RAINFALL INTENSITY STUDIES FOR SRI LANKA

by

G.T. Dharmasena

and

S.M. Premasiri

Abstract

Rainfall intensity studies are important to engineers, who are engaged on the design of hydraulic structures, for researchers who deal with soil erosion and earth slips and to many others. Due to global heating, the total amount of annual rainfall is expected to decline in tropical countries, but rainfall intensity is expected to increase, producing unfavourable results. Therefore close monitoring of rainfall intensity can indicate any weather modifications and provide room to take remedial measures.

This paper makes an attempt to update the analysis done by V.R. Baghirathan and E.M. Shaw in 1978. The methodology adopted in this paper differs mainly in two ways. Regionalisation technique and linear interpolation of intensities for short durations adopted by the previous researchers are not adopted in the new study.

This study depends on most recent rainfall observations during last 25 years and therefore results are more relevant to future design and research. In addition, adoption of these results will lead to more economical designs and eliminate some inherent draw-backs in the previous study.

1.0 Introduction

The rainfall distribution in Sri Lanka is subject to spatial and temporal variations leading to distinct patterns of seasonality, regionality and inter annual variability in the climate. The average annual rainfall ranges from around 800 mm. to 5000 mm. as shown in Fig. 1. However, nearly two third of the country receives less than 2000 mm. of rainfall. The South West and the center experience more than 2000 mm. rainfall. A very small area in the South Western slopes of the Central hill country and the Knuckles Range in the North Eastern Sector of the hill country receive as much as 4000 - 5000 mm. of rain. The lowest mean annual rainfall of less than 1000 mm. is found in the extreme Northern, North Western and Southern areas, which are clearly distinguishable as the driest areas.

Distribution of total rainfall over the country had been studied by various researchers and their publications are very common. Moreover with global heating due to green house effect, tropical countries are expected to get less rainfall, but increased rainfall intensities. Therefore study of rainfall intensity becomes more significant to update design criteria in planning water resources development works. The aspect of rainfall depth duration studies is very important to Engineers who deal with water resources development, and urban area developments, Geo scientists who deal with stability analysis of earth slips, and to many others.

In this paper an attempt is made to analyse the rainfall intensity distributions over space and time using recent rainfall data. Large amounts of data are available in the Department of Meteorology, but these data are not in a readily accessible form and considerable amount of manual processing is required before this data could be used.

2.0 Previous Studies

Depth duration curves prepared by the Hydrology division of the Irrigation Department are available, but of limited use due to lack of documentation giving the details of studies and the origin. Moreover these intensity curves were not formally published. A commendable work in this field was first done and published in Europe by Baghirathan V.R. and Shaw E.M. in 1978, in their paper on "Rainfall depth duration study for Sri Lanka", which was published in the Journal of Hydrology in the Netherlands, Amsterdam. Mr. Baghirathan was an engineer attached to the Hydrology division of the Irrigation Department before his departure to U.K. Today, results of this research are widely used in Sri Lanka via the Irrigation Department's "Design Guidelines" and "The design of Irri-

Mr. G.T. Dharmasiri, BSc(Eng)Civil, Dip.Hydrol(Delft), MICE(Lond), MIE(SL), Deputy Director (Hydrology), Irrigation Department.

BSc(Eng)Civil in 1967 from University of Ceylon, Peradeniya, Diploma in Hydrology in the Institute of Hydraulic Engineering in Delft, the Netherlands in 1979.

Mr. S.M. Premasiri, Research Officer, Irrigation Department.

Followed short terms hydrology courses in Asian Institute of Technology in Bangkok, Thailand in 1984 and 1985, Colorado State University, Fort Colins, USA in 1983 and in California University in Davis, USA in 1989.

gation headworks in small catchments", both being works of late Mr. A.J.P. Ponrajah.

The main assumption in this previous study was the use of the method of regionalisation by compounding the data of short time series at a few stations to obtain a long time series for a region. The country was divided into five regions as shown in the Fig. 2, for the purpose of compounding data at many rainfall stations and regionalisation was done on the basis of the average annual rainfalls. For example rainfall data of Colombo, Galle, Kandy and Kurunegala were put together as intensity records were relatively short. The individual station data sets were compounded to yield larger regional data samples to obtain high return periods such as 200 years with much confidence. This approach has been successfully applied in rainfall studies by many research organisations such as NERC, in U.K. in 1975. However, some researchers believed that this method has limitations due to the following inherent draw backs.

a) Independence of annual maximum events of two or more stations.
b) Representation of a long varied period by compounded data.

Another main draw back of this study was the limitation of the total duration to a range from 3 hours to 24 hours. The intensity analysis was actually done only for 3, 6, 12 and 24 hours, but results were interpolated for short time durations such as 1/4 hour, 1/2 hour, 1 hour etc. Short durations are more relevant to small catchments and results of these interpolations were made use of in designs in small watersheds in rural and urban areas. In contrast, when considering catchments of 100 to 200 sq.miles it is necessary to design a storm for 2 to 3 days and therefore storms of 48 to 72 hours durations are also required.

Due to these limitations, and to represent the more recent rainfall pattern, ten principal rainfall stations to cover different climatic regions of Sri Lanka were selected for the present study. Data were collected from automatic rain gauges for 25 years at each station from the Department of Meteorology. The data was analysed from 15 minutes to 72 hours duration for individual stations. Method of processing is more or less similar to the methods adopted by Baghirathan and Shaw in 1978. However, number of stations selected was only ten due to non availability of stations with longer period of records. However, analysis was done for individual stations without compounding station data for regionalisation.

Table 1 shows the details of the stations used for the study.

3.0 Analysis for Individual Stations

Depth duration frequency analysis for each of the ten stations for different durations from 15 minutes, 1 hour, 3 hours up to 72 hours were extracted from the Pluviographs of Automatic rainfall recorders. Then for each station and each duration, extreme value Type 1 distribution, commonly known as Gumbel distribution (EVI) was fitted to the annual maximum series. For station Colombo the analysis was done in a different procedure for a specific study. Therefore in Table 2(ii) no equation is given for Colombo, but intensity values are given in the Table 3(1) to 3(6).

The density function of EVI distribution is defined by

P (X) = EXP [-EXP- (X-U)/ F]], where P(X) is the probability of an event not exceeding X, and U and F are the parameters of the distribution. Using the reduced variate Y,

$$P(X) = EXP[-EXP(-Y)], \quad \text{where, } X = U + FY$$

By using the return period T, Y can be expressed as

$$Y = [-Ln * Ln\{T/T(T-1\}]$$

4.0 Parameter Estimation

Parameters of the distribution F and U can be estimated by either

1. Method of moments or
2. Method of Maximum likelihood

Maximum likelihood method is superior to the method of moments, but relatively complicated and therefore not very commonly used. However, with the availability of computers for speedy calculations a computer programme is prepared to estimate parameters based on the method developed by Jenkinson (1969) and Clark (1973). The method is an iterative procedure and it requires first estimate of the parameters to initiate calculations. This first estimation is done by the method of moments.

Initial estimates of F1 and U1 are given by

$$F1 = (6.0 \ 0.5/3.54)*[(X - Xm)* \ 2/(N-1)] \ 0.5$$

$$\text{and } U1 = Xm - 0.577216*F1,$$

Where Xm = Mean of the sample

N = Number of observations

The maximum likelihood estimates of F and U are obtained by solving the following equations.

$$F2 = Xm - [Xi \ Exp (-Xi/F1) / \{ Exp - (Xi/F1)$$

$$\text{and } U2 = -F1 \ Ln [Exp\{-Xi/F1\} / N$$

Beginning with F1 and U1 estimates by method of moments, iteration continues until the difference of these parameters is negligible.

The standard error of estimates obtained from an EVI distribution fitted by the maximum likelihood method has been derived by NERC (1975) as

$$SE = (F \quad 2/N) * (1.11 + 0.52Y + 0.61 \; Y) \quad 1/2$$

where SE refers to the standard error of a particular return period to Y.

5.0 Chi Square test for goodness of fit

In order to test the fitness of extreme events to Gumbel type 1 distribution, Chi square test was carried out. It was found that empirical distribution agrees with the theoretical distribution at 5% level of significance and is therefore satisfactory. Analysis of 24 hours duration for Kurunegala is shown in Fig. 3 to illustrate the procedure of testing.

Summary of the analysis done under this study is given below.

a. For ten stations depths of rainfall from 2 year return period to 200 year return period were estimated by fitting Gumbel type 1 distribution. This was done for different durations from 1/4 hour to 72 hours. Fitted rainfall depth duration frequency relationships for the ten stations are shown in Table 2.

b. From these relationships, rainfall depth duration estimates for the same stations are shown in Table 3, with standard errors for different return periods.

6.0 Conclusions

Estimated values from this study were compared with the study carried out by Baghirathan and Shaw. It was found that values obtained for shorter durations from the recent study are lower than the interpolated results of the previous study. Therefore by adopting these results it will be possible to make more economical designs. However, results for larger durations show both lower and higher values. Therefore, it is recommended to use higher value obtained from whichever study as estimates for longer durations by both methods. Reason for lower values in the new analysis may be the result of lower average rainfall values during the recent 25 years in comparison to the period before 1975. However, raw data used by Bagihrathan and Shaw is not available for comparison.

The recent study depends on more recent data and rainfall depth duration actually measured for shorter intervals less than 3 hours and longer intervals more than 24 hours. Therefore results of this analysis are more reliable, than interpolated results of the previous study. However, more conservative values may be used for longer durations as mentioned above.

Regionalisation shows some discrepancies when one compares the result obtained for certain regions of the previous study with individual station values of the recent study. For example intensities of Anurdhapura and K.K.S. are different, but in previous study both stations were put together to represent one region. Colombo and Kandy show similar variations. Therefore this shows the disadvantage of regionalisation to obtain higher return periods for a region.

7.0 Acknowledgement

Authors thank the Director of Meteorology for granting permission to use the data available in the Meteorology Department for the study, and the staff of the Hydrology division of the Irrigation Department who carried out the laborious task of intensity analysis.

8.0 References

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2. Climate, Water and Agriculture in Sri Lanka, M.M. Yashino, I. Kayane, C.M. Maddumabandara - 1983.

3. Design of Irrigation Head Works for Small Catchments, A.J.P. Ponrajah - 1982.

TABLE 1

DETAILS OF STATIONS SELECTED FOR ANALYSIS

Rainfall Station	District	Duration of Records	Elevation in N.S.L.
Anuradhapura	Anuradhapura	1965 - 1987	95.0 M
Kurunegala	Kurunegala	1961 - 1987	150.0 M
Nuwara Eliya	Nuwara Eliya	1957 - 1982	1917.0 M
Batticaloa	Batticaloa	1963 - 1987	2.0 M
Hambantota	Hambantota	1963 - 1987	5.0 M
K.K.S.	Jaffna	1957 - 1982	5.0 M
Katugastota	Kandy	1966 - 1982	486.0 M
Colombo	Colombo	1960 - 1985	2.0 M
Puttalam	Puttalam	1958 - 1982	2.0 M
Galle	Galle	1962 - 1983	2.0 M

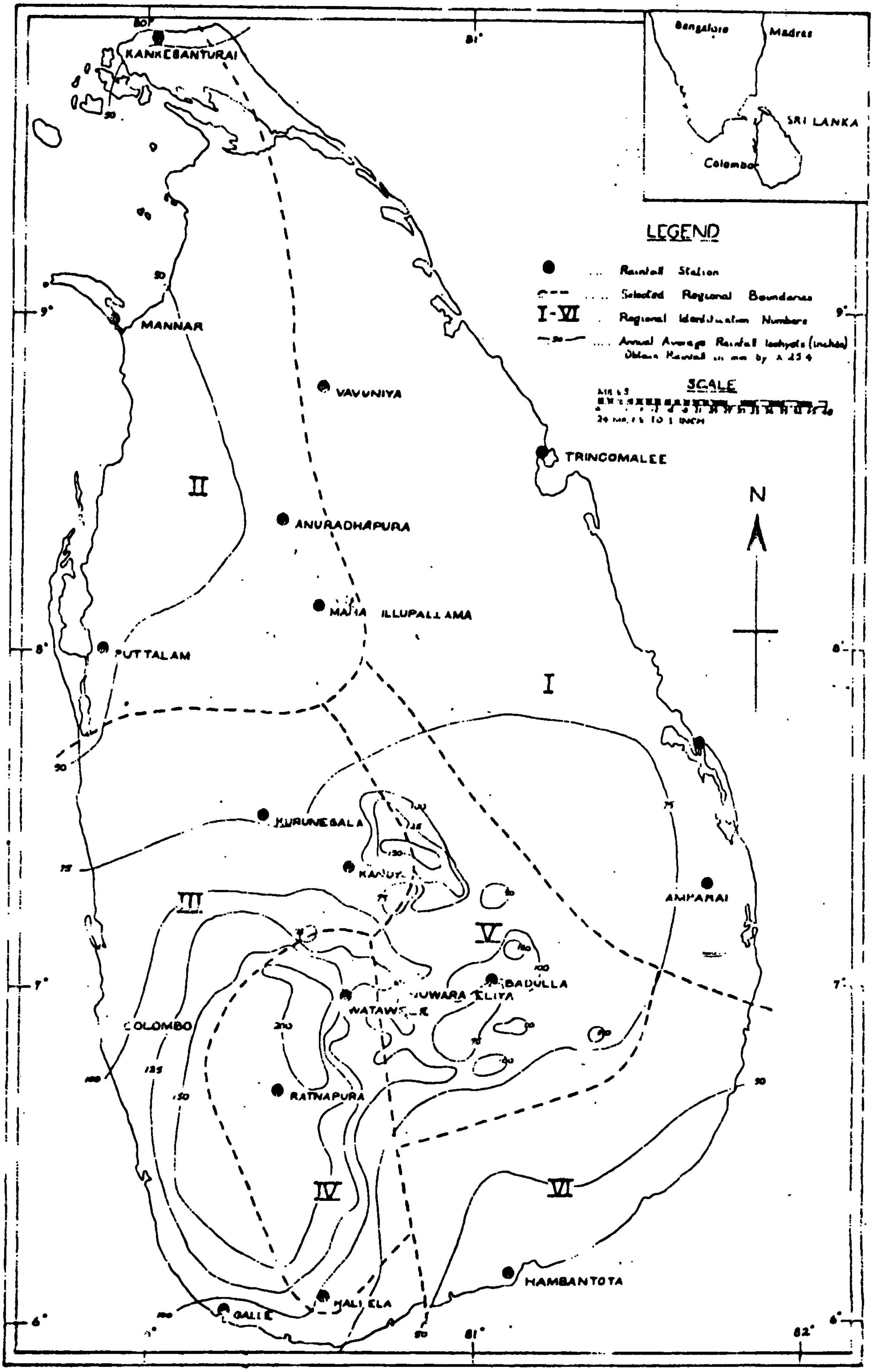
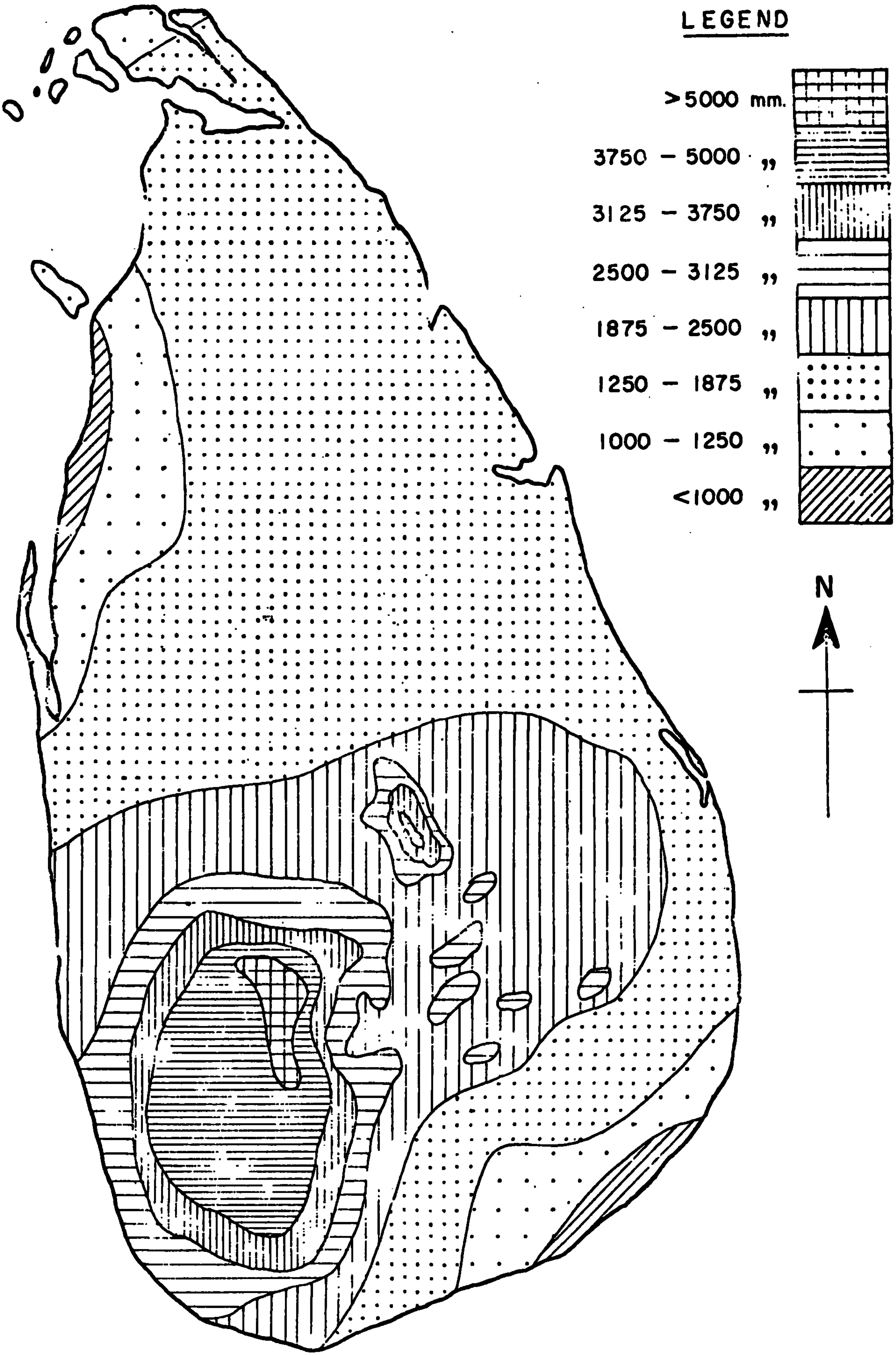


Fig.1. Sri Lanka. General locality of rain-gauge stations and of regions *I—VI*.



SRI LANKA MEAN ANNUAL RAINFALL (mm).

SOURCE - CLIMATE, WATER AND AGRICULTURE IN SRI LANKA.

TABLE 2 (1)

RAINFALL-DEPTH-DURATION-FREQUANCY RELATIONSHIPS

STATION	1/4 HOURS	1/2 HOURS	1 HOUR	2 HOURS	6 HOURS	12 HOURS
KURUNEGALA	X=0.98+0.26Y	X=1.49+0.36Y	X=2.19+0.51Y	X=2.67+0.67Y	X=2.98+0.84Y	X=3.52+1.16Y
ANURADHAPURA	X=0.63+0.22Y	X=1.16+0.48Y	X=1.70+0.65Y	X=2.16+0.83Y	X=2.64+0.68Y	X=3.14+0.93Y
BATICALOA	X=0.86+0.14Y	X=1.28+0.30Y	X=1.82+0.67Y	X=2.10+0.67Y	X=2.66+1.03Y	X=3.24+1.36Y
HAMBANTOTA	X=0.81+0.53Y	X=1.23+0.72Y	X=1.52+0.67Y	X=1.83+0.69Y	X=2.24+0.90Y	X=2.49+1.05Y
N'ELIYA	X=0.46+0.24Y	X=0.76+0.39Y	X=1.06+0.54Y	X=1.40+0.79Y	X=1.93+0.58Y	X=2.40+0.90Y
K.K.S.	X=0.73+0.48Y	X=1.08+0.42Y	X=1.54+0.60Y	X=2.11+0.81Y	X=2.72+1.10Y	X=3.28+1.38Y
KATUGASTOTA	X=0.88+1.91Y	X=1.49+0.28Y	X=1.94+0.46Y	X=2.34+0.59Y	X=2.87+0.69Y	X=3.08+0.72Y
COLOMBO				NOT DERIVED		
PUTTLAM	X=0.85+0.38Y	X=1.33+0.46Y	X=1.76+0.61Y	X=2.16+0.82Y	X=2.51+0.96Y	X=2.79+0.94Y
GALLE	X=0.74+0.23Y	X=1.30+0.44Y	X=1.91+0.60Y	X=2.38+1.24Y	X=3.18+1.37Y	X=4.17+1.59Y

TABLE 2 (II)

RAINFALL-DEPTH-DURATION-FREQUANCY RELATIONSHIPS

STATION	24 HOURS	48 HOURS	72 HOURS	96 HOURS	120 HOURS
KURUNEGALA	X=4.17+0.99Y	X=5.11+1.10Y	X=5.94+1.07Y	X=6.41+1.28Y	X=7.19+1.97Y
ANURADHAPURA	X=3.41+0.82Y	X=4.18+1.18Y	X=4.94+1.30Y	X=5.60+1.65Y	X=5.93+1.53Y
BATICALOA	X=4.39+1.56Y	X=5.88+1.80Y	X=6.76+2.27Y	X=7.51+2.69Y	X=8.06+3.04Y
HAMBANTOTA	X=2.89+1.11Y	X=3.70+1.32Y	X=4.11+1.51Y	X=4.52+1.40Y	X=4.66+1.41Y
N'ELIYA	X=2.82+1.37Y	X=3.99+1.57Y	X=4.88+2.12Y	X=5.56+2.26Y	X=6.00+2.46Y
K.K.S.	X=3.97+1.72Y	X=5.40+2.35Y	X=6.28+2.80Y	X=6.94+3.23Y	X=7.57+3.60Y
KATUGASTOTA	X=3.38+0.77Y	X=4.17+1.20Y	X=4.57+1.49Y	X=4.93+1.53Y	X=5.29+1.66Y
COLOMBO			NOT DERIVED		
PUTTLAM	X=3.02+1.00Y	X=3.79+1.42Y	X=4.24+1.52Y	X=4.63+1.75Y	X=5.24+1.88Y
GALLE	X=4.41+1.71Y	X=5.39+1.99Y	X=6.03+2.32Y	X=6.28+2.58Y	X=7.19+5.91Y

TABLE 3 (I)

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES
1/4 HOURS

STATION	RETURN PERIOD IN YEARS	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	1.08	1.37	1.57	1.82	2.01	2.19	2.37
	STD.ERR	0.12	0.18	0.23	0.3	0.35	0.41	0.46
ANURADHAPURA	VARIATE	0.72	0.97	1.14	1.35	1.51	1.67	1.83
	STD.ERR	0.11	0.17	0.22	0.28	0.33	0.38	0.43
BATICALOA	VARIATE	0.91	1.08	1.19	1.33	1.44	1.54	1.65
	STD.ERR	0.06	0.1	0.13	0.17	0.21	0.24	0.27
HAMBANTOTA	VARIATE	0.86	1.03	1.14	1.28	1.38	1.49	1.59
	STD.ERR	0.07	0.1	0.13	0.18	0.21	0.24	0.27
N'ELIYA	VARIATE	0.52	0.71	0.83	0.99	1.11	1.22	1.33
	STD.ERR	0.07	0.11	0.15	0.19	0.23	0.26	0.3
K.K.S.	VARIATE	0.77	0.91	0.99	1.1	1.19	1.27	1.35
	STD.ERR	0.05	0.08	0.1	0.37	0.16	0.18	0.21
COLOMBO	VARIATE	1.25	1.45	1.57	1.77	1.91	2.04	2.16
	STD.ERR				NOT ESTIMATED			
KATUGASTOTA	VARIATE	0.95	1.17	1.31	1.49	1.62	1.75	1.89
	STD.ERR	0.11	0.16	0.21	0.27	0.32	0.37	0.42
PUTTLAM	VARIATE	0.91	1.09	1.21	1.36	1.48	1.59	1.7
	STD.ERR	0.07	0.11	0.15	0.19	0.22	0.26	0.29
GALLE	VARIATE	0.82	1.06	1.21	1.42	1.56	1.71	1.86
	STD.ERR	0.11	0.17	0.22	0.29	0.34	0.39	0.44

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES
1/2 HOURS

STATION	RETURN PERIOD IN YEARS	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	1.63	2.05	2.32	2.67	2.93	3.19	3.44
	STD.ERR	0.16	0.25	0.32	0.42	0.49	0.57	0.64
ANURADHAPURA	VARIATE	1.3	1.75	2.05	2.42	2.69	2.97	3.24
	STD.ERR	0.19	0.3	0.38	0.5	0.59	0.67	0.76
BATICALOA	VARIATE	1.37	1.66	1.85	2.09	2.27	2.45	2.62
	STD.ERR	0.12	0.18	0.23	0.3	0.35	0.41	0.46
HAMBANTOTA	VARIATE	1.34	1.66	1.87	2.15	2.35	2.54	2.74
	STD.ERR	0.13	0.21	0.26	0.34	0.41	0.47	0.53
N'ELIYA	VARIATE	0.84	1.11	1.28	1.51	1.67	1.83	2
	STD.ERR	0.11	0.16	0.21	0.28	0.32	0.37	0.42
K.K.S.	VARIATE	1.22	1.65	1.94	2.3	2.56	2.83	3.09
	STD.ERR	0.17	0.26	0.34	0.44	0.52	0.6	0.68
COLOMBO	VARIATE	2.02	2.52	2.81	3.15	3.42	3.7	3.97
	STD.ERR				NOT ESTIMATED			
KATUGASTOTA	VARIATE	1.6	1.92	2.13	2.4	2.6	2.8	2.99
	STD.ERR	0.16	0.24	0.32	0.41	0.48	0.55	0.62
PUTTLAM	VARIATE	1.45	1.84	2.09	2.42	2.66	2.89	3.13
	STD.ERR	0.16	0.24	0.31	0.41	0.48	0.55	0.62
GALLE	VARIATE	1.45	1.91	2.21	2.59	2.88	3.16	3.45
	STD.ERR	0.21	0.33	0.43	0.55	0.65	0.75	0.85

TABLE 3 (II)

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

1 HOUR

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	2.38	2.96	3.34	3.82	4.18	4.54	4.89
	STD.ERR	0.23	0.35	0.45	0.58	0.69	0.79	0.89
ANURADHAPURA	VARIATE	1.92	2.61	3.06	3.63	4.05	4.47	4.89
	STD.ERR	0.3	0.46	0.59	0.77	0.9	1.04	1.17
BATICALOA	VARIATE	1.95	2.37	2.65	2.99	3.25	3.51	3.77
	STD.ERR	0.17	0.26	0.34	0.44	0.52	0.59	0.67
HAMBANTOTA	VARIATE	1.71	2.3	2.69	3.18	3.55	3.91	4.27
	STD.ERR	0.24	0.38	0.49	0.63	0.74	0.85	0.96
N'ELIYA	VARIATE	1.19	1.57	1.82	2.14	2.38	2.61	2.85
	STD.ERR	0.15	0.24	0.31	0.4	0.47	0.54	0.61
K.K.S.	VARIATE	1.76	2.45	2.9	3.47	3.89	4.31	4.73
	STD.ERR	0.27	0.42	0.54	0.7	0.83	0.95	1.08
COLOMBO	VARIATE	2.87	3.62	4.03	4.58	5.02	5.45	5.86
	STD.ERR	NOT ESTIMATED						
KATUGASTOTA	VARIATE	2.11	2.64	2.99	3.43	3.76	4.09	4.22
	STD.ERR	0.26	0.41	0.52	0.68	0.8	0.92	1.04
PUTTLAM	VARIATE	1.97	2.62	3.05	3.59	4	4.4	4.8
	STD.ERR	0.27	0.41	0.53	0.68	0.8	0.92	1.05
GALLE	VARIATE	2.11	2.72	3.13	3.65	4.04	4.42	4.8
	STD.ERR	0.29	0.45	0.58	0.75	0.88	1.01	1.14

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

2 HOURS

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	2.92	3.68	4.18	4.82	5.29	5.76	6.22
	STD.ERR	0.3	0.46	0.59	0.77	0.91	1.04	1.18
ANURADHAPURA	VARIATE	2.39	3.08	3.54	4.12	4.55	4.98	5.41
	STD.ERR	0.3	0.47	0.6	0.78	0.92	1.05	1.19
BATICALOA	VARIATE	2.35	3.11	3.61	4.25	4.72	5.19	5.66
	STD.ERR	0.31	0.48	0.62	0.8	0.94	1.08	1.22
HAMBANTOTA	VARIATE	2.07	2.82	3.32	3.95	4.41	4.87	5.33
	STD.ERR	0.31	0.48	0.62	0.8	0.95	1.09	1.23
N'ELIYA	VARIATE	1.51	1.83	2.04	2.31	2.51	2.7	2.9
	STD.ERR	0.13	0.2	0.26	0.33	0.39	0.45	0.51
K.K.S.	VARIATE	2.4	3.3	3.89	4.64	5.19	5.75	6.29
	STD.ERR	0.36	0.55	0.71	0.92	1.09	1.25	1.41
COLOMBO	VARIATE	3.11	3.78	4.25	4.88	5.35	5.83	6.34
	STD.ERR	NOT ESTIMATED						
KATUGASTOTA	VARIATE	2.56	3.24	3.68	4.24	4.66	5.07	5.49
	STD.ERR	0.33	0.52	0.66	0.86	1.01	1.16	1.31
PUTTLAM	VARIATE	2.46	3.39	4.01	4.78	5.36	5.93	6.5
	STD.ERR	0.38	0.59	0.76	0.98	1.15	1.32	1.5
GALLE	VARIATE	2.75	3.91	4.67	5.64	6.35	7.07	7.78
	STD.ERR	0.55	0.84	1.08	1.4	1.64	1.89	2.14

TABLE 3(III)

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

6 HOURS

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	3.29	4.24	4.87	5.67	6.26	6.85	7.43
	STD.ERR	0.38	0.58	0.75	0.97	1.14	1.31	1.48
ANURADHAPURA	VARIATE	2.89	3.66	4.17	4.82	5.3	5.78	6.25
	STD.ERR	0.34	0.52	0.67	0.87	1.02	1.17	1.33
BATICALOA	VARIATE	3.04	4.21	4.99	5.97	6.69	7.41	8.13
	STD.ERR	0.48	0.74	0.95	1.23	1.45	1.67	1.89
HAMBANTOTA	VARIATE	2.57	3.59	4.27	5.12	5.75	6.38	7.01
	STD.ERR	0.43	0.66	0.85	1.1	1.29	1.48	1.68
N'ELIYA	VARIATE	2.15	2.81	3.25	3.8	4.21	4.62	5.03
	STD.ERR	0.27	0.42	0.54	0.7	0.82	0.94	1.07
K.K.S.	VARIATE	3.13	4.38	5.21	6.27	7.04	7.82	8.59
	STD.ERR	0.51	0.78	1	1.3	1.53	1.76	1.99
COLOMBO	VARIATE	3.74	4.6	5.19	5.98	6.61	7.24	7.83
	STD.ERR	NOT ESTIMATED						
KATUGASTOTA	VARIATE	3.12	3.91	4.42	5.08	5.57	6.05	6.53
	STD.ERR	0.39	0.6	0.77	1	1.18	1.35	1.53
PUTTLAM	VARIATE	2.86	3.95	4.67	5.58	6.26	6.93	7.6
	STD.ERR	0.45	0.69	0.89	1.15	1.35	1.56	1.76
GALLE	VARIATE	3.67	5.2	6.22	7.5	8.45	9.4	10.34
	STD.ERR	0.73	1.12	1.43	1.86	2.18	2.51	2.84

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

12 HOURS

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	3.87	4.94	5.65	6.54	7.2	7.86	8.52
	STD.ERR	0.42	0.65	0.84	1.09	1.28	1.47	1.66
ANURADHAPURA	VARIATE	3.39	4.15	4.66	5.3	5.78	6.25	6.72
	STD.ERR	0.33	0.52	0.66	0.86	1.01	1.16	1.31
BATICALOA	VARIATE	3.73	5.25	6.26	7.54	8.49	9.42	10.36
	STD.ERR	0.63	0.97	1.24	1.61	1.89	2.17	2.46
HAMBANTOTA	VARIATE	2.88	4.08	4.87	5.88	6.62	7.36	8.1
	STD.ERR	0.5	0.78	1.01	1.29	1.52	1.75	1.98
N'ELIYA	VARIATE	2.73	3.75	4.43	5.28	5.91	6.54	7.17
	STD.ERR	0.42	0.65	0.83	1.08	1.26	1.45	1.64
K.K.S.	VARIATE	3.79	5.36	6.4	7.72	8.69	9.66	10.63
	STD.ERR	0.63	0.98	1.26	1.63	1.91	2.2	2.49
COLOMBO	VARIATE	4.84	5.9	6.69	7.83	8.58	9.45	10.23
	STD.ERR	NOT ESTIMATED						
KATUGASTOTA	VARIATE	3.35	4.16	4.7	5.38	5.88	6.38	6.88
	STD.ERR	0.41	0.63	0.8	1.04	1.22	1.4	1.59
PUTTLAM	VARIATE	3.13	4.2	4.91	5.81	6.47	7.13	7.79
	STD.ERR	0.44	0.68	0.87	1.13	1.33	1.53	1.73
GALLE	VARIATE	4.59	5.88	6.74	7.83	8.63	9.43	10.22
	STD.ERR	0.61	0.94	1.21	1.57	1.84	2.12	2.4

TABLE 3(IV)

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

24 HOURS

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	4.54	5.66	6.41	7.35	8.08	8.75	9.44
	STD.ERR	0.45	0.69	0.88	1.14	1.34	1.54	1.75
ANURADHAPURA	VARIATE	3.72	4.65	5.27	6.05	6.63	7.2	7.77
	STD.ERR	0.41	0.63	0.81	1.05	1.23	1.42	1.6
BATICALOA	VARIATE	4.97	6.74	7.92	9.41	10.51	11.6	12.69
	STD.ERR	0.73	1.13	1.45	1.88	2.21	2.54	2.87
HAMBANTOTA	VARIATE	3.3	4.56	5.4	6.46	7.24	8.02	8.8
	STD.ERR	0.53	0.82	1.05	1.36	1.6	1.84	2.08
N'ELIYA	VARIATE	3.33	4.89	5.93	7.24	8.21	9.17	10.13
	STD.ERR	0.64	0.99	1.27	1.65	1.94	2.23	2.52
K.K.S.	VARIATE	4.6	6.56	7.85	9.48	10.69	11.89	13.09
	STD.ERR	0.79	1.21	1.56	2.02	2.38	2.73	3.09
COLOMBO	VARIATE	5.82	7.36	8.46	9.92	11.1	12.2	13.31
	STD.ERR	NOT ESTIMATED						
KATUGASTOTA	VARIATE	3.65	4.49	5.05	5.75	6.28	6.79	7.31
	STD.ERR	0.42	0.65	0.83	1.08	1.26	1.45	1.65
PUTTLAM	VARIATE	3.39	4.53	5.28	6.24	6.94	7.65	8.35
	STD.ERR	0.47	0.72	0.93	1.2	1.41	1.63	1.84
GALLE	VARIATE	4.89	6.37	7.36	8.6	9.52	10.44	11.35
	STD.ERR	0.7	1.08	1.39	1.8	2.12	2.43	2.75

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

48 HOURS

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	5.51	6.76	7.58	8.63	9.4	10.17	10.93
	STD.ERR	0.49	0.76	0.98	1.27	1.49	1.71	1.94
ANURADHAPURA	VARIATE	4.61	5.94	6.82	7.93	8.76	9.58	10.4
	STD.ERR	0.58	0.9	1.16	1.5	1.76	2.02	2.29
BATICALOA	VARIATE	6.54	8.59	9.95	11.67	12.94	14.2	15.46
	STD.ERR	0.85	1.3	1.67	2.17	2.55	2.93	3.31
HAMBANTOTA	VARIATE	4.19	5.69	6.68	7.93	8.86	9.79	10.71
	STD.ERR	0.63	0.97	1.25	1.62	1.9	2.18	2.47
N'ELIYA	VARIATE	4.57	6.35	7.53	9.03	10.14	11.23	12.33
	STD.ERR	0.74	1.13	1.45	1.89	2.22	2.55	2.88
K.K.S.	VARIATE	6.26	8.93	10.69	12.91	14.56	16.2	17.83
	STD.ERR	1.08	1.66	2.13	2.76	3.24	3.72	4.21
COLOMBO	VARIATE	7.24	9.09	10.71	12.2	13.6	15.03	16.42
	STD.ERR					NOT ESTIMATED		
KATUGASTOTA	VARIATE	4.61	5.97	6.87	8.01	8.86	9.7	10.53
	STD.ERR	0.68	1.05	1.35	1.75	2.05	2.36	2.67
PUTTLAM	VARIATE	4.31	5.92	6.98	8.32	9.32	10.31	11.3
	STD.ERR	0.66	1.02	1.31	1.7	2	2.29	2.59
GALLE	VARIATE	6.01	7.94	9.21	10.82	12.01	13.2	14.38
	STD.ERR	0.91	1.4	1.8	2.33	2.74	3.15	3.56

TABLE 3(v)

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

72 HOURS

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	6.33	7.55	8.36	9.38	10.13	10.89	11.64
	STD.ERR	0.48	0.74	0.95	1.24	1.46	1.67	1.89
ANURADHAPURA	VARIATE	5.42	6.88	7.85	9.08	9.99	10.9	11.8
	STD.ERR	0.64	0.99	1.27	1.65	1.94	2.23	2.52
BATICALOA	VARIATE	7.6	10.18	11.9	14.06	15.67	17.27	18.85
	STD.ERR	1.07	1.65	2.11	2.74	3.22	3.7	4.18
HAMBANTOTA	VARIATE	4.67	6.39	7.53	8.97	10.04	11.1	12.16
	STD.ERR	0.72	1.12	1.43	1.86	2.18	2.51	2.84
N'ELIYA	VARIATE	5.66	8.07	9.67	11.69	13.19	14.67	16.15
	STD.ERR	1	1.53	1.97	2.55	3	3.44	3.89
K.K.S.	VARIATE	7.31	10.49	12.6	15.27	17.24	19.2	21.16
	STD.ERR	1.29	1.99	2.55	3.3	3.88	4.46	5.04
COLOMBO	VARIATE	7.87	9.37	11.65	13.78	15.43	17.04	18.74
	STD.ERR	NOT ESTIMATED						
KATUGASTOTA	VARIATE	5.12	6.81	7.94	9.36	10.41	11.46	12.5
	STD.ERR	0.85	1.31	1.68	2.18	2.56	2.94	3.32
PUTTLAM	VARIATE	4.8	6.52	7.66	9.1	10.17	11.23	12.29
	STD.ERR	0.71	1.09	1.41	1.82	2.14	2.46	2.78
GALLE	VARIATE	6.73	8.9	10.33	12.14	13.49	14.82	16.15
	STD.ERR	1.03	1.58	2.03	2.63	3.09	3.55	4.01

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

96 HOURS

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	6.88	8.33	9.3	10.51	11.41	12.31	13.2
	STD.ERR	0.57	0.89	1.14	1.48	1.73	1.99	2.25
ANURADHAPURA	VARIATE	6.18	8	9.2	10.71	11.84	12.95	14.06
	STD.ERR	0.8	1.23	1.57	2.04	2.4	2.76	3.12
BATICALOA	VARIATE	8.5	11.56	13.59	16.15	18.05	19.94	21.82
	STD.ERR	1.27	1.95	2.5	3.24	3.8	4.37	4.94
HAMBANTOTA	VARIATE	5.03	6.62	7.68	9.01	10	10.98	11.96
	STD.ERR	0.67	1.03	1.32	1.72	2.02	2.32	2.62
N'ELIYA	VARIATE	6.39	8.95	10.65	12.79	14.39	15.96	17.54
	STD.ERR	1.06	1.63	2.09	2.71	3.18	3.66	4.14
K.K.S.	VARIATE	8.13	11.79	14.22	17.29	19.56	21.82	24.07
	STD.ERR	1.49	2.29	2.93	3.8	4.47	5.14	5.8
COLOMBO	VARIATE	8.58	11.18	13.31	15.35	17.2	19.09	21.02
	STD.ERR	NOT ESTIMATED						
KATUGASTOTA	VARIATE	5.49	7.24	8.39	9.85	10.94	12.01	13.08
	STD.ERR	0.87	1.34	1.73	2.24	2.63	3.02	3.49
PUTTLAM	VARIATE	5.27	7.26	8.57	10.23	11.46	12.68	13.9
	STD.ERR	0.82	1.26	1.62	2.1	2.46	2.83	3.2
GALLE	VARIATE	6.95	9.02	10.4	12.13	13.42	14.7	15.97
	STD.ERR	0.98	1.51	1.94	2.52	2.96	3.4	3.84

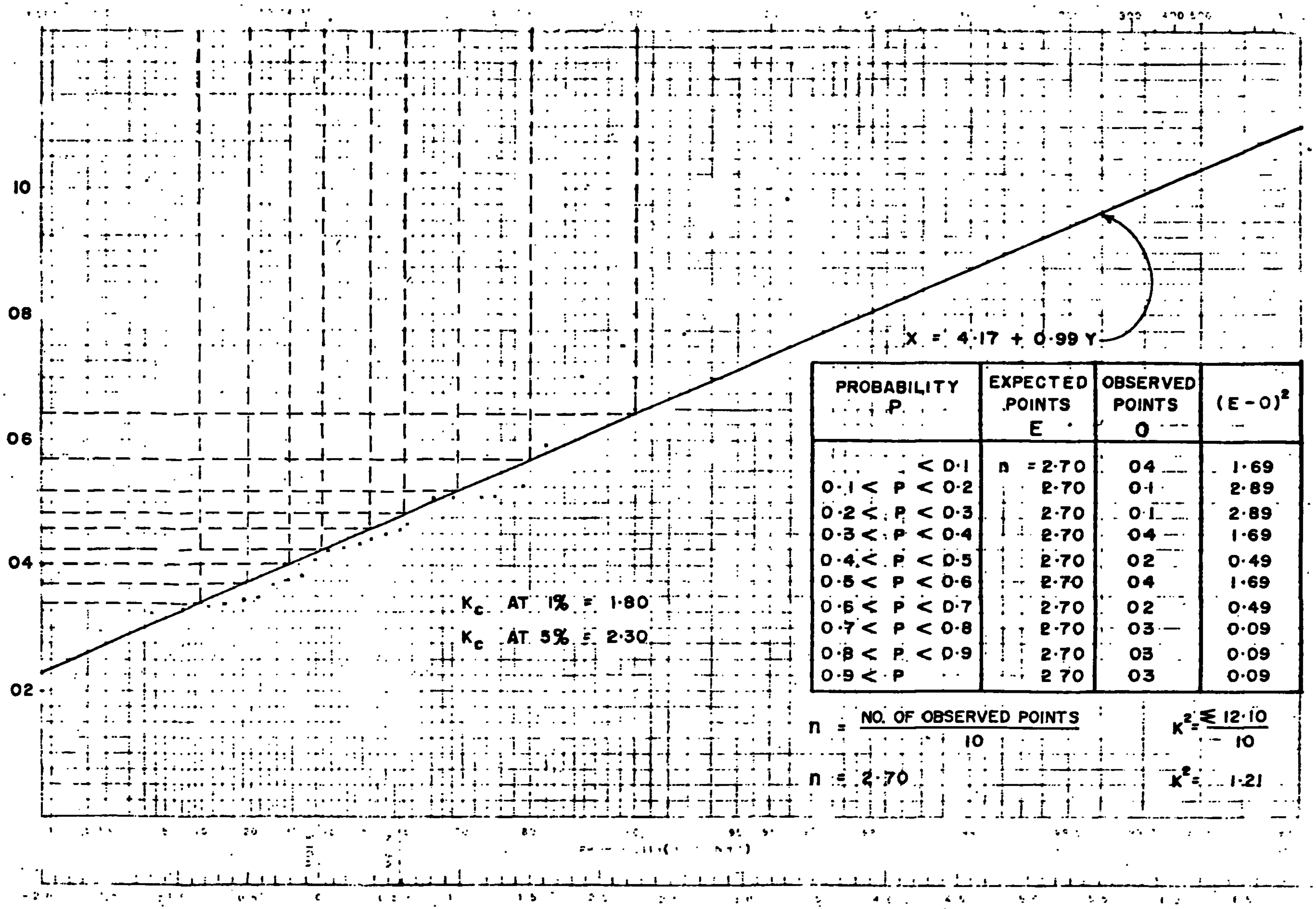
TABLE 3 (VI)

RAINFALL DEPTH-DURATIN ESTIMATES IN INCHES

120 HOURS

STATION	RETURN PERIOD	2	5	10	25	50	100	200
KURUNEGALA	VARIATE	7.92	10.15	11.63	13.5	14.89	16.26	17.64
	STD.ERR	0.89	1.37	1.75	2.27	2.67	3.07	3.47
ANURADHAPURA	VARIATE	6.49	8.21	9.36	10.8	11.88	12.94	14
	STD.ERR	0.76	1.17	1.5	1.95	2.29	2.63	2.97
BATICALOA	VARIATE	9.17	12.61	14.89	17.76	19.9	22.02	24.13
	STD.ERR	1.42	2.19	2.81	3.64	4.27	4.91	5.55
HAMBANTOTA	VARIATE	5.18	6.78	7.84	9.18	10.17	11.16	12.14
	STD.ERR	0.67	1.04	1.33	1.73	2.03	2.33	2.63
N'ELIYA	VARIATE	6.91	9.7	11.55	13.88	15.62	17.34	19.05
	STD.ERR	1.15	1.78	2.28	2.95	3.47	3.99	4.51
K.K.S.	VARIATE	8.89	12.98	15.69	19.11	21.65	24.17	26.68
	STD.ERR	1.66	2.55	3.27	4.24	4.98	5.73	6.48

CHI SQUARE TEST FOR 24 HOURS



PROBABILITY P	EXPECTED POINTS E	OBSERVED POINTS O	$\frac{(E-O)^2}{}$
< 0·1	n = 2·70	04	1·69
0·1 < P < 0·2	2·70	01	2·89
0·2 < P < 0·3	2·70	01	2·89
0·3 < P < 0·4	2·70	04	1·69
0·4 < P < 0·5	2·70	02	0·49
0·5 < P < 0·6	2·70	04	1·69
0·6 < P < 0·7	2·70	02	0·49
0·7 < P < 0·8	2·70	03	0·09
0·8 < P < 0·9	2·70	03	0·09
0·9 < P	2 70	03	0·09

$n = \frac{\text{NO. OF OBSERVED POINTS}}{10}$

$n = 2·70$

$K^2 = \frac{\leq 12·10}{10}$

$K^2 = 1·21$

STATION KURUNEGALA