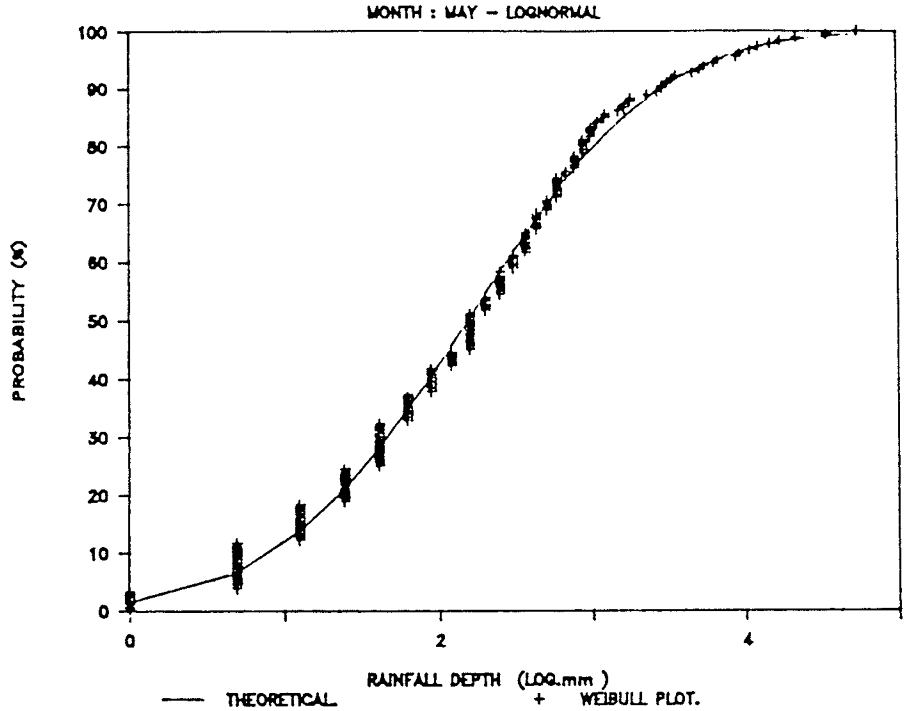


FIG. D. 6 STATION : PROCOT

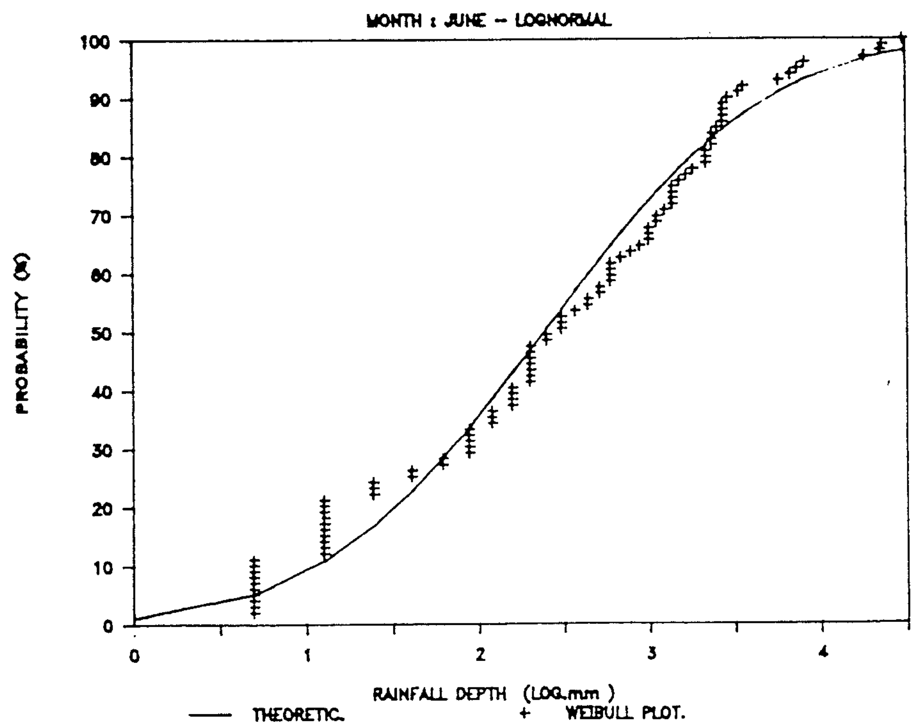


FIG. D. 7. STATION : PROCOT

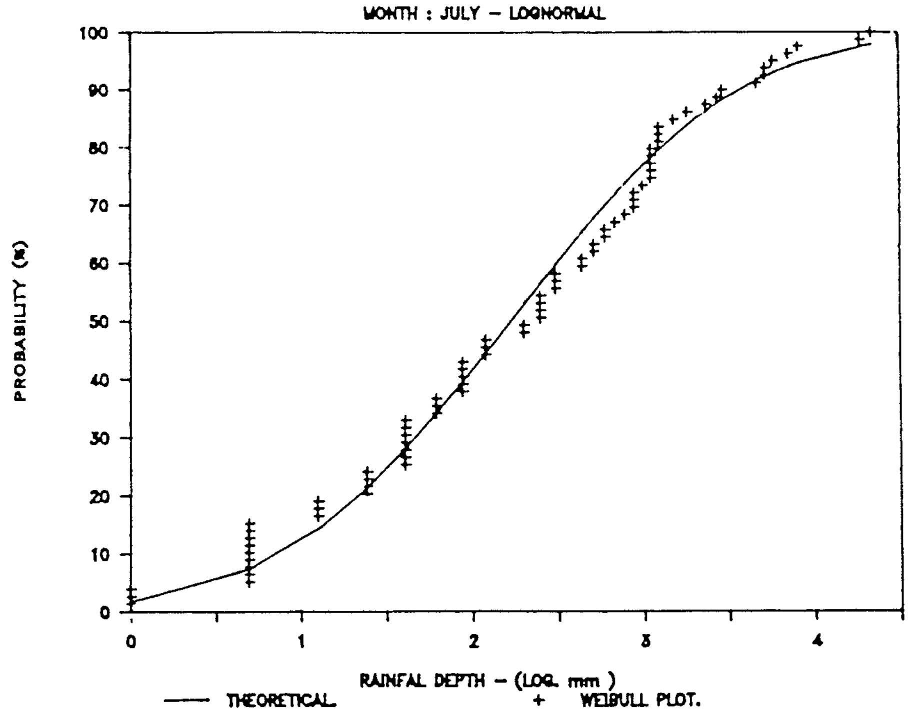


FIG. D. 8. STATION : PROCOT

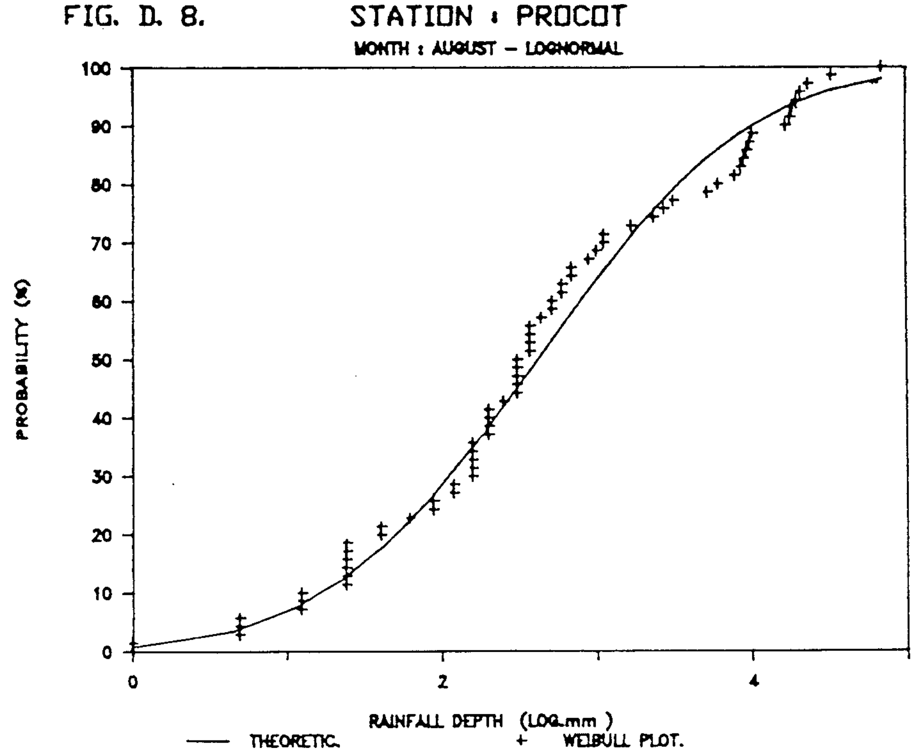


FIG. D. 9. STATION : PROCOT

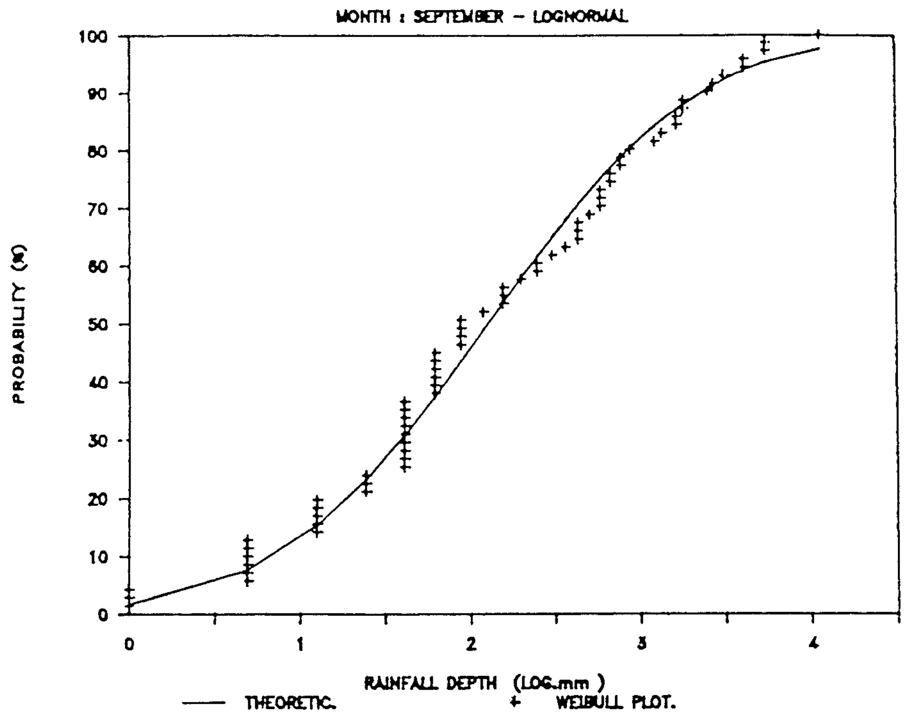


FIG. D. 10. STATION : PROCOT

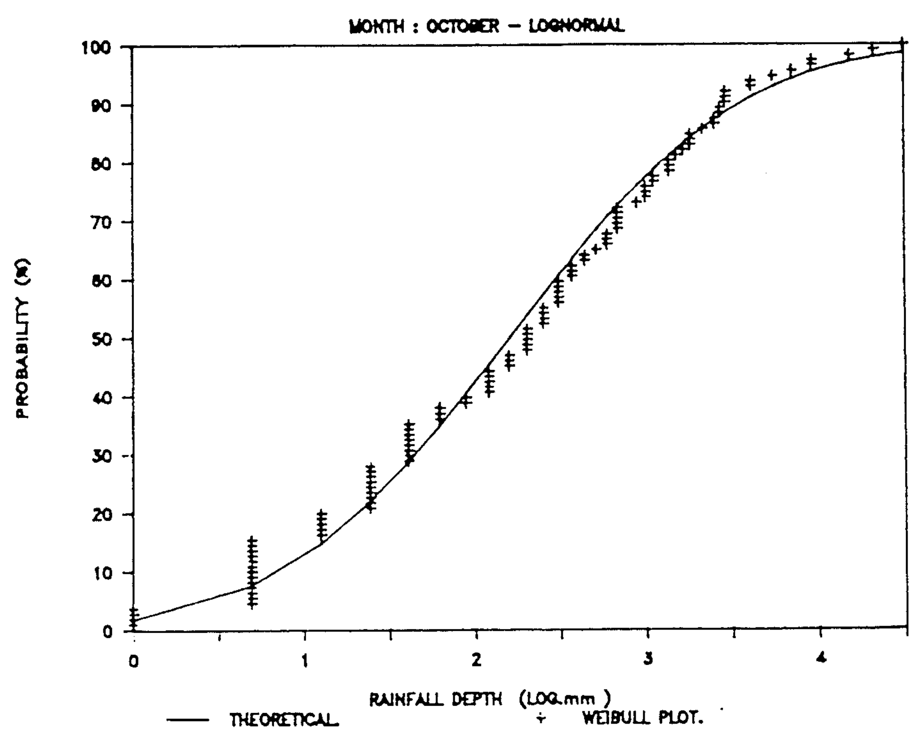


FIG. D. 11. STATION : PROCOT

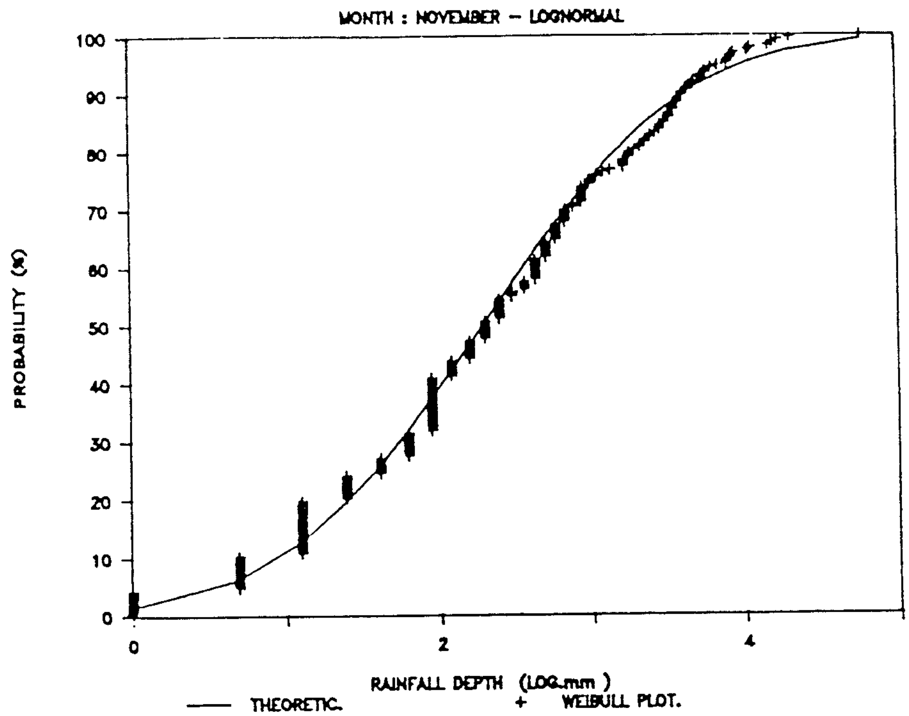
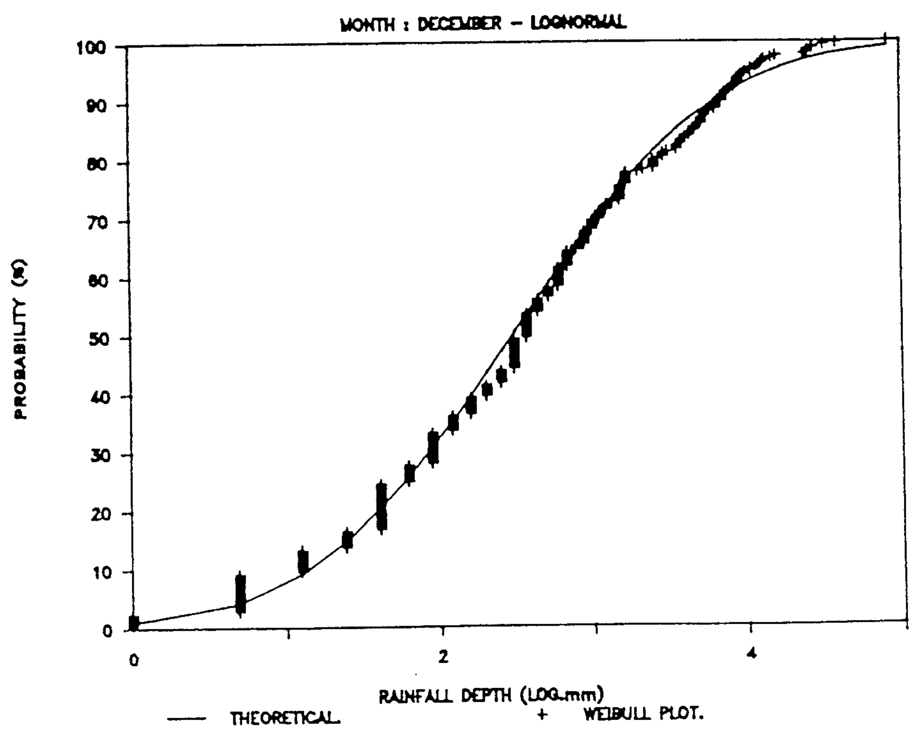


FIG. D. 12. STATION : PROCOT



APPENDIX E
THE RESULT OF RAINFALL GENERATION

TABLE E.1. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : PANGKAH.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	2.5953	2.6500	2.4871	2.3123	2.1914	2.2441	2.3060	2.5266	2.0589	2.3021	2.1970	2.4319
ST. DEV. :	1.0791	1.0479	1.0172	1.0438	1.0407	1.0956	1.0652	1.0672	0.9202	1.0023	1.0046	1.0381
SYNTHETIC												
MEAN OF												
MEAN :	2.5837	2.6408	2.4710	2.3215	2.1886	2.2674	2.2754	2.5106	2.0337	2.2990	2.1958	2.4108
ST. DEV. :	1.0648	1.0477	0.9920	1.0459	1.0553	1.1714	1.0731	1.1528	0.8725	0.9530	1.1098	1.0108
ST. DEVIATION OF												
MEAN :	0.0495	0.0499	0.0562	0.0632	0.0717	0.1009	0.1145	0.1440	0.0978	0.0807	0.0521	0.0481
ST. DEV. :	0.0348	0.0354	0.0497	0.0531	0.0666	0.0938	0.1214	0.1796	0.0840	0.0760	0.0444	0.0404

TABLE E.2 SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : LARANGAN.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	2.4204	2.5003	2.3555	2.2482	2.1500	1.8179	2.0018	2.2312	2.0704	2.1554	2.3921	2.4347
ST. DEV. :	1.2056	1.1320	1.1470	1.0043	1.0922	1.2322	1.2414	1.1743	1.0831	1.0489	1.0623	1.1412
SYNTHETIC												
MEAN OF												
MEAN :	2.4164	2.4879	2.3397	2.2508	2.1742	1.7875	2.0373	2.2232	2.0862	2.1524	2.3038	2.4269
ST. DEV. :	1.1635	1.1255	1.1685	1.0697	1.6463	1.2067	1.2340	1.7225	1.1475	1.0663	1.0986	1.1169
ST. DEVIATION OF												
MEAN :	0.0579	0.0554	0.0631	0.0535	0.1240	0.1088	0.1114	0.1184	0.1125	0.0585	0.7586	0.0563
ST. DEV. :	0.0454	0.0391	0.0620	0.0604	0.1011	0.0795	0.1225	0.1358	0.1280	0.0667	0.0529	0.0474

TABLE E.3. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : TEGAL.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	2.5310	2.5606	2.3913	2.3272	2.1947	2.2031	2.0107	2.4559	1.9993	2.1391	2.2995	2.4052
ST. DEV. :	1.1633	1.1200	1.1670	1.4570	1.1964	1.1059	1.2235	1.1056	1.0672	1.0604	1.0493	1.0234
SYNTHETIC												
MEAN OF												
MEAN :	2.5263	2.5535	2.3626	2.3126	2.2058	2.2808	1.9992	2.4555	2.0059	2.1398	2.3023	2.4607
ST. DEV. :	1.5650	1.1330	1.5564	1.1077	1.2055	1.2638	1.1840	1.2703	1.0088	1.2031	1.0038	1.0321
ST. DEVIATION OF												
MEAN :	0.0501	0.0654	0.0712	0.0856	0.0895	0.1232	0.1002	0.1020	0.1354	0.1300	0.1013	0.0700
ST. DEV. :	0.0520	0.0534	0.0706	0.0689	0.0880	0.1026	0.1335	0.1790	0.1204	0.1122	0.0795	0.0559

TABLE E.4. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : PROCOT.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	2.6306	2.6523	2.5250	2.2374	2.1053	2.3040	2.2223	2.6164	2.1022	2.2034	2.2077	2.4736
ST. DEV. :	1.0761	1.0093	1.1109	1.0048	0.9916	1.0348	1.0491	1.0858	0.9795	1.0533	1.0471	1.0412
SYNTHETIC												
MEAN OF												
MEAN :	2.6212	2.6437	2.5155	2.2240	2.1723	2.3860	2.2305	2.6207	2.1114	2.2061	2.2729	2.4628
ST. DEV. :	1.0068	1.0143	1.0744	1.0303	1.0339	0.9609	1.0877	1.1430	0.9037	1.0033	1.0100	0.9812
ST. DEVIATION OF												
MEAN :	0.0535	0.0546	0.0613	0.0730	0.0696	0.0937	0.1020	0.1141	0.0941	0.1020	0.0698	0.0587
ST. DEV. :	0.0490	0.0402	0.0420	0.0541	0.0659	0.0857	0.1058	0.1067	0.0920	0.0844	0.0559	0.0455

TABLE E.5. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : BREBES.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	2.3197	2.3869	2.2049	2.0103	1.9410	2.1322	1.9163	2.0310	1.0082	1.0604	2.0058	2.2532
ST. DEV. :	1.2668	1.1020	1.1075	1.1061	1.2057	1.1510	1.2000	1.2792	1.1097	1.0542	1.1039	1.1037
SYNTHETIC												
MEAN OF												
MEAN :	2.3002	2.3705	2.1058	2.0213	1.9414	2.1410	1.0790	2.0101	1.0170	1.0646	2.0021	2.2371
ST. DEV. :	1.2109	1.1597	1.2020	1.1711	1.1550	1.1243	1.2462	1.2653	1.2644	1.0150	1.1530	1.1630
ST. DEVIATION OF												
MEAN :	0.0646	0.0654	0.0614	0.0602	0.0947	0.1100	0.1213	0.1514	0.1199	0.1063	0.0671	0.0493
ST. DEV. :	0.0520	0.0496	0.0602	0.0604	0.0707	0.0001	0.1330	0.1292	0.1206	0.0774	0.0763	0.0160

TABLE E.6. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : BUMIAYU.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	2.5319	2.6756	2.6116	2.4078	2.3051	2.3725	2.0270	2.3958	2.0911	2.3074	2.3694	2.4078
ST. DEV. :	1.1221	1.0908	1.1235	1.1324	1.1049	1.2234	1.3946	1.4066	1.0491	1.6923	1.2177	1.3243
SYNTHETIC												
MEAN OF												
MEAN :	2.5105	2.6649	2.6040	2.4093	2.3009	2.3311	2.0270	2.4035	2.0837	2.3044	2.3509	2.4106
ST. DEV. :	1.0094	1.0813	1.1505	1.1336	1.1586	1.2037	1.3695	1.3519	1.1092	1.7274	1.2006	1.3517
ST. DEVIATION OF												
MEAN :	0.0527	0.0567	0.0606	0.0503	0.0919	0.0974	0.1727	0.1269	0.0781	0.0974	0.0658	0.0737
ST. DEV. :	0.0405	0.0438	0.0472	0.0423	0.0558	0.0969	0.1289	0.1726	0.0935	0.1104	0.0731	0.0598

TABLE E.7. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : LOSARI.

MONTH -- :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	2.4475	2.3611	2.4179	2.2329	2.2124	2.1979	2.2682	2.0101	2.2038	2.1547	2.2630	2.4374
ST. DEV. :	1.0351	1.0587	1.0656	1.1100	1.2353	1.0531	1.0535	1.1501	0.9724	1.1094	0.1032	1.0926
SYNTHETIC												
MEAN OF												
MEAN :	2.4307	2.3547	2.4033	2.2297	2.2073	2.2059	2.2707	2.0230	2.2560	2.1417	2.2327	2.4297
ST. DEV. :	0.9969	1.0677	1.0766	1.1044	1.1053	1.0214	1.0388	1.1497	1.0008	1.1371	1.1744	1.0704
ST. DEVIATION OF												
MEAN :	0.0572	0.0617	0.0591	0.0703	0.0815	0.1151	0.1297	0.1972	0.1435	0.1224	0.0710	0.0523
ST. DEV. :	0.0300	0.0473	0.0588	0.0662	0.0755	0.1989	0.1290	0.2256	0.1231	0.1040	0.0871	0.0582

TABLE E.8. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION :PETUGURAN.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	2.5300	2.6000	2.5901	2.6451	2.6150	2.4140	2.3000	2.3020	2.6760	2.9300	2.9302	2.6322
ST. DEV. :	1.0700	1.0700	1.1010	1.1044	1.1420	1.1470	1.2540	1.2050	1.2210	1.1020	1.0550	1.0919
SYNTHETIC												
MEAN OF												
MEAN :	2.5161	2.5974	2.5888	2.6419	2.5995	2.4138	2.2692	2.3874	2.6760	2.9294	2.9482	2.6289
ST. DEV. :	1.0575	1.0514	1.1223	1.1293	1.1179	1.0894	1.3313	1.1720	1.2260	2.2037	1.0562	1.1070
ST. DEVIATION OF												
MEAN :	0.0496	0.0525	0.0524	0.0516	0.0624	0.0551	0.0792	0.1004	0.0799	0.0516	0.0467	0.0477
ST. DEV. :	0.0388	0.0376	0.0444	0.0457	0.0581	0.0629	0.0892	0.1144	0.0822	0.0531	0.0330	0.1420

TABLE E.9. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : BANDAR.

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).													
MEAN	:	3.0032	2.8024	2.5734	2.3437	2.1962	2.1450	2.1001	2.0995	1.9891	2.0642	2.2333	2.4039
ST. DEV.	:	1.9255	1.2247	1.2495	1.2399	1.2384	1.3010	1.3576	1.2205	1.1746	1.1802	1.2678	1.1606
SYNTHETIC													
MEAN OF													
MEAN	:	2.9843	2.7898	2.5592	2.3308	2.1885	2.1277	2.0805	2.0916	1.9741	2.0515	2.2218	2.3878
ST. DEV.	:	1.2702	1.2252	1.2288	1.2064	1.2169	1.2689	1.3621	1.2520	1.1247	1.1170	1.2272	1.1581
ST. DEVIATION OF													
MEAN	:	0.0502	0.0533	0.0468	0.0622	0.0729	0.9238	0.0911	0.0975	0.0807	0.0694	0.0679	0.0510
ST. DEV.	:	0.0341	0.0401	0.0387	0.0479	0.0589	0.0709	0.0851	0.0963	0.0643	0.0453	0.0521	0.0397

TABLE E.10. SUMMARY OF DAILY RAINFALL OF LOGARITHMIC

STATION : BUMIJAWA.

MONTH	:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).													
MEAN	:	2.0903	2.7343	2.7100	2.3777	2.3441	2.2670	2.1154	2.1791	2.0577	2.1255	2.2623	2.5070
ST. DEV.	:	1.2120	1.2181	1.1747	1.1077	1.1456	1.1084	1.1172	1.1092	1.0609	0.9937	1.1550	1.1997
SYNTHETIC													
MEAN OF													
MEAN	:	2.0755	2.7191	2.7054	2.3639	2.3347	2,2531	2.1002	2.1702	2.0430	2.1187	2.2469	2.4919
ST. DEV.	:	1.2147	1.2236	1.1663	1.1061	1.1108	1.1306	1.0173	0.9932	1.0850	0.9632	1.1454	1.1793
ST. DEVIATION OF													
MEAN	:	0.0429	0.0526	0.0489	0.0452	0.0588	0.0702	0.0853	0.8963	0.0712,	0.0539	0.0468	0.0515
ST. DEV.	:	0.0333	0.0356	0.0402	0.0430	0.0509	0.0613	0.0822	0.0814	0.0669	0.0387	0.0441	0.0441

TABLE E.11. SUMMARY OF MONTHLY RAINFALL

STATION : PANGKAH.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	416.6	380.9	274.2	176.1	124.5	70.7	60.2	43.0	41.2	80.9	156.1	269.9
ST. DEV. :	137.7	169.2	131.0	83.4	86.7	63.9	61.4	69.6	52.2	66.3	88.7	146.0
SYNTHETIC												
MEAN OF												
MEAN :	436.3	394.0	279.4	186.4	125.7	82.1	63.1	43.9	41.2	87.1	167.5	277.7
ST. DEV. :	142.1	149.6	124.2	90.9	70.3	67.9	59.7	54.4	36.8	62.8	87.0	120.0
ST. DEVIATION OF												
MEAN :	32.0	27.1	26.5	10.0	14.4	13.0	13.2	10.1	7.1	12.5	14.3	23.0
ST. DEV. :	37.2	27.3	25.4	26.9	12.3	20.0	15.6	16.3	8.8	21.6	21.4	21.2

TABLE E.12. SUMMARY OF MONTHLY RAINFALL

STATION : LARANGAN.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	373.6	399.3	202.3	177.0	132.6	63.7	65.7	65.0	40.1	91.4	187.0	305.6
ST. DEV. :	135.4	193.6	106.5	90.4	87.4	50.5	65.0	51.0	50.0	60.0	90.0	140.1
SYNTHETIC												
MEAN OF												
MEAN :	390.29	390.34	306.26	190.42	139.50	65.17	63.52	60.97	43.39	95.08	202.08	323.23
ST. DEV. :	177.02	160.39	153.09	95.19	82.50	57.95	63.96	75.31	46.41	62.08	107.51	149.01
ST. DEVIATION OF												
MEAN :	33.32	29.16	32.78	20.05	16.10	12.14	11.39	15.47	10.90	11.34	22.76	27.70
ST. DEV. :	42.33	38.90	40.73	16.94	10.60	19.18	15.08	27.64	23.15	14.21	24.13	30.59

TABLE E.13. SUMMARY OF MONTHLY RAINFALL

STATION : TEGAL.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	340.4	310.1	212.5	117.2	102.0	69.8	52.0	40.2	30.2	48.9	99.1	194.9
ST. DEV. :	148.0	136.7	116.5	70.0	63.0	79.7	52.3	67.8	37.8	56.4	73.8	114.4
SYNTHETIC												
MEAN OF												
MEAN :	346.67	322.55	226.00	123.04	116.51	72.32	51.16	40.80	30.52	58.54	106.01	190.65
ST. DEV. :	162.27	143.42	141.72	87.20	95.27	68.70	51.83	52.53	34.65	57.19	73.24	107.10
ST. DEVIATION OF												
MEAN :	33.32	30.72	26.51	19.24	19.66	14.93	11.69	11.98	7.33	11.42	23.15	21.41
ST. DEV. :	35.10	32.23	43.55	25.28	45.32	22.37	15.79	10.27	12.03	19.07	14.70	21.04

TABLE E.14. SUMMARY OF MONTHLY RAINFALL

STATION : PROCOT.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	370.0	343.0	270.0	140.2	103.2	67.0	47.0	33.1	37.0	65.9	145.6	259.4
ST. DEV. :	145.2	150.2	129.7	91.4	70.1	54.0	52.0	50.0	55.3	62.3	80.4	107.0
SYNTHETIC												
MEAN OF												
MEAN :	403.72	359.70	290.00	152.39	99.91	68.77	48.33	38.56	36.33	68.24	137.00	250.42
ST. DEV. :	169.11	130.64	142.26	85.07	62.17	58.92	48.95	80.93	39.00	58.08	77.64	118.59
ST. DEVIATION OF												
MEAN :	35.63	25.08	25.06	15.09	12.04	10.92	9.82	15.49	7.64	11.76	15.37	23.79
ST. DEV. :	31.31	20.75	20.54	20.20	15.11	17.92	14.21	24.81	12.07	17.10	19.68	24.10

TABLE E.15. SUMMARY OF MONTHLY RAINFALL

STATION : BREBES.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	331.0	203.1	234.7	137.0	108.6	70.0	44.1	26.9	36.7	51.3	107.2	249.3
ST. DEV. :	158.5	131.7	123.1	69.4	77.9	60.4	52.4	33.4	48.4	47.4	71.5	123.1
SYNTHETIC												
MEAN OF												
MEAN :	371.74	302.97	259.41	148.44	114.19	87.09	43.90	30.64	38.17	54.07	117.20	273.16
ST. DEV. :	104.44	147.73	133.94	92.92	73.95	70.83	46.21	50.46	42.37	44.94	73.23	139.20
ST. DEVIATION OF												
MEAN :	30.29	29.37	27.50	14.72	15.69	15.60	9.20	7.55	7.30	8.81	16.73	24.52
ST. DEV. :	53.45	20.53	32.64	31.40	17.03	27.70	16.46	16.03	16.70	17.50	19.92	35.03

TABLE E.16. SUMMARY OF MONTHLY RAINFALL

STATION : BUMIAYU.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	392.4	374.1	404.5	272.0	161.0	117.7	76.1	40.9	66.6	156.4	214.1	340.6
ST. DEV. :	164.7	173.0	134.9	135.9	124.0	114.0	61.7	76.2	72.9	140.0	147.3	169.1
SYNTHETIC												
MEAN OF												
MEAN :	426.16	413.99	423.20	208.69	185.20	118.24	81.02	46.34	70.37	145.50	260.26	408.75
ST. DEV. :	160.77	171.75	190.26	129.06	110.82	103.06	107.12	115.74	58.87	138.50	149.70	229.28
ST. DEVIATION OF												
MEAN :	37.09	35.52	37.04	26.38	21.30	20.92	29.43	26.55	11.80	33.61	35.98	57.67
ST. DEV. :	36.70	34.03	40.64	26.90	41.44	34.35	83.92	74.81	14.21	42.90	41.18	229.28

TABLE E.17. SUMMARY OF MONTHLY RAINFALL

STATION : LOSARI.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	279.0	248.2	232.5	138.4	116.5	57.0	43.7	17.8	26.7	50.7	110.4	230.3
ST. DEV. :	107.6	114.1	83.0	63.0	74.8	60.6	51.8	32.8	39.5	57.8	87.0	134.3
SYNTHETIC												
MEAN OF												
MEAN :	209.49	254.66	243.12	149.71	134.73	61.71	40.05	18.81	20.51	54.07	116.50	241.07
ST. DEV. :	117.24	109.52	120.74	96.53	97.39	52.82	46.56	30.45	32.53	52.02	77.00	129.10
ST. DEVIATION OF												
MEAN :	22.40	25.19	25.63	21.73	19.05	12.16	8.75	7.03	6.70	9.99	17.13	25.53
ST. DEV. :	21.94	21.18	27.70	32.24	26.32	14.56	16.04	16.23	13.70	16.40	19.61	35.18

TABLE E.18. SUMMARY OF MONTHLY RAINFALL

STATION : PETUGURAN.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	421.0	383.9	445.3	423.2	321.8	198.1	139.8	110.3	261.9	494.5	590.2	459.6
ST. DEV. :	136.0	116.2	120.6	203.2	173.2	184.1	142.0	141.5	322.4	344.7	214.8	120.7
SYNTHETIC												
MEAN OF												
MEAN :	446.75	389.40	487.51	463.08	363.11	206.74	160.40	124.87	281.40	554.08	634.99	514.47
ST. DEV. :	155.34	155.91	186.67	181.64	188.58	126.70	126.72	189.17	284.81	295.68	232.15	183.53
ST. DEVIATION OF												
MEAN , :	29.13	29.49	39.52	38.56	42.95	24.82	25.05	24.57	50.25	57.52	40.87	34.64
ST. DEV. :	33.39	30.10	48.91	42.24	56.48	32.84	37.74	31.77	92.60	112.32	49.22	36.17

TABLE E.19. SUMMARY OF MONTHLY RAINFALL

STATION : BANDAR.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	975.4	693.3	578.7	365.7	242.2	136.3	144.6	83.8	117.2	175.8	324.2	438.5
ST. DEV. :	445.5	218.5	202.1	177.6	125.5	84.5	120.7	95.3	119.9	137.5	266.7	173.3
SYNTHETIC												
MEAN OF												
MEAN :	1158.23	783.71	648.13	392.07	265.66	151.86	156.97	92.76	124.47	186.00	352.09	463.05
ST. DEV. :	471.80	311.55	261.21	179.90	139.07	117.35	128.65	80.17	82.82	101.60	166.91	173.96
ST. DEVIATION OF												
MEAN :	81.59	52.62	44.98	36.01	29.74	23.14	28.12	17.57	16.59	19.40	35.20	34.36
ST. DEV. :	109.91	68.80	68.84	44.89	33.99	35.32	48.16	25.69	19.53	19.48	38.60	39.71

TABLE E.20. SUMMARY OF MONTHLY RAINFALL

STATION : BUMIJAWA.

MONTH :	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGT	SEP	OCT	NOV	DEC
HISTORICAL (OBSERVED).												
MEAN :	856.8	709.6	657.4	349.8	270.7	154.0	102.1	86.0	100.6	166.6	331.1	468.0
ST. DEV. :	333.8	284.9	213.1	128.1	173.7	124.5	103.8	91.4	122.3	112.2	140.7	207.5
SYNTHETIC												
MEAN OF												
MEAN :	938.09	761.02	705.69	375.80	286.18	161.33	102.19	89.10	103.45	176.23	350.49	506.69
ST. DEV. :	349.72	293.79	260.37	142.15	138.82	96.59	74.40	72.31	74.46	77.43	144.69	215.42
ST. DEVIATION OF												
MEAN :	62.61	53.35	50.45	25.74	24.66	18.00	16.64	12.91	13.62	15.84	24.79	45.50
ST. DEV. :	82.63	71.55	59.68	26.36	27.81	23.01	19.59	17.55	15.73	13.39	31.64	44.51

FIG. E. 1. MEAN OF DAILY RAIFALL .

STATION : PANGKAH 1959 – 1985

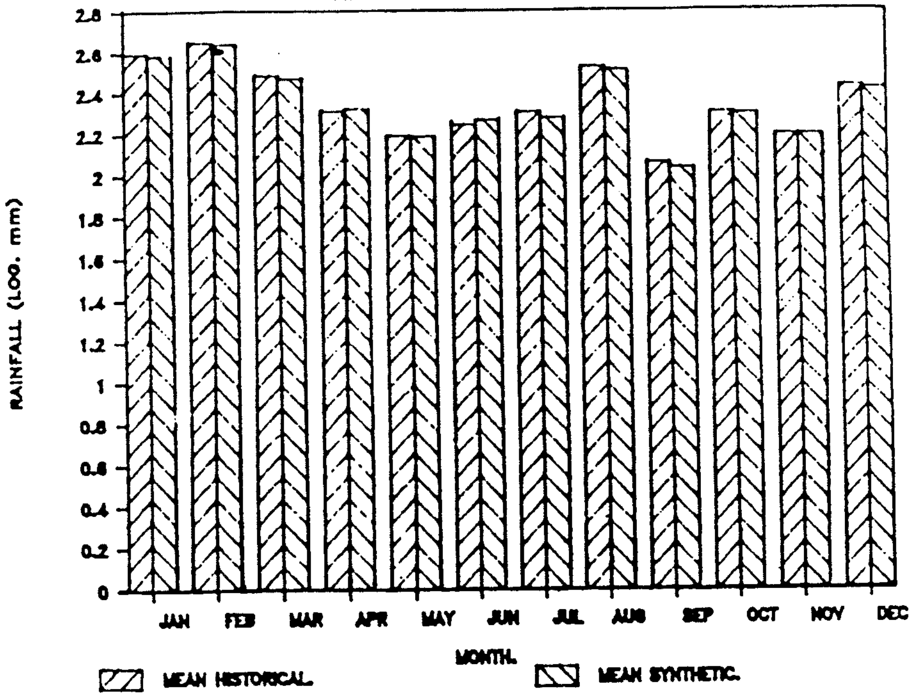


FIG. E. 2. MEAN DAILY RAINFALL.

STATION : LARANGAN 1969 – 1985.

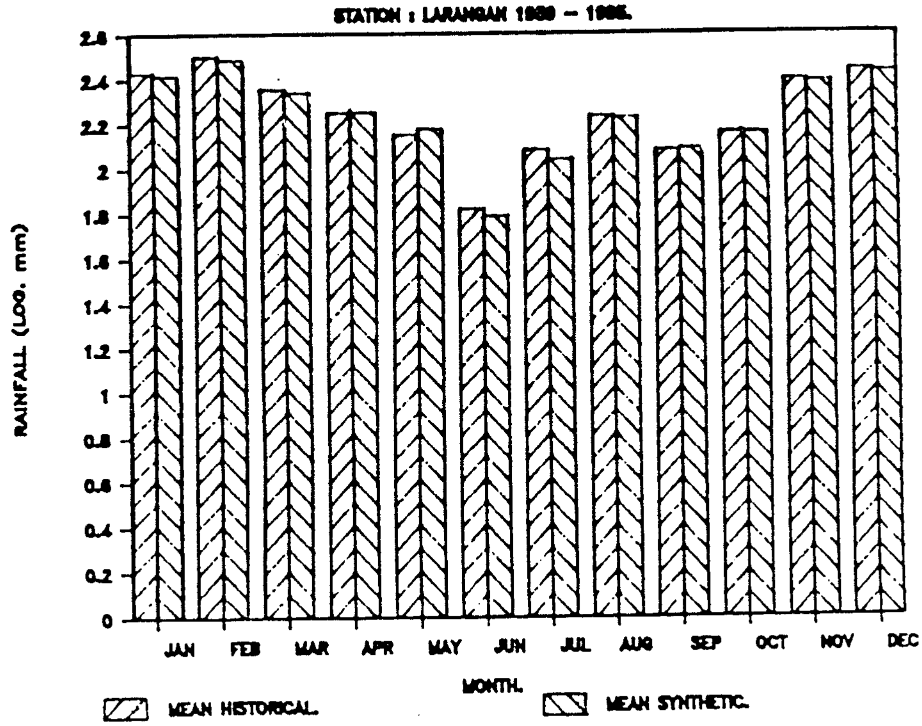


FIG. E. 3. MEAN DAILY RAINFALL.

STATION : TERAL 1950 – 1965.

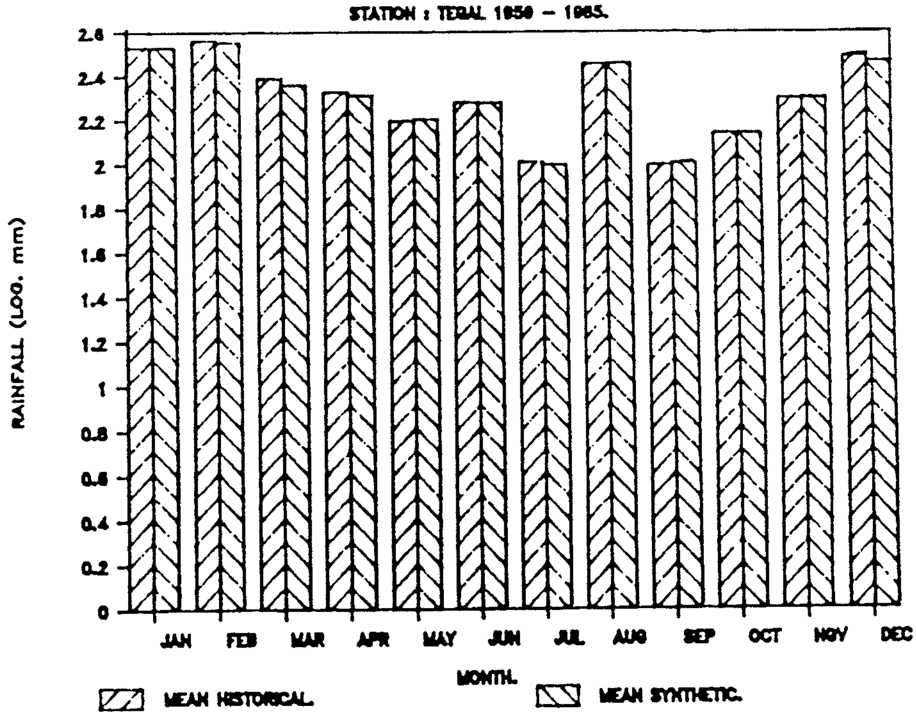


FIG. E. 4. MEAN DAILY RAINFALL.

STATION : PROCOT 1959 – 1985.

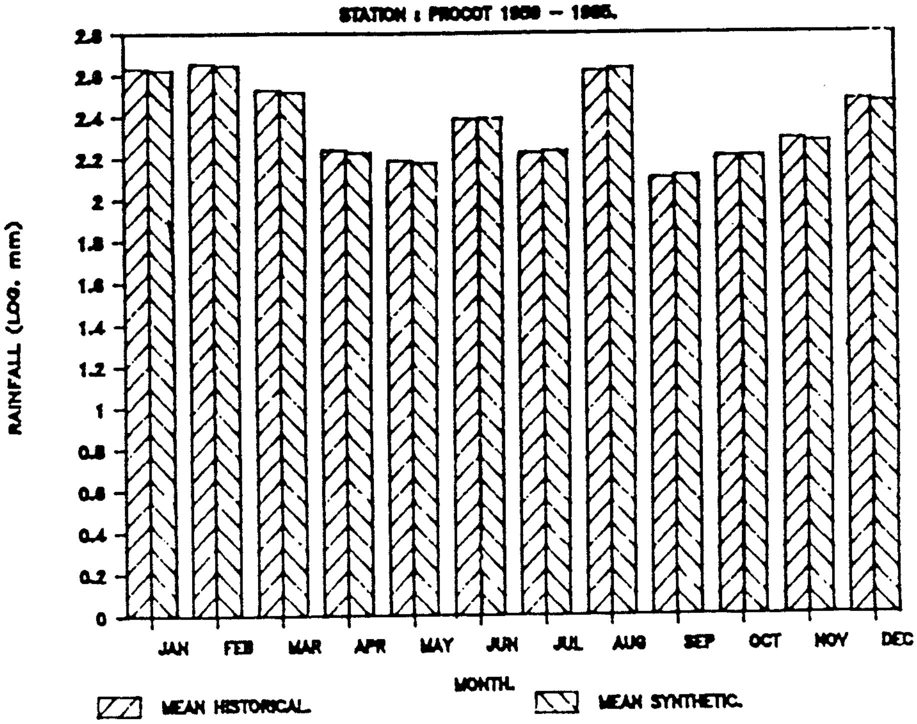


FIG. E. 5. MEAN DAILY RAINFALL.

STATION : BREBES 1950 – 1965.

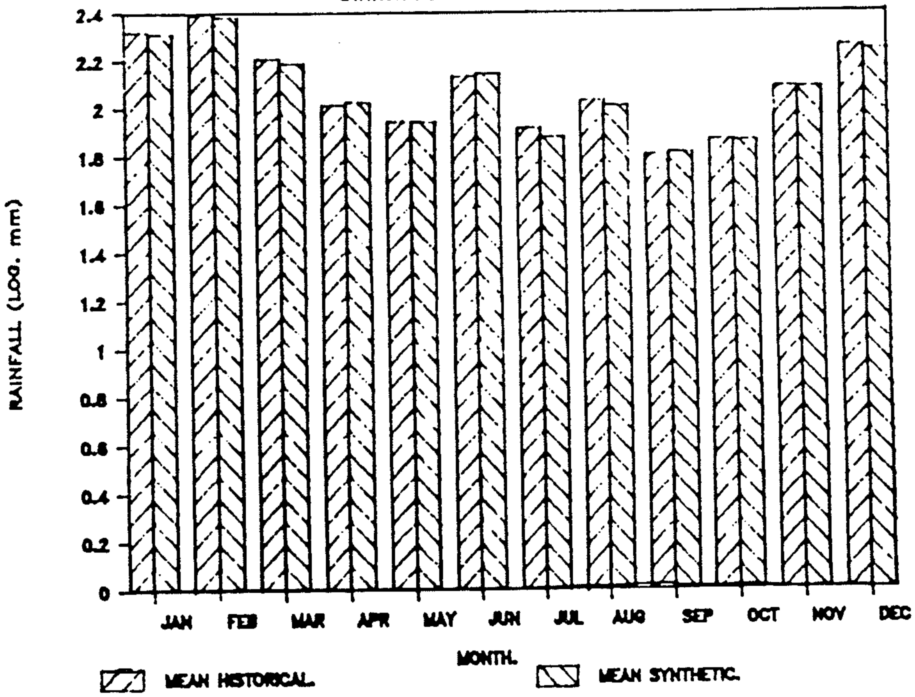


FIG. E. 6. MEAN DAILY RAINFALL.

STATION : BUMIAYU 1960 – 1965.

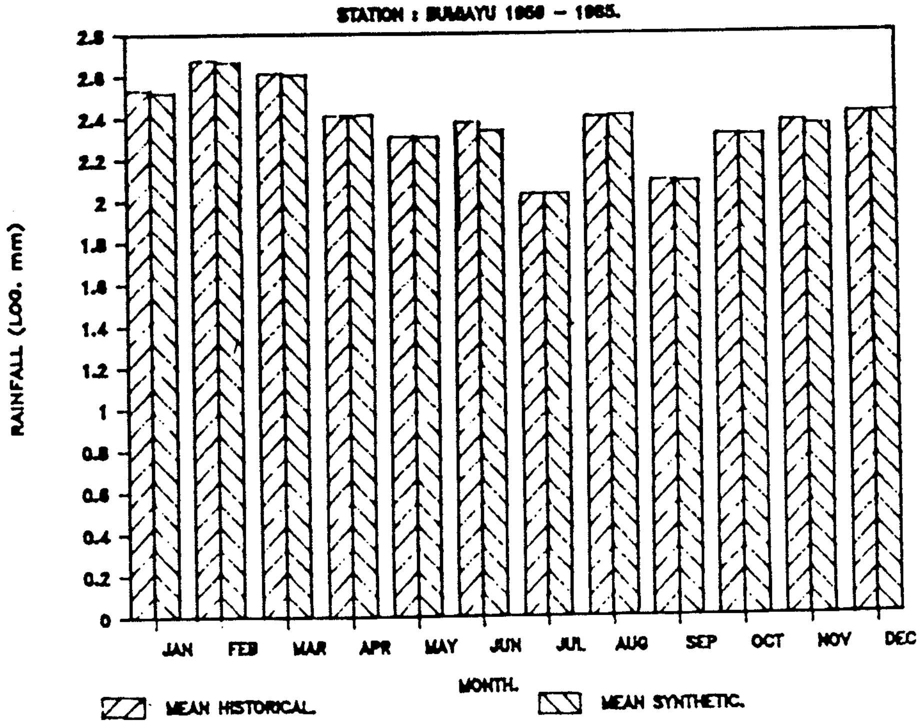


FIG. E. 7. MEAN DAILY RAINFALL.

STATION : LOSARI 1959 – 1985.

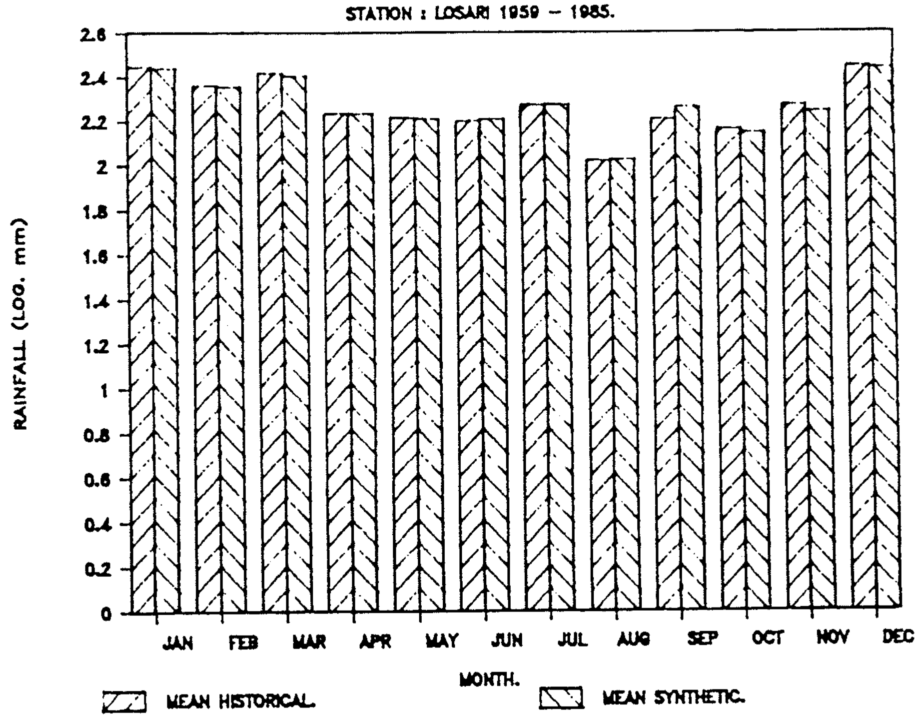


FIG. E. 8. MEAN DAILY RAINFALL.

STATION : PETUGURAN 1959 – 1985.

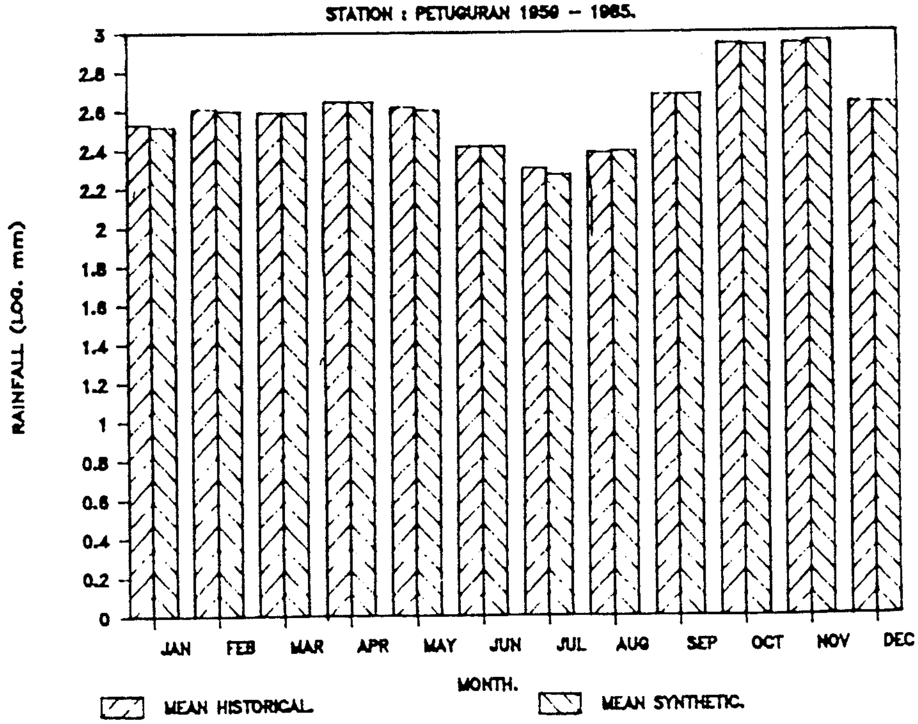


FIG. E. 9. MEAN DAILY RAINFALL.

STATION : BANDAR 1958 – 1985.

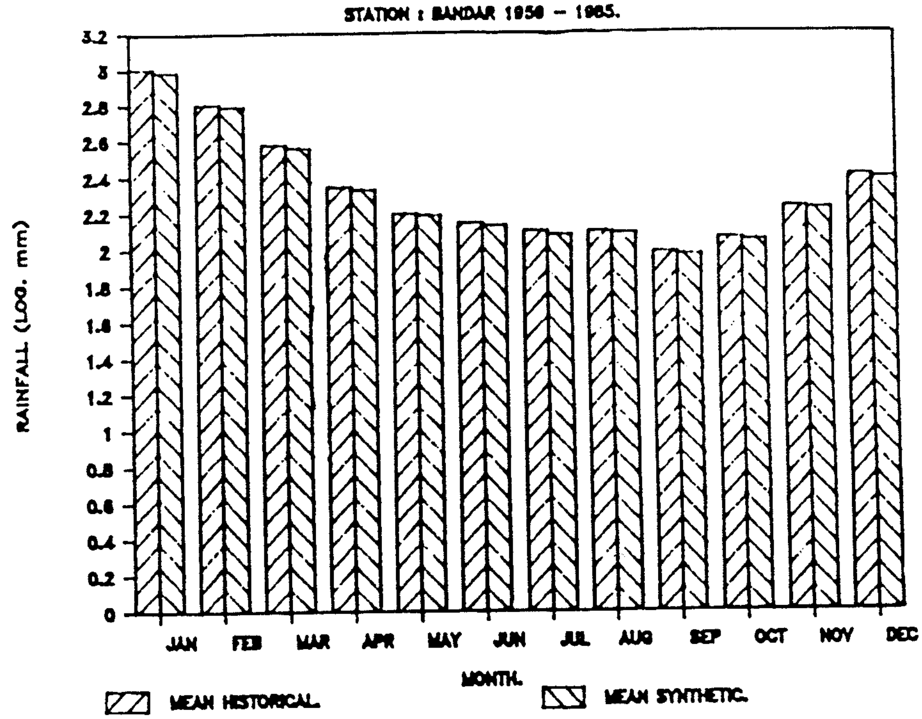


FIG. E. 10. MEAN DAILY RAINFALL.

STATION : BUMIJAWA 1958 – 1985.

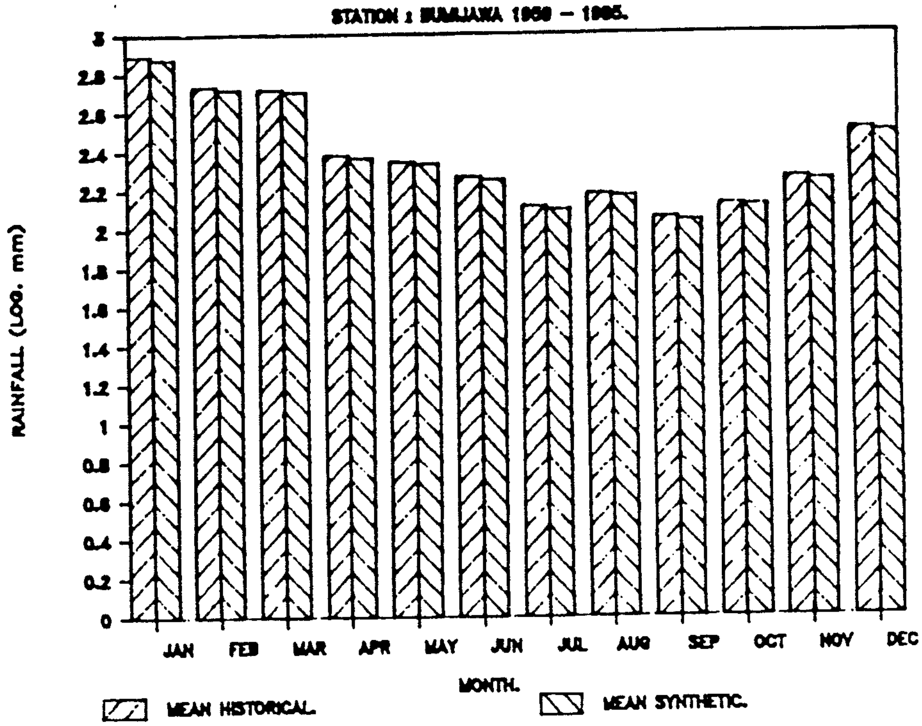


FIG. E. 11. MONTHLY RAINFALL.

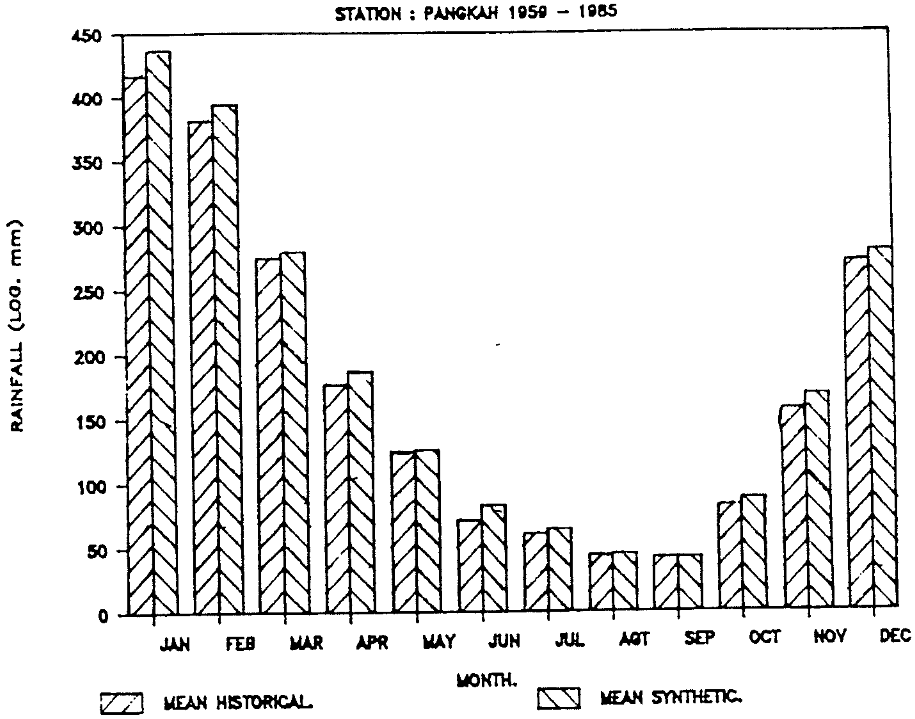


FIG. E. 12. MONTHLY RAINFALL.

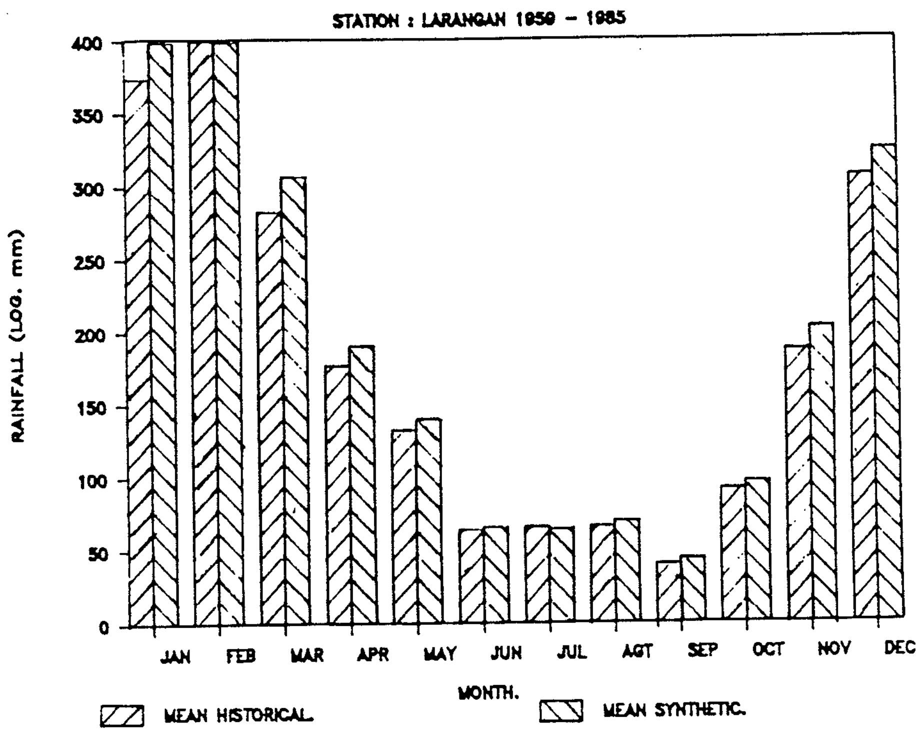


FIG. E. 13. MONTHLY RAINFALL.

STATION : TEGAL 1959 – 1985

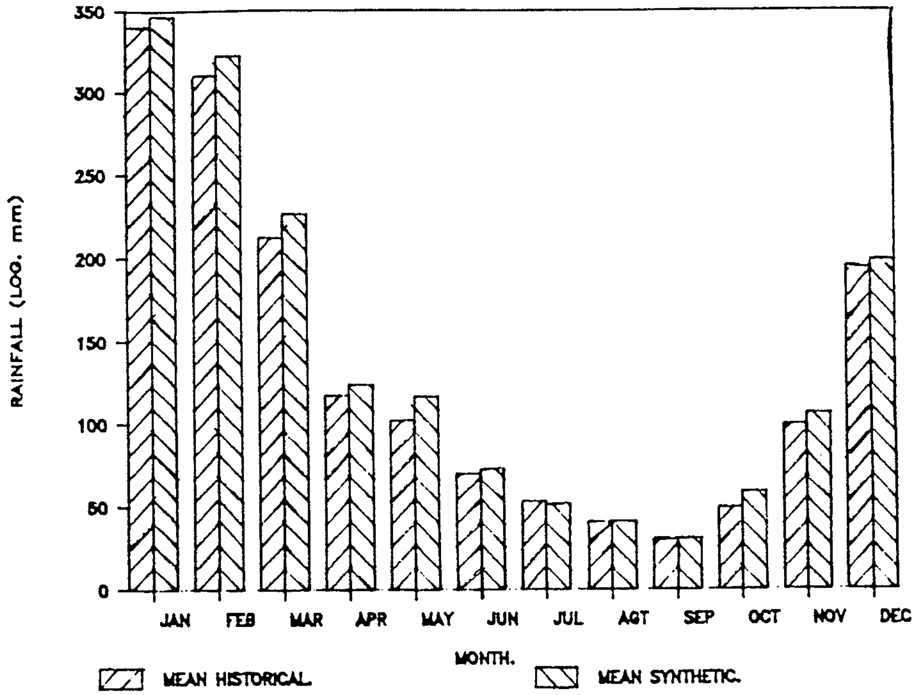


FIG. E. 14. MONTHLY RAINFALL.

STATION : PROCOT 1959 – 1985

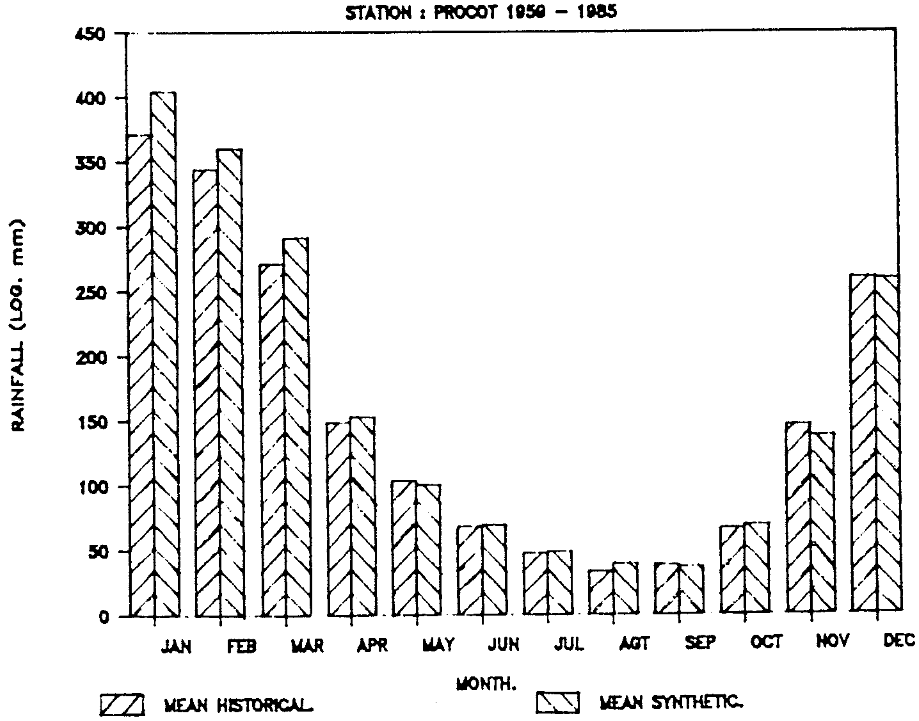


FIG. E. 15. MONTHLY RAINFALL.

STATION : BREBES 1959 – 1985

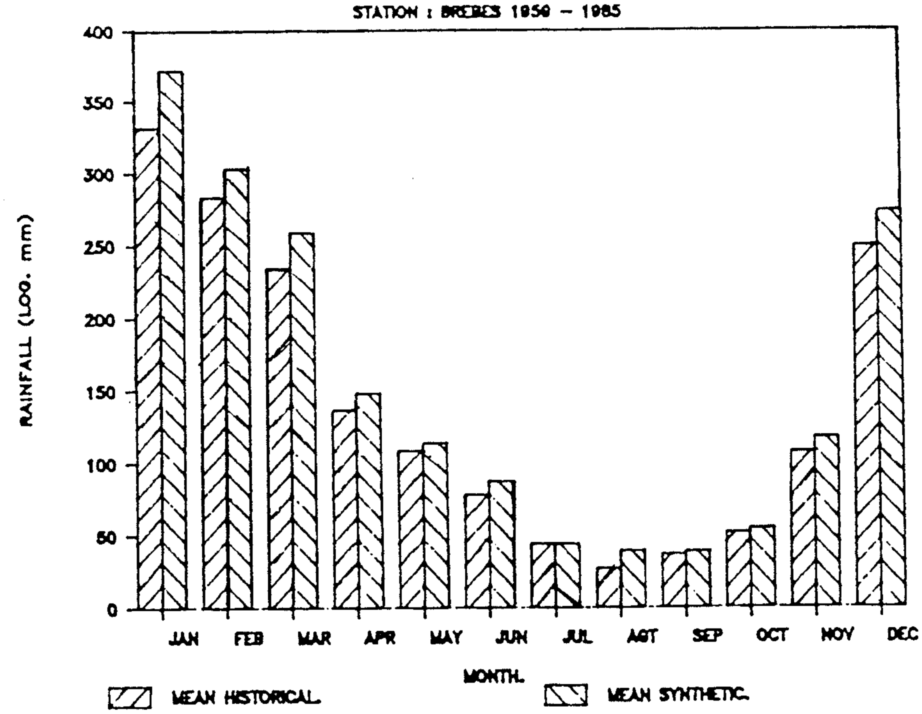


FIG. E. 16. MONTHLY RAINFALL.

STATION : BUMIAYU 1959 – 1985

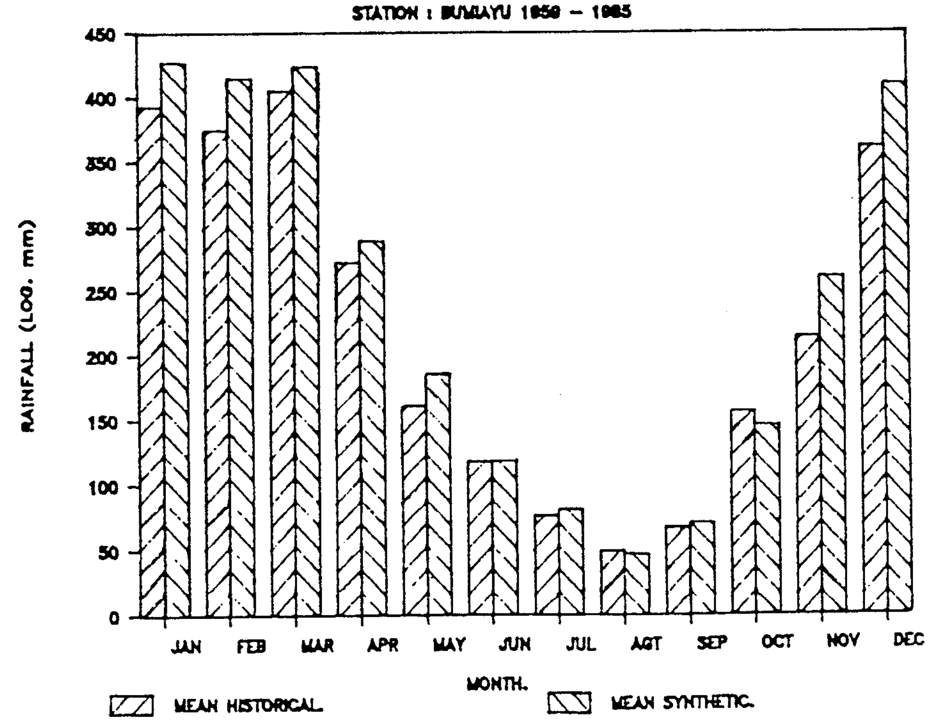


FIG. E. 17. MONTHLY RAINFALL.

STATION : LOSARI 1959 – 1985

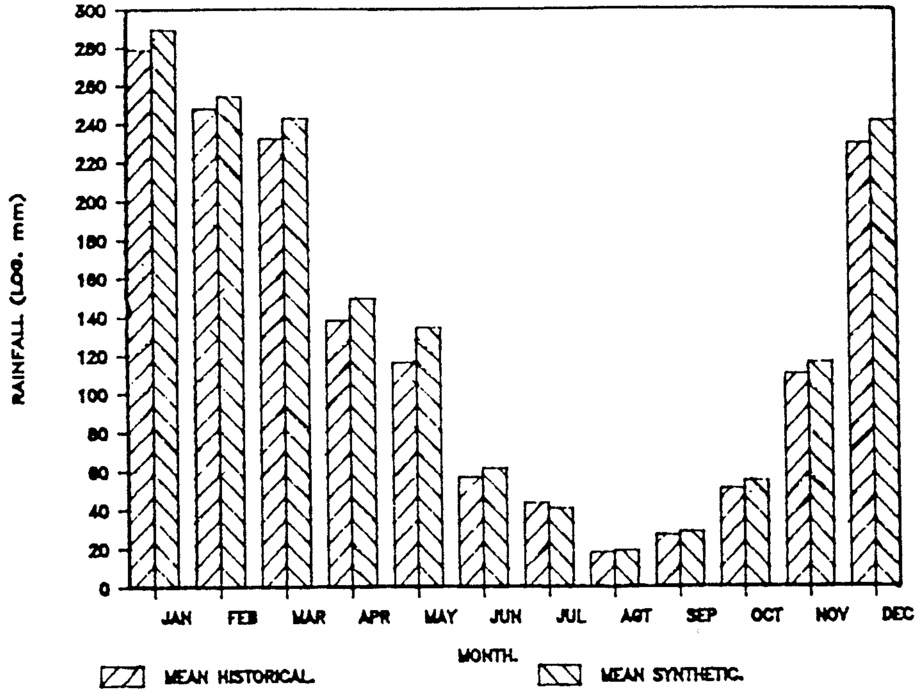


FIG. E. 18. MONTHLY RAINFALL.

STATION : PETUGURAN 1959 – 1985

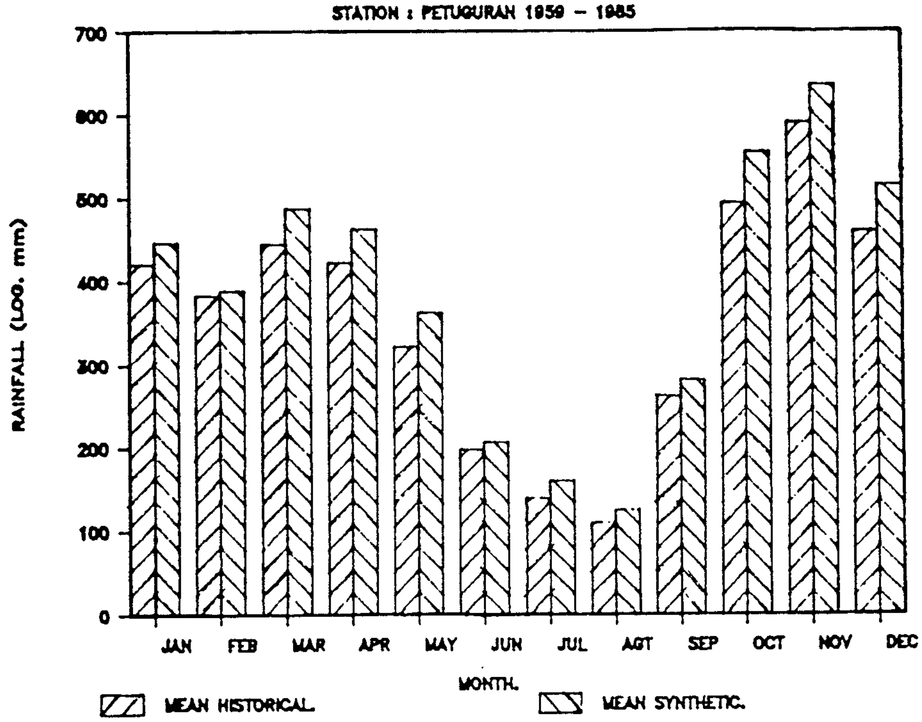


FIG. E. 19. MONTHLY RAINFALL.

STATION : BANDAR 1959 — 1985

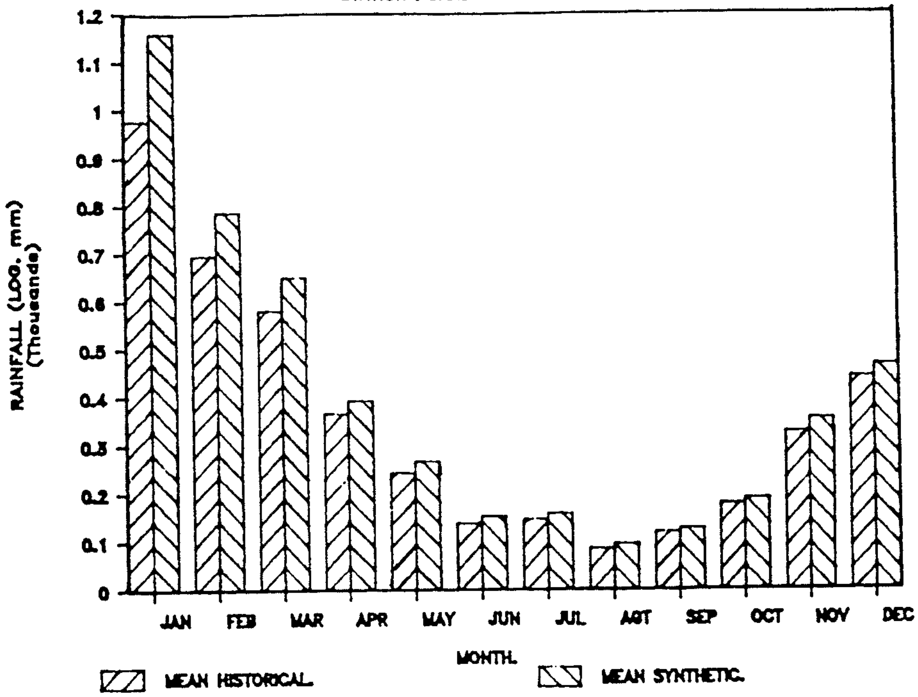
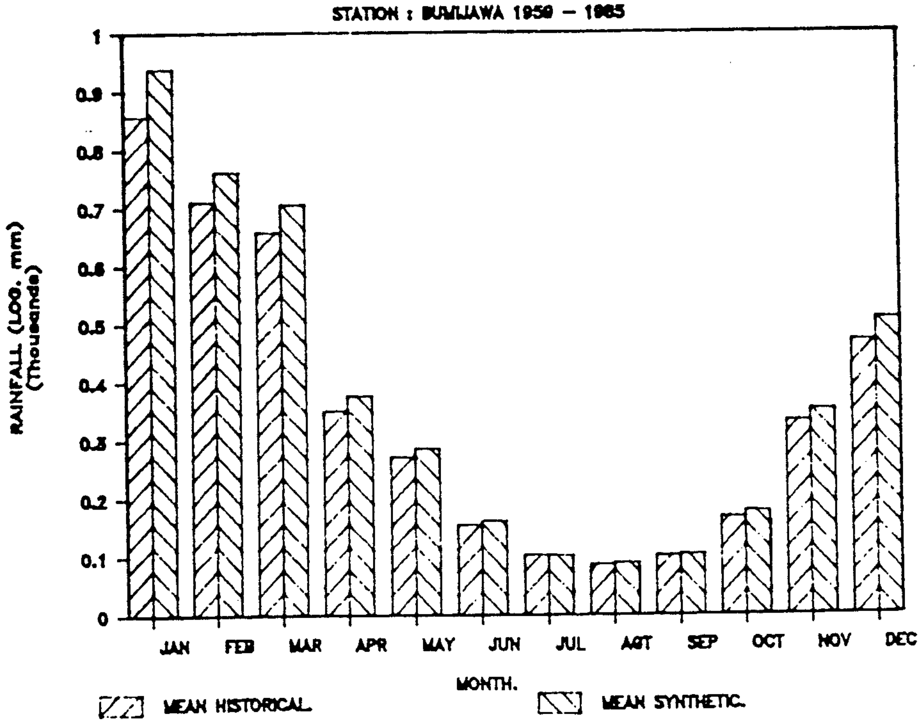


FIG. E. 20. MONTHLY RAINFALL.

STATION : BUMIJAWA 1959 — 1985



APPENDIX F

REGRESSION ANALYSES FOR UNGAGED SITE

APPENDIX F

F.1. SUMMARY OF REGRESSION ANALYSIS FOR THE MATRIX OF PROBABILITY RAINFALL OCCURRENCE

Dependent Variable (Y) = Probability of rainfall occurrence.

Independent Variable X_1 = Elevation of station.

X_2 = Azimuth of the station.

Regression Equation :

$$Y = B_0 + B_1 X_1 + B_2 X_2$$

MONTH : FEBRUARY

	R	F*	t(7)	b0 and b1
Prob.wet/wet	0.9233	40.168	6.36142	b0= 0.596988620 b1= 0.000281
Prob.wet/dry	0.9157	36.340	- 6.02825	b0= 0.399932922 b1= -0.000283
Prob.dry/wet	0.8971	28.874	5.37344	b0= 0.420460671 b1= 0.000264
Prob.dry/dry	0.8993	29.592	- 5.43981	b0= 0.578199651 b1= -0.000262

MONTH : MARCH

	R	F*	t(7)	b0 and b1
Prob.wet/wet	0.9016	30.412	5.51473	b0= 0.542807433 b1= 0.000309
Prob.wet/dry	0.9016	30.412	- 5.51473	b0= 0.457192552 b1= -0.000309
Prob.dry/wet	0.8857	25.484	5.04816	b0= 0.353083082 b1= 0.000304
Prob.dry/dry	0.8857	25.484	- 5.04816	b0= 0.646916931 b1= -0.000304

MONTH : APRIL

	R	F*	t(7)	b0 and b1
Prob.wet/wet	0.7277	7.881	2.80732	b0= 0.449591466 b1= 0.000333
Prob.wet/dry	0.7277	7.881	- 2.80372	b0= 0.55048544 b1= -0.000333
Prob.dry/wet	0.8260	15.037	3.8777	b0= 0.283379498 b1= 0.000265
Prob.dry/dry	0.8260	15.037	- 3.8777	b0= 0.716620495 b1= -0.000265

MONTH : MAY

	R	F*	t(7)	b0 and b1
Prob.wet/wet	0.8468	17.741	4.21205	b0= 0.362729042 b1= 0.000343
Prob.wet/dry	0.8468	17.741	- 4.21205	b0= 0.637270966 b1= -0.000343
Prob.dry/wet	0.8313	15.655	3.9566	b0= 0.204747675 b1= 0.000126
Prob.dry/dry	0.8313	15.655	- 3.9566	b0= 0.795252331 b1= -0.000126

MONTH : JUNE

	R	F*	t(7)	b0 and b1
Prob.wet/wet	0.6686	5.659	2.37896	b0= 0.302878572 b1= 0.000241
Prob.wet/dry	0.6686	5.656	- 2.37896	b0= 0.697121439 b1= -0.000241
Prob.dry/wet	0.9041	31.343	5.5985	b0= 0.119013522 b1= 0.000132
Prob.dry/dry	0.9041	31.343	- 5.5985	b0= 0.880986477 b1= -0.000132

MONTH : JULY

	R	F*	t(7)	b0 and b1
Prob.wet/wet	0.7701	10.200	3.19381	b0= 0.304564 b1= 0.000248
Prob.wet/dry	0.7701	10.200	- 3.19381	b0= 0.6954356 b1= -0.000248
Prob.dry/wet	0.7094	7.093	2.66331	b0= 0.08678335 b1= 0.000065
Prob.dry/dry	0.7094	7.093	- 2.66331	b0= 0.913216641 b1= -0.000065

MONTH : AUGUST

	R	F*	t(7)	b0 and b1
Prob.wet/wet	0.5946	3.829	1.95668	b0= 0.283475915 b1= 0.000257
Prob.wet/dry	0.5946	3.829	- 1.9568	b0= 0.716524091 b1= -0.000257
Prob.dry/wet	0.76134	9.775	3.12645	b0= 0.057749981 b1= 0.000069
Prob.dry/dry	0.76134	9.650	- 3.10644	b0= 0.941423590 b1= -0.000068

MONTH : SEPTEMBER

	R	F*	t(7)	b0, b1 & b2
Prob.wet/wet	0.8621	8.692	2.51860 - 2.03775	b0= 1.02227590 b1= 0.000329 b2= -0.0022178
Prob.wet/dry	0.8621	8.682	- 2.517 2.03630	b0= -0.022178731 b1= -0.000329 b2= 0.002217
Prob.dry/wet	0.9129	15.005	3.17081 - 2.82569	b0= 0.216088896 b1= 0.000057 b2= 0.000426
Prob.dry/dry	0.9129	15.005	- 3.17081 2.82568	b0= 0.78391115 b1= -0.000057 b2= 0.000426

MONTH : OCTOBER

	R	F*	t(7)	b0, b1 & b2
Prob.wet/wet	0.9448	24.948	3.27724 4.42381	b0= 1.327503806 b1= 0.000278 b2= -0.003126
Prob.wet/dry	0.9448	24.948	- 3.27724 4.42381	b0= -0.327503747 b1= -0.000278 b2= 0.003126
Prob.dry/wet	0.9196	16.438	4.04091 - 2.11143	b0= 0.358414647 b1= 0.00157 b2= -0.000685
Prob.dry/dry	0.8980	12.498	- 3.68193 1.62665	b0= 0.67235291 b1= -0.000154 b2= 0.000568

MONTH : NOVEMBER

	R	F^*	t(7) t1 & t2	b0, b1 & b2
Prob.wet/wet	0.9599	35.164	5.17436 - 3.97832	b0= 1.087806730 b1= 0.000317 b2= -0.002034
Prob.wet/dry	0.9599	35.164	- 5.17436 3.97832	b0= -0.087806612 b1= -0.000317 b2= 0.002034
Prob.dry/wet	0.8421	7.315	2.63029 1.49265	b0= 0.574245074 b1= 0.000218 b2= -0.001032
Prob.dry/dry	0.8421	7.315	- 2.63029 1.49265	b0= 0.425754901 b1= -0.000218 b2= 0.001032

MONTH : DECEMBER

	R	F^*	t(7) t1 & t2	b0 and b1
Prob.wet/wet	0.8707	21.934	4.68342	b0= 0.58464523 b1= 0.000233
Prob.wet/dry	0.8707	21.934	- 4.68342	b0= -0.415354366 b1= -0.000233
Prob.dry/wet	0.7780	10.7732	- 3.27603	b0= 0.914818232 b1= -0.001779
Prob.dry/dry	0.7780	10.732	3.27603	b0= 0.085180910 b1= 0.001779

F.2 SUMMARY OF REGRESSION ANALYSIS FOR THE MEAN DAILY RAINFALL

MONTH : FEBRUARY

Dependent Variable (Y) = Mean of rainfall.

Independent Variables X(1) = Elevation of station.

$X_{(2)}$ = Azimuth of station.

Coefficient of Determination (R^2) = 0.6686

F value from calculation = 5.658

F (0.95;1,7) = 3.590

t_1 (7) from calculation = 2.37874

t (0.05,7) = 1.895

REGRESSION EQUATION :

$$Y = 2.351270381 + 0.000470 X_1$$

MONTH : MARCH

Dependent Variable (Y) = Mean of rainfall.

Independent variables (X1) = Elevation of station.

(X_2) = Azimuth of station.

Coefficient of Determination (R^2) = 0.6123

F (value from calculation) = 4.198

F (0.95;1,7) = 3.590

t_2 (7) from calculation = -2.04902

t_2 (0.05,7) = 1.895

REGRESSION EQUATION :

$$Y = 3.312859008 - 0.002729 X_2$$

MONTH : APRIL

Dependent Variable (Y) = Mean of rainfall.

Independent variables (X_1) = Elevation of station.

(X_2) = Azimuth of station.

Coefficient of Determination (R^2) = 0.8106

F (value from calculation) = 13.417

F (0.95;1,7) = 3.590

t_2 (7) from calculation = -3.66290

t_2 (0.05,7) = 1.895

REGRESSION EQUATION :

$$Y = 3.589567615 - 0.004135 X_2$$

F.3. CHI-SQUARE TEST FOR THE PREDICTIONS OF STANDARD DEVIATION.

	LOSARI	LARANGAN	BREBES	TEGAL	PROCOT	PANGKAH	PETUGURAN	BUMIAYU	BUMIJAWA	MEAN
JANUARY	1.0351	1.2056	1.2668	1.1633	1.0961	1.0791	1.0780	1.1221	1.2120	1.1398
CHI SQUARE CALCULATION	365.0766	496.0799	500.1453	374.5703	410.6328	456.3356	517.3467	486.3334	727.3347	
TABLE UPPER LIMIT	460.0309	531.4813	511.2535	422.5581	486.7320	545.3071	614.2787	558.0596	758.9408	
LOWER LIMIT	348.8107	411.3603	393.5881	316.2835	372.1096	423.5345	484.5629	434.7820	613.9008	
FEBRUARY	1.0587	1.1320	1.1820	1.1288	1.0093	1.0479	1.0700	1.0908	1.2181	1.1042
CHI SQUARE CALCULATION	349.9667	431.6080	405.7118	368.0277	367.4577	402.3896	445.7616	431.7055	714.0566	
TABLE UPPER LIMIT	420.4133	480.3283	435.4187	415.0496	460.0309	483.5305	521.9028	497.3984	721.0088	
LOWER LIMIT	314.4283	346.5133	327.4229	309.7920	348.8107	369.3111	402.9388	381.4432	579.8336	
MARCH	1.0656	1.1470	1.1875	1.1678	1.1109	1.0172	1.1010	1.1235	1.1747	1.1217
CHI SQUARE CALCULATION	317.2987	419.2517	405.4712	290.4693	325.8355	331.9059	525.1322	445.7185	668.1519	
TABLE UPPER LIMIT	387.1163	468.5809	439.7025	327.7614	381.7360	421.4858	601.5640	505.9261	710.4617	
LOWER LIMIT	285.7253	356.2607	331.1391	235.0802	281.1056	315.3558	473.2776	388.9155	570.3799	
APRIL	1.1100	1.0863	1.1861	1.1578	1.0848	1.0438	1.1044	1.1324	1.1077	1.1126
CHI SQUARE CALCULATION	232.4570	340.7536	277.1788	170.6643	230.1055	252.3683	481.4303	378.6240	512.7370	
TABLE UPPER LIMIT	277.7768	403.2405	307.1586	201.9720	281.0480	316.9249	540.4961	427.9184	500.3548	
LOWER LIMIT	193.0648	299.6011	217.6830	130.8694	195.7936	225.9167	426.3455	320.9232	454.4868	
MAY	1.2353	1.0922	1.2057	1.1966	0.9916	1.0407	1.1470	1.1869	1.1456	1.1380
CHI SQUARE CALCULATION	194.3122	224.5912	220.0589	161.9364	155.9783	193.0814	366.8931	253.4516	391.6132	
TABLE UPPER LIMIT	218.5575	270.0674	259.2058	190.8745	218.5575	254.0272	419.3408	288.6742	446.1255	
LOWER LIMIT	144.2841	193.9742	177.6358	121.9671	144.2841	174.0144	313.5808	202.1674	336.7161	
JUNE	1.0531	1.2322	1.1510	1.1859	1.0348	1.0956	1.2540	1.2234	1.1086	1.1487
CHI SQUARE CALCULATION	95.3419	139.4458	137.2703	98.0737	88.2802	108.7271	280.5508	156.5549	240.3007	
TABLE UPPER LIMIT	134.7562	164.0856	171.9237	118.7000	123.1800	146.0818	303.9083	183.0849	295.2039	
LOWER LIMIT	78.0854	100.7560	106.9179	63.2650	66.5170	86.7606	214.9413	115.7567	207.6377	

F.3. CHI-SQUARE TEST FOR THE PREDICTIONS OF STANDARD DEVIATION.

	LOSARI	LARANGAN	BREBES	TEGAL	PROCOT	PANGKAH	PETUGURAN	BUMIAYU	BUMIJAWA	MEAN
JULY	1.0535	1.2414	1.2080	1.2235	1.0491	1.0652	1.2050	1.3946	1.1172	1.1731
CHI SQUARE CALCULATION	61.0696	109.0010	98.8598	94.9132	69.7570	85.3573	196.2013	127.2081	174.2864	
TABLE										
UPPER LIMIT	89.3850	133.6203	120.9400	115.3400	100.7630	118.7000	231.7700	138.1600	222.9690	
LOWER LIMIT	42.5050	77.2213	64.8910	60.8260	42.6310	53.2650	155.0620	80.6816	147.8726	
AUGUST	1.1501	1.1743	1.2792	1.1856	1.0858	1.0672	1.2210	1.4066	1.1092	1.1866
CHI SQUARE CALCULATION	32.9554	97.9775	64.6847	45.9630	63.1409	44.9705	154.3543	195.5909	140.2210	
TABLE										
UPPER LIMIT	49.7650	124.3000	80.2250	63.9700	85.5300	60.6500	186.4255	203.0799	186.4255	
LOWER LIMIT	17.2500	67.3300	36.3050	25.0080	43.2000	20.7440	110.4161	131.7617	110.4161	
SEPTEMBER	0.9724	1.0831	1.1897	1.0672	0.9795	0.9202	1.1020	1.0491	1.0609	1.0560
CHI SQUARE CALCULATION	46.9620	80.0009	93.5076	62.6549	91.0272	80.1601	275.3494	136.1034	250.1528	
TABLE										
UPPER LIMIT	69.8160	100.7630	106.3800	82.5150	124.3000	116.4400	291.9399	171.9237	295.2039	
LOWER LIMIT	29.4580	50.3810	54.3820	37.8550	66.5170	69.7690	204.9017	106.9179	207.6377	
OCTOBER	1.1094	1.0489	1.0542	1.0604	1.0533	1.0023	1.0558	1.6923	0.9937	1.1189
CHI SQUARE CALCULATION	85.2681	162.1736	116.8274	82.4497	103.5400	120.0335	340.4501	314.5870	305.5018	
TABLE										
UPPER LIMIT	109.7400	211.9316	157.3491	110.8600	141.5503	160.5472	430.6317	250.4451	397.0685	
LOWER LIMIT	56.7910	138.9100	95.4925	57.5940	83.2833	104.2744	330.2099	170.3965	294.9731	
NOVEMBER	1.1032	1.0623	1.1039	1.0493	1.0471	1.0046	1.0919	1.2177	1.1550	1.1017
CHI SQUARE CALCULATION	170.2477	272.8874	212.4290	147.6322	220.5000	263.0482	494.5762	330.4923	539.9319	
TABLE										
UPPER LIMIT	217.4539	332.0919	254.0272	191.9858	276.6860	315.0404	563.3704	349.3908	580.3548	
LOWER LIMIT	143.3877	238.7497	174.0144	122.8558	192.1556	225.0012	439.4712	253.4508	454.4868	
DECEMBER	1.0926	1.1412	1.1837	1.0236	1.0412	1.0381	1.1922	1.3243	1.1997	1.1374
CHI SQUARE CALCULATION	289.1429	408.3579	401.7111	233.0853	292.9335	326.7436	553.4570	433.1259	555.8634	
TABLE										
UPPER LIMIT	351.5507	465.3753	442.9144	306.8727	372.0440	412.9034	594.1434	427.9184	593.0831	
LOWER LIMIT	255.2909	353.4663	333.9272	216.7689	272.7976	307.9382	466.6982	320.9232	465.7585	