CHAPTER IV

RESULTS OF THE ANALYSIS

4.1 Data Used

The data used in this analysis consist of the annual peak discharges of the Mae Klong river, collected by the Royal Irrigation Department and the National Energy Authority during the year 1960 to 1974. Ten gaging stations in the Mae Klong basin (nine stations from the Royal Irrigation Department and one station from the National Energy Authority) are selected according to the available recorded data and the locations of the stations. Four stations are on the Khwai Yai river, four on the Khwai Noi river, one on the Lam Taphoen river and one on the Lam Pachee river. Details and locations of these gaging stations are shown in Table 4.1 on page 37.

4.2 Determination of Basin Characteristics

The topographic map of scale 1:250,000 of the Mae Klong basin is used to determine the basin characteristics. The 1:50,000 topographic map is also used to determine the stream length between the contour lines in the mountainous region, because these contour lines (in the 1:250,000 map) are shown too close. The methods for determination of the basin characteristics are as follow :

Table 4.1 Details of gaging stations in Mae Klong basin

Gaging Station	River	Location		Village	Years of record
		Lat. °N	Long. °E		
K 6	Khwai Yai	14° 25' 43"	99° 07' 04"	Pak Kaeng Riang	1960 - 72
K 9	Khwai Noi	14 06 56	99 08 20	Wang Pho	1962 - 73
K 10	Khwai Noi	14 05 40	99 10 28	Lum Sum	1965 - 73
K 12	Lam Taphoen	14 09 15	99 25 06	Thung Na Nang Rok	1966 - 73
K 13	Khwai Noi	14 43 50	98 38 32	Tha Khanum	1966 - 73
K 17	Lam Pachee	13 32 41	99 21 22	Ban Bo	1966 - 73
K 19	Khwai Yai	14 52 11	99 03 50	Khao Ong Kha	1966 - 72
K 20	Khwai Yai	14 20 52	99 10 45	Tha Thong Mon	1966 - 73
K 22A	Khwai Noi	14 26 44	98 48 08	Mae Num noi	1969 - 73
N 1	Khwai Yai	14 55 36	99 07 12	Khao Chod	1965 - 71

Note Code K = R.I.D. gaging station

Code N = N.E.A. gaging station

4.2.1 The basin area of each gaging station is measured directly by using a polar plannimeter. Three readings are taken and the basin area is obtained by taking the average of the three.

4.2.2 The stream lengths are measured by using a curvimeter. The measured lengths are then multiplied by the coefficient of meandering to obtain the corrected stream lengths. The average coefficient of meandering of the subbasins used in this study are sunmitted below :

Gaging station	Coefficient of meandering	Approximately % of mountain area in the basin
K 6	1.08	80
K 9	1.07	70
K 10	1.07	70
K 12	1.05	50
K 13	1.07	70
K 17	1.06	60
K 19	1.08	80
K 20	1.08	80
K 22A	1.06	60
N 1	1.08	80

The stream lengths in this article are L, ΣL and L_c. L is measured along the main stream from the gaging station to the headwater, ΣL is the summation measurement of all the stream channels (main stream and its tributaries) between the gaging station and the headwater, and L_c is measured along the stream to the point nearest the centroid of the basin.

4.2.3 The slope of the main stream is obtained by measuring the stream length between the adjacent contour lines and calculating the difference in elevation between the lines. This process is carried out, starting from the gaging station to the headwater of the stream, then the graph between the distance from gaging station and the difference in elevation is plotted. From this graph, the average slope of the main stream is obtained as described in the article 3.5.4

From the values of A, L and $\Sigma \bar{L}$, the shape number and the drainage density of that subbasin can be determined by using Eq.(26) and (27) respectively. The results showing the basin characteristics of each gaging station are shown in Table 4.2 on the next page.

4.3 Flood Flow Estimation

The frequency analysis of the annual peak discharges are obtained by using Gumbel's Formula. The recorded data of ten gaging stations shown in Appendix III are inserted to Eq. (1) , (2) and (13). In order to cut the calculating time to a minimum, the calculations are done with the aid of a computer. The Fortran IV program is included in Appendix I.

Table 4.2 Physical Characteristics of subbasins in Mae Klong River

Station	Basin Area (sq.km.)	Shape Number	Drainage Density (km./sq.km.)	Slope of the Main Stream	Stream Length (km.)		
					L	L_c	ΣL
K 6	11071	0.08834	0.30313	0.00146	354	176	3356
K 9	6901	0.07984	0.32720	0.00060	294	137	2258
K 10	7004	0.07679	0.32824	0.00058	302	145	2299
K 12	2340	0.10683	0.33248	0.00193	148	74	778
K 13	4047	0.16008	0.32691	0.00107	159	47	1323
K 17	1353	0.19640	0.39616	0.00449	83	35	536
K 19	8491	0.12658	0.30185	0.00227	259	115	2563
K 20	11253	0.08355	0.30383	0.00140	367	188	3419
K 22A	327	0.18537	0.33945	0.00642	42	28	111
N 1	5800	0.09584	0.27776	0.00226	246	114	1611

The flood flow at the return period of 2, 2.33, 5,10,20,50 100,500 and 1,000 years are shown in Table 4.3 on page 42. The flood flow at other return periods are also found and shown in Appendix II.

4.4 Relationship between Flood Flow and Basin Characteristics

The annual flood for T-year return period is first assumed to relate with the basin characteristics and can be shown by the eq. (14) to (21). As an example, eq. (21) is rewritten here as

$$Q_T = K\ A^{n_1}\ S_n^{n_2}\ D^{n_3}\ S^{n_4}$$

By logarithmic transformation, the result is

$$\ln(Q_T) = \ln(K) + n_1\ln(A) + n_2\ln(S_n) + n_3\ln(D) + n_4\ln(S)$$

which is in the form of a multiple linear regression. The values of K, n_1, n_2, n_3 and n_4 for T - year return period can then be determined by inserting the values of A, S_n, D, S and Q_T of ten gaging stations (from Table 4.2 and 4.3) into eq. (23). The computer is used to solve eq. (23) and the Fortran IV programs are shown in Appendix I. The degree of correlation of each equation is also found in the value of multiple correlation coefficient. The results are shown in Table 4.4.1 to 4.4.9 for the return period of 2,2.33,5,10 20,50,100,500 and 1,000 years respectively.

Table 4.3 Flood flow at any return period by Gumbel's Formula in cu.m./sec.

Station	Return Period in years								
	2	2.33	5	10	20	50	100	500	1000
K 6	806	901	1318	1657	1982	2403	2719	3448	3761
K 9	1707	1813	2278	2656	3018	3488	3839	4652	5002
K 10	1792	1897	2355	2728	3086	3550	3897	4699	5044
K 12	22	24	33	40	46	55	62	77	83
K 13	1818	1934	2439	2850	3245	3756	4138	5022	5403
K 17	176	195	275	341	404	486	547	649	750
K 19	707	767	1031	1246	1452	1718	1918	2379	2578
K 20	708	759	983	1164	1339	1564	1734	2124	2292
K 22A	142	149	180	205	230	261	285	339	363
K 1	631	659	780	878	972	1094	1185	1396	1487

Table 4.4.1 The relationship between flood flow and basin characteristics for 2-yr. return period

Independent variable included	K	Multiple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	0.83217	0.767				0.608
A S_n	0.93077	0.978	0.855			0.623
A D	1.09663	0.788	0.394			0.608
A S	0.15694	0.374	-0.775			0.675
A S_n D	0.77831	0.970	0.876	-0.260		0.624
A D S	0.05656	0.280	-1.296	-0.827		0.678
A S S_n	0.08556	0.689	-1.185	2.123		0.740
A S_n D S	0.00144	0.448	2.899	-4.905	-1.535	0.773

Table 4.4.2 The relationship between flood flow and basin characteristics for 2.33-yr. return period

Independent variable included	K	Muliple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	0.86954	0.771				0.613
A S_n	0.97724	0.990	0.892			0.630
A D	1.28415	0.799	0.557			0.614
A S	0.16982	0.386	-0.758			0.678
A S_n D	0.90272	0.987	0.901	-0.155		0.630
A D S	0.07242	0.307	-1.082	-0.802		0.680
A S S_n	0.09194	0.704	-1.174	2.147		0.745
A S_n D S	0.00187	0.474	2.888	-4.676	-1.508	0.775

Table 4.4.3 The relationship between flood flow and basin characteristics for 5-yr. return period

Independent variable included	K	Multiple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	1.02907	0.782				0.631
A S_n	1.17220	1.027	0.994			0.651
A D	2.12767	0.836	1.038			0.633
A S	0.22214	0.421	-0.712			0.688
A S_n D	1.45670	1.037	0.969	0.315		0.652
A D S	0.15534	0.388	-0.454	-0.730		0.688
A S S_n	0.11798	0.749	-1.140	2.214		0.759
A S_n D S	0.00422	0.553	2.847	-3.998	-1.426	0.782

Table 4.4.4 The relationship between flood flow and basin characteristics for 10-yr.return period

Independent variable included	K	Multiple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	1.15650	0.788				0.639
A S_n	1.32787	1.048	1.055			0.662
A D	2.88861	0.856	1.308			0.643
A S	0.26282	0.439	-0.688			0.692
A S_n D	1.94641	1.066	1.009	0.555		0.662
A D S	0.24167	0.432	-0.107	-0.692		0.692
A S S_n	0.13784	0.774	-1.125	2.258		0.767
A S_n D S	0.00669	0.596	2.833	-3.633	-1.384	0.785

Table 4.4.5 The relationship between flood flow and basin characteristics for 20-yr. return period

Independent variable included	K	Multiple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	1.27888	0.793				0.643
A S_n	1.47744	1.064	1.102			0.668
A D	3.62888	0.870	1.490			0.648
A S	0.30151	0.452	-0.671			0.693
A S_n D	2.41269	1.087	1.044	0.712		0.669
A D S	0.33413	0.462	0.130	-0.666		0.693
A S S_n	0.15651	0.793	-1.115	2.294		0.770
A S_n D S	0.00926	0.626	2.832	-3.394	-1.357	0.786

Table 4.4.6 The relationship between flood flow and basin characteristics for 50-yr. return period

Independent variable included	K	Multiple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	1.44222	0.797				0.648
A S_n	1.67446	1.078	1.140			0.675
A D	4.67513	0.884	1.680			0.655
A S	0.35072	0.464	-0.657			0.697
A S_n D	3.07959	1.106	1.067	0.384		0.677
A D S	0.46927	0.491	0.370	-0.642		0.697
A S S_n	0.18059	0.808	-1.106	2.322		0.776
A S_n D S	0.01321	0.654	2.820	-3.140	-1.330	0.790

Table 4.4.7 The relationship between flood flow and basin characteristics for 100-yr. return period

Independent variable included	K	Multiple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	1.57414	0.799				0.652
A S_n	1.83205	1.084	1.158			0.679
A D	5.48695	0.892	1.784			0.659
A S	0.38947	0.470	-0.649			0.699
A S_n D	3.59948	1.116	1.078	0.980		0.681
A D S	0.57779	0.506	0.501	-0.628		0.699
A S S_n	0.19982	0.816	-1.100	2.335		0.779
A S_n D S	0.01648	0.669	2.809	-2.996	-1.314	0.792

Table 4.4.8 The relationship between flood flow and basin characteristics for 500-yr. return period

Independent variable included	K	Multiple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	1.85290	0.804				0.656
A S_n	2.16804	1.099	1.199			0.686
A D	7.38240	0.906	1.975			0.665
A S	0.47257	0.482	-0.634			0.701
A S_n D	4.79259	1.136	1.104	1.151		0.689
A D S	0.84661	0.535	0.740	-0.604		0.703
A S S_n	0.24020	0.833	-1.093	2.367		0.784
A S_n D S	0.02435	0.698	2.803	-2.748	-1.289	0.794

Table 4.4.9 The relationship between flood flow and basin characteristics for 1000-yr. return period

Independent variable included	K	Multiple regression coefficient				R_1
		n_1	n_2	n_3	n_4	
A	1.97514	0.805				0.657
A S_n	2.31570	1.104	1.214			0.687
A D	8.19724	0.911	2.033			0.667
A S	0.50917	0.486	-0.630			0.702
A S_n D	5.29755	1.142	1.116	1.201		0.690
A D S	0.96748	0.545	0.815	-0.596		0.703
A S S_n	0.25786	0.839	-1.090	2.380		0.785
A S_n D S	0.02778	0.707	2.804	-2.675	-1.281	0.795

4.5 Relationship between A and $LL_c / \sqrt{S}$

For each gaging station, the values of S, L and L_c from Table 2 are used to determine the basin shape factor in the form of $LL_c / \sqrt{S}$.

Station	A (sq.km.)	S	L (km.)	L_c (km.)	$LL_c / \sqrt{S}$ ($x10^4$)
K 6	11071	0.00146	354	176	163
K 9	6901	0.00060	294	137	164
K 10	7004	0.00058	302	145	182
K 12	2340	0.00193	148	74	24.9
K 13	4047	0.00107	159	47	22.9
K 17	1353	0.00449	83	35	4.34
K 19	8491	0.00227	259	115	62.5
K 20	11253	0.00140	367	188	184
K 22A	327	0.00642	42	28	1.47
N 1	5800	0.00226	246	114	59.0

The basin area is then related to this factor and the relationship is assumed to be in the form

$$A = K \left(LL_c / \sqrt{S} \right)^n$$

Using the linear regression method and substituing Q by A and A by $LL_c / \sqrt{S}$ into the Fortran IV program in the article 4.4 the value of K and n are found to be 1.14443 and 0.633 respectively. Therefore the relationship between the basin area and the basin shape factor can be written as

$$A = 1.14443 \left(LL_c / \sqrt{S} \right)^{0.633}$$

where A = basin area in sq.km.

L = length of the main stream in km.

L_c = length in km. along the stream from the outlet to a point nearest the centroid of the basin

S = slope of the main stream

Relationship between A and $LL_c/\sqrt{S}$