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REGIONAL FLOOD STUDY

NORTHEASTERN

BRITISH COLUMBIA

AUGUST 1984

Inland Waters Directorate
Pacific and Yukon Region
Vancouver, B.C.

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ABSTRACT

A method of regional flow analysis is provided to estimate the magnitude and frequency of floods for streams in Northeastern British Columbia. The annual series of peak flow data from 26 stream gauging stations on unregulated streams were used to determine a log Pearson Type III frequency curve for each station. Flood magnitudes having recurrence intervals of 5, 10, 25, 50 and 100 years were related to the Mean Annual Flood (2.33 year). These ratios were used to develop a regional frequency curve. The entire area was represented by one regional curve. The drainage area vs. Mean Annual Flood was represented by three regions; plateau; mountains and foothills south; and mountains and foothills north.

RESUME

Ce rapport présente une méthode d'analyse régionale de ruissellement qui vise à estimer l'amplitude et la fréquence des crues se produisant dans les cours d'eau du nord-est de la Colombie-Britannique. Une loi log Pearson Type III est adjustée à la série de débit maximum annuels, pour chacune des 26 stations hydrométriques situées sur des cours d'eau non contrôlés. Les crues de périodes de retour de 5, 10, 25, 50 et 100 ans sont divisées par le débit moyen annuel (période de récurrence de 2.33 ans) pour chaque station. Ces rapports sont utilisés pour développer une courbe de fréquence régionale. De plus, des relations "surface de drainage" vs "crue moyenne annuelle" ont été obtenues. L'étude des relations de surface indique trois sous régions: plateau; montagnes et contrefort du sud; montagnes et contrefort du nord. Par contre, la courbe de fréquence régionale n'indique pas de telles subdivisions.

1. INTRODUCTION

1.1 Purpose and Scope of Study

The purpose of this study is to extend the results of the frequency analysis of point data to the area of Northeastern B.C. This provides a means of estimating design flood flows for streams in a region that has a scarcity of data and is highly variable in precipitation.

Historical flood data at streamflow stations in this area were analyzed to establish the range of flood flows that could be expected and to identify general trends and similarities among the data in order to produce a regional flood frequency curve. The results of this study are intended for use as a design aid for feasibility and preliminary studies in highway, pipeline and railway crossings, flood control structures, reservoirs, levees and flood plain mapping etc. Site specific streamflow data would be required for final design studies of large projects.

1.2 Description of Study Area

The study concentrates on the eastern slopes of the Rocky Mountains an area bounded by the B.C. - Alberta border in the south and the Toad River basin northwest of Fort Nelson in British Columbia. See map of B.C. Figure 1 for general location of region.

Physiography

The area consists of the Front Ranges of the Rocky Mountains, the Foothills and the Plains. The Front Ranges extend from the Divide east to the Foothills. The gradient of the streams in the area is very steep averaging 3%. The area contains many icefields and alpine glaciers which are generally small in size.

The Foothills are mainly composed of rounded hills and outlying mountain ridges some nearly as high and rugged as the Front Ranges. The stream gradient changes drastically in this area averaging 0.6%.

The Plains region is characterized by high buttes and mesas. The stream gradient is very flat averaging 0.03%.

The drainage pattern consists of parallel stream systems flowing easterly and transecting the regional physiographic trends, which run in a Northwest-Southeast direction. Glaciation has considerably modified the major river valleys. The physiographic divisions are shown on Figure 2.

Climate

The climate of the region is dominated by continental climatic influences. During the winter, continental Arctic air masses which restricts precipitation, move in and out of the area.

The region is characterized by semi-arid conditions on the Interior Plains and progressively heavier precipitation in the foothills and mountains. Many depressions, caused by the Aleutian Low, enter British Columbia from the Pacific and continue their eastern course over the western mountains. To a great extent, their tracts are affected by the position of mountain passes and the location of Artic air masses.

Types of Runoff

Floods on the Northeast slopes of the Rocky Mountains in British Columbia usually occur from: 1) snowmelt, 2) rainstorms or rain plus snowmelt and 3) thunderstorms. Snowmelt peaks generally occur from April through June and can be augmented by rainfall or rainstorms. Rainfall peaks generally occur from June to freeze-up.

1.3 Source of Data

Most of the data used in this study were obtained from listings of streamflows that were produced from magnetic tape files maintained by the Water Survey of Canada. These listings provide the latest revised version of surface water data to 1982.

2. DESCRIPTION OF STUDY

In general, flood records represent relatively short samples of a large population of events. For this reason, the record at any individual station may deviate considerably from a true representation of the overall long-term flood frequency relation. Therefore other methods have been developed to study flood frequencies. These methods involve studies of frequency relationships on a regional basis in an attempt to reduce large sample errors inherent in individual records and to arrive at the basic long-term relation.

2.1 Selection of Stations

The selection of stations for the study was based on several considerations, location, size and natural flow. It is possible that the homogeneous area extends outside the selected region of the northeast slopes of the Rocky Mountains in British Columbia.

The immediate area southeast of the Wapiti basin was included as it was thought to give some stability to short-term records available on streams in that portion of the region.

Large streams usually traverse more than one hydrologic area. The occurrence of floods in these streams is usually not the same as that of small tributaries. Large streams therefore should not be combined with tributary streams in order to define a general relationship. Streams that do not represent natural flow should not be included. As a result of the above considerations, Stoddart Creek and all Peace River stations were excluded.

Selected stations and their period of record are shown on a bar chart in Figure 3.

2.2 Single Station Frequency Curves

Frequency analysis of peak daily discharges is used to estimate a long-term distribution. This distribution can then be considered as the best representation of future expectations. In the use of past records to predict the future, it is assumed that there has been no change in the nature of factors influencing the size of flood peaks during the period of record. Some factors are logging, land clearing, and storage or diversion works. The method of obtaining stage values can also be a problem. For example, replacing staff gauges with automatic recorders part way through the period of record.

To obtain estimates of the T-year flood events the log Pearson III distribution was fitted to all stations in the area. This distribution has been recommended by the U.S. Water Resources Council for flood analysis in the United States. The log Pearson III distribution appears to fit the data in this region reasonably well. The frequency curves are shown in Figures 4 to 8.

2.3 Mean Annual Flood

The mean annual flood, as used in the applied regional flood frequency method, is the value of the recurrence interval of 2.33 years as estimated by the log Pearson III distribution. The actual arithmetic mean is not used because of the possible bias due to the occurrence of a rare flood within the period of record. The magnitude of the mean annual flood (arithmetic) can vary considerably from period to period as a result of dry or wet cycles or a combination of both.

Table 1 lists the mean annual flood and recorded maximum daily discharge for each station used in the analysis. These two characteristics are also given in terms of runoff to indicate the range of climatic influences in the region.

Due to the inclusion of many stations with very short records a statistical test was used on all long-term data to determine whether a difference in sample means (arithmetic) is statistically significant.

Figure 9 illustrates the variation of mean annual flood and basin location.

2.4 Hydrologic Zones

The range of ratios of the 5, 10, 25, 50 and 100-year flood to mean annual flood can be tested with drainage area size and location to help define any hydrologic division boundaries.

TABLE 1

MEAN ANNUAL FLOOD AND MAXIMUM DAILY DISCHARGE

Station Name	Drainage Area km^2	Mean Annual Flood m 3/s	Runoff $l/s/km^2$	Recorded Maximum Daily Flow m 3/s	Runoff $l/s/km^2$
Toad River Above Nonda Creek	2570	268	104	648	252
Ft. Nelson River Above Muskwa River	22800	912	40	1500	66
Ft. Nelson River at Ft. Nelson	43500	2630	60.5	5240	120
Muskwa River Near Ft. Nelson	20300	2040	100	3990	197
Raspberry Creek at the Mouth	273	17	62.3	39.4	144
Sikanni Chief River Near Ft. Nelson	2160	186	86.1	479	222
Beatton River Near Ft. St. John	15600	731	46.9	1700	109
Blueberry River Below Aitken Creek	1750	128	73.1	368	210
St. John Creek Near Montney	201	16	79.6	30.3	151
Halfway River Above Graham River	3780	327	86.5	498	132
Halfway River Near Farrell Creek	9400	678	72.1	1980	211
Pine River At East Pine	12100	1650	136	3960	327
Sukunka River Ab. Chamberlain Creek	927	210	227	266	287
Sukunka River Near The Mouth	2510	480	191	704	280
Dickebusch Creek Near The Mouth	85.5	12	140	16.1	188
Murray River Above Wolverine River	2410	392	163	600	249
Murray River Near The Mouth	5620	636	113	736	131
Quality Creek Near The Mouth	29.5	3.6	122	9.2	312
Wapiti River Above Mistanusk Creek	2400	336	140	650	271
Kiskatinaw River Near Farmington	3570	153	42.9	413	116
Pouce Coupe R. Bel. Henderson Cr.	2850	133	46.7	368	129
Beaverlodge River Near Beaverlodge	1610	45.5	28.3	102	63
Wapiti River Near Grande Prairie	11300	852	75.4	3680	326
Cutbank River Near Grande Prairie	842	136	162	506	600
Kakwa River Near Grande Prairie	3290	361	110	1680	511
Smoky River Above Hells Creek	3830	453	118	1230	321

2.5 Regional Frequency Curve

Regional frequency analysis is composed of two main parts. First, the development of a dimensionless frequency curve which represents the ratio of the flood of any frequency to an index flood. The index flood is the mean annual flood as obtained by the log Pearson III distribution fitted to the annual series of station flood data. The second step is the study of the relationship between the index flood and drainage area.

2.6 Regionalized Skew

Regionalization of skew values was not attempted for this study as it is impractical to obtain skew values from small samples. Skew is very sensitive to extreme events.

The recommended procedure for developing generalized skew coefficients requires the use of at least 40 stations or all stations within a 160 kilometer radius. The stations used should have 25 or more years of good record.

The mean, standard deviation and coefficient of skew of the logs for the maximum daily discharge are given for each station used in the study and are presented in Table 2.

2.7 Flood Estimation Criteria

The criteria governing flood estimates, for this study, are based on

TABLE 2
STATION STATISTICS

Station Name	Drainage Area in km^2	Log of Mean Annual Flow	SD	CS
Toad River Above Nonda Creek	2570	5.5628	0.4235	0.6941
Ft. Nelson River Above Muskwa River	22800	6.6404	0.6900	-0.4993
Ft. Nelson River At Ft. Nelson	43500	7.8102	0.4726	0.1221
Muskwa River Near Ft. Nelson	20300	7.4521	0.5960	-0.6872
Raspberry Creek At The Mouth	273	2.5946	1.0477	-0.4223
Sikanni Chief River Near Ft. Nelson	2160	5.1595	0.4901	0.2815
Beatton River Near Ft. St. John	15600	6.5315	0.4881	0.2914
Blueberry River Below Aitken Creek	1750	4.7559	0.7115	0.2379
St. John Creek Near Montney	201	2.6512	0.5122	-0.0449
Halfway River Above Graham River	3780	5.7463	0.3710	0.3784
Halfway River Near Farrell Creek	9400	6.4763	0.5459	0.5891
Pine River At East Pine	12100	7.3864	0.4348	0.7677
Sukunka River Ab. Chamberlain Creek	927	5.2854	0.2668	-0.3241
Sukunka River Near The Mouth	2510	6.1374	0.3728	-0.0551
Dickebusch Creek Near The Mouth	85.5	2.1946	0.7457	-1.7358
Murray River Above Wolverine River	2410	5.9349	0.3269	0.3892
Murray River Near The Mouth	5620	6.3383	0.2927	-1.6528
Quality Creek Near The Mouth	29.5	1.1928	0.7656	0.3080
Wapiti River Above Mistanusk Creek	2400	5.8276	0.4060	1.2213
Kiskatinaw River Near Farmington	3570	4.6763	1.0129	-1.2159
Pouce Coupe R. Bel. Henderson Cr.	2850	4.8542	0.6481	-0.0403
Beaverlodge River Near Beaverlodge	1610	3.4953	0.8933	-1.2829
Wapiti River Near Grande Prairie	11300	6.7500	0.6611	1.0895
Cutbank River Near Grande Prairie	842	4.7925	0.9750	0.3505
Kakwa River Near Grande Prairie	3290	5.9481	0.7620	1.5439
Smoky River Above Hells Creek	3830	6.1537	0.3220	1.8269

the length of record for each station. These are summarized in Table 3. (LAMKE 1979)

TABLE 3

Length of Record (years)	Largest T-year Flood Estimated (Years)
8	5
8 - 12	10
13 - 17	25
18 - 22	50
22	100

3. UNGAUGED STREAMS

The regionalization of frequency curves has provided a means of estimating the flood probabilities of streams having no hydrometric record.

In order to estimate the flood probabilities for a point on a stream having no hydrometric records, the first step is to define the drainage area. The second step is to determine from Figure 10 the zone in which the stream is located and from Figure 11 the mean annual flood corresponding to that zone and drainage area. Next, knowing the frequency required, obtain the ratio of QT/Q2.33 from Figure 12. By multiplying the mean annual flood by the ratios given in the regional frequency curve, a flood frequency curve may be prepared for that stream.

4. RESULTS OF ANALYSIS

4.1 Mean Annual Flood

The arithmetic mean for the period prior to 1978 was tested against means of the five year period to 1982. All but two tested negative, ie. there was no significant difference between means, which indicate they can be considered as samples from the same population at the 95% confidence level.

Short-term data can be used with some degree of confidence as representing the longer period of other stations. In this study the mean annual flood of short term stations was considered directly comparable to the longer term data.

Figure 13 shows the relationship of mean annual flood runoff to drainage area.

4.2 Hydrologic Zones

The ratios of QT/Q2-33 appear to be independent of drainage area size as shown in figures 14 to 18. The plot of these ratios on the map produced no apparent divisional frequency characteristics, with the exception of an area within Alberta comprising the lower Wapiti, Cutbank and Kakwa basins. This division appeared at and above the 10-year flood.

4.3 Regional Frequency Curve

In order to develop the dimensionless frequency curve, the median value of all station ratios for each order of magnitude was plotted on frequency paper and a composite curve was fitted by eye as shown in Figure 12. The median value, rather than the arithmetic mean, is used because it gives greater weight to the medium rather than to extreme floods where the measurement and sampling errors are always greater.

The index flood was plotted against drainage area for each station and by using distinctive symbols for various geographical regions a series of trendlines became apparent. A least square fit was made to three sets of data, as shown in Figure 11. The equation of the lines and standard error of estimate are given for the relationships.

A general division appears to exist for that area to the southeast of the Pine River Basin and the area to the northwest.

The area to the southeast excludes two small foothill basins. This is an arbitrary division, based on the effect of snowmelt and rainfall events, which time will verify or discount as longer records are obtained. The Wapiti River at Grande Prairie is included with the northwest group because the majority of its drainage basin consists of foothills and plateau.

The map shown on Figure 10 illustrates the zones representing variation in the mean annual flood.

4.4 Flood Estimation Criteria

These criteria limit the use of the short-term station for regionalization purposes. The number of stations used for the development of the regional frequency curve in the higher T-year events,has been reduced drastically. In order to obtain enough samples those stations with 21 years of data had to be included to obtain a regional ratio for the 100 year event.

4.5 Regional Frequency Values Vs. Log Pearson III

Table 4 shows the comparison between the regional flow analysis values and those values computed by the log Pearson III distribution. The regionalized frequency curve for each station is also shown on figures 4-8.

5. OBSERVATIONS AND CONCLUSIONS

The following observations and conclusions can be drawn, from the analysis of the published data, for this region.

a. There is a relationship between mean annual flood (2.33 year) and location. Dividing the region into three areas instead of two, for the estimation of mean annual flood, reduces the standard error of estimate from a maximum of ± 36% to ± 20%.

b. In future studies, when other basin parameters, eg. mean basin elevation, main channel length and slope, stream density, base flow index, channel storage, area of lakes and swamps and

TABLE 4

COMPARISON OF REGIONAL VS LOG PEARSON III FREQUENCY VALUES

STATION NAME	Drainage Area Km^2	2.33 year	5 year (QT/Q2.33=1.41)		10 year (QT/Q2.33=1.78)		25 year (QT/Q2.33=2.30)		50 year (QT/Q2.33=2.78)		100 year (QT/Q2.33=3.24)		Max Daily Discharge of Record m^3/s
		R.F. m^3/s	R.F. m^3/s	Log Pearson III	R.F. m^3/s	Log Pearson III	R.F. m^3/s	Log Pearson III	R.F. m^3/s	Log Pearson III	R.F. m^3/s	Log Pearson III	
Toad River Above Nonda Creek	2570	236	333	364	420	458	543	598	656	722	765	862	648
Ft. Nelson River Above Muskwa River	22800	957	1350	1380	1700	1770	2200	2260	2660	2610	3100	2960	1500
Ft. Nelson River at Ft. Nelson	43500	3090	4360	3660	5500	4550	7110	5670	8590	6710	10000	7720	5240
Muskwa River Near Ft. Nelson	20300	1550	2190	2870	2760	3490	3570	4200	4310	4680	5020	5110	3990
Raspberry Creek at The Mouth	273	19	27	33	34	49	44	71	53	90	62	111	39.4
Sikanni Chief River Near Ft. Nelson	2160	201	283	261	358	330	462	430	559	572	651	602	479
Beatton River Near Ft. St. John	15600	686	967	1030	1220	1300	1580	1690	1910	2020	2220	2370	1700
Blueberry River Below Aitken Creek	1750	100	141	210	178	294	230	426	278	548	324	689	368
St. John Creek Near Montney	201	15	21	22	27	27	35	35	42	40	49	46	30.3
Halfway River Above Graham River	3780	335	472	424	596	510	770	627	931	722	1090	822	498
Halfway River Near Farrell Creek	9400	767	1080	1000	1370	1340	1760	1870	2130	2350	2490	2920	1980
Pine River at East Pine	12100	1340	1890	2270	2390	2880	3080	3820	3730	4660	4340	5630	3960
Sukunka River Ab Chamberlain Creek	927	167	235	248	297	275	384	306	464	326	541	345	266
Sukunka River Near The Mouth	2510	374	527	634	666	745	860	855	1040	985	1210	1090	704
Dickebusch Creek Near The Mouth	85.5	10	14	17	18	18	23	20	28	27	32	31	16.1
Murray River Above Wolverine River	2410	362	510	494	644	581	833	698	1010	790	1170	887	600
Murray River Near The Mouth	5620	719	1010	725	1280	834	1650	782	2000	1070	2330	1170	736
Quality Creek Near The Mouth	29.5	4	5.6	6.0	7.0	9.0	9.2	14	11	18	13	23	9.2
Wapiti River Above Mistanusk Creek	2400	361	509	456	642	583	830	791	1000	990	1170	1230	650
Kiskatinaw River Near Farmington	3570	187	264	251	333	322	430	393	520	435	606	468	413
Pouce Coupe R Bel Henderson Creek	2850	154	217	222	274	294	354	370	428	479	499	568	368

R.F. Regional Flow Analysis

location parameters etc. become available they should be included to describe the residual differences in mean annual flood.

c. The ratio of the QT/Q2.33 shows no relationship to drainage area.

d. The spread in ratios, (QT/Q2.33), of the higher frequencies increase rapidly due to some highly skewed data.

e. Runoff of the maximum daily discharge increases as drainage area decreases and shows a relationship to location.

f. The regional frequency curve and the equations for the mean annual flood can be used to produce, within limits, the magnitude of floods for different recurrence intervals on the eastern slopes of the Rocky Mountain in B.C.

g. Floods cannot be predicted within narrow confidence bands from the length of record available in this region if by predicting floods, is meant to predict the true T-year peak discharge.

h. Weaknesses in the method include; the possible bias that results from interdependence of flood events at many sites, the unknown effects on derivation of sample statistics caused by using different periods of record, basic data limitations in the temporal and spacial spheres and range of basin size.

i. Some caution must be taken in using the results of this study as the sample size is small and the length of streamflow data is quite limited.

j. Use of the regional frequency curve for estimating flood beyond the 25-year event should be undertaken with care. If rare floods must be estimated, several approaches should be considered, such as the empirical formulae, correlation with precipitation, regression on basin parameters and mathematically fitted curves, in order to approach a realistic value and reduce the risk involved.

k. The area comprising the Wapiti, Cutbank and Kakwa basins has been excluded from the regional study and should be treated as a separate unit. Extreme rainfall storms have been experienced in this area resulting in highly skewed data. It appears that a very long period of record may be required to obtain a reliable regional frequency curve.

l. Future studies covering a greater area and having a larger and longer data base may develop more definite guidelines for estimating flood frequencies.

m. The Regional curve is superior to a single-station curve, although the estimate would be described as less inaccurate rather than more accurate.

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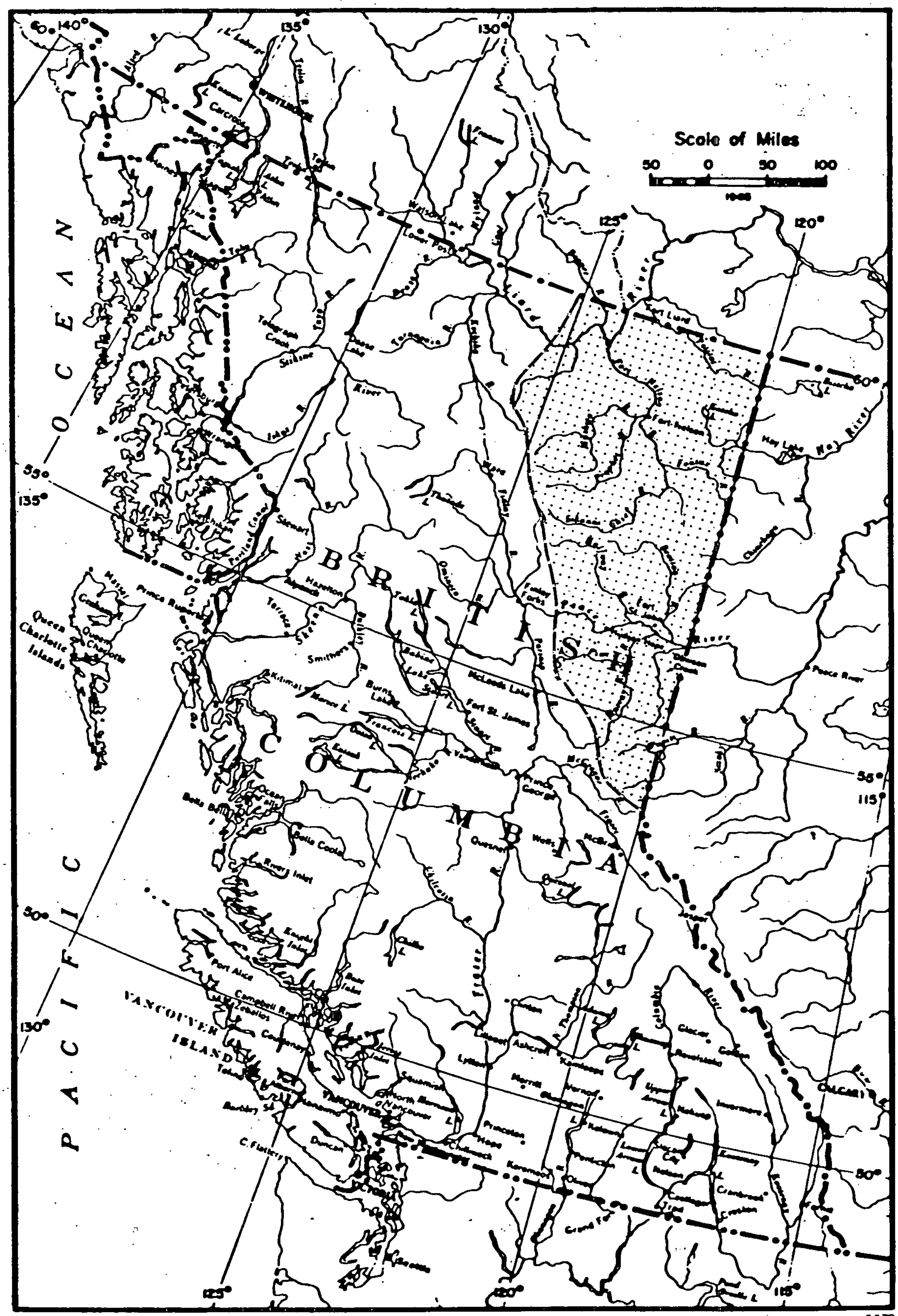


Figure 1. Map of British Columbia with Study Area

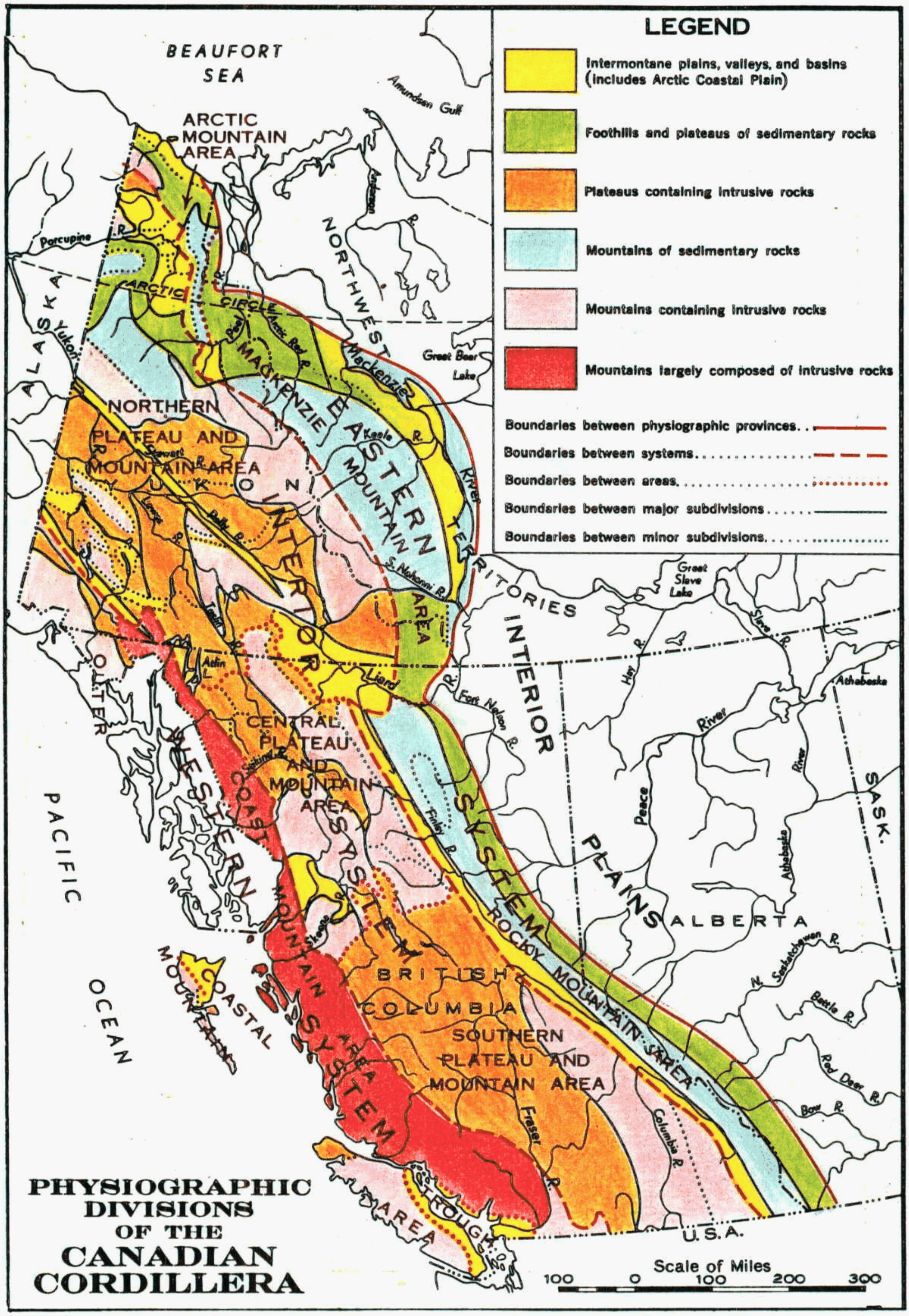


Figure 2 Geological Survey of Canada Memoir 247

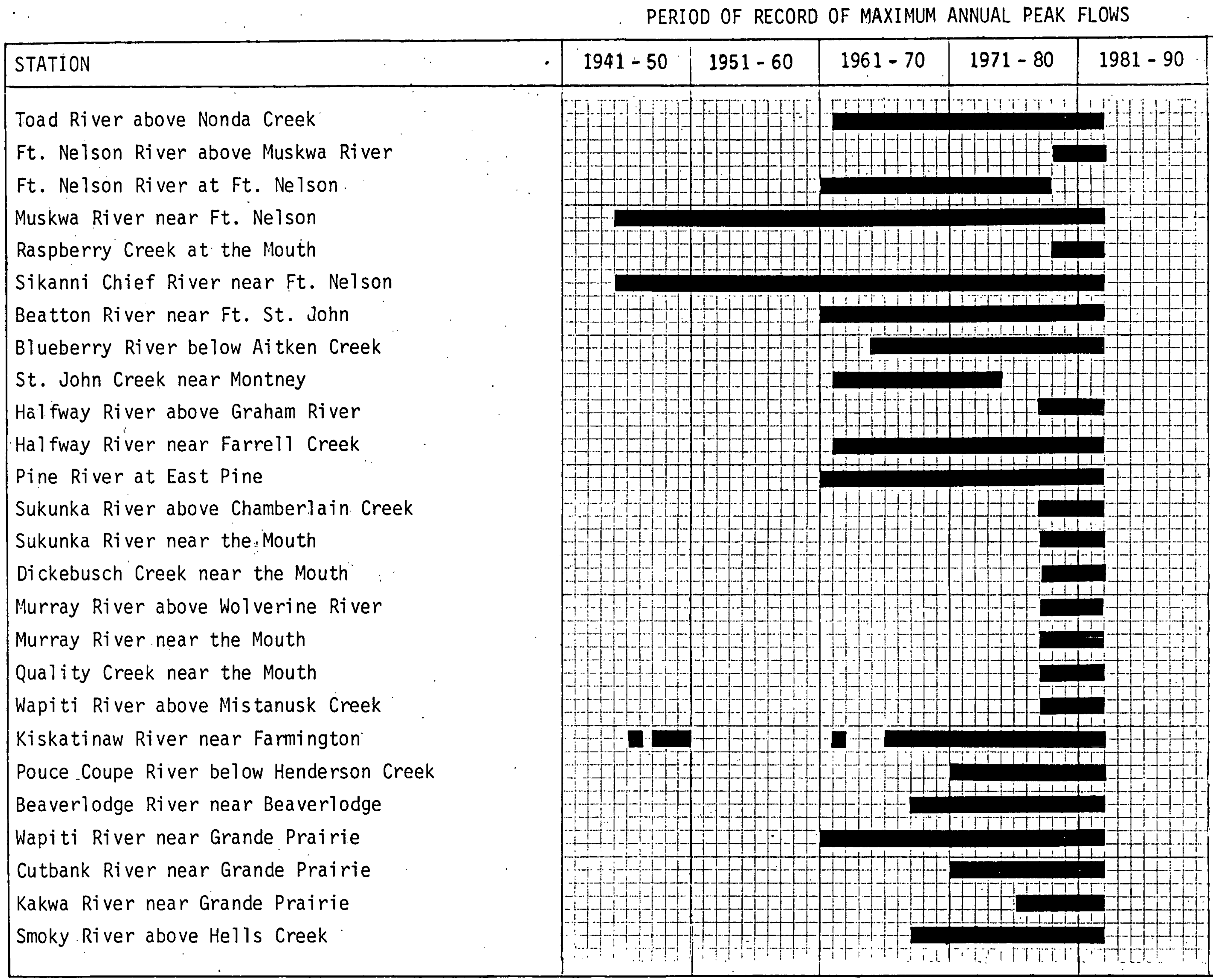


Figure 3 Bar Chart of Streamflow Records

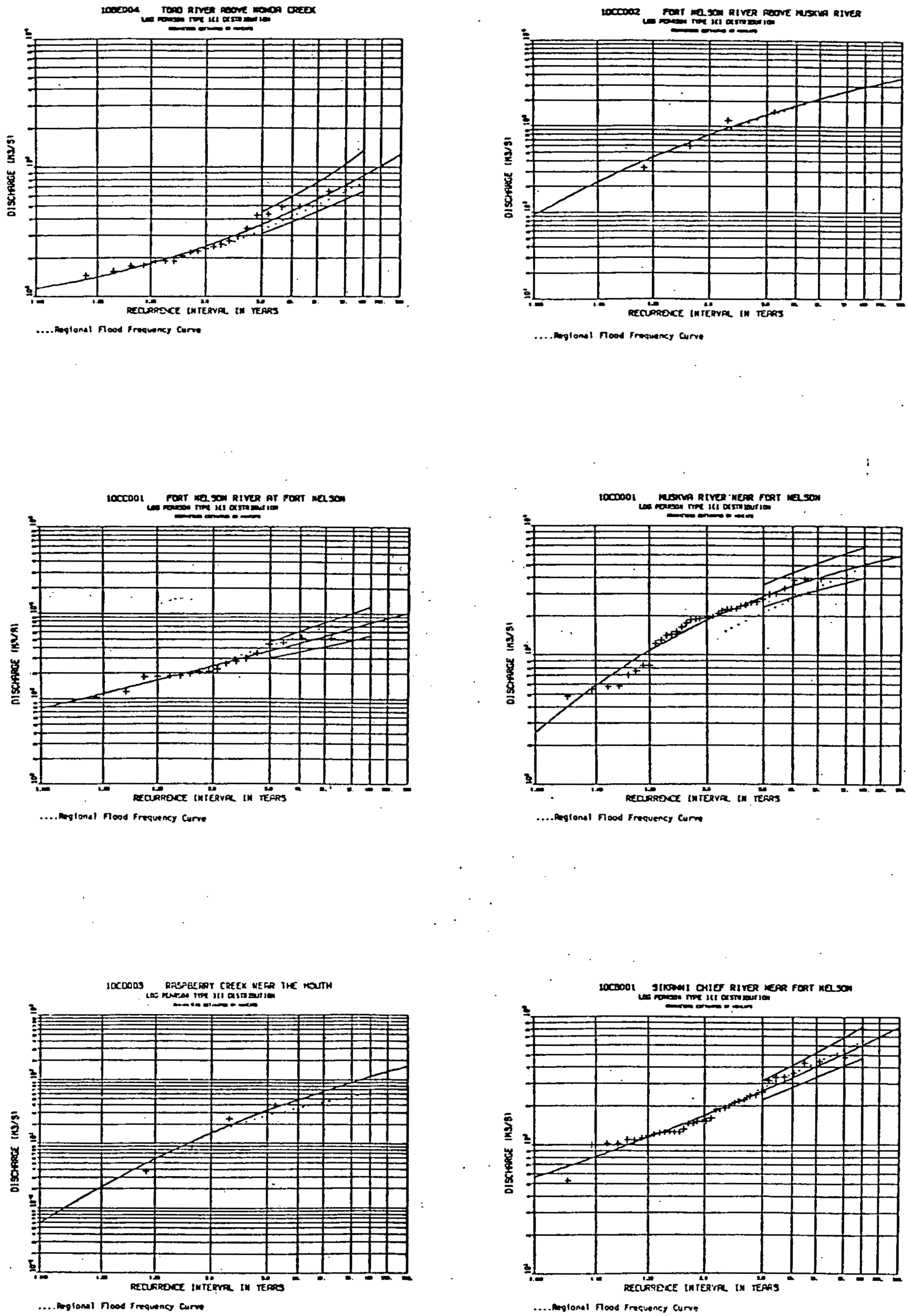


Figure 4. Flood Frequency Curves

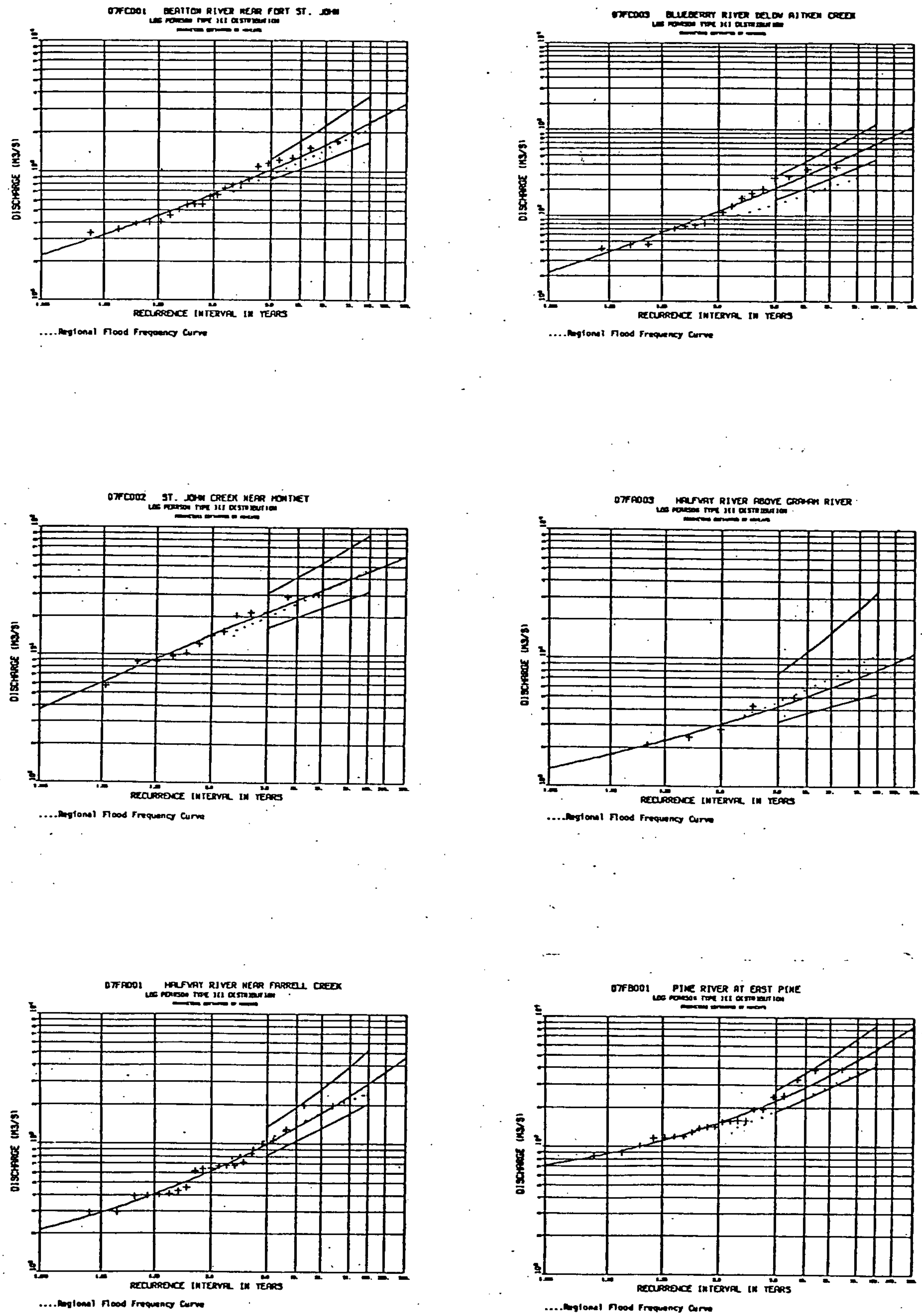
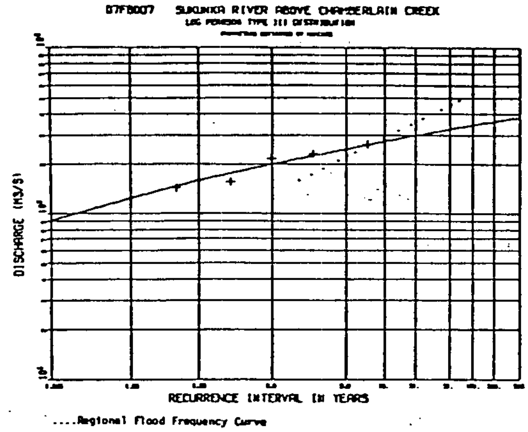
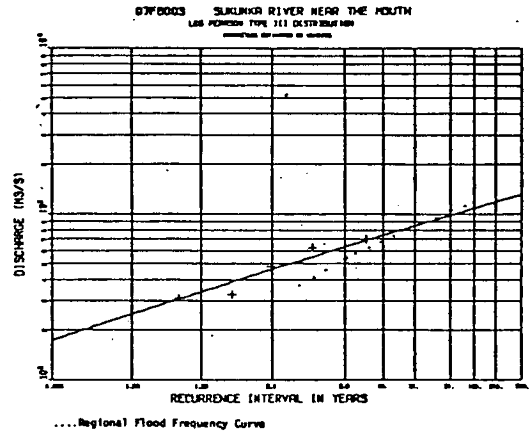
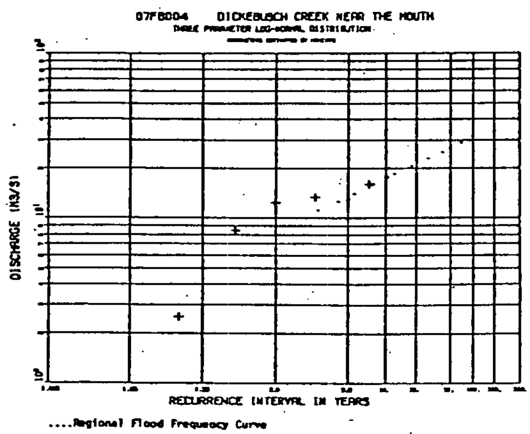
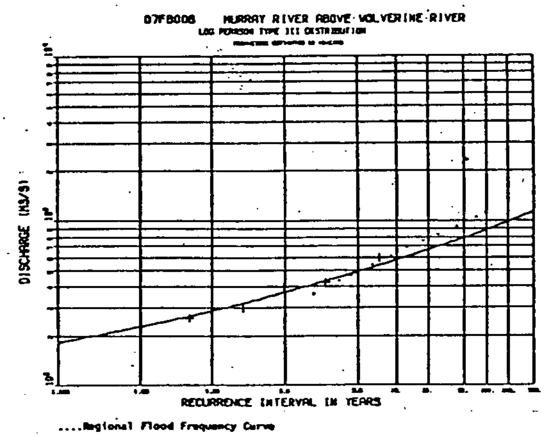


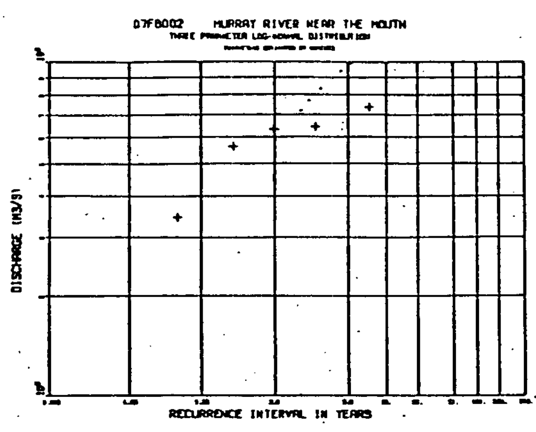
Figure 5. Flood Frequency Curves











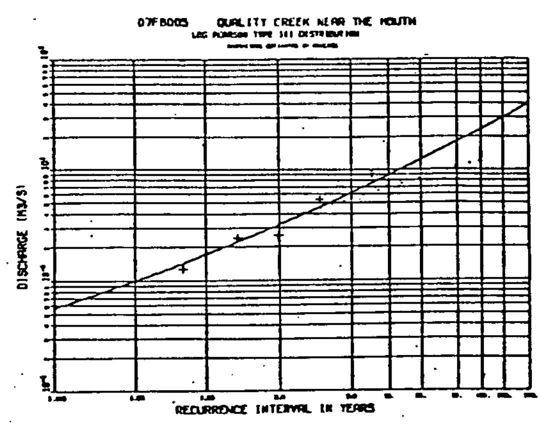


Figure 6. Flood Frequency Curves

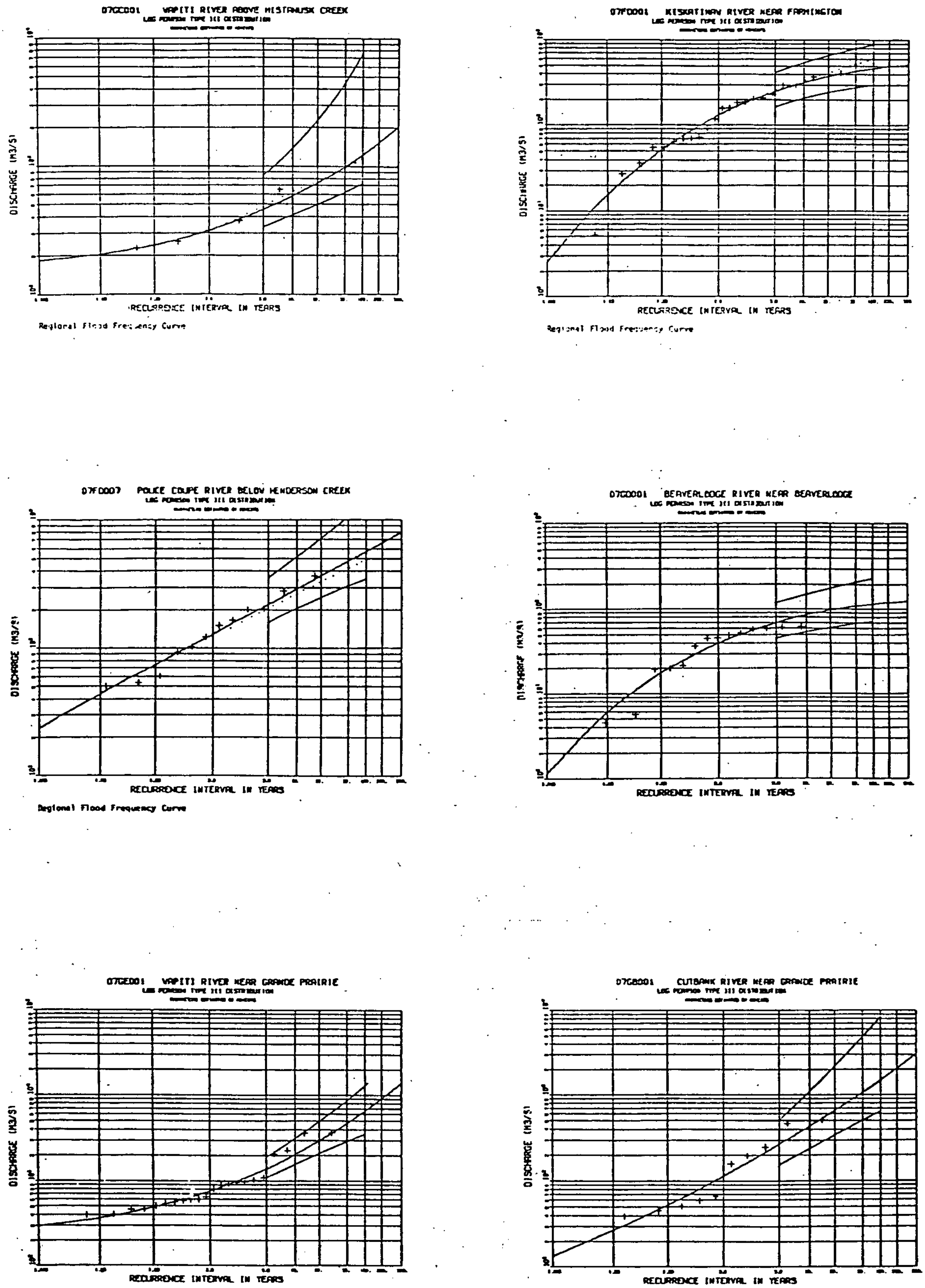
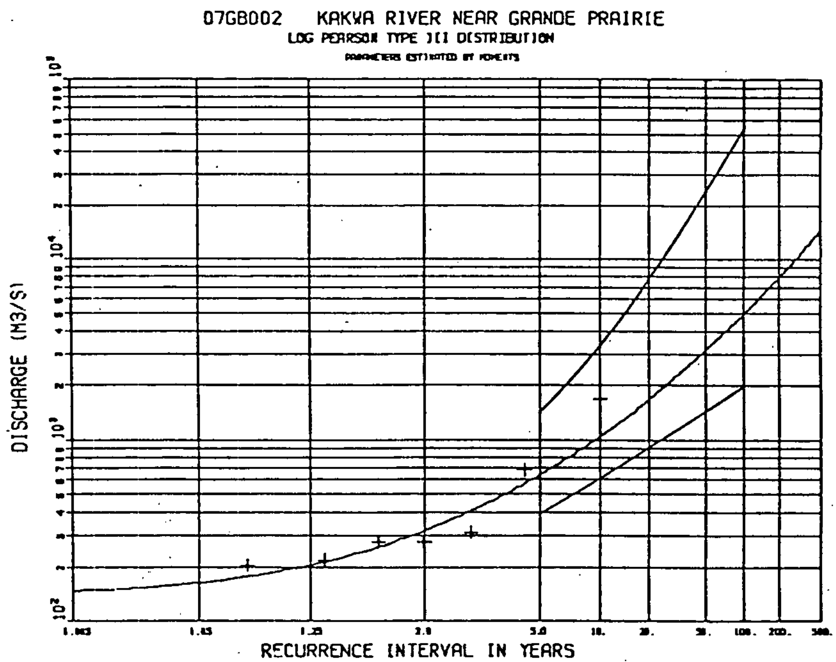


Figure 7. Flood Frequency Curves



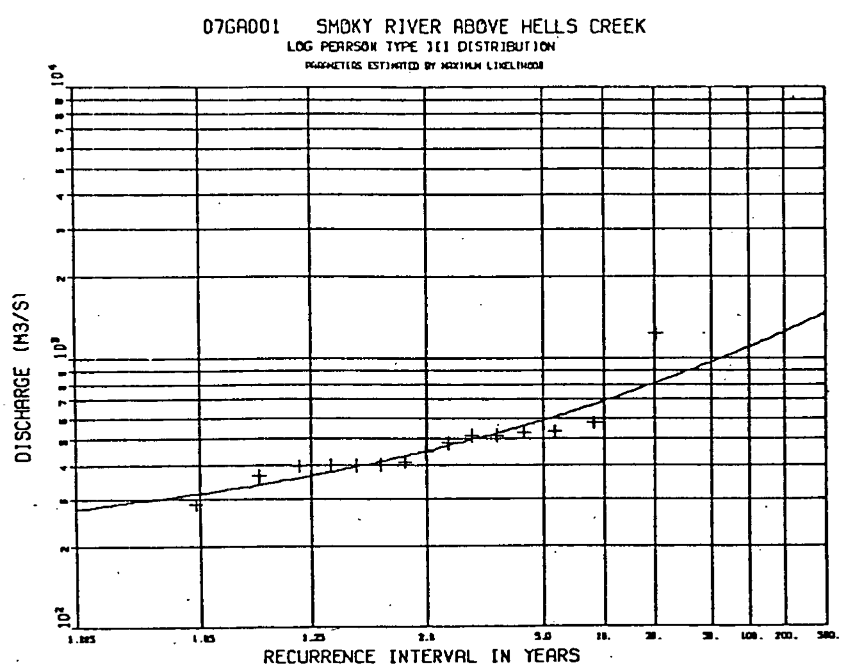


Figure 8. Flood Frequency Curves

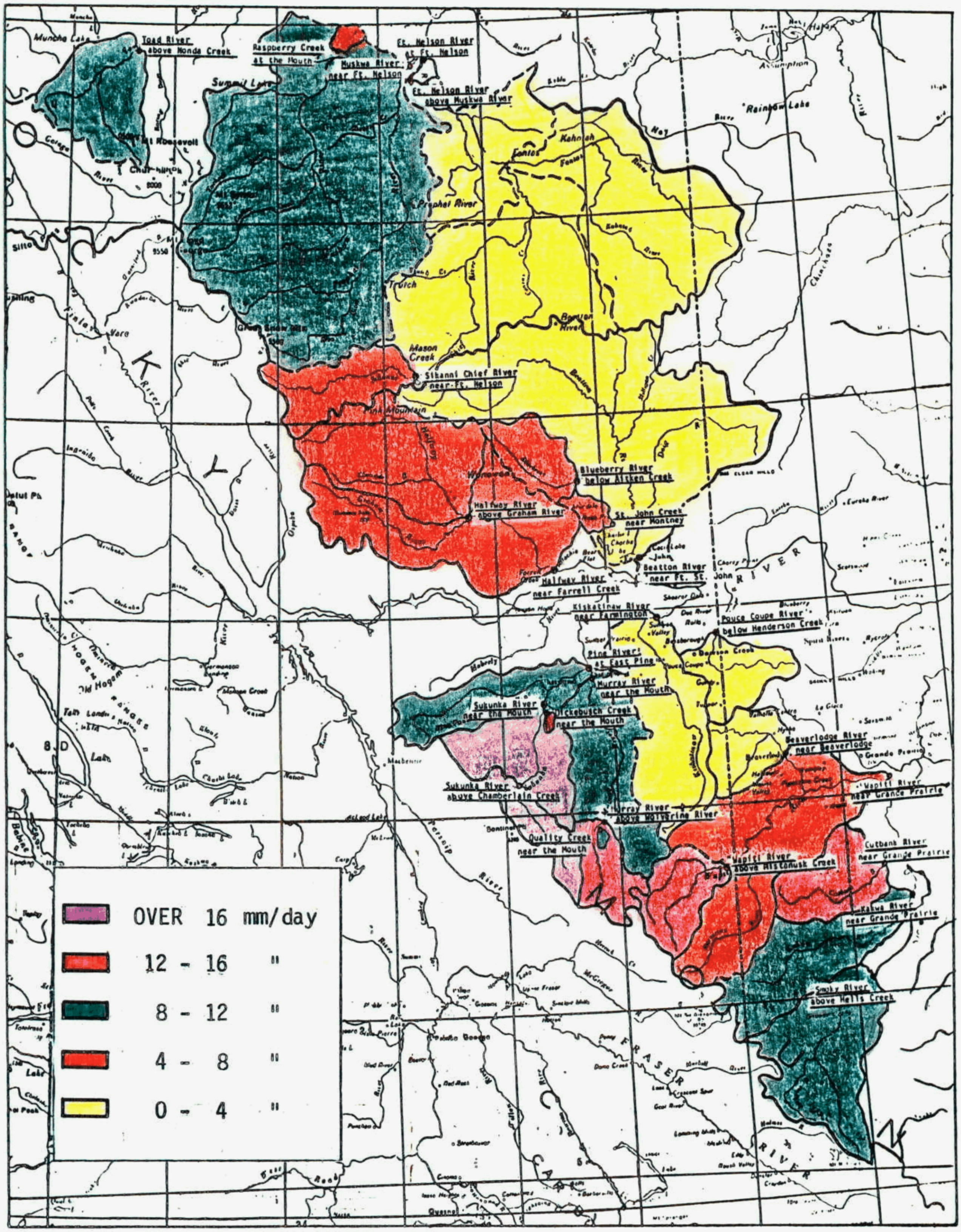


Figure 9. Mean Annual Flood Runoff in mm/day, Northeastern British Columbia

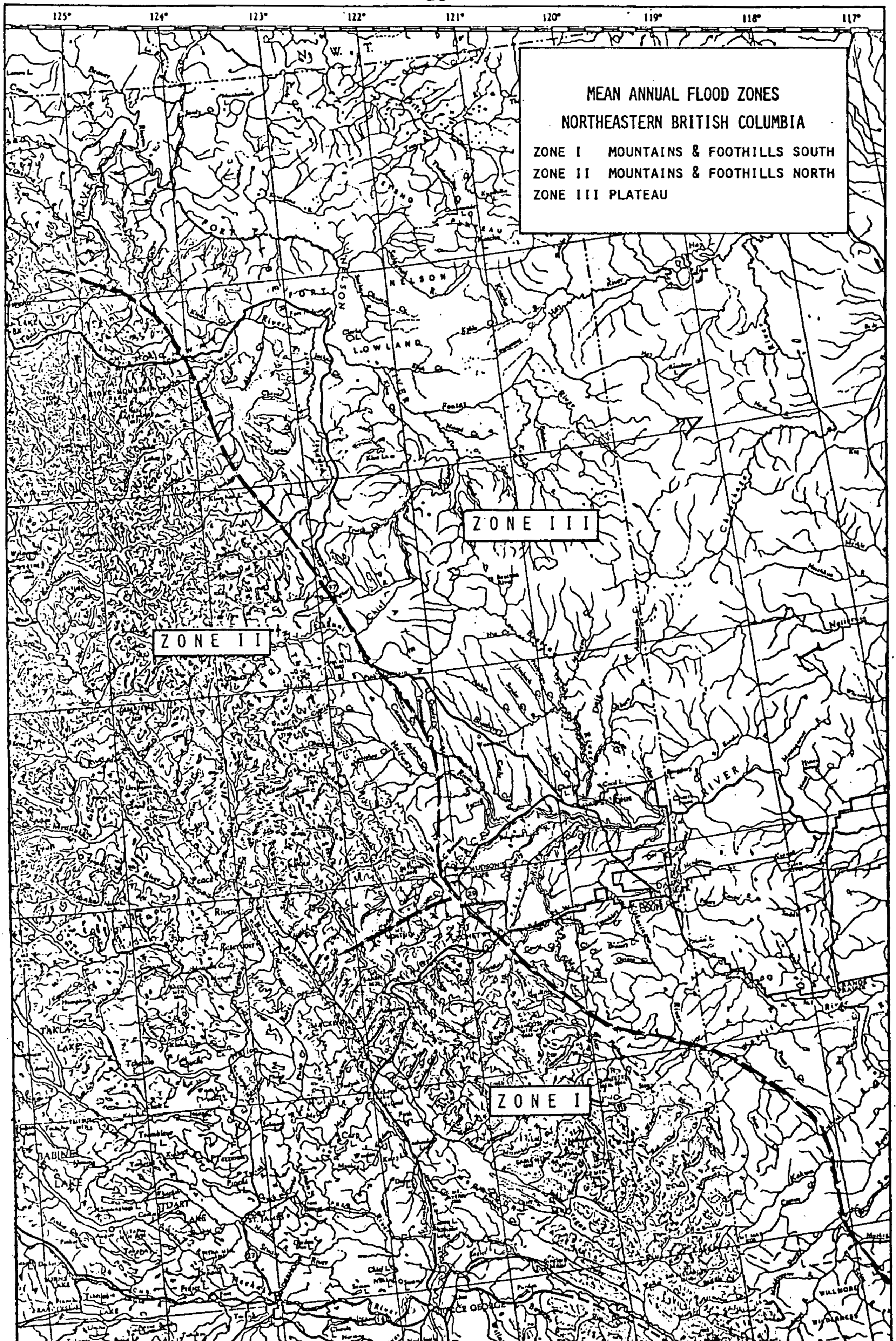


Figure 10. Mean Annual Flood Zones

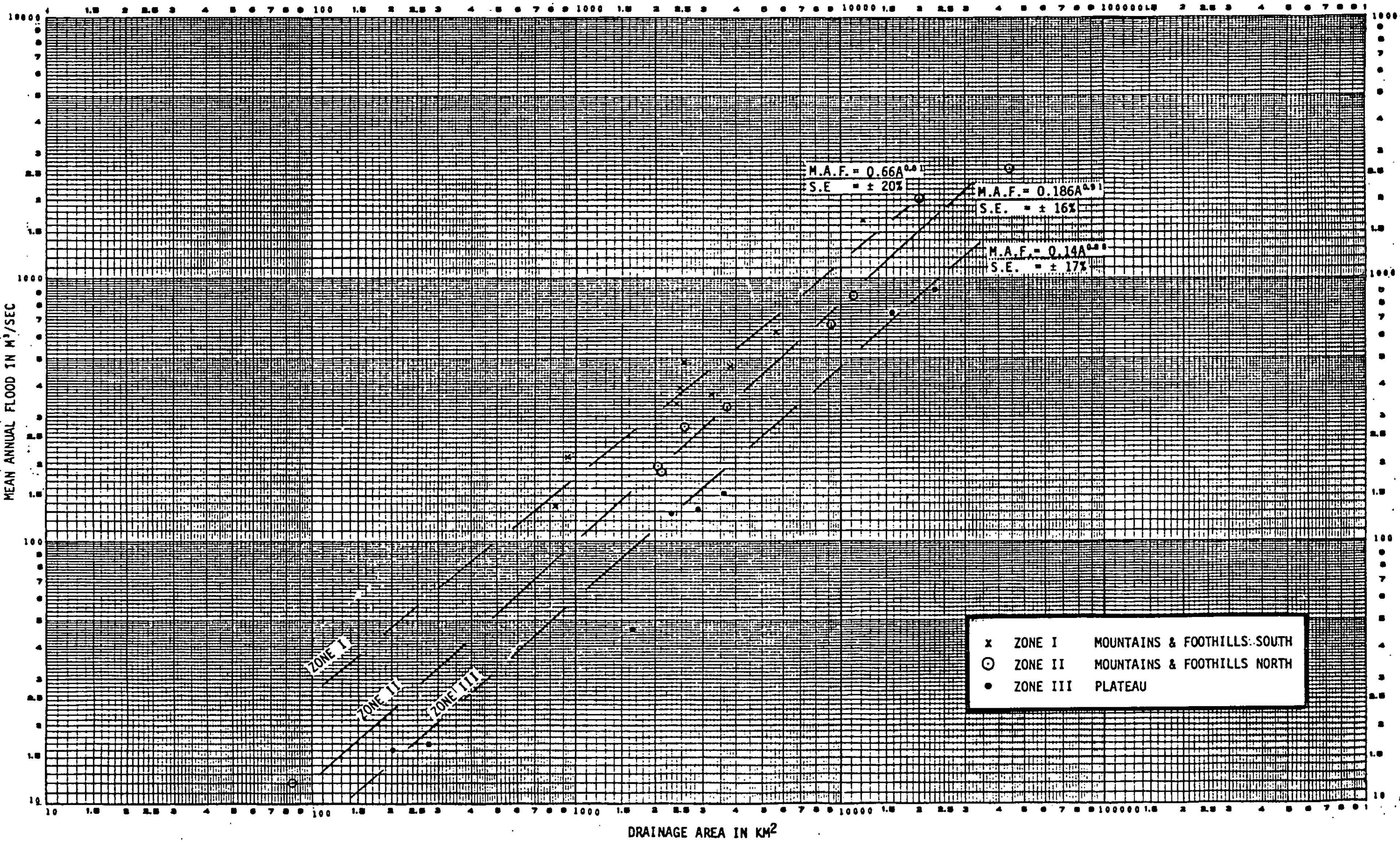


Figure 11. Variation of Mean Annual Flood with Drainage Area

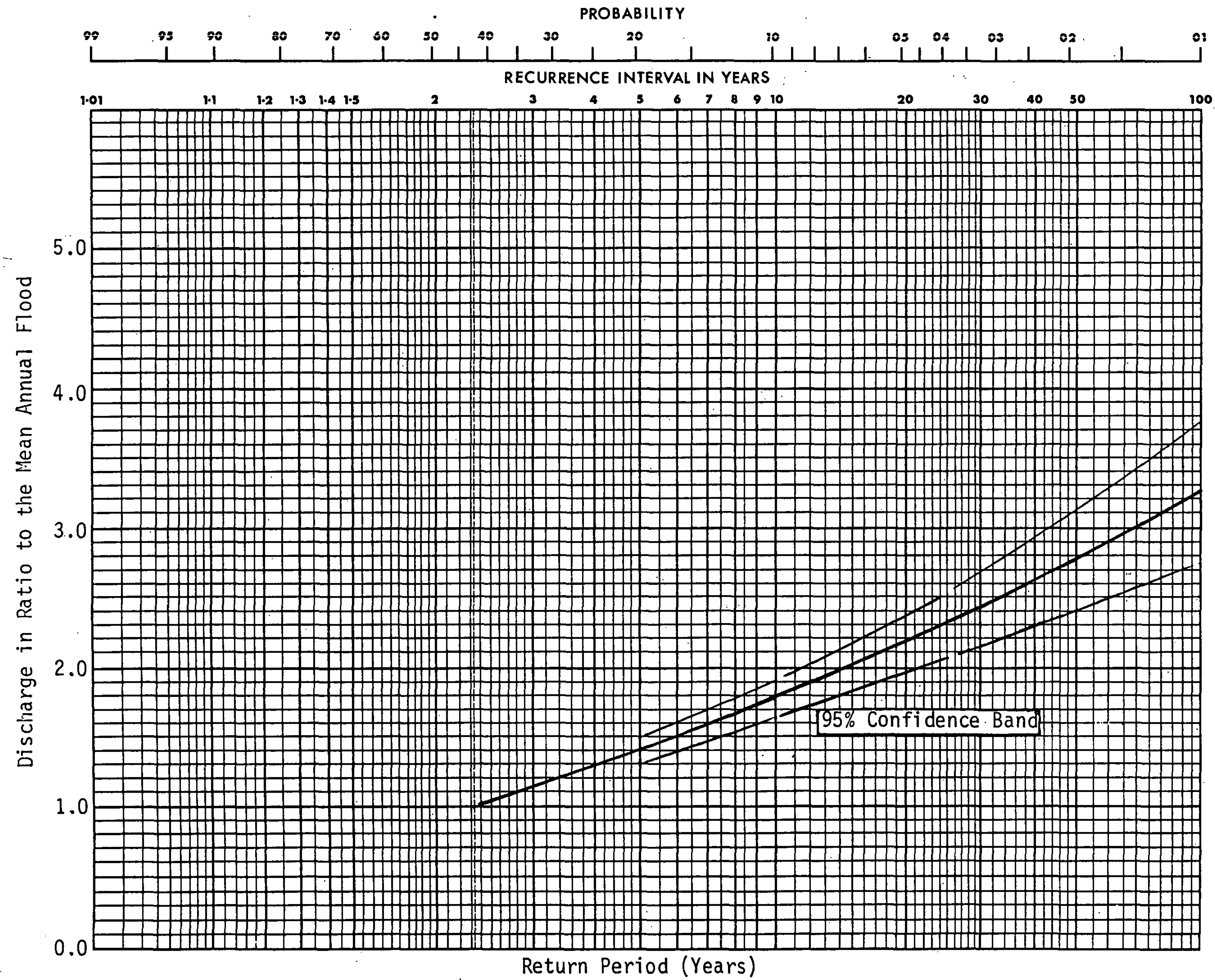


Figure 12. Regional Flood Frequency Curve - Northeast Slopes of Rocky Mountains in British Columbia

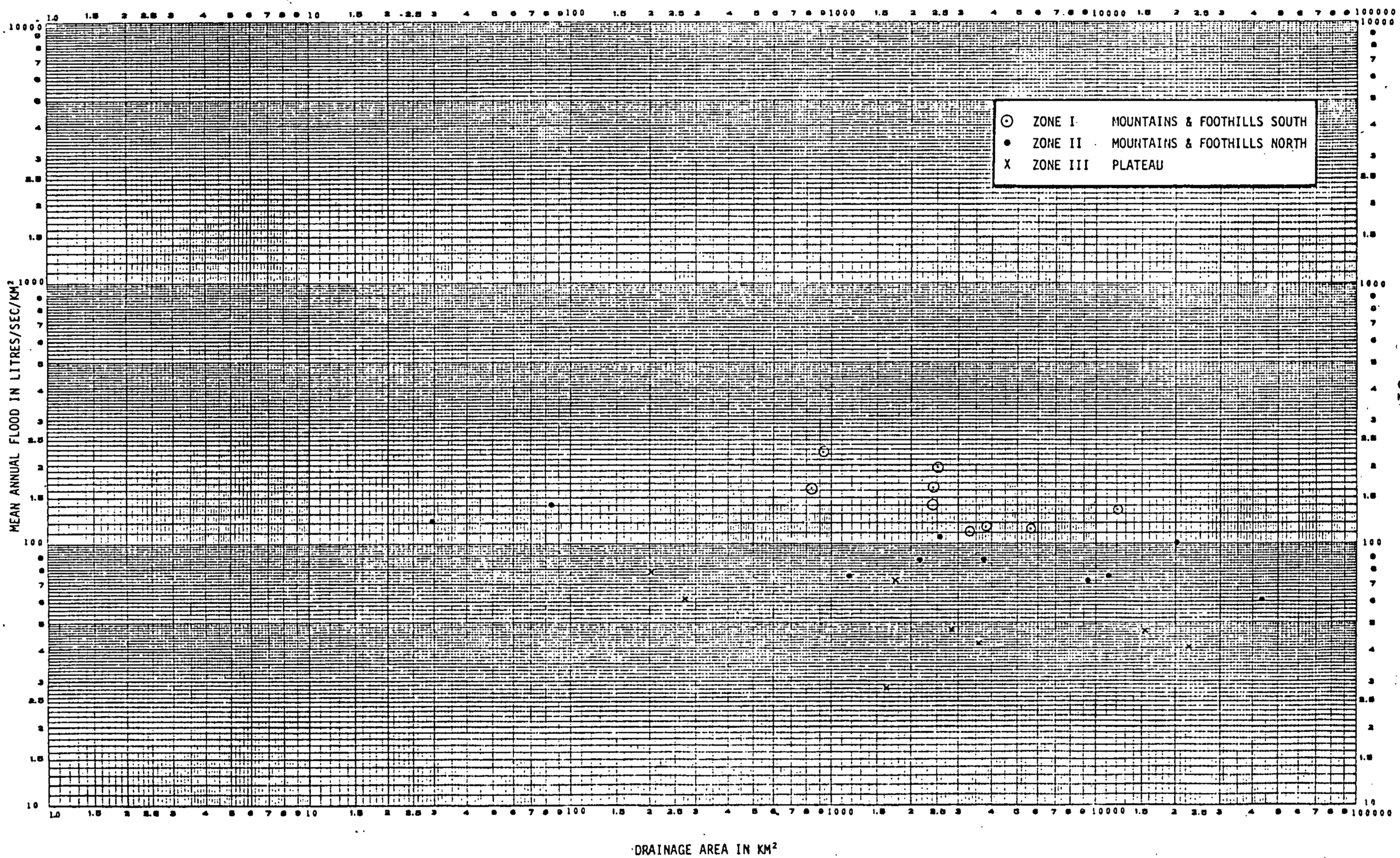
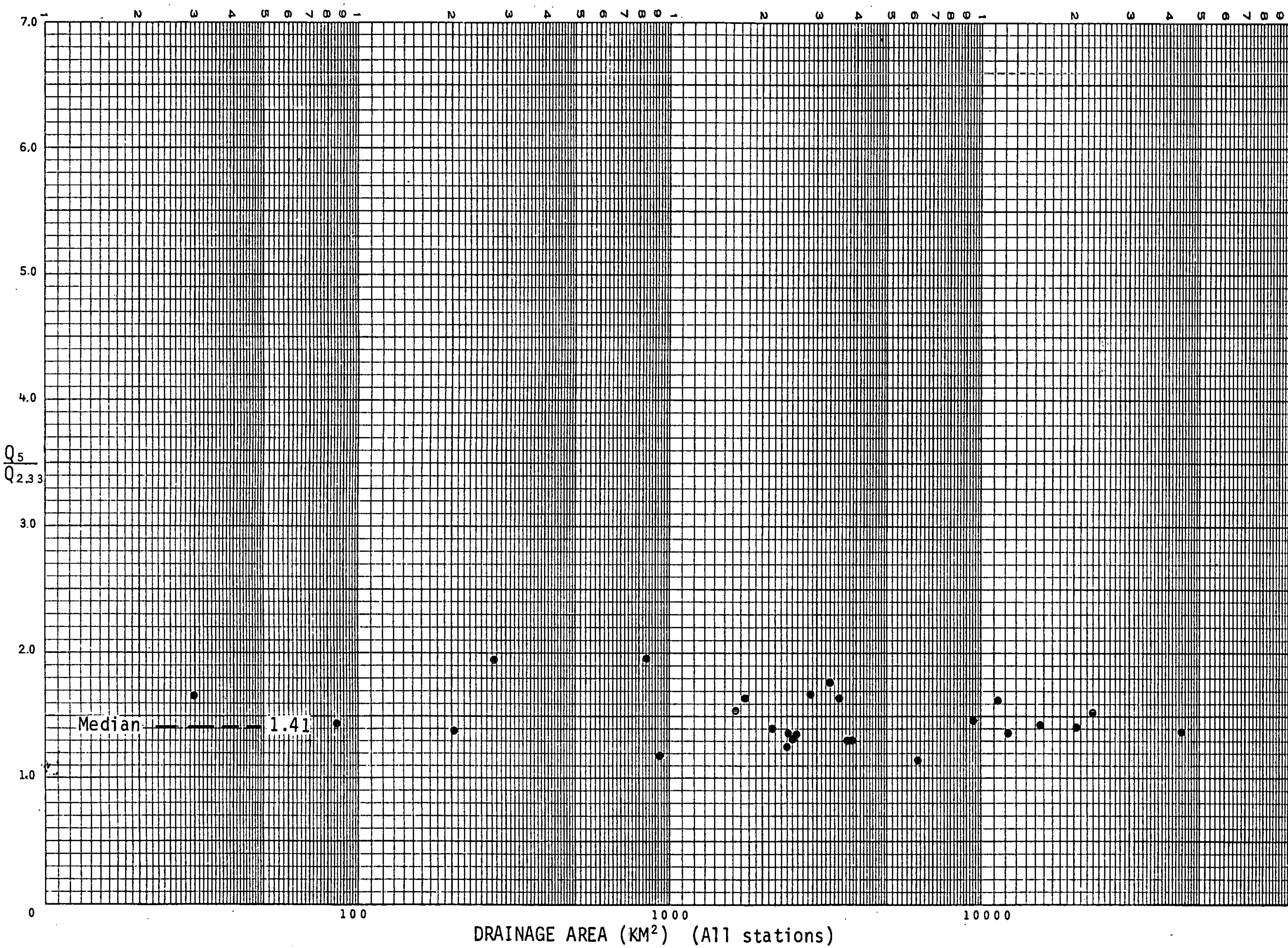
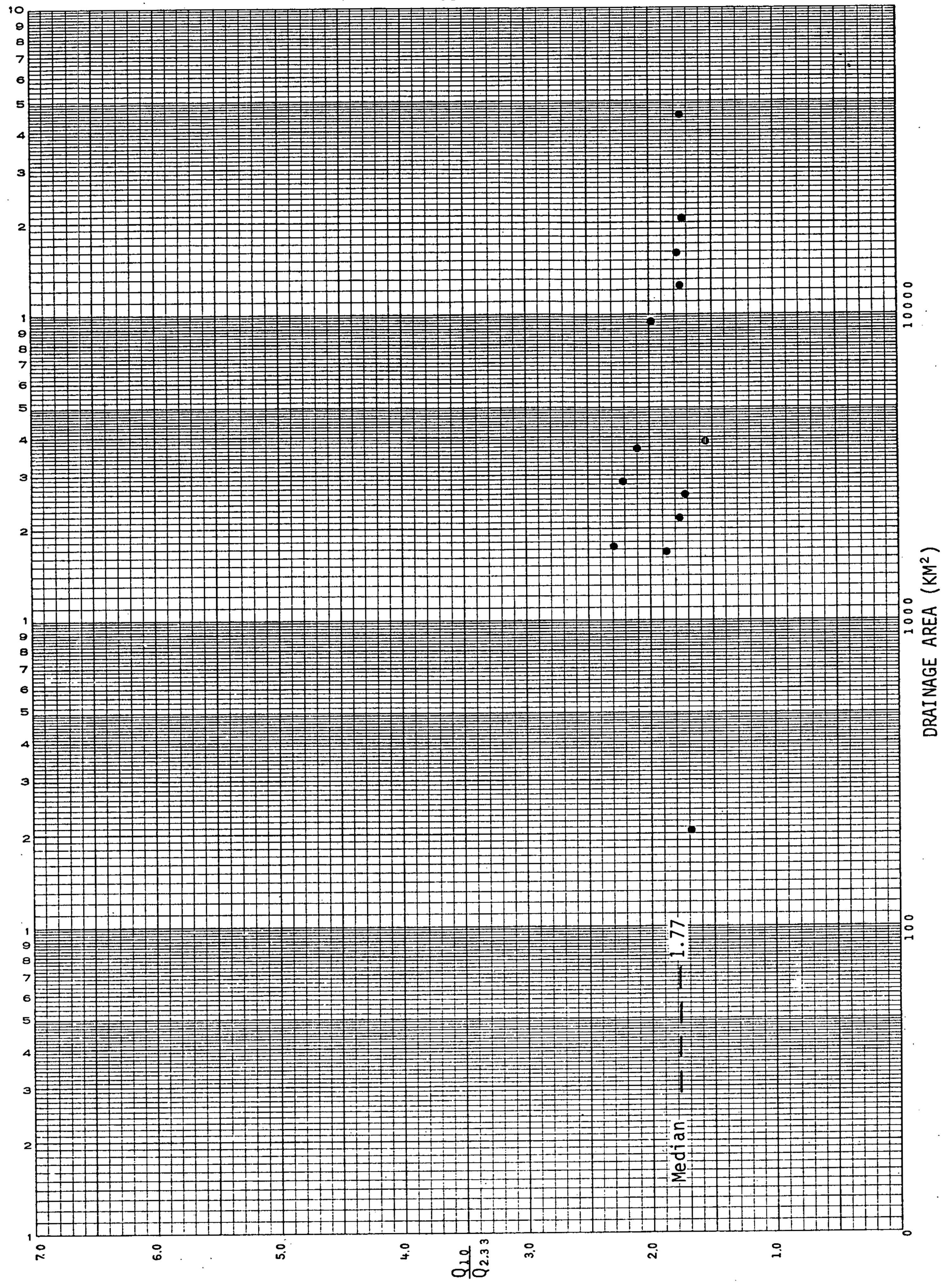


Figure 13. Relationship of Mean Annual Flood Runoff to Drainage Area


Median 1.41
DRAINAGE AREA (KM²) (All stations)
Q5/Q2.33


DRAINAGE AREA (KM²)
10000
1000
100
0
Median
1.77
7.0
6.0
5.0
4.0
3.0
2.0
1.0
$\frac{Q_{10}}{Q_{2.33}}$

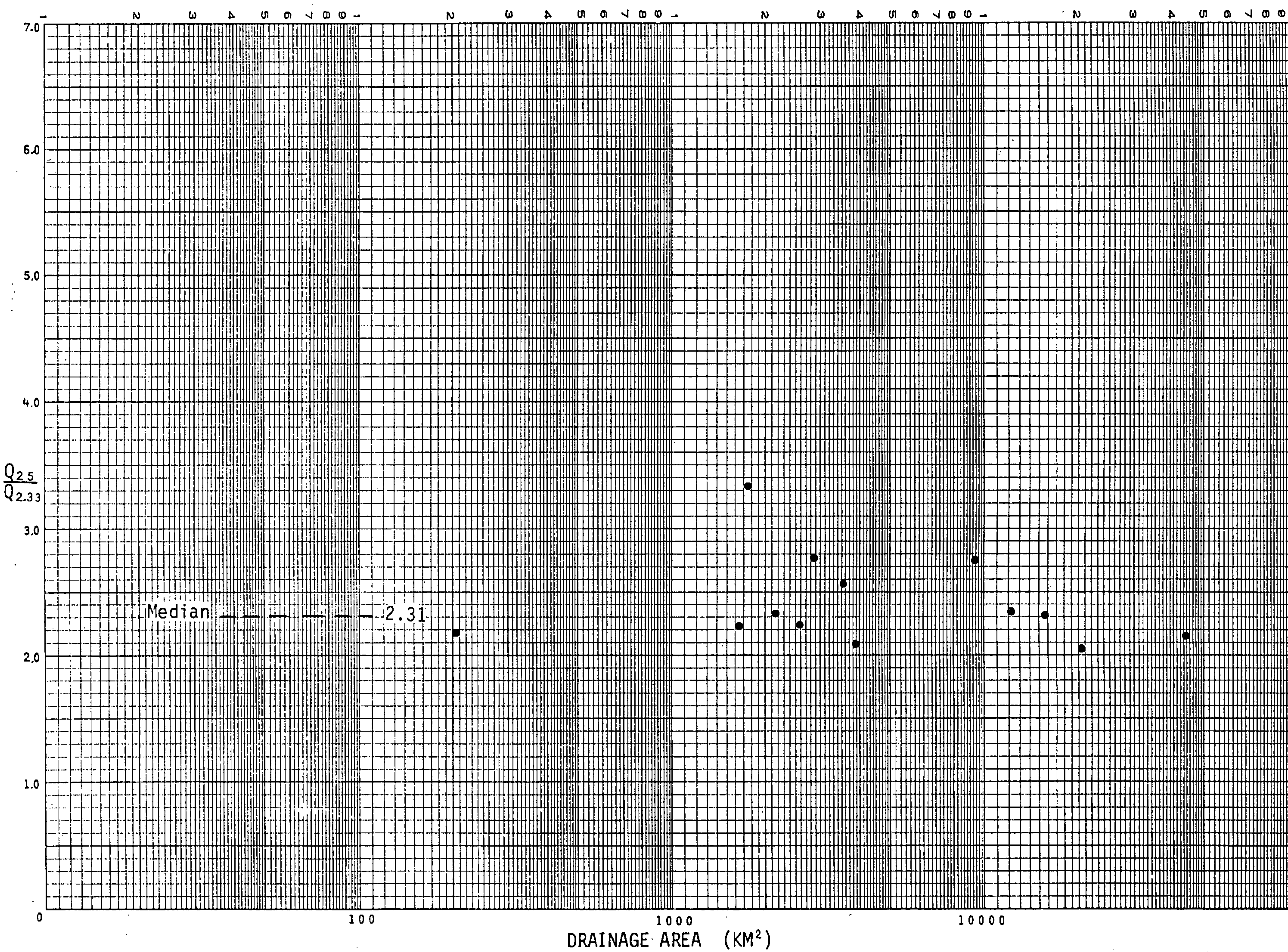
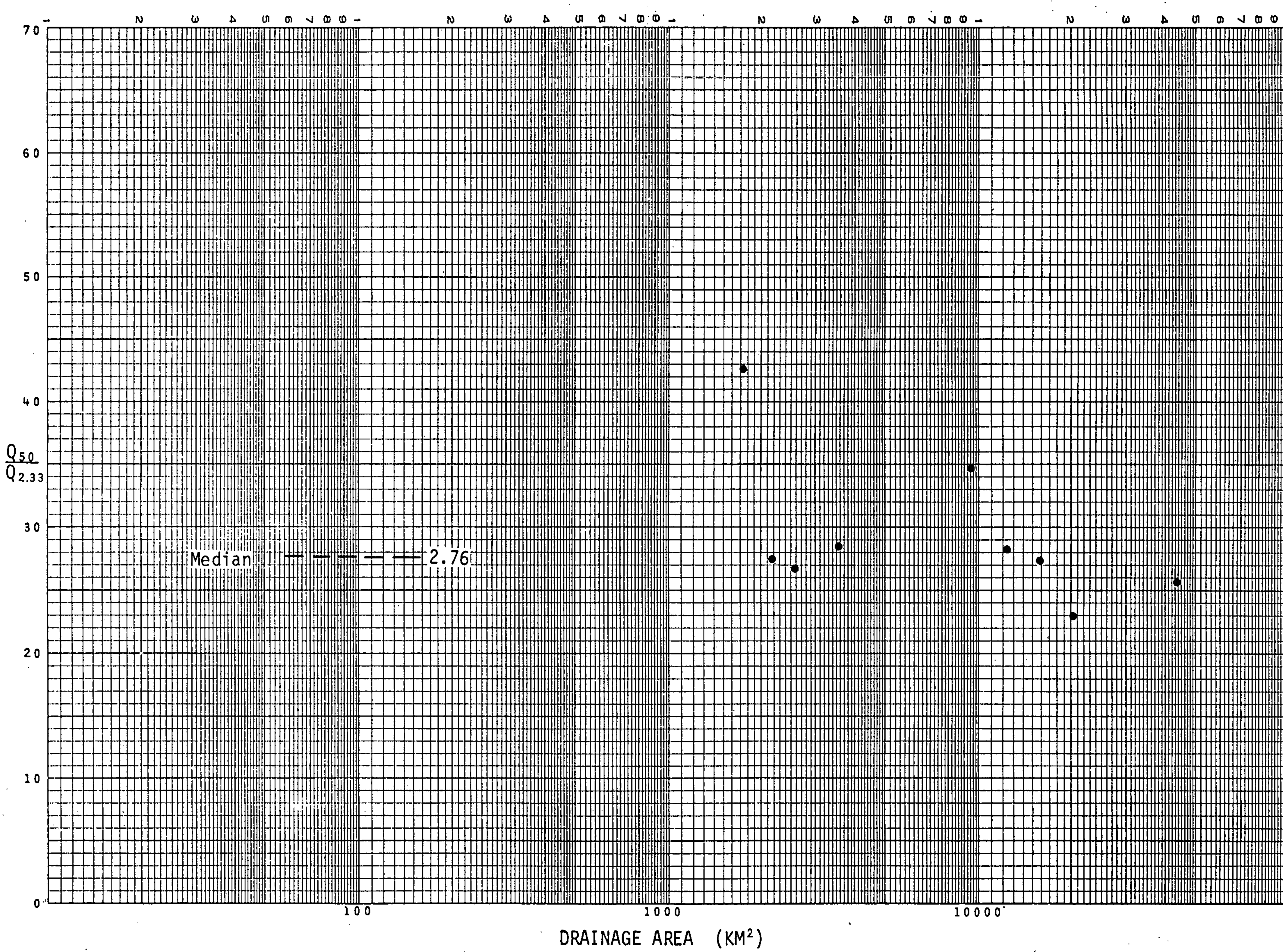


Figure 16 - Ratio of $Q_{25}/Q_{2.33}$ vs. Drainage Area


$\frac{Q_{50}}{Q_{2.33}}$
Median
2.76
100
1000
10000
DRAINAGE AREA (KM²)

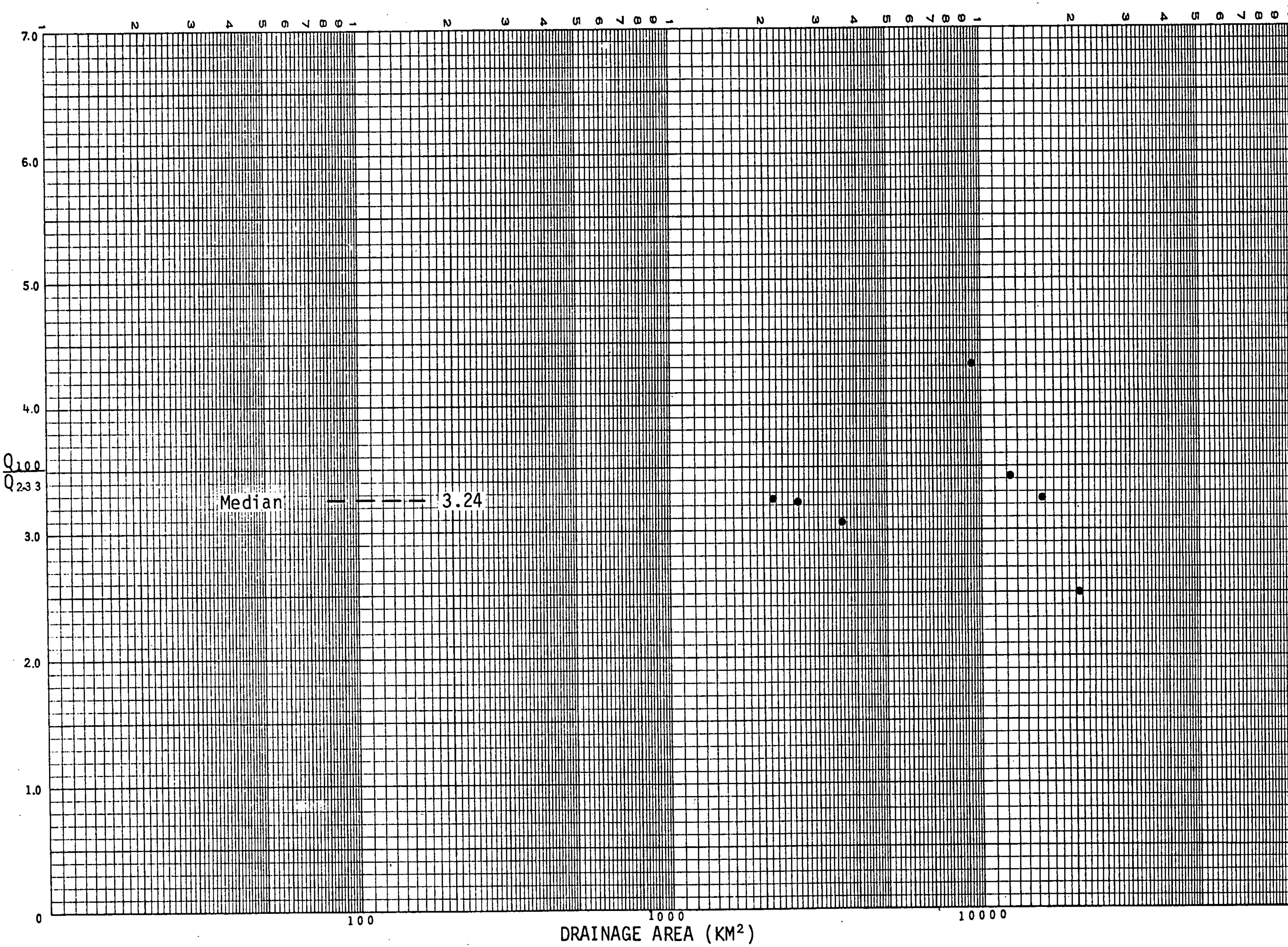


Figure 18. Ratio of $Q_{100}/Q_{2.33}$ vs. Drainage Area

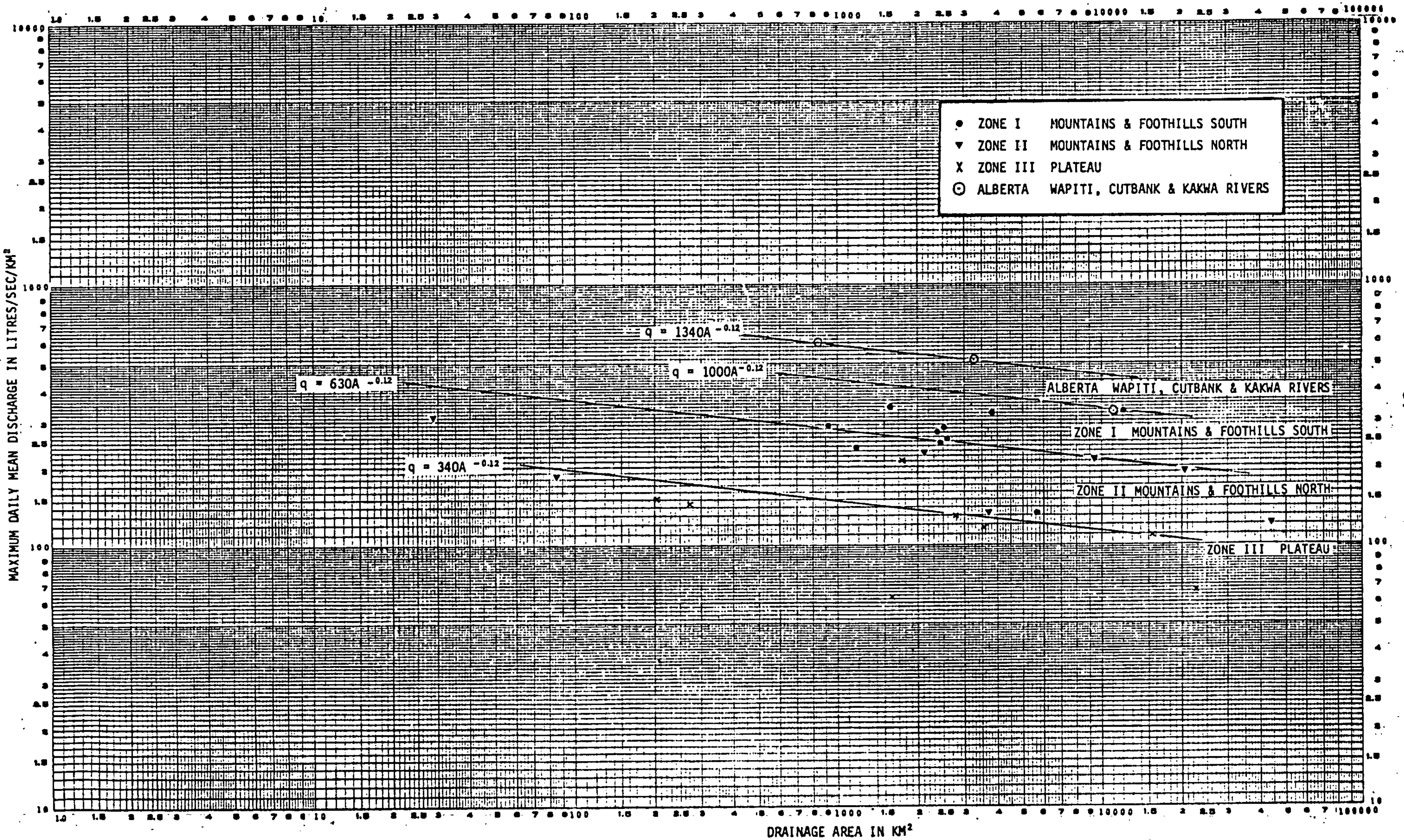


Figure 19 Envelope Curves for Subdivided Region