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VARIATION OF RAINFALL WITH AREA IN PENINSULAR MALAYSIA

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KEMENTERIAN PERTANIAN MALAYSIA

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VARIATION OF RAINFALL WITH AREA IN PENINSULAR MALAYSIA

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ABSTRACT

"Areal rainfall reduction factors" (ARFs) are factors for converting point rainfall to areal rainfall. There is a need for ARFs because many engineers are interested to determine areal rainfall for their project planning and design whereas usually available are point rainfall data. ARFs determined for the United States by the United States Weather Bureau (USWB) have been used by engineers here to determine areal rainfall. The validity of these factors to Malaysian conditions has not been verified. In this study, ARFs were studied for typical Malaysian climatic conditions. The areas considered in this study were (i) Kuala Lumpur where the rain is usually of the thunderstorm type and (ii) North Kelantan where heavy rain is usually of the monsoonal type. The factors derived from both areas were lower compared with those derived for U.S.A by the United States Weather Bureau (USWB) and for United Kingdom by the Natural Environmental Research Council (NERC).

CONTENTS

		Page
	ABSTRACT	
1.	INTRODUCTION	1
2.	INTERPRETATION AND DERIVATION OF ARF	2
3.	STORM-CENTRED ARF	2
4.	FIXED-AREA ARF	4
5.	METHODS OF DERIVING DESIGN AREAL RAINFALL	4
6.	ESTIMATION OF ARFs FOR KUALA LUMPUR	5
	6.1 Rainfall Data	5
	6.2 Sampling of Areas and Duration of Storms Studied	5
	6.3 Estimation of ARF	9
	6.4 Results	9
7.	ESTIMATION OF 24-HOUR ARFs FOR NORTH KELANTAN	12
	7.1 Data Extraction	12
	7.2 Areal Rainfall Frequency Curve	12
	7.3 Average Point Rainfall Frequency Curve	13
	7.4 Test on Goodness-of-Fit of Frequency Curves	13
	7.5 Computation of ARFs	13
	7.6 Results	13
8.	CONCLUSION	15
9.	REFERENCES	16
	APPENDIX I : Location of Rainfall Stations and "Fixed Areas" Used in the Kuala Lumpur ARF Study	17
	APPENDIX II : Maximum Areal Rainfall (MAR) and Maximum Point Rainfall (MPR) Extracted for the Computation of	20

APPENDIX III : Location of Rainfall Stations and "Fixed Areas" Used in the Kelantan ARF Study 41

APPENDIX IV(a): Areal Rainfall Frequency Curves for Kelantan 46

(b): Point Rainfall Frequency Curves for Kelantan

(c): Areal Rainfall and Average Point Rainfall Frequency Curves Used in the Derivation of ARFs for Kelantan

APPENDIX V : Maximum Areal Rainfall (MAR) and Maximum Point Rainfall (MPR) Extracted for the Computation of ARFs for Kelantan 54

1. INTRODUCTION

Generally, in the planning and design of water resources projects, engineers are more interested to know the average areal rainfall over a catchment rather than rainfall at a specific point in the catchment. Rainfall intensity varies with time and space. Depending on the nature of the rain, rainfall over a certain location may be more intense at a certain time and then less intense than its surroundings at another time. Therefore point rainfall recorded by a rainfall station do not represent the areal rainfall of the area around it.

Rainfall stations collect point rainfall data. Hydrological procedures for computing design rainstorm were mainly developed based on point rainfall data. The designed rainstorm derived from such data or procedures, without accounting for the spatial distribution of rainfall would tend to be over-estimated.

The Drainage and Irrigation Department's Hydrological Procedure No. 1 - Estimation of the Design Rainstorm (Revised and updated 1982) recommends multiplying estimated rainfall by a factor to obtain areal rainfall. These factors are "areal reduction factors" (ARFs) derived by the United States Weather Bureau (USWB 1957-58) for the United States. They may not apply to Malaysian conditions. Taylor and Toh (1976) compared locally derived 24-hour ARFs with the USWB curve and found that the USWB curve forms the upper limit of the locally derived values (see Figure 1). The National Environmental Research Council (NERC) of United Kingdom in their Flood Studies Report in 1975 presented a set of ARFs derived for the United Kingdom. The factors obtained by NERC, however were fairly close to those obtained by USWB.

In Malaysia, two distinct types of rainfall are commonly experienced:

(i) convectional rain, and
(ii) monsoon rain

Convectional rain is more dominant on the west coast of Peninsular Malaysia. This type of rain is very localised , could be very intense and normally lasts for about two to three hours. However, on the east coast of Peninsular Malaysia and the coastal regions of Sabah and Sarawak, monsoon rains brought by the North-East Monsoon dominate. Monsoon rains are more widespread and could persist for several days to a week.

In this study, analyses were carried out to determine the ARFs for Kuala Lumpur and North Kelantan, areas characterised by convectional rains and by monsoon rains respectively. This study also checks whether the ARFs derived for the United States and United Kingdom are applicable here.

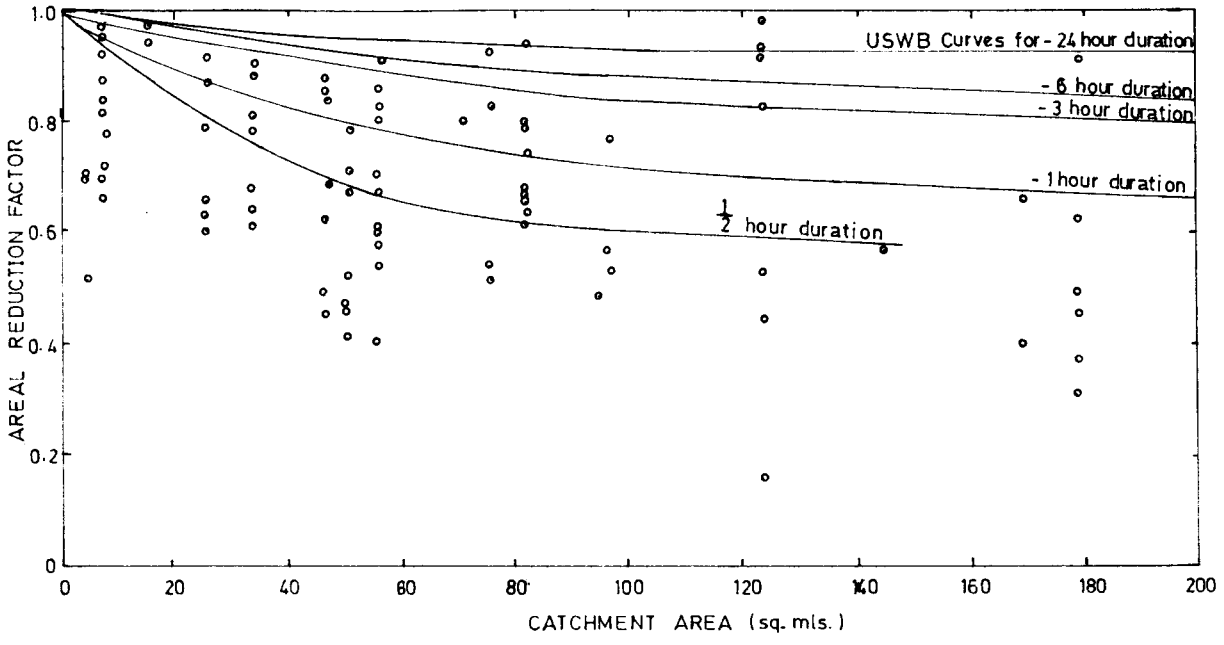


Figure 1: Variation of the 24-hour ARF with catchment area (Taylor and Toh (1976))

2. INTERPRETATION AND DERIVATION OF ARF

The areal reduction factor (ARF) is a factor for converting point rainfall to areal rainfall:

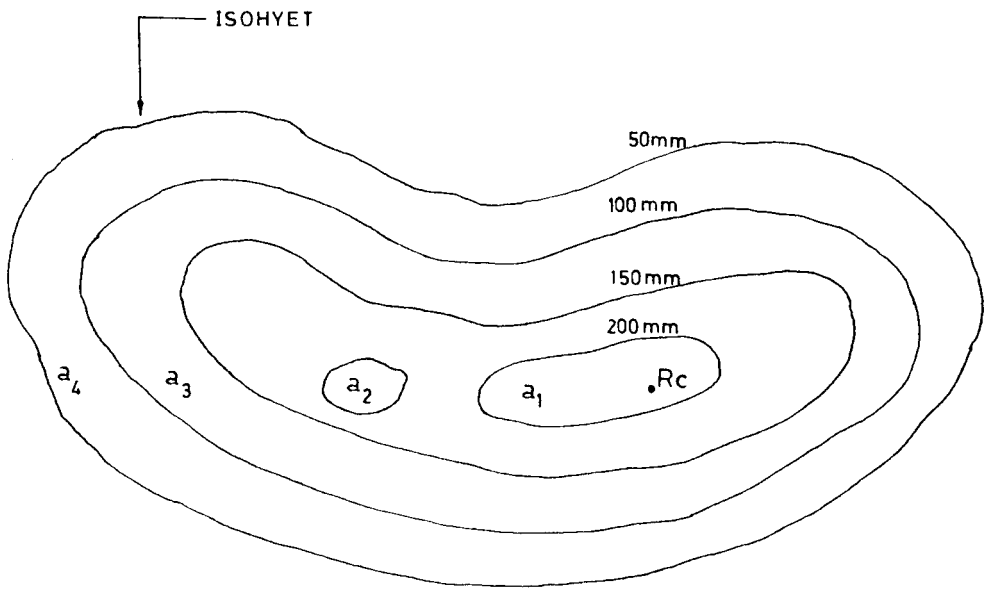
$$\text{Areal rainfall} = \text{ARF} \times \text{Point rainfall} \quad \ldots\ldots\ldots(1)$$

Two types of ARFs are used in the United States:

(i) storm-centred ARF and
(ii) fixed-area ARF

3. STORM-CENTRED ARF

The storm-centred ARF converts, for a particular storm or a hypothetical storm event, point rainfall at the storm centre to areal rainfall. It is derived by dividing areal rainfall of a particular storm event by its corresponding storm centre rainfall. The method of deriving storm-centred ARF is shown in Figure 2. The storm-centred ARF is mainly used for converting point estimate of probable maximum precipitation (PMP) to areal PMP, with the point estimate of PMP being taken as the storm centre rainfall.



1. Plot isohyetal map of storm event of interest.

2. Determine storm centre rainfall, Rc.

3. Determine area (a_1, a_2, a_3, ...) within each isohyet.

4. Determine areal rainfalls (Rm_1, Rm_2, Rm_3, ...) over a_1, a_2, a_3, ... respectively.

5. Compute for each area the ARFs :

$$ARF1 = \frac{Rm_1}{Rc}, \quad ARF2 = \frac{Rm_2}{Rc}, \quad ARF3 = \frac{Rm_3}{Rc}, \ldots\ldots$$

6. Obtain ARFs from other storm events to get average ARF

Figure 2: Derivation of storm-centred ARF

4. FIXED-AREA ARF

The fixed-area ARF can be simply defined as follows:

$$ARF = Ra/Rp \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where Ra = average rainfall depth over the area for a given duration and return period.
Rp = mean of point rainfall values within the same area for the same duration and return period.
ARF = areal reduction factor, varying with the rainfall duration and the size of the area.

Thus fixed-area ARF, unlike storm-centred ARF, is not the ratio of areal to point rainfall of any particular recorded or hypothetical design storm. It is more a statistical relation between areal and point rainfall of the same duration and return period. This concept was clearly illustrated by F.C. Bell(1976) (see Figure 3.). He recommended using frequency curves of areal and point rainfalls to derive the fixed-area ARF.

However, the USWB (1957-1958) and the NERC (1975), both being agencies which have conducted major ARF studies in United States and United Kingdom respectively, did not derive ARFs using frequency curves as described above. Instead simpler methods were used (see Figure 4 and Figure 5), although such methods ignored the possible variation of ARFs with return period.

For design purposes, fixed-area ARFs are recommended because:

(i) The asssumption in the storm-centred ARF that the storm centre occurs within the catchment of interest is not necessarily true.
(ii) Even if the storm centre does occur in the area of interest, it may not be directly over any of the rainfall stations.

5. METHODS OF DERIVING DESIGN AREAL RAINFALL

There are several ways to determine the design areal rainfall of a catchment:

(i) Select a particular station in the catchment likely to record rainfall that is representative of the actual catchment rainfall. Treating the rainfall at this station as the areal rainfall, use it to compute the design areal rainfall. Areal rainfall derived this way would tend to be over-estimated and could be improved by multiplying it with an appropriate ARF.

(ii) If there are several stations in the catchment with good quality data, apply Thiessen weights to the point rainfalls recorded at each individual station to obtain the areal rainfall.

If this is done to the whole range of point rainfall time series for all the stations in the catchment, an areal rainfall time series for the catchment could be obtained. From the areal rainfall time series, the design areal rainfall could be computed. This is a more accurate method and is recommended if data are available.

(iii) Obtaining the areal rainfall time series requires a lot of computation and usually have to be done using the computer. Moreover, working directly with areal rainfall time series is not always possible due to the non-uniform period and length of data recorded by the stations. An easier method could be applied. For example, to determine the 20-year return period areal rainfall for an area with N number of rainfall stations, frequency analyses could be carried out on each station's data to obtain the 20-year return period point rainfall, P_1, P_2,.....,P_N. The 20-year return period areal rainfall P could then be computed by taking the weighted average of P_1, P_2,...., P_N and multiplying the weighted average with the appropriate ARF.

$$P = (W_1 . P_1 + W_2 . P_2 + ...+ W_N . P_N) * ARF \quad ...(5)$$

where W_1, W_2, ...W_N are Thiessen weights.

This method of computing the design areal rainfall conforms to the method of deriving ARFs recommended by F.C. Bell.

6. ESTIMATION OF ARFs FOR KUALA LUMPUR

6.1. Rainfall Data

For the purpose of this study, 23 rainfall stations equipped with Hattori weekly recorders were installed in the study area in 1981, to supplement the existing network of stations. Data collected over a 3 year period, from 1982 to 1984, were used for this study.

6.2. Sampling of Areas and Duration of Storms Studied

Circular study areas of various sizes were demarcated; the sizes chosen were 50, 100, 150 and 200 square km (see Appendix I). For each area, storms of 1, 3, 6, 12, and 24 hour duration were investigated.

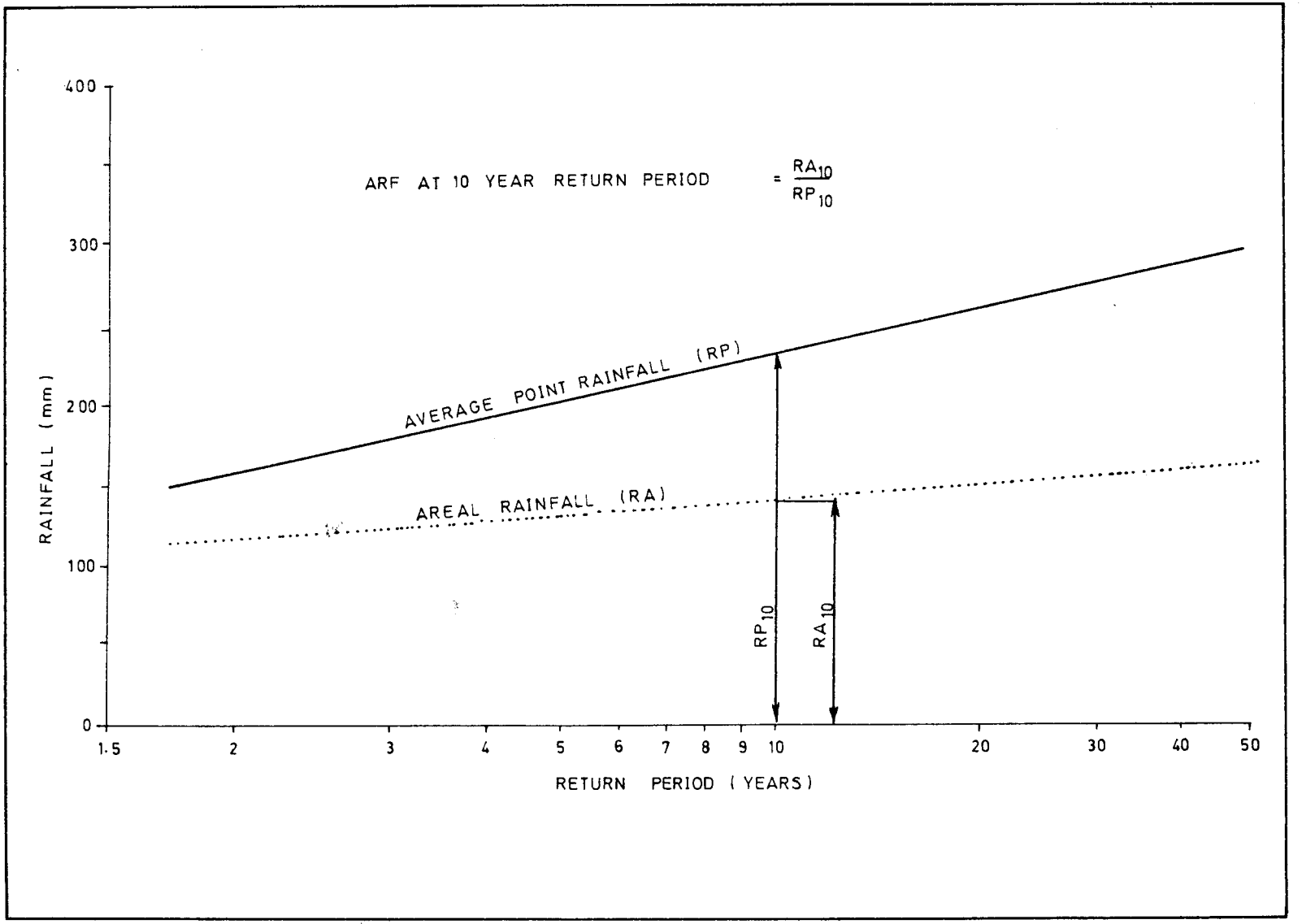
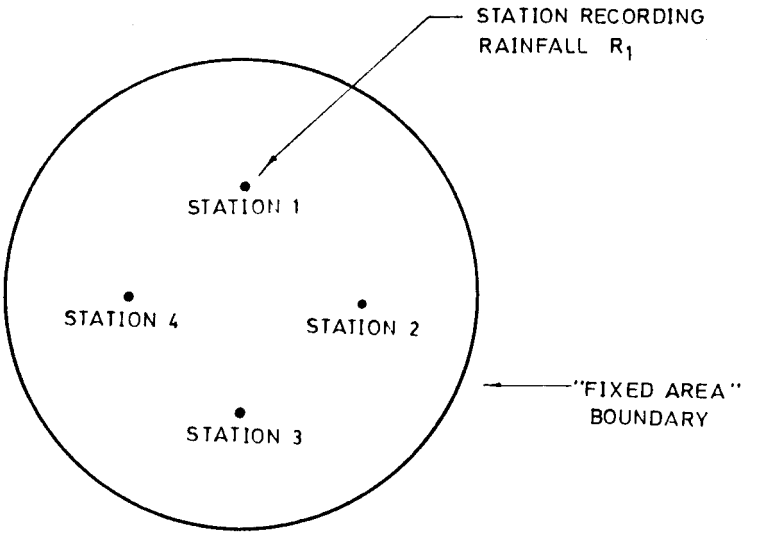


Figure 3: Derivation of ARF using areal and point rainfall frequency curves



1. For a particular area and storm duration, determine for each year :

   (a) the maximum areal rainfall (Ra) and
   (b) the maximum point rainfall recorded by each station in the study area e.g. R_1, R_2, R_3,... (Note that the storms from which maximum point rainfalls were extracted need not be from the storm where maximum areal rain was recorded)

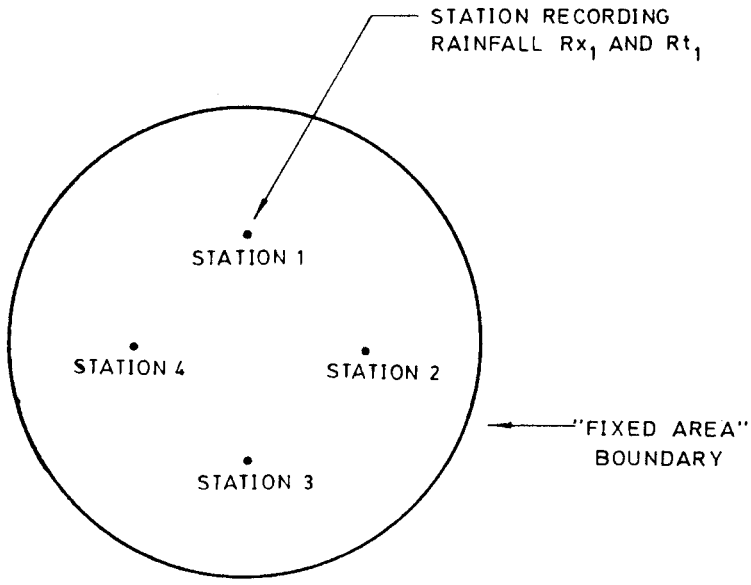
2. Calculate Rp, the weighted average (using Thiessen weights for instance) of maximum point rainfalls obtained in 1.(b) above :

   $$Rp = W_1 . R_1 + W_2 . R_2 + W_3 . R_3 + ...$$
   where W_1, W_2, W_3 .... are Theissen weights

3. Compute ARF = Ra/Rp

4. Obtain ARFs from other years and average to get ARF

Figure 4: Derivation of ARF by USWB



1. For a particular area and storm duration, determine for each year :

   (a) the period when maximum areal rain occurred, and the rainfalls (Rx_1, Rx_2, Rx_3, ...) recorded by each station in the study area, during that period, and

   (b) the maximum point rainfalls (Rt_1, Rt_2, Rt_3, ...) recorded by each station in the study area. These rainfalls need not necessarily be from the same storm as 1(a).

2. Compute $$ARF = \frac{(Rx_1 + Rx_2 + Rx_3 + \ldots.) / N}{(Rt_1 + Rt_2 + Rt_3 + \ldots.) / N}$$
   where N = Number of stations in fixed area

3. Obtain ARFs from other years and average to get ARF

Figure 5: Derivation of ARF by NERC

6.3. Estimation of ARF

The fixed area method used by the USWB was adopted for estimating the ARFs for Kuala Lumpur. However, one set of data for each year for three years was considered inadequate for this study. It was necessary to try to increase the data size. Since the study area, Kuala Lumpur, experiences two distinct wet seasons, the data for each year was divided into two sets: (i) January to June and (ii) July to December, each set containing a wet season. Thus from the three years, six sets of data, one from each season, were extracted for analysis.

For each season, (i) maximum point rainfalls from each station and (ii) maximum areal rainfall were extracted for each study area and each duration considered. The ARF was then estimated by dividing the maximum areal rainfall by the average of the maximum point rainfalls:

$$ARF = \frac{\text{maximum areal rainfall}}{\text{average of maximum point rainfalls}} \quad \ldots.(4)$$

ARF estimates obtained in this manner for each season were averaged to give the final estimated ARF for the area and storm duration considered. The computation is shown in Appendix II.

6.4. Results

The ARF curves for the various storm durations were plotted (see Figure 6). ARFs estimated from these curves are tabulated in Table 1. The ARF curves derived for various storm durations from the Kuala Lumpur Study were compared with curves derived by USWB (1957 - 1958) and NERC (1975) for the United States and United Kingdom respectively and it is evident, from the comparison (see Figures 7 and 8) that the ARFs for Kuala Lumpur are much lower.

Table 1: ARFs estimated for Kuala Lumpur

Area(sq.km)	ARFs for various storm duration (hours)				
	1	3	6	12	24
50	0.79	0.83	0.86	0.87	0.88
100	0.70	0.75	0.79	0.80	0.81
150	0.64	0.72	0.75	0.77	0.79
200	0.63	0.70	0.74	0.76	0.78

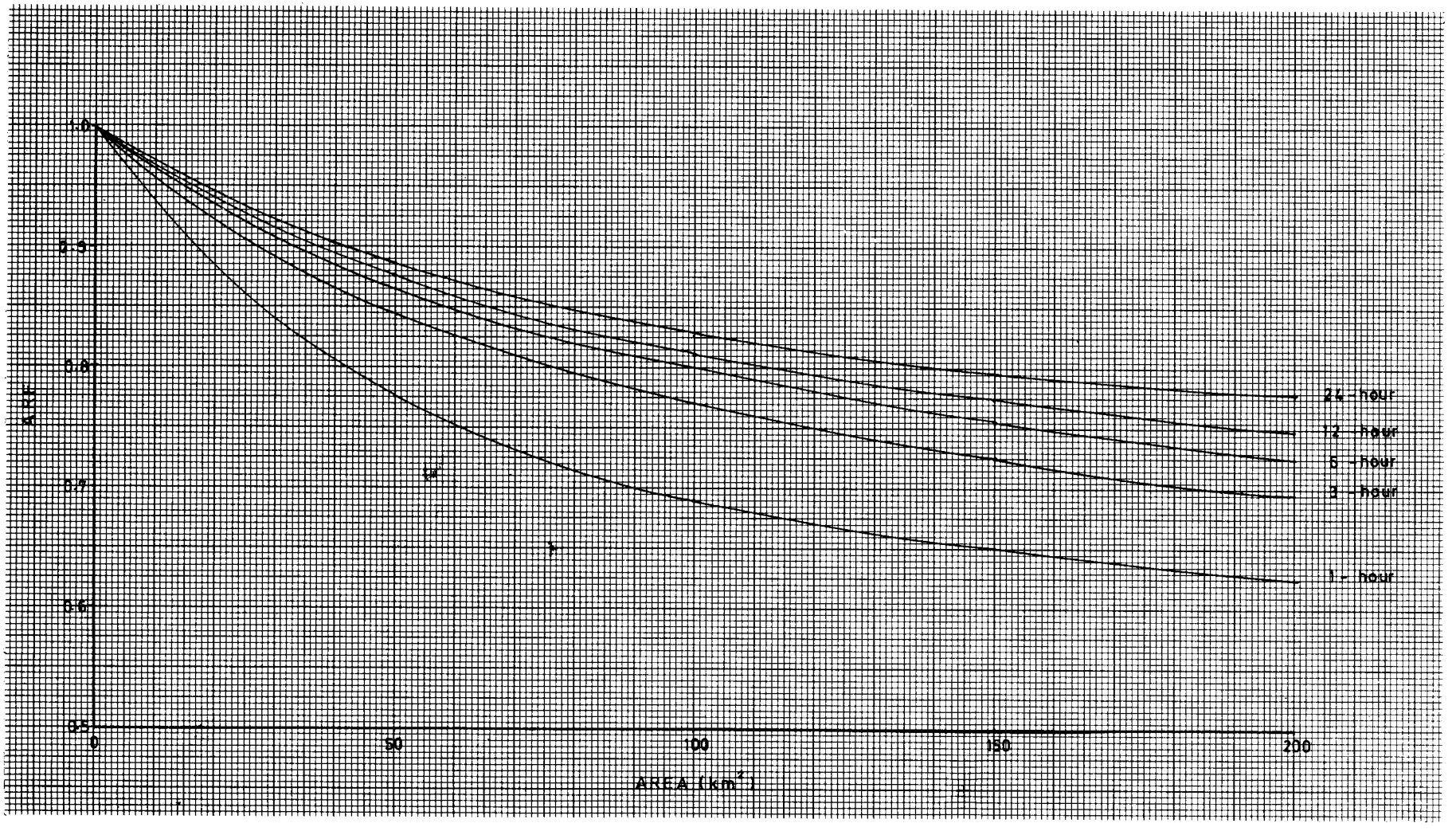


Figure 6: ARF curves of various storm durations derived for Kuala Lumpur

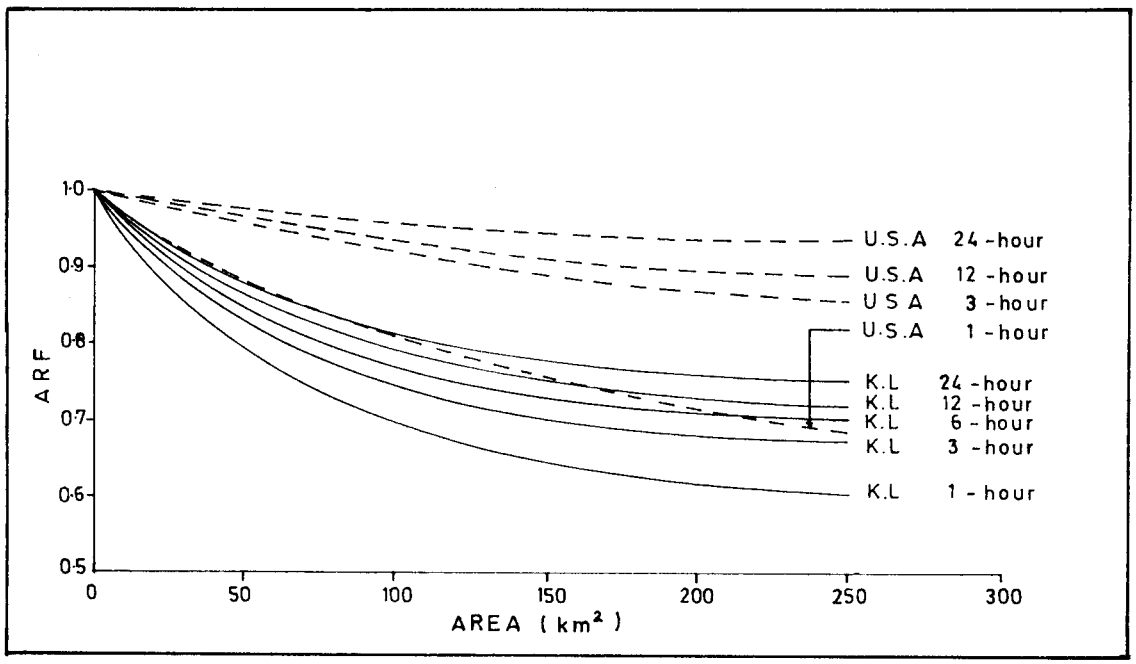


Figure 7: Comparison of the Kuala Lumpur and U.S.A.(USWB) ARF curves

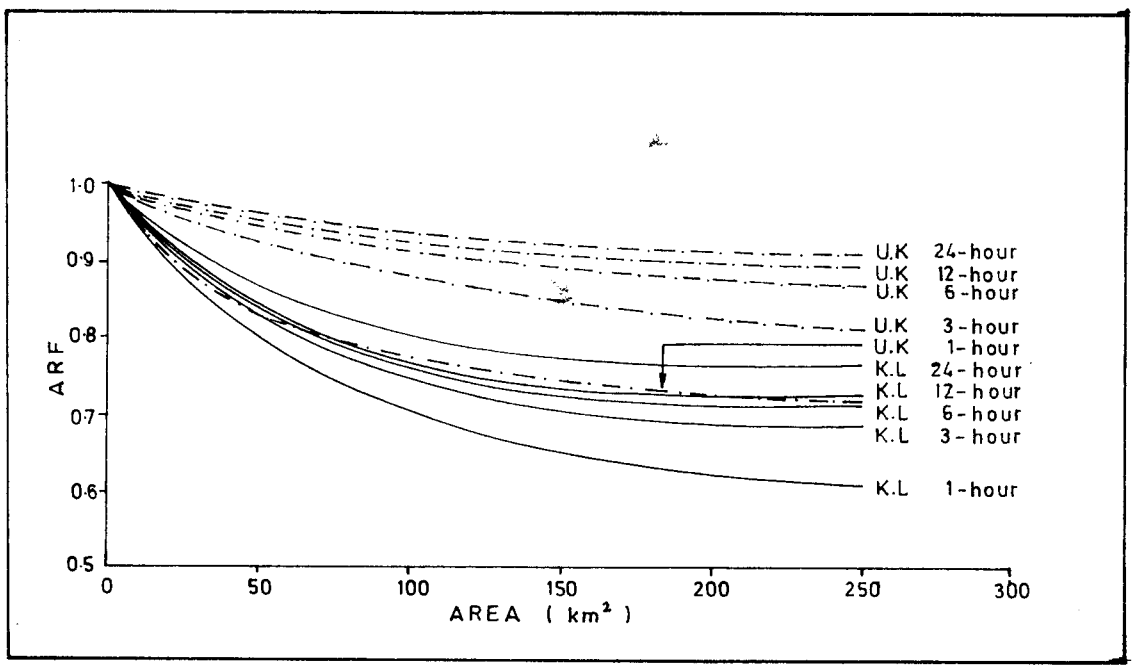


Figure 8: Comparison of the Kuala Lumpur and U.K.(NERC) ARF curves

7. ESTIMATION OF 24-HOUR ARFs FOR NORTH KELANTAN

North Kelantan, around Kota Bharu district, was selected for this study as it has an adequate network of manual rainfall stations for determining the 24-hour ARFs for areas as small as 50 square kilometres. Shorter duration ARFs could not be determined due to the lack of stations equipped with self-recording gauges.

In this study 10 to 15 years of data were analysed and the 24-hour ARFs derived using 2 methods:

i) The method recommended by F.C.Bell (see Figure 3)

ii) USWB's fixed area method (see Figure 4)

7.1. Data Extraction

Circular study areas of sizes 50, 100, 150, 200, and 250 square km were demarcated. The areas were demarcated with the aim of having as many stations as possible in each study area (see Appendix III). The quality and length of records of each station were examined from data printouts available at Hydrology Branch, Drainage and Irrigation Department. Years where there are substantial missing records, especially if records are missing during the monsoon season, were not included for analyses. Stations and study areas with insufficient length of good records were also rejected. A computer programme was written to extract daily areal rainfalls from the Drainage and Irrigation Department's databank tapes and to print out for each year:

(i) the maximum 24-hour point rainfalls recorded by each station in the study area

(ii) the maximum 24-hour areal rainfall, the areal rainfall being the arithmetic average of the point rainfalls. (Note again that maximum areal rainfall over the study area need not necessarily occur on the same day as the maximum point rainfalls at each station)

7.2. Areal Rainfall Frequency Curves

For each study area, the annual maximum 24-hour areal rainfalls were fitted with the Gumbel Type I distribution using the method of moments. The curves are shown in Appendix IVa.

7.3. Average Point Rainfall Frequency Curves

For each station in a study area, the annual maximum 24-hour point rainfalls were fitted with the Gumbel Type I distribution using the method of moments. The average point rainfall

frequency curve for the study area was obtained by averaging the ordinates of the point rainfall frequency curves in the study area. All these curves were fitted and plotted using computer programmes written specially for this study (see Appendix IVb and Appendix IVc).

7.4. Test on Goodness-of-Fit of Frequency Curves

The Gumbel Type I probability curve used to fit the frequency distribution of the rainfall data was in each case tested for goodness-of-fit. The Kolmogorov-Smirnov goodness-of-fit test was used. Curves which were tested to be within the 95 percent confidence limits were accepted and used in this study.

7.5. Computation of ARFs

(i) ARFs derived from frequency curves

ARFs for various return periods were obtained by dividing the ordinate of the average point rainfall frequency curve by the areal rainfall frequency curve (refer Figure 3 and Appendix IVc).

(ii) ARFs derived using the USWB's method

The ARFs were also derived using the method adopted by USWB(1957 -1958). The annual maximum areal rainfall was divided by the mean of the annual maximum point rainfall to obtain the ARF for a particular year. This was averaged over many years to obtain the mean ARF (see Appendix V).

7.6. Results

The 24-hour ARFs obtained from both methods were plotted as shown in Figure 9. The ARFs derived using the method recommended by Bell were scattered and therefore no conclusion can be made on the effect of return period on ARFs. ARFs determined using the USWB method were fitted with a curve.

The 24-hour ARF curves for North Kelantan, Kuala Lumpur, U.S.A. and U.K. were plotted in Figure 10 for comparison. The ARFs for North Kelantan were found to be higher than the ARFs for Kuala Lumpur but they are lower than the ARFs for United States and United Kingdom. It was found that both the ARF curves of the United States and United Kingdom forms an upper envelope to the values derived for North Kelantan.

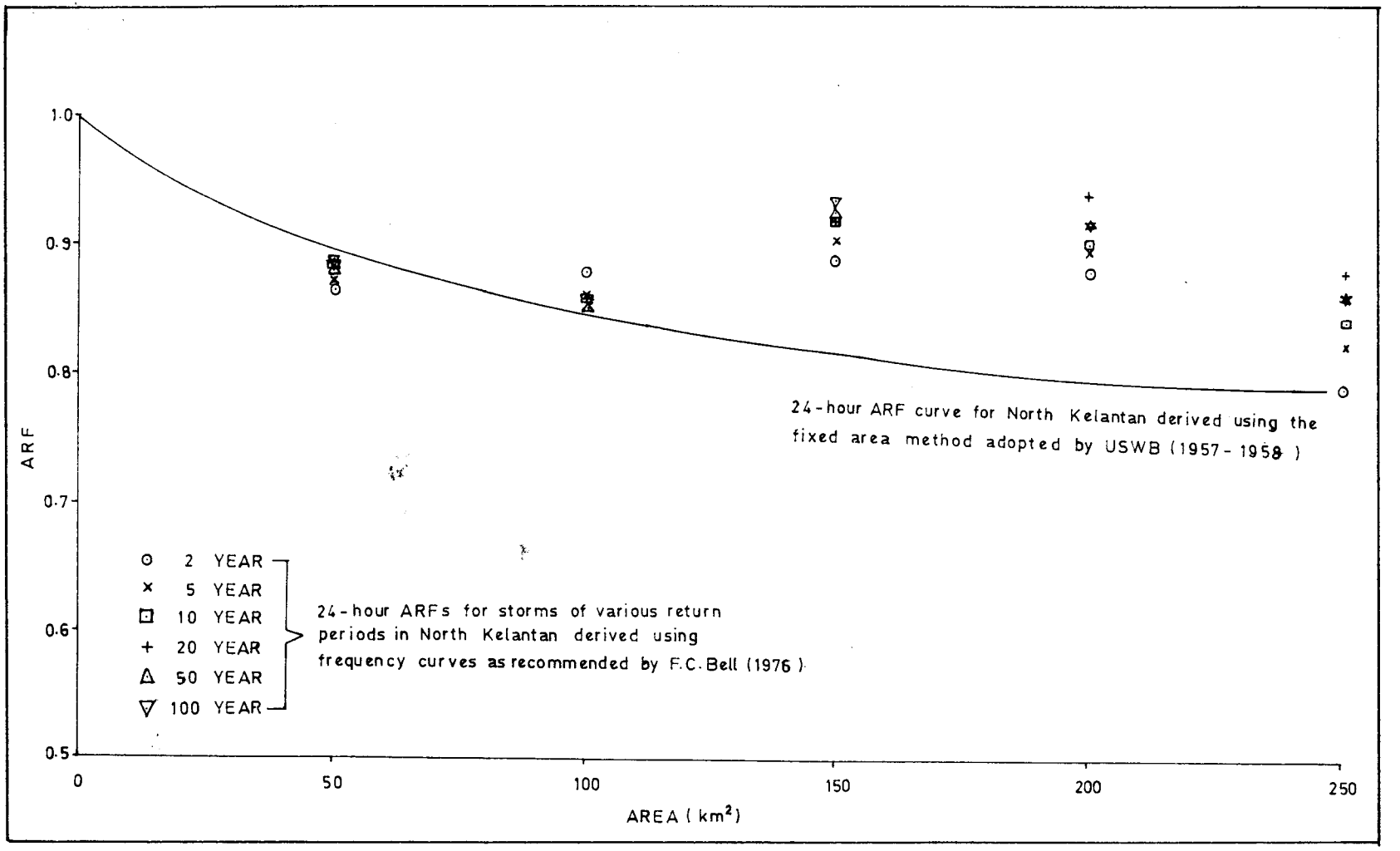


Figure 9: 24-hour storm duration ARFs derived for North Kelantan

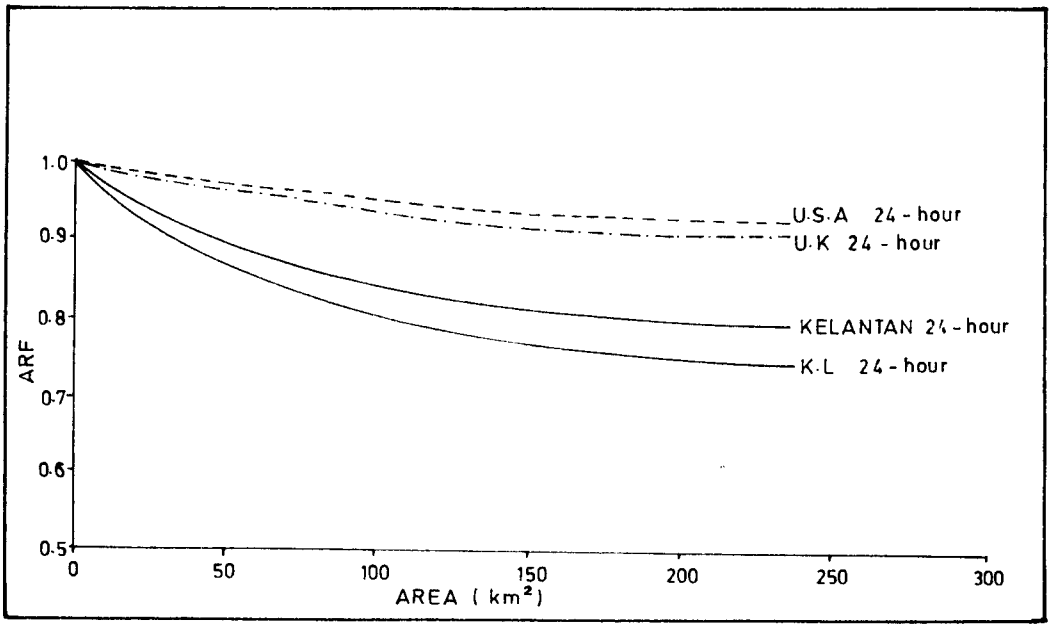


Figure 10: Comparison of the Kelantan 24-Hour ARF curve with the Kuala Lumpur, U.S.A (USWB) and U.K (NERC) 24-Hour ARF curves

8. CONCLUSION

Due to lack of research in this country on the spatial variation of rainfall, the ARFs of USWB are popularly used by engineers in Malaysia for computing the design areal rainfall. In this study, locally derived ARFs were compared with those derived for the United States and United Kingdom. The locally derived ARFs are lower than those recommended by USWB or NERC.

This is expected as the nature of the rain in Malaysia is very different from the rain in temperate countries such as U.K. and U.S.A. The convectional rain in Kuala Lumpur, in particular, is not widespread like the frontal rain found in temperate countries. It is very localised and its intensity varies very significantly from place to place. In Kelantan it was found that the annual maximum 24-hour rain occurred mainly during the North-east Monsoon season and are therefore likely to be monsoonal rains. Monsoonal rain is more widespread and more evenly distributed in space than convectional rain. But it is not as uniformly distributed as the frontal rain of temperate countries. Therefore, as expected, the ARFs of North Kelantan are lower than U.K.'s or U.S.A.'s but are slightly higher that the ARFs of Kuala Lumpur.

The ARFs derived in this study were based on very short data records and therefore should be used with caution. Studies of this nature should continue and preferably, a more detailed

study involving higher density instrumentation and longer periods of data should be carried out. Studies of 24-hour ARFs, similar to that carried out for North Kelantan should be extended to other areas in the country.

9. REFERENCES

Bell, F.C. (1976) "Areal Reduction Factor in Rainfall Frequency Estimation", Report No.35 - Institute of Hydrology, Wallingford, United Kingdom.

Irish, J.L.(1980) "ARF for Estimating Design Floods from Rainfall Data", UNESCO Letter-report, UNESCO, Indonesia.

Linsley, R.K., Kohler, M.A. and Paulhus, J.H. (1975) "Hydrology for Engineers", 2nd Ed., McGraw-Hill, U.S.A.

Mahmood, M.F., Salleh, S., Leong, T.M. and Teh, S.K. (1982) "Estimation of the Design Rainstorm (Revised and Updated)", Hydrological Procedure No. 1, Drainage and Irrigation Department, Malaysia.

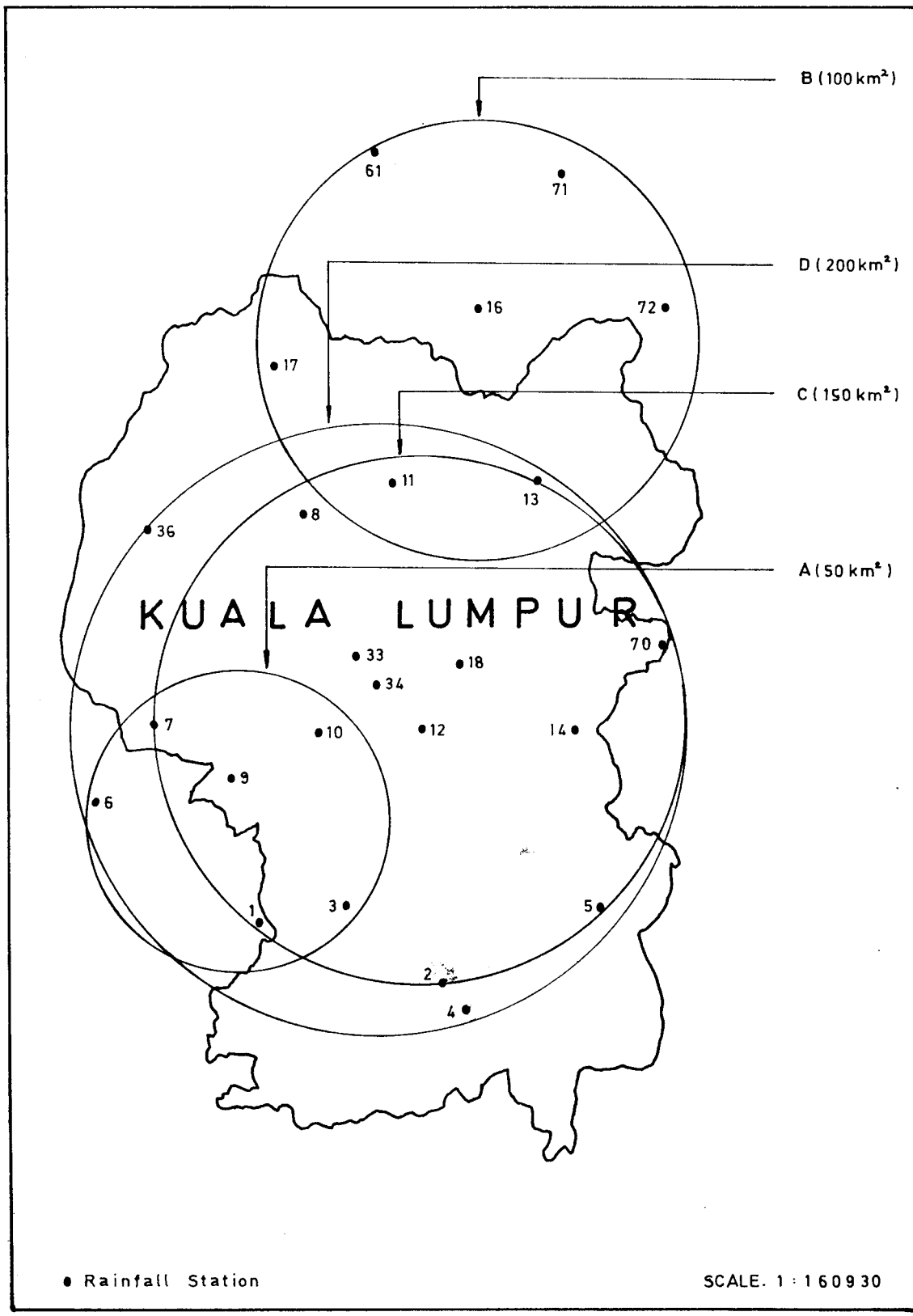
Natural Environment Research Council (NERC) (1975) " Flood Studies Report Volume II - Meteorological Studies", United Kingdom.

Rodriguez-Iturbe, I. and Meija, J.M. (1974)" On the Transformation of Point Rainfall to Areal Rainfall", Water Resources Research Vol. 10, American Geophysical Union, U.S.A.

Shahin, M.A. (1980) "Statistical Analysis in Hydrology Vol. I and Vol. II", International Institute for Hydraulic and Environmental Engineering, Delft, Netherlands.

Taylor, M.A.W. and Toh, Y.K. (1976) "Design Flood Hydrograph Estimation for Rural Catchments in Peninsular Malaysia", Hydrological Procedure No.11, Drainage and Irrigation Department, Malaysia.

APPENDIX I: Location of Rainfall Stations and "Fixed Areas" Used in the Kuala Lumpur ARF Study


B (100 km²)
D (200 km²)
C (150 km²)
A (50 km²)
KUALA LUMPUR
61
71
16
72
17
11
13
8
36
33
18
34
70
7
10
12
14
9
6
1
3
5
2
4
• Rainfall Station
SCALE. 1 : 160930

Stations used in the Kuala Lumpur ARF study

AREA	SIZE (sq. km)	STATION	LOCATION
A	50	7	STN 3116008 at Taman Tun Dr. Ismail
		6	STN 3116007 at Taman SEA
		9	STN 3116010 at Universiti Malaya
		1	STN 3016003 at Jalan Gasing
		3	STN 3017001 at Bangsar Baru
B	100	71	STN 3217001 at Jalan Bentong
		72	STN 3217002 at Klang Gates Dam
		13	STN 3117002 at Setapak
		11	STN 3116012 at Sentul
		17	STN 3216005 at Jinjang Utara
		61	STN 3216001 at Jalan Bayan-Sg. Tua
		16	STN 3216004 at Taman Sri Gombak
C	150	11	STN 3116012 at Sentul
		13	STN 3117002 at Setapak
		8	STN 3116009 at Kampung Segambut
		70	STN 3117070 at Jalan Ampang
		14	STN 3117003 at Kampung Pandan
		33	STN 3116003 at Ibu Pejabat JPT
		18	STN 3117071 at Bukit Weld
		12	STN 3116013 at Jalan Belfield
		9	STN 3116010 at Universiti Malaya
		3	STN 3017001 at Jalan Kuchai Lama
		5	STN 3017003 at Cheras
		7	STN 3116008 at Taman Tun Dr. Ismail
D	200	13	STN 3117002 at Setapak
		70	STN 3117070 at Jalan Ampang
		5	STN 3017003 at Cheras
		2	STN 3016004 at Taman Salak Selatan
		3	STN 3017001 at Jalan Kuchai Lama
		1	STN 3016003 at Jalan Gasing
		9	STN 3116010 at Universiti Malaya
		6	STN 3116007 at Taman SEA
		7	STN 3116008 at Taman Tun Dr. Ismail
		36	STN 3116006 at Ladang Edinburgh 2
		11	STN 3116012 at Sentul
		14	STN 3117003 at Kampung Pandan
		12	STN 3116013 at Jalan Belfield
		10	STN 3116011 at Bangsar Baru
		33	STN 3116003 at Ibu Pejabat JPT
		18	STN 3117071 at Bukit Weld
		34	STN 3116064 at JPT Wilayah

APPENDIX II: Maximum Areal Rainfall (MAR) and Maximum Point Rainfall (MPR) Extracted for the Computation of ARFs for Kuala Lumpur

Size of area = 50 km2
Duration of storm = 1 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station: 7	6	9	1	3	10	MAR
28/12/81	76	55	8	73	35	10	42.8
04/06/82	48	49	43	70	10	36	42.7
30/09/82	35	50	62	39	49	82	52.8
16/05/83	46	12	39	39	58	40	39.0
13/11/83	0	3	39	59	68	38	34.5
24/02/84	35	37	38	59	63	57	48.2

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station: 7	6	9	1	3	10	MPR
Jul-Dec'81	76	55	19	73	41	41	50.8
Jan-Jun'82	72	55	60	70	75	50	63.7
Jul-Dec'82	43	50	62	39	50	82	54.3
Jan-Jun'83	69	39	40	50	68	40	51.0
Jul-Dec'83	38	53	38	65	68	38	50.0
Jan-Jun'84	64	52	80	59	63	68	64.3

Computation of ARF

Season	ARF
Jul-Dec'81	.84
Jan-Jun'82	.67
Jul-Dec'82	.97
Jan-Jun'83	.76
Jul-Dec'83	.69
Jan-Jun'84	.75
Average ARF =	.78

Size of area = 50 km2
Duration of storm = 3 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:						MAR
	7	6	9	1	3	10	
28/12/81	90	70	25	73	40	9	51.2
05/04/82	56	62	88	46	72	119	73.8
01/11/82	49	25	60	38	49	72	48.8
16/06/83	76	39	14	61	51	21	43.7
13/11/83	0	42	53	66	72	42	45.8
18/02/84	34	30	91	73	91	72	65.2

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:						MPR
	7	6	9	1	3	10	
Jul-Dec'81	90	70	76	73	74	67	75.0
Jan-Jun'82	87	88	88	76	119	119	96.2
Jul-Dec'82	49	63	60	40	52	85	58.2
Jan-Jun'83	76	39	49	61	70	60	59.2
Jul-Dec'83	38	62	53	70	72	42	56.2
Jan-Jun'84	100	91	91	75	91	77	87.5

Computation of ARF

Season	ARF
Jul-Dec'81	.68
Jan-Jun'82	.77
Jul-Dec'82	.84
Jan-Jun'83	.74
Jul-Dec'83	.82
Jan-Jun'84	.74
Average ARF =	.76

Size of area = 50 km2
Duration of storm = 6 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:						MAR
	7	6	9	1	3	10	
28/12/81	90	71	25	73	40	11	51.7
05/04/82	63	64	94	92	123	68	84.0
30/09/82	35	60	63	40	49	84	55.2
16/06/83	76	39	39	61	51	21	47.8
13/11/83	0	47	61	70	77	50	50.8
18/02/84	38	35	96	78	97	78	70.3

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:						MPR
	7	6	9	1	3	10	
Jul-Dec'81	90	71	50	73	59	41	64.0
Jan-Jun'82	88	90	94	92	123	88	95.8
Jul-Dec'82	90	71	63	61	52	85	70.3
Jan-Jun'83	76	65	49	71	70	60	65.2
Jul-Dec'83	48	53	61	71	77	50	60.0
Jan-Jun'84	101	61	97	79	97	78	85.5

Computation of ARF

Season	ARF
Jul-Dec'81	.81
Jan-Jun'82	.88
Jul-Dec'82	.78
Jan-Jun'83	.73
Jul-Dec'83	.85
Jan-Jun'84	.82
Average ARF =	.81

Size of area = 50 km2
Duration of storm = 12 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station: 7	6	9	1	3	10	MAR
13/07/82	32	65	70	74	53	48	57.0
05/04/82	63	64	94	92	123	68	84.0
30/09/82	35	60	63	40	49	84	55.2
16/06/83	76	39	45	61	51	21	48.8
13/11/83	0	47	61	70	77	51	51.0
18/02/84	44	41	104	85	104	93	78.5

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station: 7	6	9	1	3	10	MPR
Jul-Dec'81	70	65	70	74	57	48	64.0
Jan-Jun'82	88	90	107	92	123	90	98.3
Jul-Dec'82	85	85	63	62	59	85	73.2
Jan-Jun'83	76	65	73	71	70	68	70.5
Jul-Dec'83	48	53	74	71	77	51	62.3
Jan-Jun'84	101	61	104	85	104	93	91.3

Computation of ARF

Season	ARF
Jul-Dec'81	.89
Jan-Jun'82	.85
Jul-Dec'82	.75
Jan-Jun'83	.69
Jul-Dec'83	.82
Jan-Jun'84	.86
Average ARF =	.81

Size of area = 50 km2
Duration of storm = 24 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station: 7	6	9	1	3	10	MAR
27/12/81	90	82	25	129	101	9	72.7
05/04/82	66	65	97	96	130	85	89.8
25/12/82	40	45	50	57	63	92	57.8
13/06/83	59	49	70	47	28	81	55.7
13/11/83	0	47	61	70	77	51	51.0
24/02/84	64	58	81	74	95	103	79.2

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station: 7	6	9	1	3	10	MPR
Jul-Dec'81	90	82	84	129	101	70	92.7
Jan-Jun'82	88	91	110	130	130	92	107.0
Jul-Dec'82	84	90	52	66	71	94	76.2
Jan-Jun'83	75	65	95	71	70	81	76.2
Jul-Dec'83	48	62	61	71	77	51	61.7
Jan-Jun'84	101	81	97	80	95	103	92.8

Computation of ARF

Season	ARF
Jul-Dec'81	.78
Jan-Jun'82	.84
Jul-Dec'82	.76
Jan-Jun'83	.73
Jul-Dec'83	.83
Jan-Jun'84	.85
Average ARF =	.80

Size of area = 100 km2
Duration of storm = 1 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:							MAR
	71	72	13	11	17	61	16	
12/09/81	40	35	35	25	20	45	24	32.0
30/04/82	10	50	75	50	39	47	104	53.6
27/11/82	40	23	8	10	50	45	55	33.0
25/02/83	39	20	26	50	18	43	45	34.4
13/11/83	54	75	32	32	31	51	30	43.6
06/04/84	30	33	51	56	49	20	60	42.7

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:							MPR
	71	72	13	11	17	61	16	
Jul-Dec'81	58	60	45	38	20	45	46	44.6
Jan-Jun'82	60	50	75	50	48	48	104	62.1
Jul-Dec'82	45	31	48	35	50	49	55	44.7
Jan-Jun'83	39	64	36	50	55	50	45	48.4
Jul-Dec'83	61	75	75	33	52	60	81	62.4
Jan-Jun'84	73	58	51	70	49	44	91	62.3

Computation of ARF

Season	ARF
Jul-Dec'81	.72
Jan-Jun'82	.86
Jul-Dec'82	.74
Jan-Jun'83	.71
Jul-Dec'83	.70
Jan-Jun'84	.69
Average ARF =	.74

Size of area = 100 km2
Duration of storm = 3 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:							MAR
	71	72	13	11	17	61	16	
07/09/81	31	25	33	50	88	74	52	50.4
30/04/82	74	106	79	52	41	48	108	72.6
29/11/82	61	24	39	34	24	50	45	39.6
13/06/83	73	32	21	80	32	37	20	42.1
13/11/83	74	100	110	52	45	65	80	75.1
30/04/84	81	23	22	25	38	42	113	49.1

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:							MPR
	71	72	13	11	17	61	16	
Jul-Dec'81	69	63	68	66	88	74	56	69.1
Jan-Jun'82	75	106	79	67	86	65	108	83.7
Jul-Dec'82	61	41	50	70	53	53	60	55.4
Jan-Jun'83	73	77	50	53	60	83	45	63.0
Jul-Dec'83	74	100	110	52	75	74	90	82.1
Jan-Jun'84	81	58	52	80	54	48	113	69.4

Computation of ARF

Season	ARF
Jul-Dec'81	.73
Jan-Jun'82	.87
Jul-Dec'82	.71
Jan-Jun'83	.67
Jul-Dec'83	.91
Jan-Jun'84	.71
Average ARF =	.77

Size of area = 100 km2
Duration of storm = 6 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:							MAR
	71	72	13	11	17	61	16	
07/09/81	32	29	42	51	94	75	53	53.7
30/04/82	75	106	79	52	48	48	109	73.9
27/11/82	42	24	8	11	53	54	60	36.0
13/06/83	77	38	21	80	32	51	24	46.1
13/11/83	77	102	118	59	51	71	94	81.7
30/04/84	81	24	23	26	38	43	114	49.9

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:							MPR
	71	72	13	11	17	61	16	
Jul-Dec'81	68	63	69	109	94	75	53	75.9
Jan-Jun'82	75	106	79	67	63	65	109	80.6
Jul-Dec'82	61	65	50	74	53	54	60	59.6
Jan-Jun'83	77	78	51	80	61	83	55	69.3
Jul-Dec'83	77	102	118	59	76	74	94	85.7
Jan-Jun'84	81	58	60	100	79	50	114	77.4

Computation of ARF

Season	ARF
Jul-Dec'81	.71
Jan-Jun'82	.92
Jul-Dec'82	.60
Jan-Jun'83	.67
Jul-Dec'83	.95
Jan-Jun'84	.64
Average ARF =	.75

Size of area = 100 km2
Duration of storm = 12 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:							MAR
	71	72	13	11	17	61	16	
07/09/81	35	30	42	51	94	75	56	54.7
30/04/82	77	107	80	53	48	49	109	74.7
29/11/82	61	24	39	35	25	51	45	40.0
13/06/83	77	38	21	80	32	51	24	46.1
13/11/83	77	102	118	59	51	71	94	81.7
30/04/84	82	24	23	26	38	43	114	50.0

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:							MPR
	71	72	13	11	17	61	16	
Jul-Dec'81	68	63	70	81	94	75	66	73.9
Jan-Jun'82	77	107	80	67	60	60	109	80.0
Jul-Dec'82	61	42	54	80	61	54	60	58.9
Jan-Jun'83	77	92	51	54	63	83	55	67.9
Jul-Dec'83	77	102	118	41	78	74	94	83.4
Jan-Jun'84	82	58	62	109	79	49	114	79.0

Computation of ARF

Season	ARF
Jul-Dec'81	.74
Jan-Jun'82	.93
Jul-Dec'82	.68
Jan-Jun'83	.68
Jul-Dec'83	.98
Jan-Jun'84	.63
Average ARF =	.77

Size of area = 100 km2
Duration of storm = 24 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:							MAR
	71	72	13	11	17	61	16	
07/09/81	53	63	55	67	113	88	56	70.7
30/04/82	86	137	93	69	125	85	151	107.0
26/11/82	69	54	47	72	61	53	85	63.0
22/05/83	78	92	14	25	8	63	26	43.7
13/11/83	77	102	118	59	51	71	94	81.7
30/04/84	82	24	58	49	66	43	114	62.3

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:							MPR
	71	72	13	11	17	61	16	
Jul-Dec'81	68	63	70	117	113	88	83	86.0
Jan-Jun'82	86	137	93	90	168	85	151	116.0
Jul-Dec'82	69	65	59	84	61	67	85	70.0
Jan-Jun'83	79	92	52	53	63	66	60	66.4
Jul-Dec'83	77	102	118	59	78	90	94	88.3
Jan-Jun'84	82	58	62	109	79	50	114	79.1

Computation of ARF

Season	ARF
Jul-Dec'81	.82
Jan-Jun'82	.92
Jul-Dec'82	.90
Jan-Jun'83	.66
Jul-Dec'83	.93
Jan-Jun'84	.79
Average ARF =	.84

Size of area = 150 km2
Duration of storm = 1 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:															MAR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
05/12/81	15	10	30	27	40	57	60	65	2	24	63	8	5	0	37	29.5
01/03/82	2	0	9	66	17	75	81	60	38	25	2	34	20	8	50	32.5
01/11/82	35	34	39	78	60	63	51	18	34	37	30	31	29	20	63	41.5
26/04/83	19	4	15	40	32	62	50	64	15	17	32	10	10	10	38	27.9
13/11/83	32	75	28	42	61	20	45	8	38	68	14	0	0	68	35	35.6
18/02/84	41	16	38	23	44	51	40	50	80	61	30	20	50	82	68	46.3

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:															MPR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
Jul-Dec'81	38	45	56	41	61	57	60	65	19	41	63	76	73	33	42	51.3
Jan-Jun'82	50	75	70	66	47	75	81	75	60	75	39	72	70	50	50	63.7
Jul-Dec'82	35	48	80	78	71	63	57	54	62	50	50	43	39	42	82	56.9
Jan-Jun'83	50	36	40	40	49	62	50	64	40	68	50	69	50	41	40	49.9
Jul-Dec'83	33	75	28	59	61	57	63	77	38	68	34	38	65	68	38	53.5
Jan-Jun'84	70	51	62	52	44	55	40	66	80	63	64	64	59	82	68	61.3

Computation of ARF

Season	ARF
Jul-Dec'81	.58
Jan-Jun'82	.51
Jul-Dec'82	.73
Jan-Jun'83	.56
Jul-Dec'83	.67
Jan-Jun'84	.75
Average ARF =	.63

Size of area = 150 km2
Duration of storm = 3 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:															MAR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
05/12/81	64	63	24	27	34	23	37	69	65	74	62	9	5	22	40	41.2
26/04/82	52	35	61	70	47	38	22	63	73	63	76	45	50	45	67	53.8
01/11/82	70	50	45	83	79	84	84	46	45	48	29	45	38	33	71	56.7
26/04/83	36	23	20	112	82	87	91	78	20	30	46	16	14	20	60	49.0
13/11/83	41	110	40	55	89	40	58	8	52	72	16	0	0	77	42	46.7
18/02/84	51	16	52	23	65	58	45	55	84	81	44	35	75	101	71	57.1

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:															MPR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
Jul-Dec'81	66	68	72	64	69	74	74	73	71	74	77	90	73	70	67	72.1
Jan-Jun'82	67	79	78	70	70	81	89	86	88	119	76	87	76	63	119	83.2
Jul-Dec'82	70	50	84	83	79	84	84	46	60	52	54	49	40	42	85	64.1
Jan-Jun'83	53	50	41	112	82	87	91	78	49	70	67	75	61	55	60	68.7
Jul-Dec'83	52	110	40	71	89	60	67	78	53	72	35	38	70	77	42	63.6
Jan-Jun'84	80	52	65	60	65	69	59	55	91	91	65	100	75	101	77	73.7

Computation of ARF

Season	ARF
Jul-Dec'81	.57
Jan-Jun'82	.65
Jul-Dec'82	.88
Jan-Jun'83	.71
Jul-Dec'83	.73
Jan-Jun'84	.77
Average ARF =	.72

Size of area = 150 km2
Duration of storm = 6 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:															MAR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
29/08/81	109	64	43	11	10	62	69	69	48	26	45	10	25	48	9	43.2
26/04/82	54	45	62	71	50	40	23	64	74	63	77	60	56	47	67	56.9
01/11/82	74	50	45	84	90	101	86	46	48	49	32	73	61	39	72	63.3
26/04/83	36	23	20	112	82	88	91	78	20	30	46	16	14	20	60	49.1
13/11/83	41	118	40	62	95	40	65	8	61	77	16	0	0	80	50	50.2
18/02/84	65	16	66	84	66	70	60	70	97	87	65	36	79	103	78	69.5

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:															MPR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
Jul-Dec'81	109	69	70	109	70	77	69	81	50	59	64	90	73	48	41	71.9
Jan-Jun'82	67	79	78	89	79	86	89	89	94	123	77	88	92	61	88	85.3
Jul-Dec'82	74	50	85	84	90	101	86	46	63	52	54	90	61	42	85	70.9
Jan-Jun'83	80	51	43	112	82	88	91	78	49	70	67	76	71	55	60	71.5
Jul-Dec'83	59	118	40	73	95	61	68	78	61	77	35	48	71	80	50	67.6
Jan-Jun'84	100	60	81	84	66	70	75	70	97	97	70	101	79	103	78	82.1

Computation of ARF

Season	ARF
Jul-Dec'81	.60
Jan-Jun'82	.67
Jul-Dec'82	.89
Jan-Jun'83	.69
Jul-Dec'83	.74
Jan-Jun'84	.85
Average ARF =	.74

Size of area = 150 km2
Duration of storm = 12 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:															MAR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
07/09/81	43	37	39	46	70	51	42	26	56	50	50	30	64	64	35	46.9
11/03/82	36	70	62	71	60	46	45	48	35	57	78	60	88	54	73	58.9
01/11/82	80	53	49	113	93	105	104	49	50	50	35	75	62	40	81	69.3
26/04/83	36	23	50	112	82	88	91	78	20	30	46	16	15	20	60	51.1
13/11/83	41	118	40	62	95	40	65	8	61	77	16	0	9	80	51	50.9
18/02/84	65	16	66	92	66	73	60	70	97	87	66	37	79	103	85	70.8

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:															MPR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
Jul-Dec'81	81	70	70	109	70	90	63	66	70	57	65	70	74	69	48	71.5
Jan-Jun'82	67	80	78	89	79	82	90	90	107	123	70	88	92	61	90	85.7
Jul-Dec'82	80	54	85	113	130	105	104	49	63	59	54	75	62	43	85	77.4
Jan-Jun'83	54	51	62	112	82	88	91	78	73	70	67	76	71	58	60	72.9
Jul-Dec'83	41	118	40	73	95	61	68	78	61	77	35	48	71	80	51	66.5
Jan-Jun'84	109	62	82	92	66	73	76	70	104	104	70	101	85	103	93	86.0

Computation of ARF

Season	ARF
Jul-Dec'81	.66
Jan-Jun'82	.69
Jul-Dec'82	.89
Jan-Jun'83	.70
Jul-Dec'83	.77
Jan-Jun'84	.82
Average ARF =	.75

Size of area = 150 km2
Duration of storm = 24 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:															MAR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
07/09/81	60	70	96	77	81	67	55	60	84	68	70	70	64	94	64	72.0
04/04/82	75	50	129	97	46	30	25	52	96	73	82	60	96	64	85	70.7
01/11/82	84	59	51	120	102	105	118	54	52	52	37	84	66	44	94	74.8
26/04/83	36	23	20	112	82	88	91	78	20	30	46	17	15	21	60	49.3
13/11/83	41	118	40	62	95	40	65	8	61	77	16	0	9	80	51	50.9
18/02/84	65	16	66	92	66	75	50	70	97	87	66	37	80	104	85	70.4

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:															MPR
	11	13	8	70	14	33	18	12	9	3	5	7	1	2	10	
Jul-Dec'81	117	70	96	109	81	118	70	84	84	101	70	90	129	94	70	92.2
Jan-Jun'82	90	93	113	102	85	81	94	96	110	130	82	88	130	66	92	96.8
Jul-Dec'82	84	59	114	120	131	105	118	57	52	71	54	84	66	61	94	84.7
Jan-Jun'83	53	52	43	112	82	88	91	78	95	70	67	75	71	47	81	73.7
Jul-Dec'83	59	118	40	73	95	61	68	75	61	77	35	48	71	83	51	67.7
Jan-Jun'84	109	62	82	92	66	75	76	70	97	95	70	101	80	104	103	85.5

Computation of ARF

Season	ARF
Jul-Dec'81	.73
Jan-Jun'82	.73
Jul-Dec'82	.88
Jan-Jun'83	.67
Jul-Dec'83	.75
Jan-Jun'84	.82
Average ARF =	.77

Size of area = 200 km2
Duration of storm = 1 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:																	MAR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
05/12/81	10	27	63	0	24	5	2	4	8	22	30	15	40	65	37	57	60	67	29.8
03/06/82	30	52	20	50	70	30	20	2	2	13	3	22	31	40	35	20	53	31	29.1
01/11/82	34	78	30	28	37	29	34	22	31	30	39	35	60	18	63	63	51	89	42.8
26/04/83	4	40	32	10	17	10	15	15	10	19	15	19	32	64	38	62	50	42	27.4
13/11/83	75	42	14	68	68	0	38	3	0	58	28	32	61	8	38	20	45	30	34.9
18/02/84	16	23	30	82	61	50	80	32	20	6	38	41	44	50	68	51	40	20	41.8

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:																	MPR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
Jul-Dec'81	45	41	63	33	41	73	19	55	76	22	56	38	61	66	41	57	60	67	50.8
Jan-Jun'82	75	66	39	50	75	70	60	55	72	79	70	50	47	75	50	75	81	50	63.3
Jul-Dec'82	48	78	50	42	50	39	62	50	43	59	80	35	71	33	82	63	57	89	57.3
Jan-Jun'83	36	40	50	41	68	50	40	39	69	25	40	50	49	64	40	62	50	68	48.9
Jul-Dec'83	75	59	34	68	68	65	38	53	38	58	28	33	61	77	35	57	63	64	54.1
Jan-Jun'84	51	52	64	82	63	59	80	52	64	55	62	70	44	66	68	55	40	50	59.8

Computation of ARF

Season	ARF
Jul-Dec'81	.59
Jan-Jun'82	.46
Jul-Dec'82	.75
Jan-Jun'83	.56
Jul-Dec'83	.64
Jan-Jun'84	.70
Average ARF =	.62

Size of area = 200 km2
Duration of storm = 3 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:																	MAR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
26/04/81	23	53	35	46	61	50	71	40	44	38	49	38	45	73	67	60	74	45	50.7
11/03/82	42	32	67	51	53	40	66	68	40	27	50	29	47	75	65	50	73	50	51.4
01/11/82	50	83	29	33	48	38	45	22	45	30	45	70	79	46	71	84	84	89	55.1
26/04/83	23	112	46	20	30	14	20	18	16	19	20	36	82	78	60	87	91	63	46.4
13/11/83	40	55	16	77	72	0	52	43	0	62	40	41	89	8	42	40	58	41	43.1
18/02/84	52	23	44	101	81	75	84	44	35	21	52	51	65	55	71	58	45	28	54.7

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:																	MPR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
Jul-Dec'81	68	64	77	70	74	73	71	70	90	54	72	66	69	73	67	74	74	67	70.7
Jan-Jun'82	79	70	76	63	119	76	88	88	87	80	78	67	70	86	119	81	89	85	83.4
Jul-Dec'82	50	83	54	42	52	40	60	63	49	69	84	70	79	46	85	84	84	89	65.7
Jan-Jun'83	50	112	67	55	70	61	49	39	76	32	41	53	82	78	60	87	91	72	65.3
Jul-Dec'83	110	71	35	77	72	70	53	62	38	62	40	44	89	78	42	60	67	81	63.9
Jan-Jun'84	52	60	65	101	91	75	91	91	100	72	63	80	65	55	77	69	59	60	73.7

Computation of ARF

Season	ARF
Jul-Dec'81	.72
Jan-Jun'82	.62
Jul-Dec'82	.84
Jan-Jun'83	.71
Jul-Dec'83	.67
Jan-Jun'84	.74
Average ARF =	.72

Size of area = 200 km2
Duration of storm = 6 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:																		MAR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
29/08/81	69	109	64	48	43	25	11	23	10	9	10	62	69	48	9	26	45	39	39.9
11/03/82	43	32	68	57	60	87	69	75	52	43	59	23	47	75	71	54	76	57	58.2
01/11/82	50	84	32	39	49	61	48	71	73	65	45	74	90	46	72	101	86	109	66.4
26/04/83	23	112	46	20	30	14	20	18	16	19	20	36	82	78	60	88	91	47	45.6
13/11/83	118	62	16	80	77	0	61	51	0	70	40	41	95	8	50	40	65	39	50.7
18/02/84	16	84	65	103	87	79	97	54	36	34	66	65	66	70	78	70	60	30	64.4

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:																		MPR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
Jul-Dec'81	69	109	64	61	59	73	50	71	70	55	70	66	70	81	41	77	45	70	66.7
Jan-Jun'82	71	89	68	61	122	92	94	90	90	80	78	67	79	89	88	86	89	85	84.3
Jul-Dec'82	50	84	54	54	52	61	48	60	88	72	85	74	90	46	85	101	86	60	69.4
Jan-Jun'83	51	112	67	55	70	71	49	65	75	42	43	53	49	78	60	88	91	72	66.2
Jul-Dec'83	118	73	35	80	77	71	61	53	48	70	40	46	95	78	50	61	68	82	67.0
Jan-Jun'84	60	84	70	103	87	79	97	61	101	73	81	100	66	70	78	70	75	71	75.3

Computation of ARF

Season	ARF
Jul-Dec'81	.60
Jan-Jun'82	.69
Jul-Dec'82	.96
Jan-Jun'83	.69
Jul-Dec'83	.76
Jan-Jun'84	.86
Average ARF =	.76

Size of area = 200 km2
Duration of storm = 12 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:																	MAR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
05/12/81	36	65	65	23	25	6	24	3	8	24	34	23	70	66	40	77	63	70	40.1
11/03/82	45	36	70	54	62	88	71	71	60	46	60	46	48	35	23	57	78	59	56.1
01/11/82	53	113	35	40	50	62	50	85	75	87	49	80	93	46	81	105	104	111	73.3
26/04/83	50	72	76	58	63	56	73	18	47	19	62	54	50	64	68	40	24	63	53.2
13/11/83	118	62	16	80	77	9	61	51	0	70	40	41	95	8	51	40	65	39	51.3
18/02/84	16	92	66	103	87	79	97	51	37	40	66	65	66	70	85	73	60	32	65.8

Max. Point Rainfall, MPR (mm)

Season	Rainfall at station:																	MPR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
Jul-Dec'81	70	109	65	69	57	74	70	65	70	79	70	81	70	66	48	90	63	70	71.4
Jan-Jun'82	80	89	70	61	123	92	107	90	88	80	78	67	79	90	90	82	90	85	85.6
Jul-Dec'82	54	113	54	43	59	62	63	85	75	87	85	80	130	49	85	105	104	63	77.6
Jan-Jun'83	51	112	67	58	70	71	73	65	76	42	62	54	82	78	68	88	91	73	71.2
Jul-Dec'83	118	73	35	80	77	71	61	53	48	70	40	41	95	78	51	61	68	94	67.4
Jan-Jun'84	62	92	70	103	104	79	104	61	101	73	82	109	66	70	93	73	76	78	83.1

Computation of ARF

Season	ARF
Jul-Dec'81	.56
Jan-Jun'82	.65
Jul-Dec'82	.94
Jan-Jun'83	.75
Jul-Dec'83	.76
Jan-Jun'84	.79
Average ARF =	.74

Size of area = 200 km2
Duration of storm = 24 hour

Max. Areal Rainfall, MAR (mm)

Date	Rainfall at station:																		MAR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
07/09/81	55	60	70	94	96	64	77	43	70	92	81	67	60	84	64	68	70	61	70.9
04/04/82	25	75	50	64	129	96	97	65	60	58	46	30	52	96	85	73	82	88	70.6
01/11/82	59	120	37	44	52	66	52	85	84	89	51	84	102	54	94	105	118	125	78.9
26/04/83	23	112	46	21	30	15	20	18	17	19	20	36	82	78	60	88	91	63	46.6
13/11/83	118	62	16	80	77	9	61	62	0	70	40	41	95	8	51	40	65	39	51.9
18/02/84	16	92	66	104	87	80	97	51	37	42	66	65	66	70	85	75	50	46	66.4

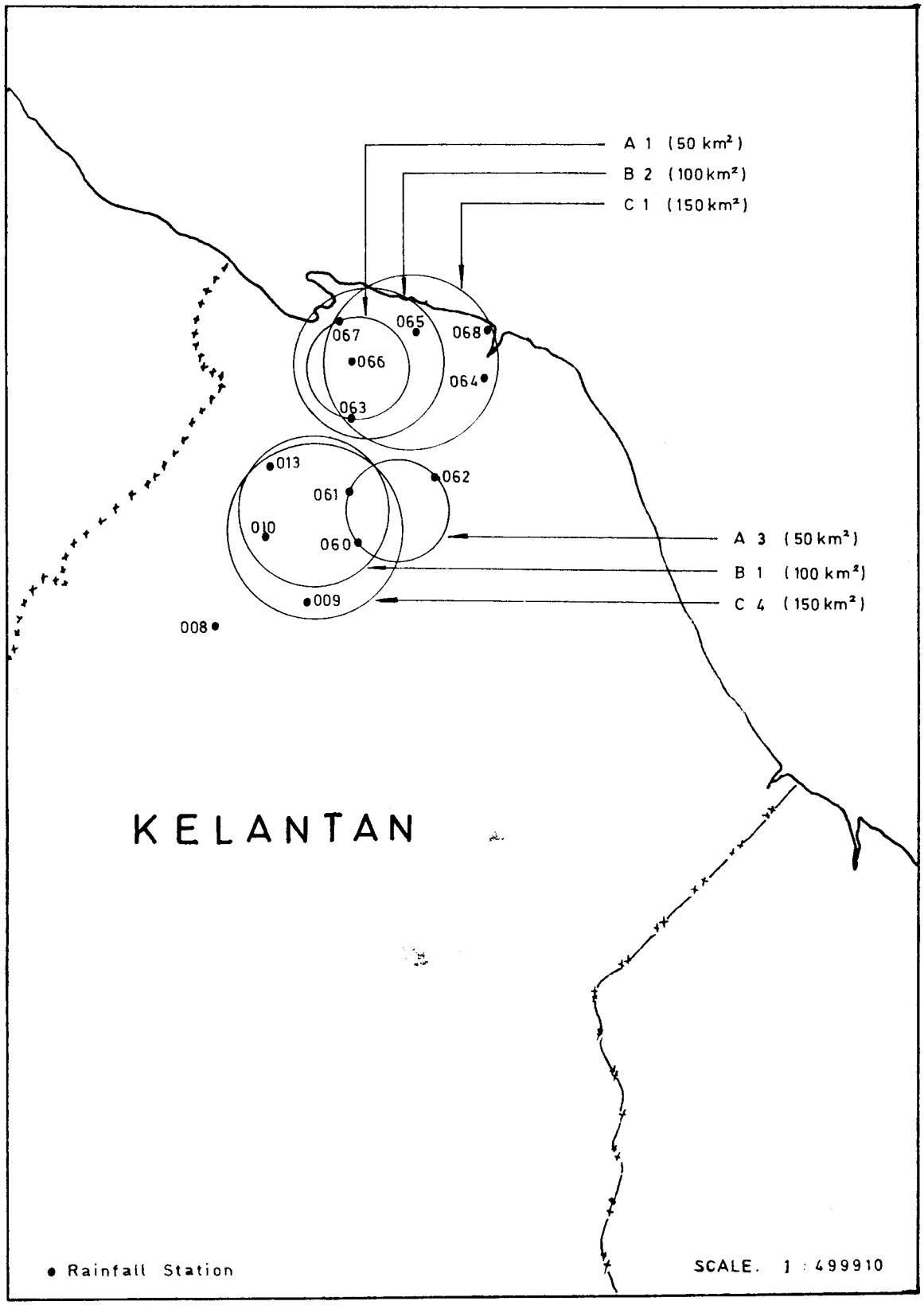
Max. Point Rainfall, MPR (mm)

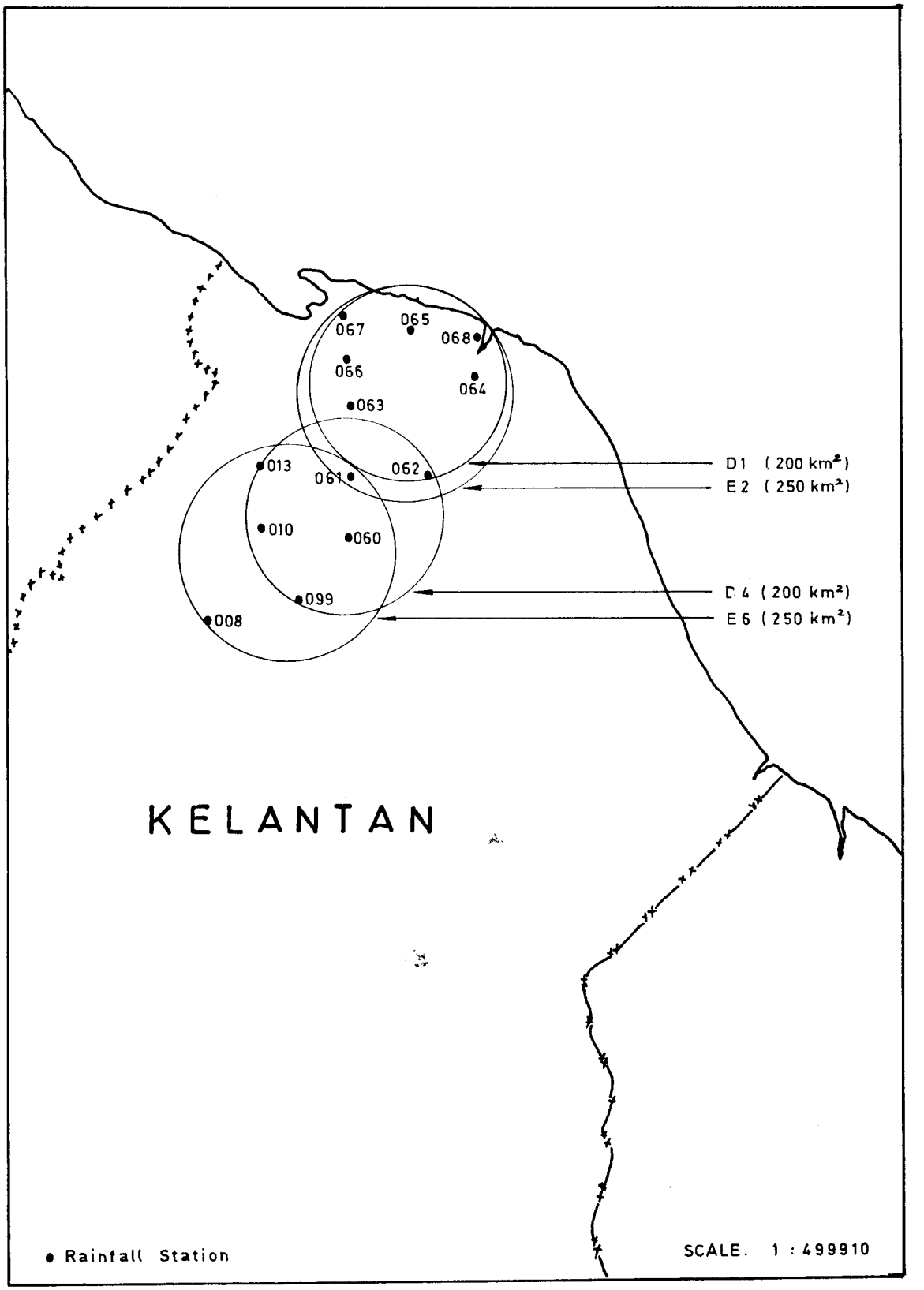
Season	Rainfall at station:																		MPR
	13	70	5	2	3	1	9	6	7	36	8	11	14	12	10	33	18	34	
Jul-Dec'81	70	109	70	94	101	129	84	82	90	92	96	117	81	84	70	118	70	70	90.4
Jan-Jun'82	93	102	82	66	130	130	110	91	88	103	113	90	85	96	92	81	94	88	96.3
Jul-Dec'82	59	120	54	61	71	66	52	90	84	89	114	84	131	57	94	105	118	125	87.4
Jan-Jun'83	52	112	67	47	70	71	95	65	75	42	43	53	82	78	81	88	91	73	71.4
Jul-Dec'83	118	73	35	83	77	71	61	62	48	70	40	46	95	75	51	61	68	94	68.2
Jan-Jun'84	62	92	70	104	95	80	97	81	101	73	82	109	66	70	103	75	76	78	84.1

Computation of ARF

Season	ARF
Jul-Dec'81	.78
Jan-Jun'82	.73
Jul-Dec'82	.90
Jan-Jun'83	.65
Jul-Dec'83	.76
Jan-Jun'84	.79
Average ARF =	.77

APPENDIX III: Location of Rainfall Stations and "Fixed Areas" Used in the Kelantan ARF Study


A 1 (50 km²)
B 2 (100 km²)
C 1 (150 km²)
065
067
068
066
064
063
013
062
061
010
060
009
008
A 3 (50 km²)
B 1 (100 km²)
C 4 (150 km²)
KELANTAN
• Rainfall Station
SCALE. 1 : 499910


067
065
068
066
064
063
013
061
062
010
060
099
008
D1 (200 km²)
E2 (250 km²)
D4 (200 km²)
E6 (250 km²)
KELANTAN
• Rainfall Station
SCALE. 1 : 499910

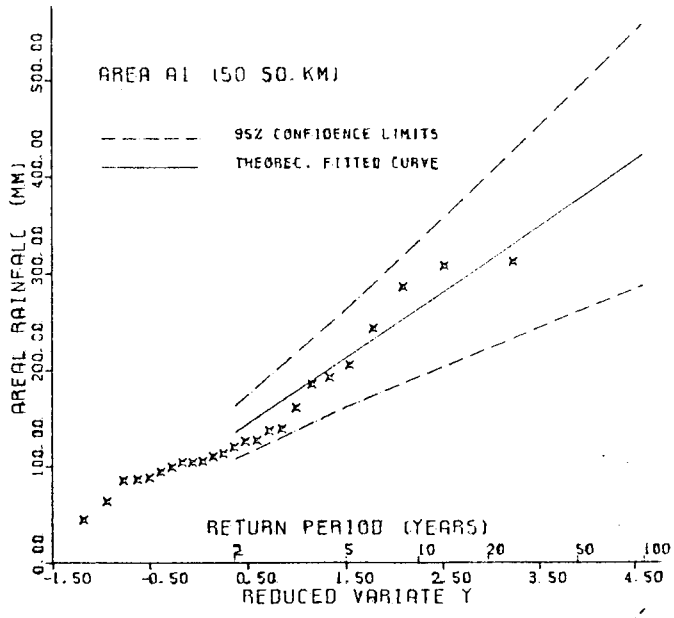
Stations used in the North Kelantan ARF study

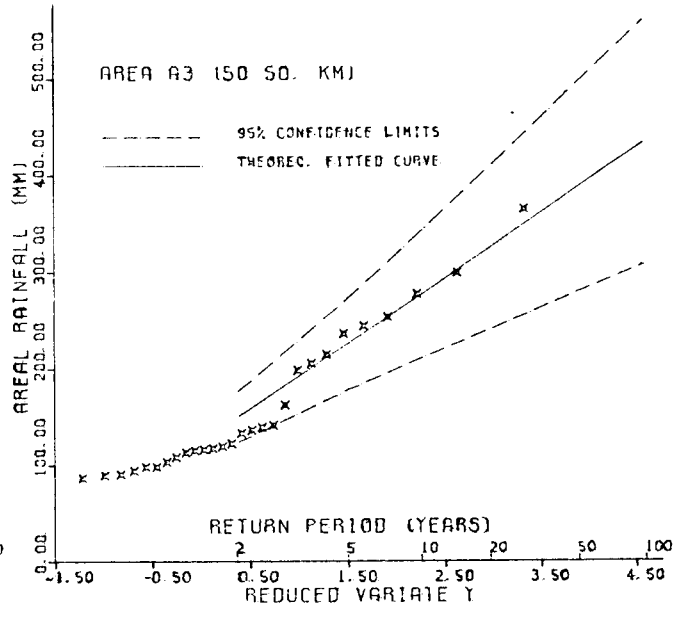
AREA	SIZE (sq. km)	STATION	LOCATION
A1	50	063	STN 6121063 at Balai Polis Wakaf Baru
		066	STN 6121066 at Stesen Keretapi Kampung Berangan
		067	STN 6121067 at Stesen Keretapi Tumpat
A3	50	060	STN 6021060 at Rumah Pam Salor Pengkalan Kubur
		061	STN 6021061 at Rumah Pam Pasir Mas
		062	STN 6022062 at Chabang Tiga Pendek
B1	100	010	STN 6021010 at Rumah Pam Repek
		013	STN 6021013 at Rumah Kerajaan JPT Meranti
		060	STN 6021060 at Rumah Pam Salor Pengkalan Kubur
		061	STN 6021061 at Rumah Pam Pasir Mas
B2	100	065	STN 6022065 at Stesen Keretapi Palekbang
		063	STN 6121063 at Balai Polis Wakaf Baru
		066	STN 6121066 at Stesen Keretapi Kampung Berangan
		067	STN 6121067 at Stesen Keretapi Tumpat
		065	STN 6062065 at Stesen Keretapi Palekbang
C1	150	063	STN 6121063 at Balai Polis Wakaf Baru
		066	STN 6121066 at Stesen Keretapi Kampung Berangan
		067	STN 6121067 at Stesen Keretapi Tumpat
		064	STN 6122064 at Setor JPT Kota Bharu
		068	STN 6122068 at Stesen Kajicuaca Pengkalan Chepa
C4	150	009	STN 5921009 at Ibu Bekalan To' Uban
		010	STN 6021010 at Rumah Pam Repek
		013	STN 6021013 at Rumah Kerajaan JPT Meranti

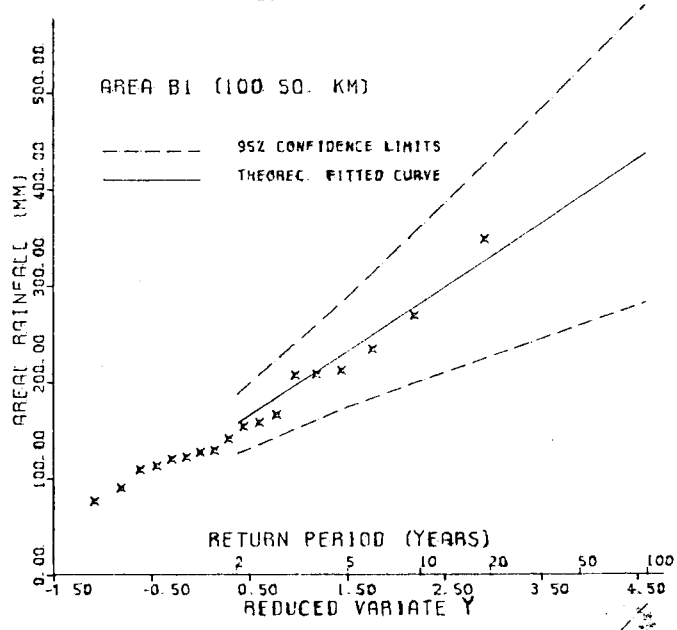
		061	STN 6021061 at Rumah Pam Pasir Mas
D1	200	062	STN 6022062 at Chabang Tiga Pendek
		063	STN 6121063 at Balai Polis Wakaf Baru
		066	STN 6121066 at Stesen Keretapi Kampung Berangan
		067	STN 6121067 at Stesen Keretapi Tumpat
		064	STN 6122064 at Setor JPT Kota Bharu
		068	STN 6122068 at Stesen Kajicuaca Pengkalan Chepa
D4	200	009	STN 5921009 at Ibu Bekalan To' Uban
		010	STN 6021010 at Rumah Pam Repek
		013	STN 6021013 at Rumah Kerajaan JPT Meranti
		060	STN 6021060 at Rumah Pam Salor Pengkalan Kubor
		061	STN 6021061 at Rumah Pam Pasir Mas
		062	STN 6022062 at Chabang Tiga Pendek
E2	250	061	STN 6021061 at Rumah Pam Pasir Mas
		062	STN 6022062 at Chabang Tiga Pendek
		063	STN 6121063 at Balai Polis Wakaf Baru
		067	STN 6121067 at Stesen Keretapi Tumpat
		064	STN 6122064 at Setor JPT Kota Bharu
		068	STN 6122068 at Stesen Kajicuaca Pengkalan Chepa
E6	250	008	STN 5920008 at Kampung Batu Karang
		009	STN 5921009 at Ibu Bekalan To' Uban
		010	STN 6021010 at Rumah Pam Repek
		013	STN 6021013 at Rumah Kerajaan JPT Meranti
		060	STN 6021060 at Rumah Pam Salor Pengkalan Kubor
		061	STN 6021061 at Rumah Pam Pasir Mas

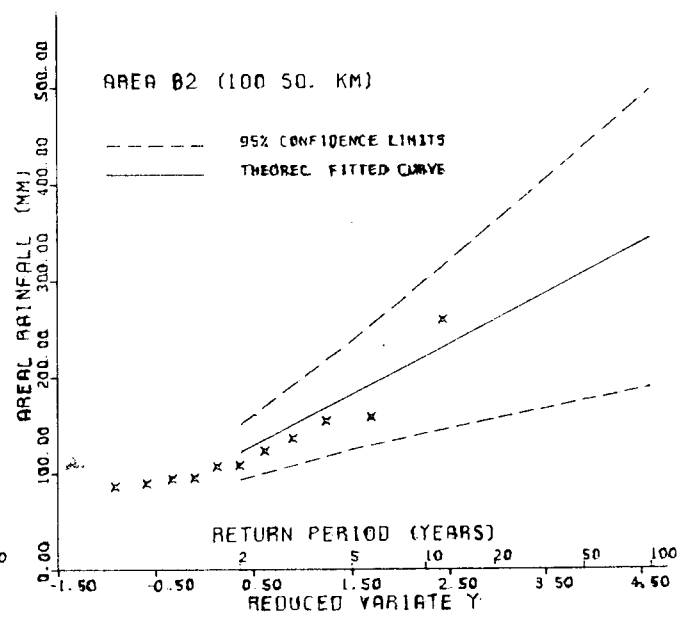
APPENDIX IV(a): Areal Rainfall Frequency Curves for Kelantan
(b): Point Rainfall Frequency Curves for Kelantan
(c): Areal Rainfall and Average Point Rainfall Frequency Curves Used in the Derivation of ARFs for Kelantan

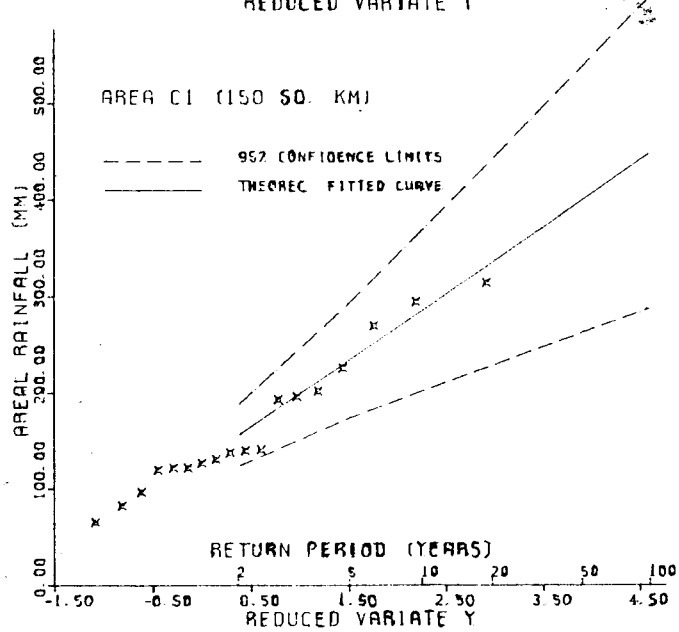
(a) Areal Rainfall Frequency Curves for Kelantan

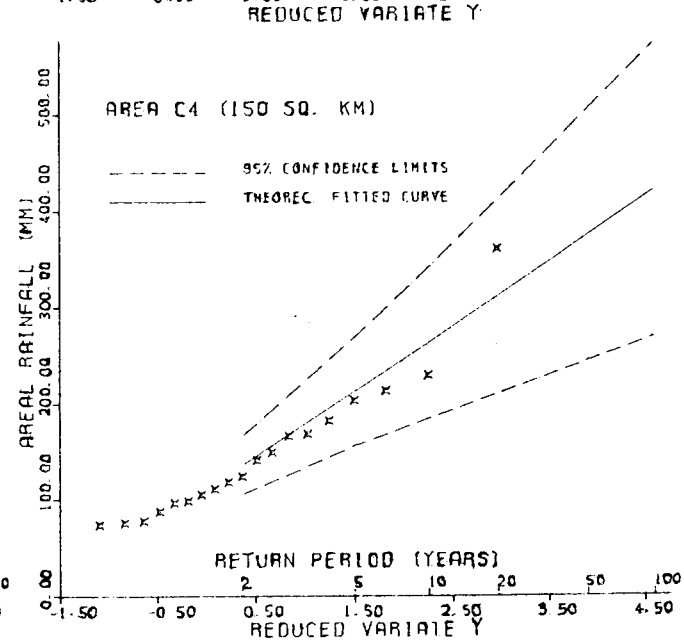




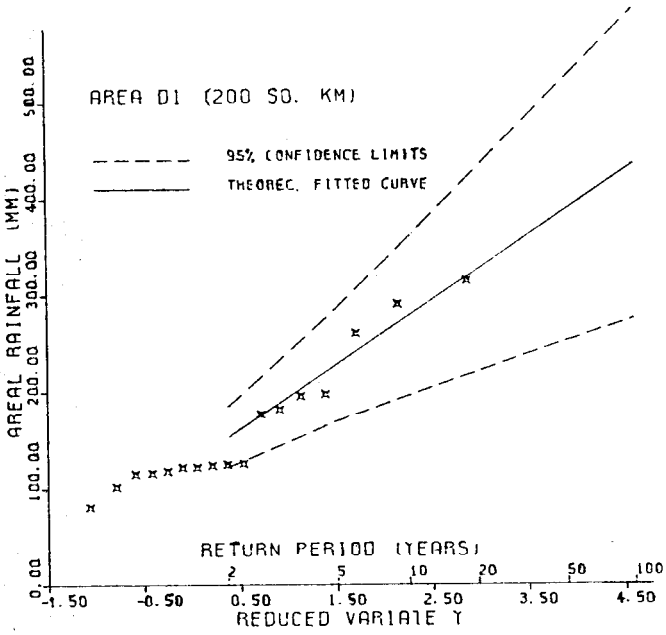


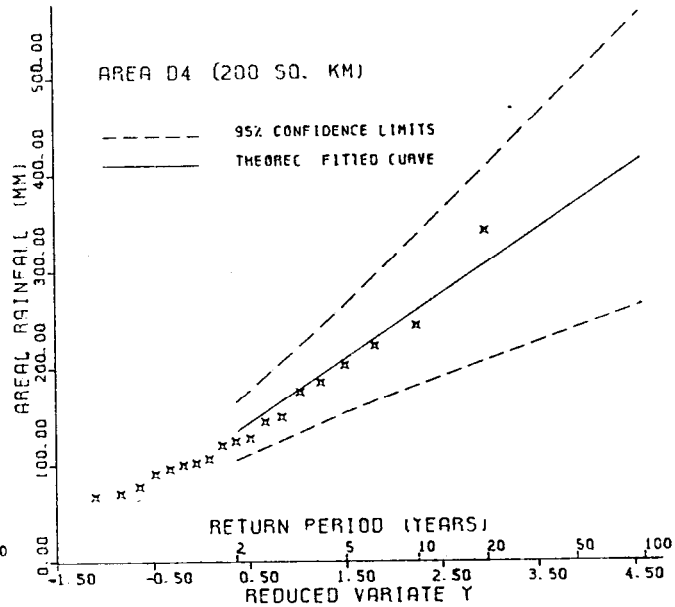


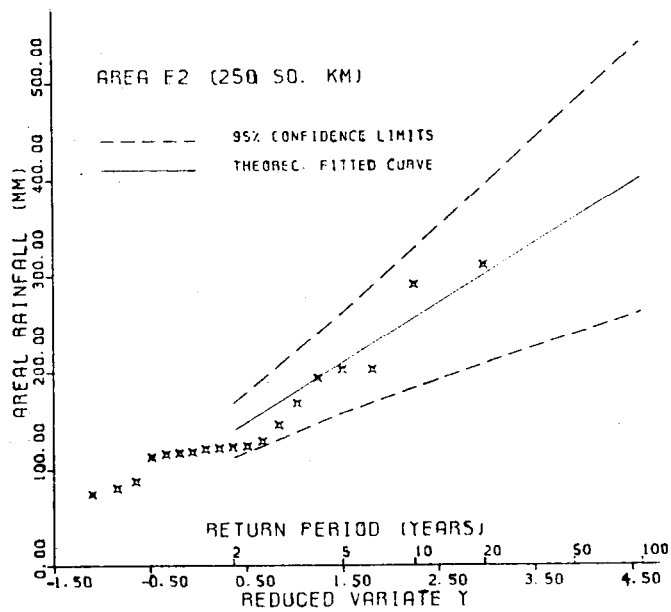


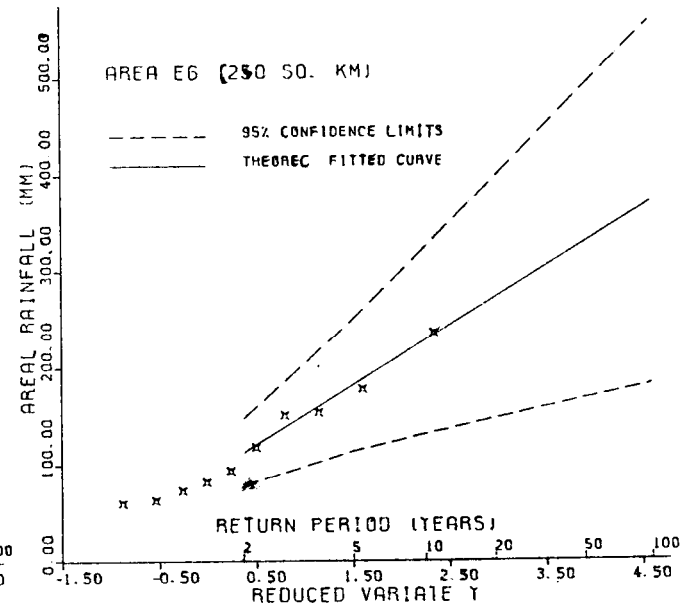


(a) Areal Rainfall Frequency Curves for Kelantan (continued)

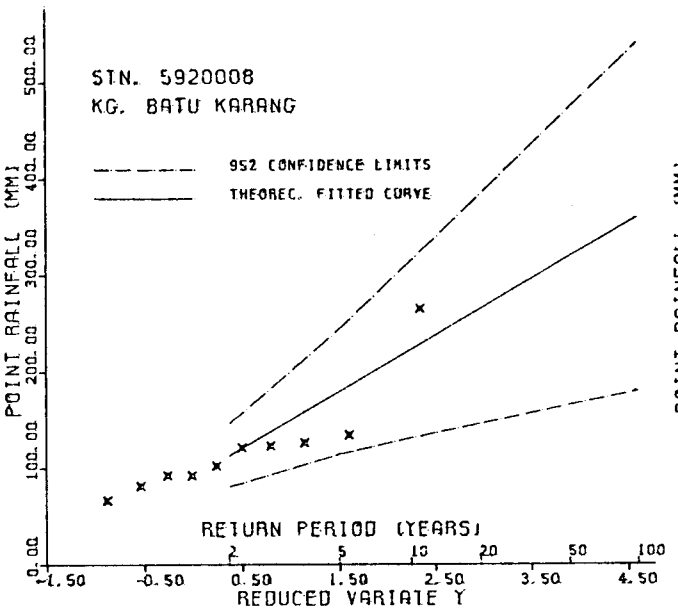


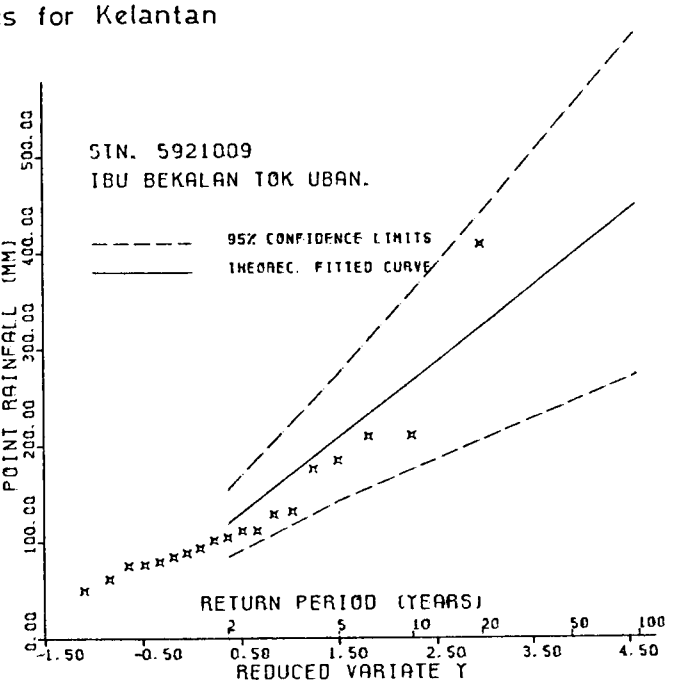


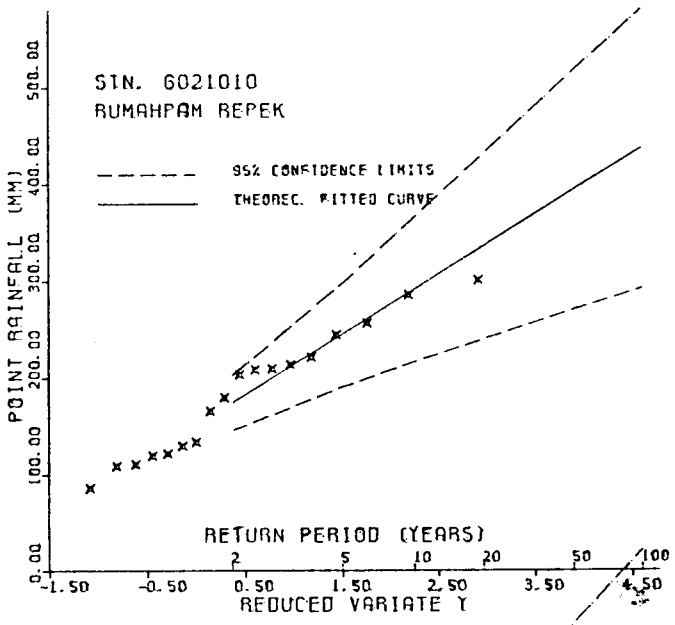


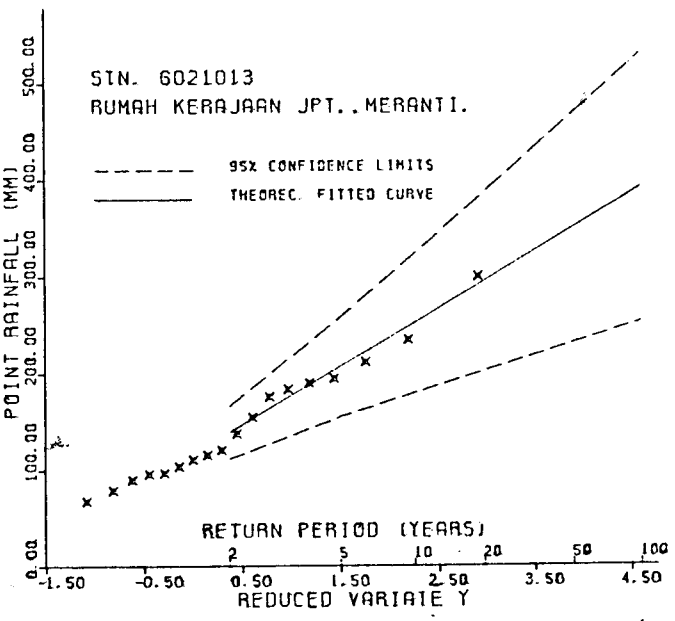


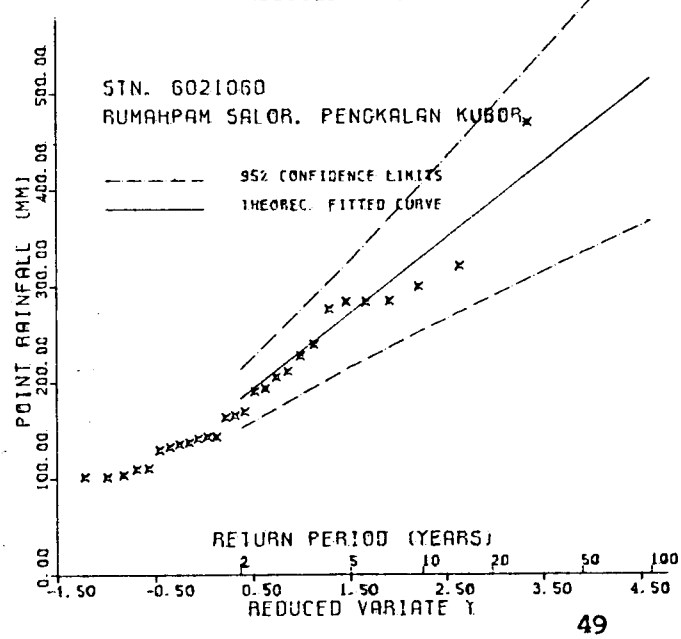
(b) Point Rainfall Frequency Curves for Kelantan

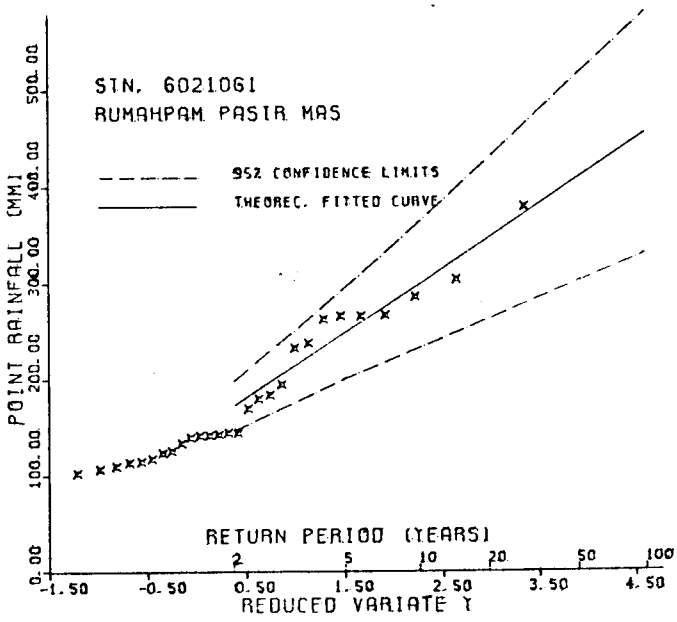




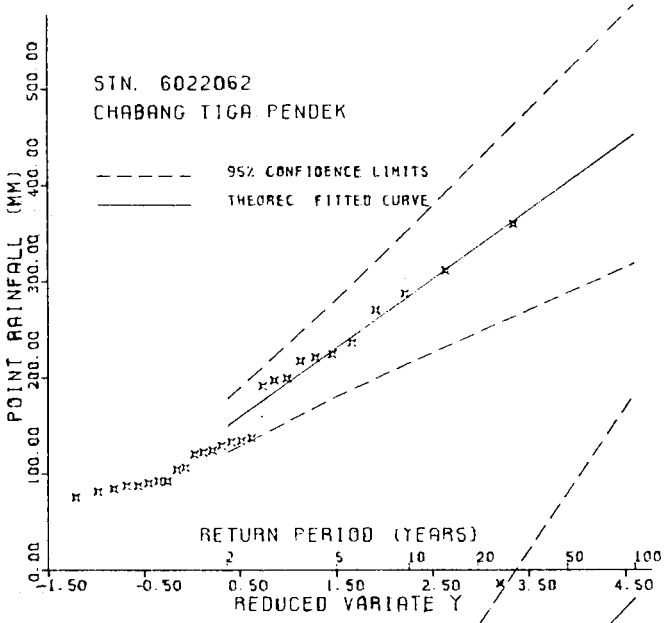


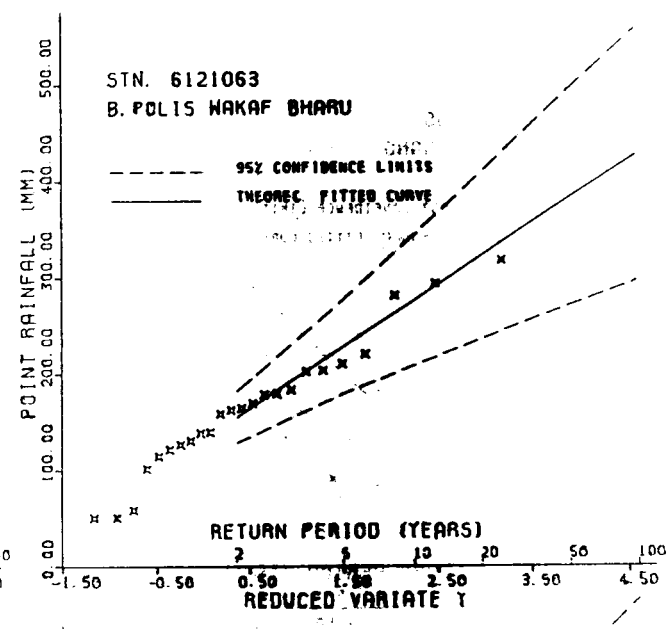


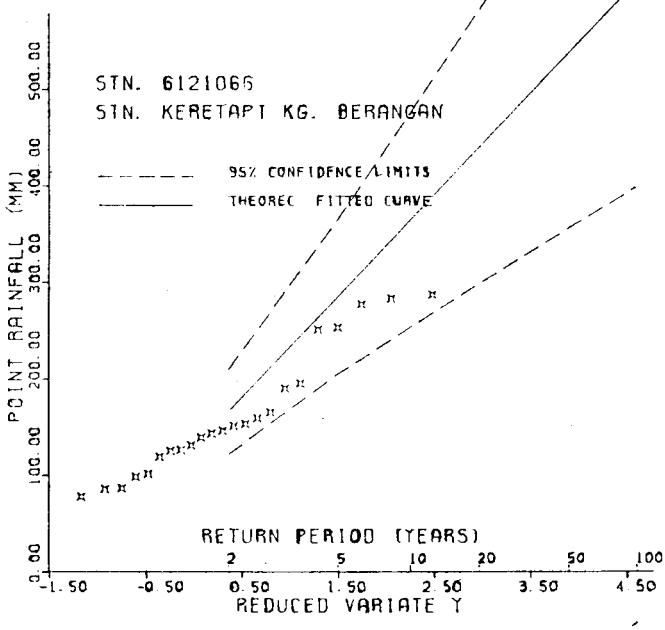


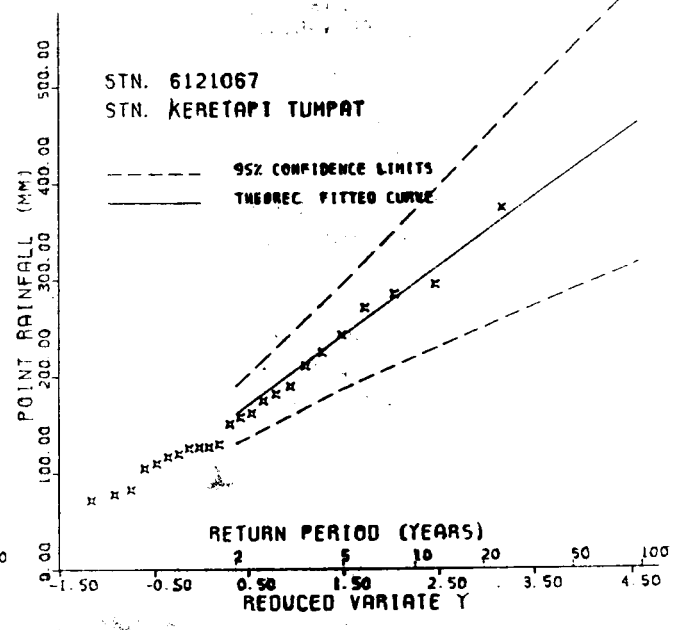


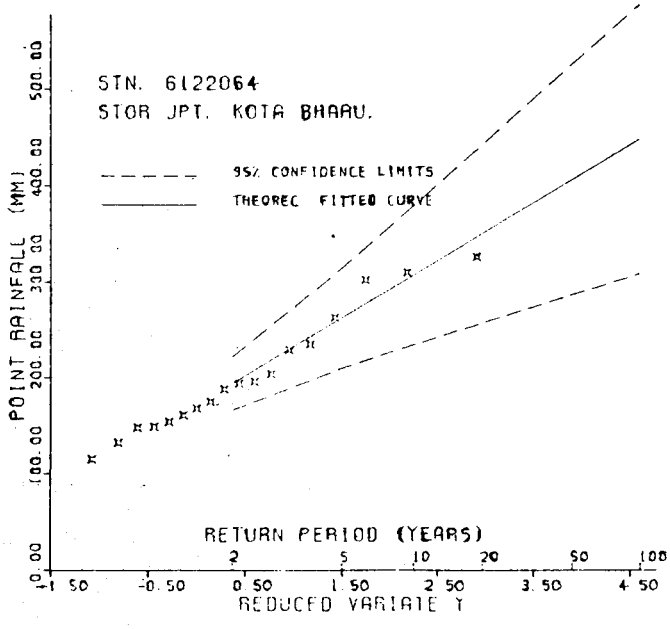
(b) Point Rainfall Frequency Curves for Kelantan (continued)

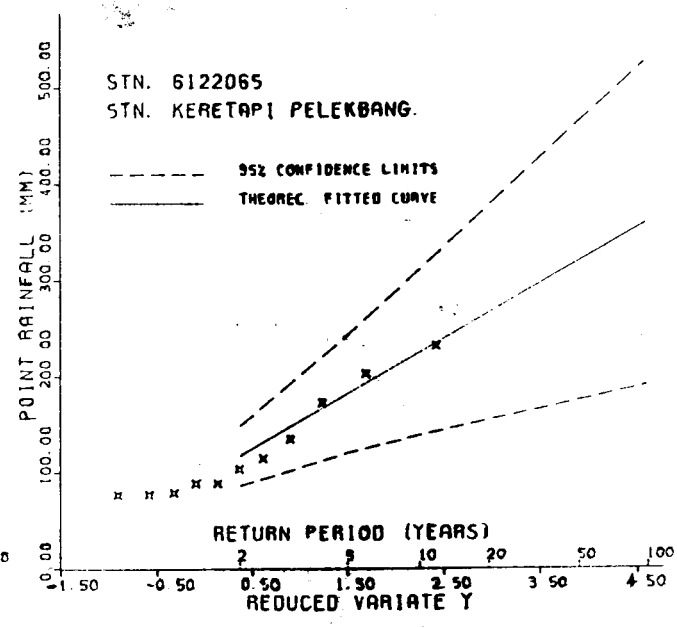




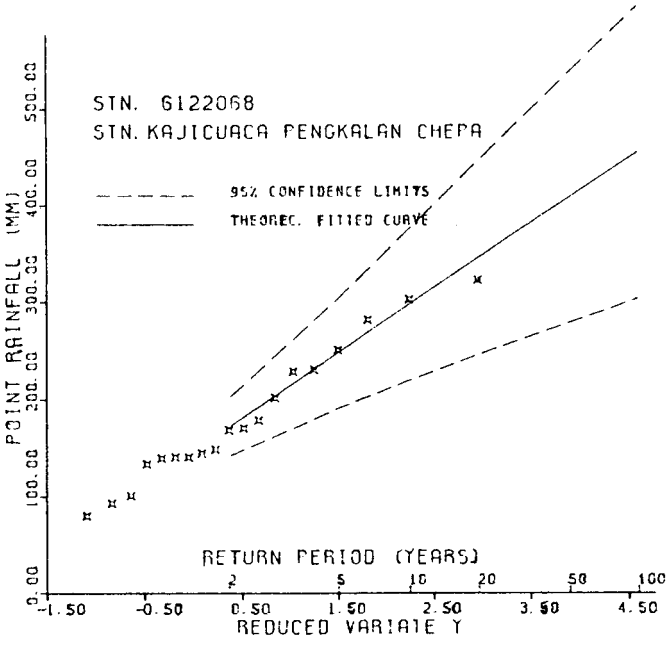




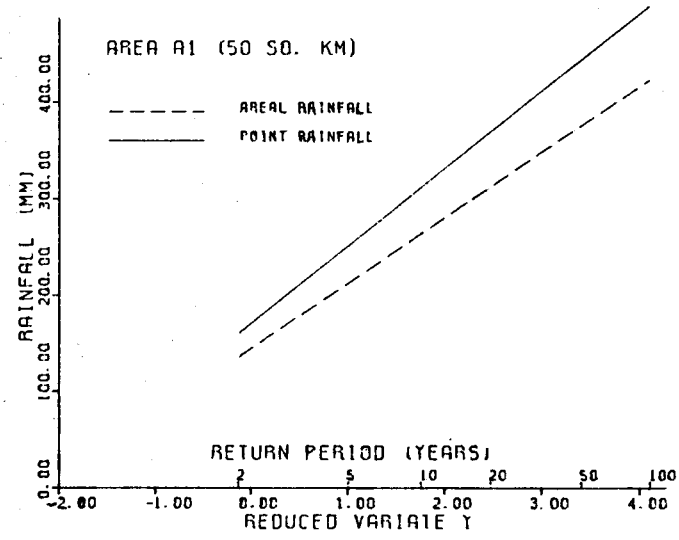


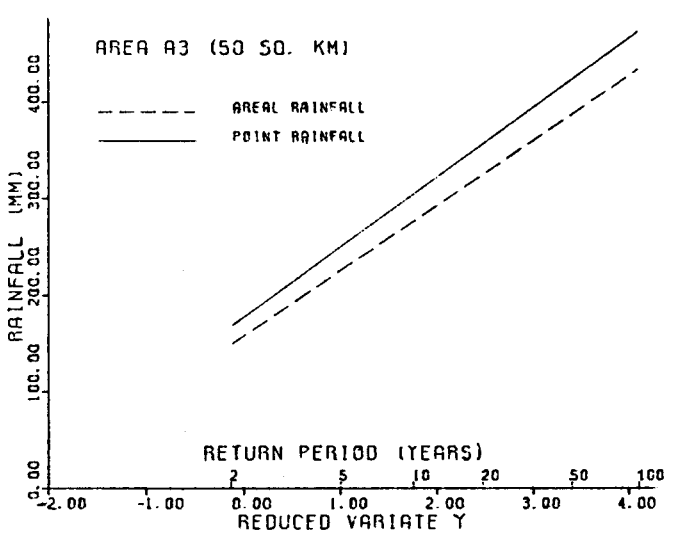


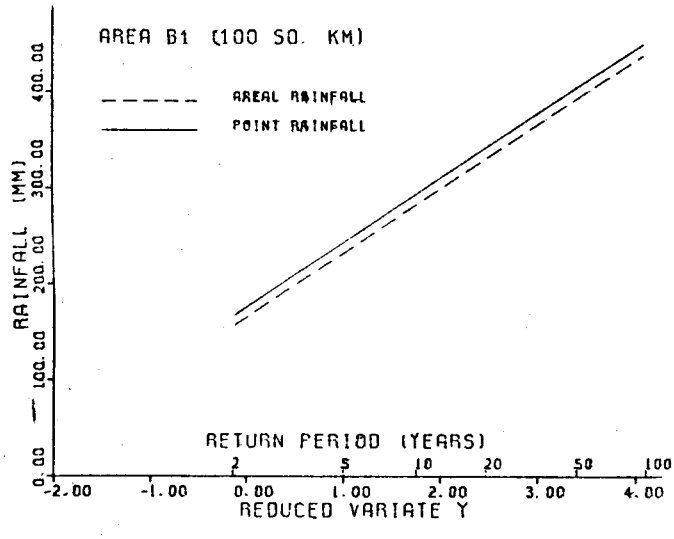
(b) Point Rainfall Frequency Curves for Kelantan (continued)

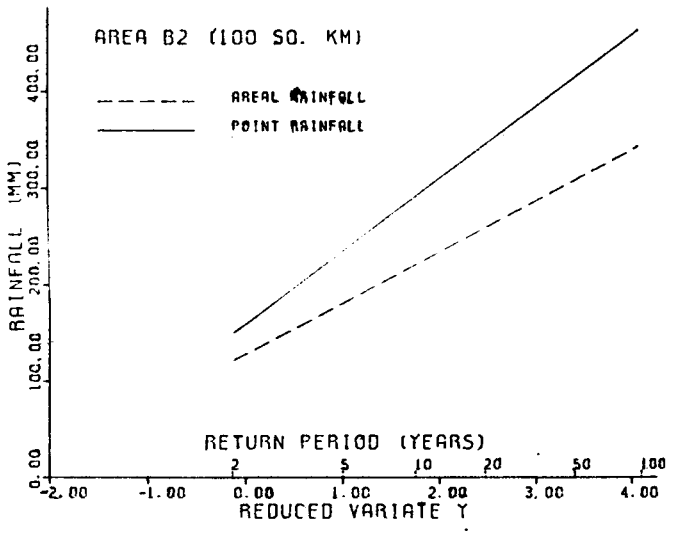


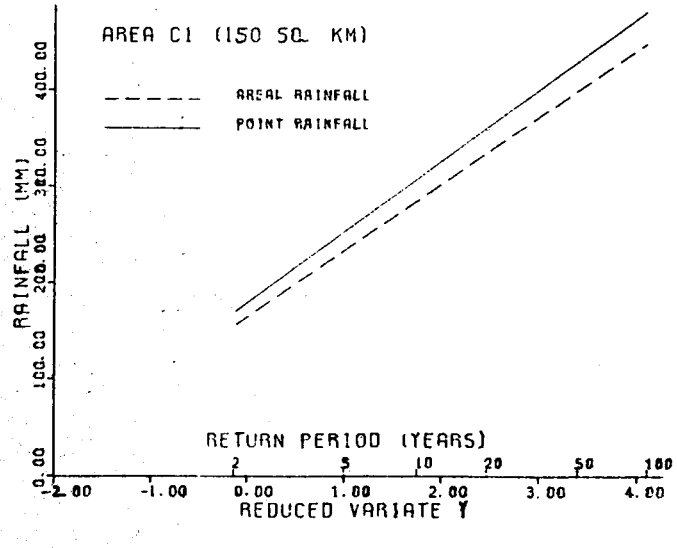
(c) Areal Rainfall and Average Point Rainfall Frequency Curves Used in the Derivation of ARFs for Kelantan

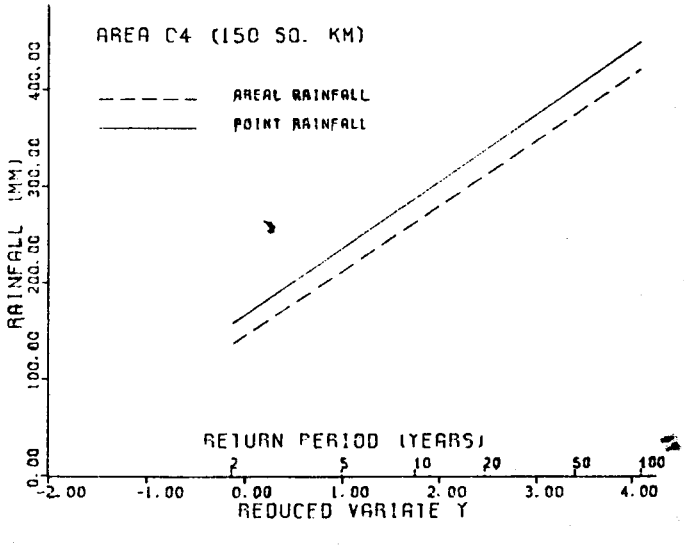




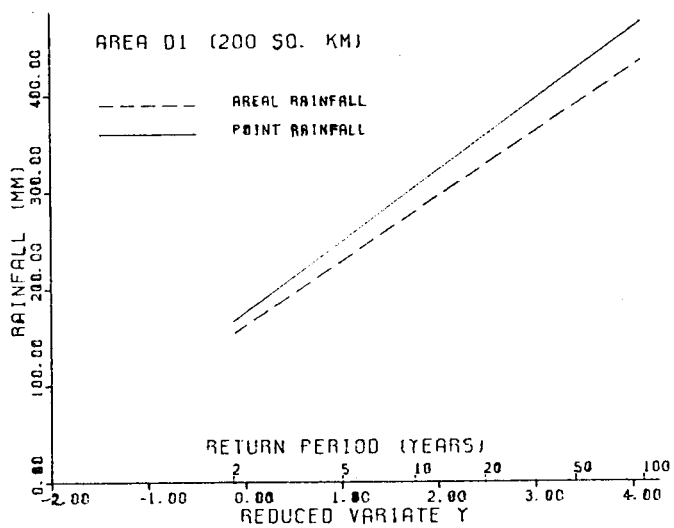


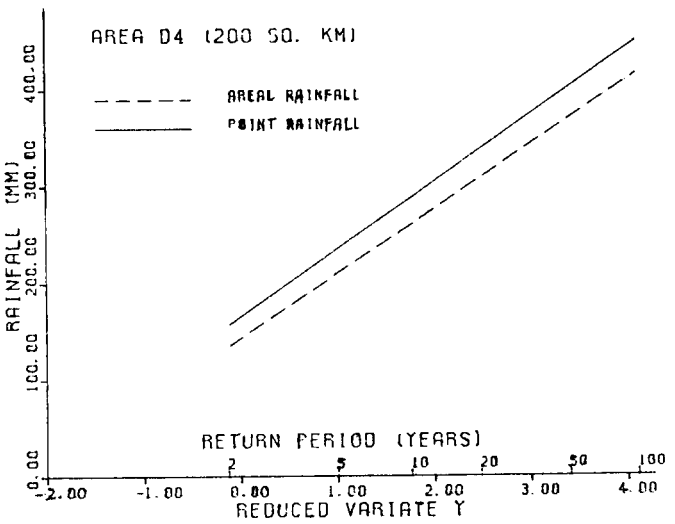


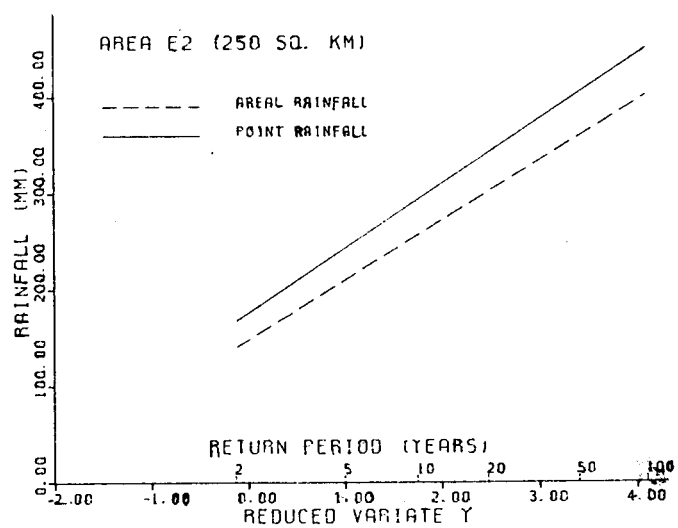


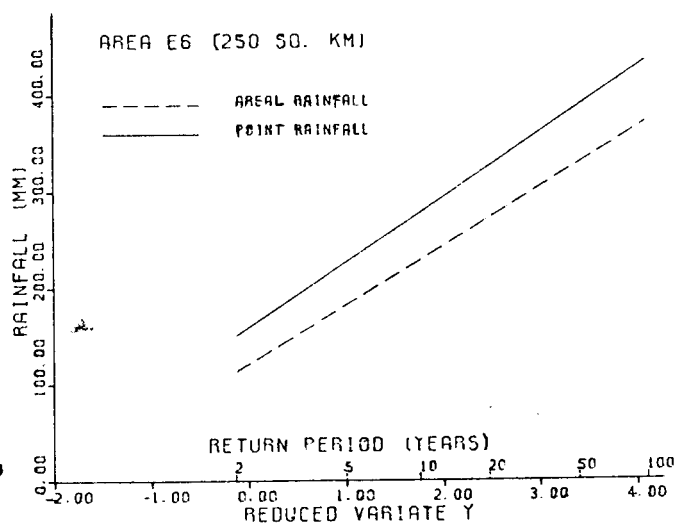


(c) Areal Rainfall and Average Point Rainfall Frequency Curves Used in the Derivation of ARFs for Kelantan (continued)









APPENDIX V: Maximum Areal Rainfall (MAR) and Maximum Point Rainfall (MPR) Extracted for the Computation of ARFs for Kelantan

Area A1
Size = 50 sq. km

Year	Max. Point Rainfall (mm) at stn			MAR (mm)	ARF
	063	066	067		
1951	51	166	78	86	0.87
1952	64	77	92	45	0.58
1953	180	140	175	128	0.78
1954	140	154	105	106	0.80
1955	122	127	127	100	0.80
1956	294	196	127	162	0.79
1957	204	120	110	105	0.72
1958	203	160	158	138	0.79
1959	221	626	182	313	0.91
1960	51	147	211	111	0.82
1961	163	191	225	193	1.00
1962	184	102	120	127	0.94
1963	131	86	83	87	0.87
1964	59	152	151	105	0.87
1965	282	284	295	287	1.00
1966	139	126	130	121	0.92
1967	159	144	117	140	1.00
1968	170	278	243	206	0.89
1969	318	288	374	309	0.95
1970	211	252	271	244	1.00
1971	179	132	126	114	0.78
1972	102	78	72	64	0.77
1973	127	254	285	186	0.84
1974	115	87	162	93	0.78
1975	165	99	190	89	0.59

Mean ARF = 0.84

Area A3
Size = 50 sq. km

Year	Max. Point Rainfall (mm) at stn			MAR (mm)	ARF
	060	061	062		
1956	191	170	134	142	0.86
1957	133	110	85	109	1.00
1958	130	142	82	87	0.74
1959	284	304	218	215	0.80
1960	110	134	138	104	0.82
1961	136	184	105	91	0.64
1962	164	180	107	117	0.78
1963	102	107	237	99	0.67
1964	102	124	123	116	1.00
1965	277	286	271	278	1.00
1966	144	126	130	114	0.86
1967	104	115	93	90	0.87
1968	144	142	135	140	1.00
1969	321	266	312	300	1.00
1970	206	238	88	163	0.92
1971	142	103	93	99	0.88
1972	212	145	88	123	0.83
1973	240	266	222	199	0.82
1974	138	145	288	118	0.62
1975	285	233	192	237	1.00
1976	36	22	29	21	0.73
1977	170	114	125	134	0.98
1978	166	118	76	120	1.00
1979	111	140	91	95	0.84
1980	194	143	121	137	0.90
1981	470	379	360	366	0.91
1982	228	195	225	206	0.95
1983	284	267	198	245	0.98

Mean ARF = 0.87

Area B1
Size = 100 sq. km

Year	Max. Point Rainfall (mm) at stn				MAR (mm)	ARF
	010	013	060	061		
1965	301	212	277	286	235	0.87
1966	209	190	144	126	126	0.76
1968	109	104	144	142	110	0.88
1969	257	235	321	266	270	1.00
1970	210	184	206	238	209	1.00
1971	86	176	142	103	123	0.97
1972	214	96	212	145	167	1.00
1973	166	121	240	266	159	0.80
1974	134	97	138	145	114	0.88
1975	286	138	285	233	213	0.91
1976	222	68	300	263	208	0.98
1977	120	111	170	114	121	0.94
1978	122	116	166	118	130	0.99
1979	180	195	111	140	91	0.58
1980	130	155	194	143	142	0.92
1981	245	300	470	379	349	1.00
1982	204	90	228	195	155	0.87
1983	111	79	108	56	77	0.87

Mean ARF = 0.90

Area B2
Size = 100 sq. km

Year	Max. Point Rainfall(mm) at stn				MAR (mm)	ARF
	063	066	067	065		
1948	109	167	214	203	124	0.72
1949	102	33	25	22	20	0.43
1950	89	150	185	232	109	0.66
1951	51	166	78	173	71	0.61
1952	64	77	92	78	39	0.50
1953	180	140	175	77	108	0.76
1954	140	154	105	79	96	0.80
1955	122	127	127	77	87	0.77
1956	294	196	127	173	159	0.80
1957	204	120	110	89	95	0.72
1958	203	160	158	135	137	0.83
1959	221	626	182	104	260	0.92
1960	51	147	211	89	90	0.72
1961	163	191	225	115	155	0.89

Mean ARF = 0.72

Area C1
Size = 150 sq. km

Year	Max. Point Rainfall (mm) at stn					MAR (mm)	ARF
	063	066	067	064	068		
1958	203	160	158	154	179	138	0.80
1959	221	626	182	263	282	270	0.86
1960	51	147	211	196	231	131	0.78
1961	163	191	225	204	229	202	1.00
1962	184	102	120	149	149	122	0.87
1963	131	86	83	115	80	83	0.84
1964	59	152	151	175	134	122	0.91
1965	282	284	295	310	303	295	1.00
1966	139	126	130	168	141	127	0.90
1967	159	144	117	147	140	141	1.00
1968	170	278	243	161	202	196	0.93
1969	318	288	374	326	323	315	0.97
1970	211	252	271	229	169	226	1.00
1971	179	132	126	188	171	140	0.88
1972	102	78	72	132	93	66	0.60
1973	127	254	285	302	251	193	0.79
1974	115	87	162	235	101	120	0.86
1975	165	99	190	194	141	97	0.61

Mean ARF = 0.87

Area C4
Size = 150 sq. km

Year	Max. Point Rainfall (mm) at stn					MAR (mm)	ARF
	009	010	013	060	061		
1965	129	301	212	277	286	214	0.89
1966	176	209	190	144	126	119	0.70
1967	85	93	143	104	115	76	0.70
1968	112	109	104	144	142	88	0.72
1969	89	257	235	321	266	230	0.98
1970	50	210	184	206	238	169	0.95
1971	112	86	176	142	103	99	0.80
1972	105	214	96	212	145	150	0.97
1973	102	166	121	240	266	142	0.79
1974	77	134	97	138	145	106	0.90
1975	76	286	138	285	233	183	0.90
1976	185	222	68	300	263	204	0.98
1977	80	120	111	170	114	97	0.81
1978	62	122	116	166	118	112	0.96
1979	132	180	195	77	140	78	0.54
1980	94	130	155	194	143	125	0.87
1981	409	245	300	470	379	361	1.00
1982	211	204	90	228	195	167	0.90
1983	210	111	79	108	56	74	0.66

Mean ARF = 0.84

Area D1
Size = 200 sq. km

Year	Max. Point Rainfall (mm) at stn						MAR (mm)	ARF
	062	063	066	067	064	068		
1958	82	203	160	153	154	179	115	0.73
1959	216	221	626	182	263	282	261	0.87
1960	138	51	147	211	196	231	125	0.77
1961	107	163	191	225	204	229	182	0.98
1962	107	135	102	120	132	149	116	0.94
1963	237	131	86	83	115	80	81	0.66
1964	123	59	152	151	175	134	122	0.92
1965	271	282	284	295	310	303	291	1.00
1966	130	139	126	130	168	141	124	0.90
1967	93	159	144	177	147	140	122	0.92
1968	135	170	278	243	161	202	177	0.89
1969	312	318	288	374	326	323	315	0.97
1970	68	211	252	271	229	169	196	0.67
1971	93	179	116	126	188	171	126	0.86
1972	88	102	76	72	132	93	57	0.60
1973	222	127	254	285	302	251	198	0.82
1974	288	115	87	162	235	101	118	0.72
1975	192	165	99	190	194	141	102	0.62

Mean ARF = 0.82

Area D4
Size = 200 sq. km

Year	Max. Point Rainfall (mm) at stn						MAR (mm)	ARF
	009	010	013	060	061	062		
1965	129	301	212	277	286	271	223	0.91
1966	176	209	190	144	126	130	120	0.74
1967	85	93	143	104	115	93	68	0.64
1968	112	109	104	144	142	135	96	0.77
1969	89	257	235	321	266	312	244	0.99
1970	50	210	184	206	238	88	149	0.91
1971	112	86	176	142	103	93	91	0.77
1972	105	214	96	212	145	88	127	0.89
1973	102	166	121	240	266	222	144	0.72
1974	77	134	97	138	145	288	100	0.69
1975	76	286	138	285	233	192	185	0.92
1976	185	222	68	300	263	200	203	0.98
1977	80	120	111	170	114	125	102	0.85
1978	62	122	116	166	118	76	106	0.96
1979	132	180	195	77	140	91	78	0.57
1980	94	130	155	194	143	121	124	0.89
1981	409	245	300	470	379	360	342	0.95
1982	211	204	90	228	195	225	175	0.91
1983	210	111	79	108	56	58	71	0.69

Mean ARF = 0.83

Area E2
Size = 250 sq. km

Year	Max. Point Rainfall (mm) at stn						MAR (mm)	ARF
	061	062	063	067	064	068		
1957	110	85	133	110	109	145	87	0.75
1958	142	82	203	158	154	179	116	0.76
1959	304	218	221	182	263	282	203	0.83
1960	134	138	51	211	196	231	123	0.77
1961	184	107	163	225	204	229	168	0.91
1962	180	107	135	120	132	149	121	0.88
1963	107	237	131	83	115	80	80	0.64
1964	124	123	59	151	175	134	117	0.92
1965	286	271	282	295	310	303	291	1.00
1966	126	130	139	130	168	141	122	0.88
1967	115	93	159	117	147	140	118	0.91
1968	142	135	170	243	161	202	146	0.83
1969	266	312	318	374	326	323	311	0.97
1970	238	88	211	271	229	169	194	0.97
1971	103	93	179	126	188	171	129	0.90
1972	145	88	102	72	132	93	74	0.70
1973	266	222	127	285	302	251	203	0.84
1974	145	288	115	162	235	101	113	0.65
1975	233	192	165	190	194	141	124	0.67

Mean ARF = 0.83

Area E6
Size = 250 sq. km

Year	Max. Point Rainfall (mm) at stn						MAR (mm)	ARF
	008	009	010	013	060	061		
1967	124	85	93	143	104	115	63	0.57
1968	103	112	109	104	144	142	73	0.62
1969	266	89	257	235	321	266	236	0.99
1970	127	50	210	184	206	238	151	0.89
1971	67	112	86	176	142	103	82	0.72
1972	82	49	78	71	100	115	60	0.73
1973	122	102	166	121	240	266	118	0.70
1974	135	77	134	97	138	145	94	0.78
1975	93	76	286	138	285	233	154	0.83
1976	93	185	222	68	300	263	178	0.94

Mean ARF = 0.78

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