9

FLOOD FREQUENCY ANALYSIS FOR THE NEW BRUNSWICK-GASPÉ REGION

TECHNICAL BULLETIN No. 9

E.P. COLLIER

G.A. NIX

INLAND WATERS BRANCH
DEPARTMENT OF ENERGY, MINES AND RESOURCES
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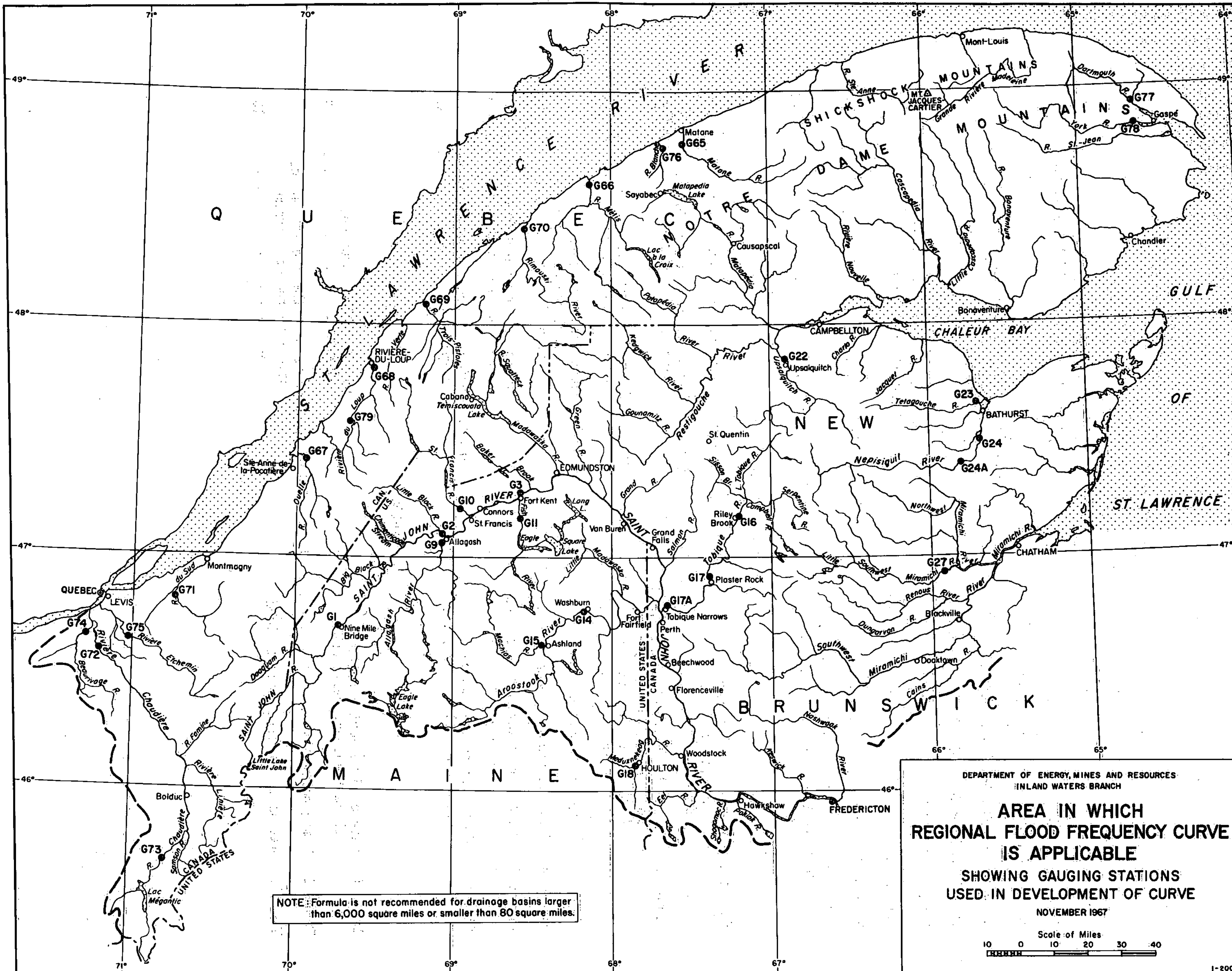
DEPARTMENT OF ENERGY, MINES AND RESOURCES
INLAND WATERS BRANCH
AREA IN WHICH
REGIONAL FLOOD FREQUENCY CURVE
IS APPLICABLE
SHOWING GAUGING STATIONS
USED IN DEVELOPMENT OF CURVE
NOVEMBER 1967
Scale of Miles
10 0 10 20 30 40
NOTE: Formula is not recommended for drainage basins larger than 6,000 square miles or smaller than 80 square miles.
1-2009
QUEBEC
NEW BRUNSWICK
MAINE
ST. LAWRENCE RIVER
GULF OF ST. LAWRENCE
CHALEUR BAY
SHICKSHOCK MOUNTAINS
NOTRE DAME MOUNTAINS
MT. JACQUES CARTIER
UNITED STATES
CANADA
CAN.
U.S.
Mont-Louis
Gaspé
Chandler
Bonaventure
Matane
Sayabec
Causapscal
CAMPBELLTON
Upsalquitch
BATHURST
CHATHAM
Blackville
Doaktown
FREDERICTON
Hawkshaw
Woodstock
HOULTON
Florenceville
Beechwood
Perth
Tobique Narrows
Plaster Rock
Riley Brook
St. Quentin
Grand Falls
Van Buren
Fort Fairfield
Washburn
Ashland
EDMUNDSTON
Fort Kent
Connors
St. Francis
Allagash
Nine Mile Bridge
Cabano
RIVIÈRE-DU-LOUP
Ste-Anne-de-la-Pocatière
Montmagny
QUEBEC
LEVIS
Bolduc
Lac Mégantic
Little Lake Saint John
Eagle Lake
Temiscouata Lake
Matapedia Lake
Lac la Croix
G1
G2
G3
G9
G10
G11
G14
G15
G16
G17
G17A
G18
G22
G23
G24
G24A
G27
G65
G66
G67
G68
G69
G70
G71
G72
G73
G74
G75
G76
G77
G78
G79
SAINT JOHN RIVER
Restigouche
Nepisiguit River
Miramichi
Southwest Miramichi
Chaudière
Etchemin
Rimouski
Matapédia
Madawaska R.
Aroostook
Allagash River
Tobique
Cascapedia River
Bonaventure R.
Rivière du Loup
Trois-Pistoles
Ouelle R.
Rivière Etchemin
Rivière Beaurivage
Tetagouche R.
Jacquet R.
Renous River
Dungarvon R.
Cains R.
Nashwaak River
Meduxnekeag
Machias
Fish R.
Green R.
Grand R.
Salmon R.
Kedgwick River
Gounamitz R.
Little Black R.
Big Black R.
Chimenticook Stream
Daaquam R.
R. Famine
Rivière Linière
Samson R.
Mitis R.
Matane R.
Dartmouth R.
York R.
R. St.-Jean
R. Ste. Anne
Rivière Madeleine
Grande Rivière
Little Cascapedia R.
Rivière Nouvelle
Patapédia
Charlo R.
Upsalquitch R.
Serpentine R.
Campbell R.
L. Tobique R.
Sisson Br.
Northwest Miramichi
Little Southwest
Keswick R.
Shogomoc R.
Pokiok R.
Eel R.
St. Francis R.
Baker Brook
R. Squatteck
Long L.
Square Lake
Eagle Lake
Little Madawaska R.
Madawaska R.
R. Blanche
Rivière Verte
Rivière du Sud

FIGURE 1

FLOOD FREQUENCY ANALYSIS FOR THE NEW BRUNSWICK-GASPÉ REGION

INTRODUCTION

This report presents the results of a flood frequency analysis for the region comprising parts of the provinces of Quebec and New Brunswick and that part of the State of Maine lying in the Saint John River basin.

A regional flood frequency curve was developed which defines the ratio of the magnitude of an annual flood of a given recurrence interval to that of the mean annual flood at any specified point in the drainage systems concerned.

An equation for the determination of the mean annual flood at the point of interest was also derived by multiple correlation. This equation relates the mean annual flood to certain basin parameters.

Methods for applying the regional flood frequency curve and the mean annual flood equation are described and the limitations in their use are discussed.

REGION COVERED

The region covered in this report is shown in Figure 1 and may be described as follows:

(a) That part of the Province of Quebec lying south of the St. Lawrence River and east of the City of Quebec.

(b) That part of the Saint John River basin in New Brunswick and upstream of Fredericton.

(c) That part of the Saint John River basin in the State of Maine.

(d) The Miramichi River basin, and all other basins north of it in New Brunswick.

The streamflow records employed in the analysis were drawn from the region described and the use of the regional curve outside this area cannot be recommended. Furthermore, the catchment areas associated with the gauging stations were confined to a range of 80 to 6,000 square miles. The application of the regional curve to areas outside this range is not recommended.

BASIC DATA USED IN THE ANALYSIS

Streamflow records from 32 gauging stations in the region were used in the analysis. The stations are listed in Table 1, together with their periods of record, and the corresponding drainage areas and their locations are shown in Figure 1.

The periods of record of flood flow vary in length from station to station, the longest being a 50-year record on the Chaudière River at St. Lambert, Quebec, and the shortest a nine-year record on the Nepisiguit River near Pabineau Falls, New Brunswick.

Individual flood frequency curves were constructed according to the method based on the first asymptotic distribution of extreme values (the Gumbel Method) described by Coulson (1966).

A typical single-station, flood frequency curve with its 95 per cent confidence limits is shown in Figure 2. This curve is for the 41 years of record, 1923 to 1964, on the Rimouski River near Rimouski, Quebec.

Similar curves with their corresponding confidence limits were constructed for the 30 gauging stations in the region with periods of record of ten years or more.

The annual flood was defined as the maximum mean daily flow occurring during the water-year October 1 to September 30. The maximum instantaneous flow was not used in the analysis, as the records of such flows are not complete. The user must bear in mind that some upward adjustment is necessary to obtain the maximum instantaneous discharge for any given recurrence interval from the maximum daily discharge computed by the method described.

The flood frequency curves for the two stations with less than ten years of record were not derived but the records were used as supporting data in other phases of the study.

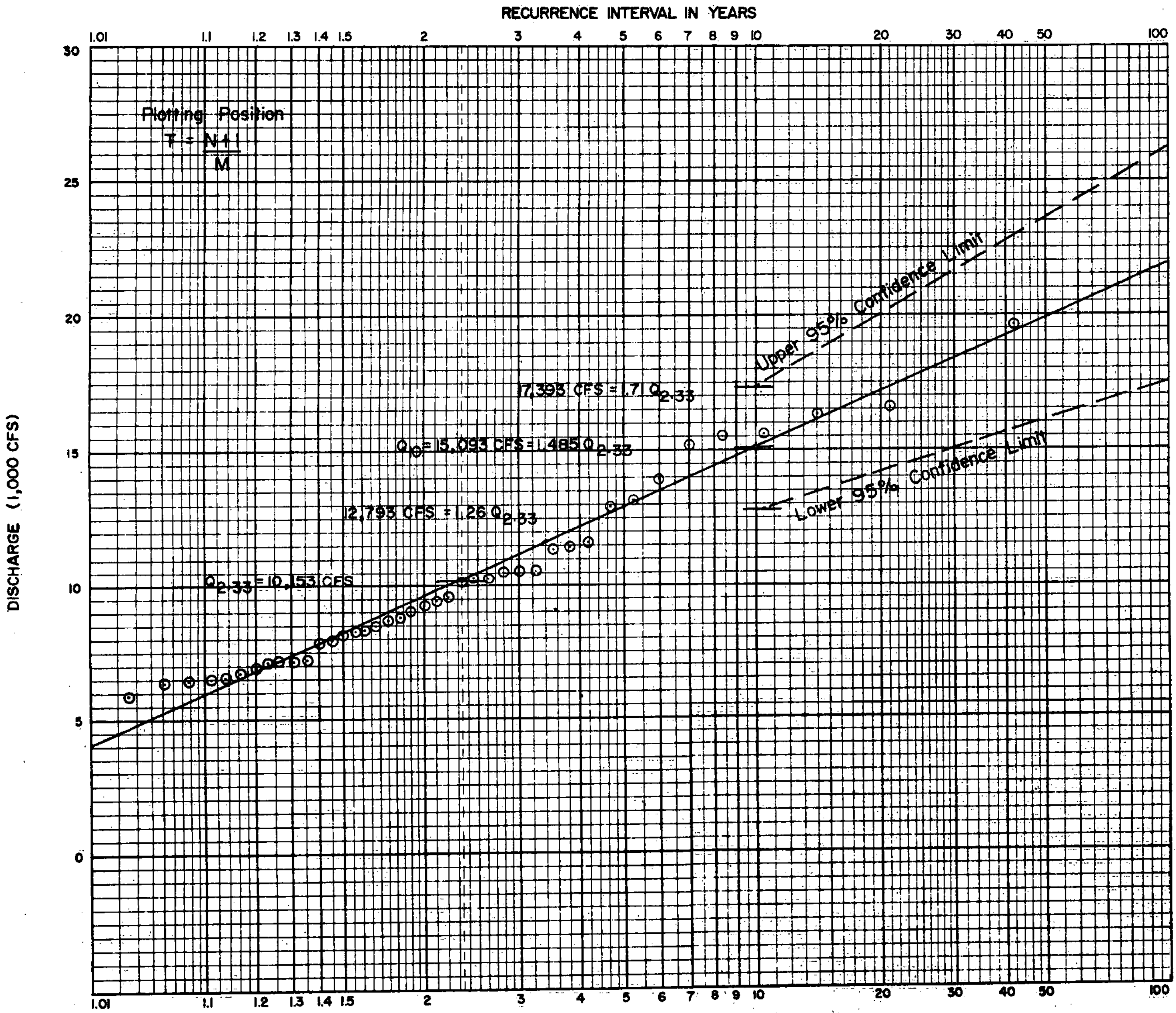

Figure 2. Frequency curve of annual floods for Rimouski River near Rimouski for the period 1923 to 1964.

TABLE 1

Data Used to Define Regional Flood Frequency Relations

Gauging Station	Drainage Area (Sq. Miles)	Location	Period of Record
G1	1,290	Saint John River at Nine Mile Bridge	1951-1966
G2	2,700	Saint John River at Dickey	1947-1966
G3	5,690	Saint John River at Fort Kent	1927-1966
G9	1,250	Allagash River near Allagash	1932-1966
G10	520	St. Francis River at Outlet Glasier Lake	1952-1966
G11	860	Fish River near Fort Kent	1930-1966
G14	1,650	Aroostook River at Washburn	1931-1966
G15	330	Machias River near Ashland	1952-1966
G16	860	Tobique River at Riley Brook	1955-1966
G17	1,210	Tobique River at Plaster Rock	1955-1966
G17A	1,600	Tobique River at Narrows	1919-1933 1954-1966
G18	175	Meduxnekeag River near Houlton	1941-1966
G22	877	Upsalquitch River at Upsalquitch	1919-1933 1944-1966
G23	140	Tetagouche River near West Bathurst	1923-1933 1952-1966
G24	807	Nepisiguit River near Pabineau Falls	1958-1966
G24A	712	Nepisiguit River at Nepisiguit Falls	1922-1966
G27	518	Little S. W. Miramichi River at Lyttleton	1952-1966
G65	640	Matane River near Matane	1923-1964
G66	739	Métis River near Price	1923-1964
G67	311	Ouelle River at St. Pacome	1921-1964
G68	404	Du Loup River at Rivière Du Loup	1923-1964
G69	387	Trois Pistoles River near Tobin	1922-1964
G70	800	Rimouski River near Rimouski	1923-1964
G71	311	Du Sud River at Arthurville	1923-1964
G72	2,261	Chaudière River at St. Lambert	1915-1964
G73	448	Chaudière River near Drolet	1916-1964
G74	274	Beaurivage River near St. Étienne	1926-1964
G75	443	Etchemin River near Jean Guérin	1919-1964
G76	85	Blanche River near St. Ulric	1934-1964
G77	288	Dartmouth River near Cortéréal	1946-1964
G78	389	York River near Sunny Bank	1946-1964
G79	195	Du Loup River above St. Joseph	1956-1964

TABLE 2

Homogeneity Test

Station	MAF $Q_{2.33}$	$Q_{10}/Q_{2.33}$	$Q = Q_{2.33} \times 1.61$	T for Q	Period of Record (years)
G1	19,838	1.51	31,939	14	16
G2	40,785	1.58	65,664	11	20
G3	77,167	1.45	124,239	18	40
G9	14,026	1.53	22,582	20	35
G10	6,298	1.67	10,140	8.5	15
G11	7,999	1.44	12,878	19	37
G14	22,382	1.51	36,035	14	36
G15	6,024	1.89	9,699	6	15
G16	8,227	2.02	13,245	5.5	12
G17	13,690	2.14	22,041	5	12
G17A	22,560	1.68	36,322	8.5	27
G18	3,310	1.60	5,329	10	26
G22	12,224	1.66	19,681	8.5	38
G23	2,624	1.64	4,225	10	26
G24A	9,310	1.51	14,989	14	45
G27	9,857	1.96	15,870	5.5	15
G65	12,634	1.42	20,341	21	42
G66	10,125	1.69	16,301	8	40
G67	5,301	1.54	8,563	14	43
G68	5,884	1.64	9,473	9	42
G69	7,360	1.57	11,850	11	43
G70	10,153	1.49	16,346	15	41
G71	8,512	1.46	13,704	17	42
G72	38,474	1.45	61,943	18	50
G73	6,104	1.54	9,827	13	49
G74	6,131	1.49	9,871	15	39
G75	8,878	1.41	14,294	23	36
G76	2,045	1.56	3,292	12	31
G77	8,774	1.60	14,126	10	19
G78	7,516	1.52	12,101	13	19

AVERAGE RATIO = 1.61

HOMOGENEOUS REGIONS FOR FLOOD FREQUENCY

A region must be shown to be homogeneous before the individual flood frequency curves can be combined with confidence to form a regional curve.

A homogeneity test as described by Dalrymple (1960), was applied with success to the 30 frequency curves of the region. The data are listed in Table 2 and the graph is shown in Figure 3.

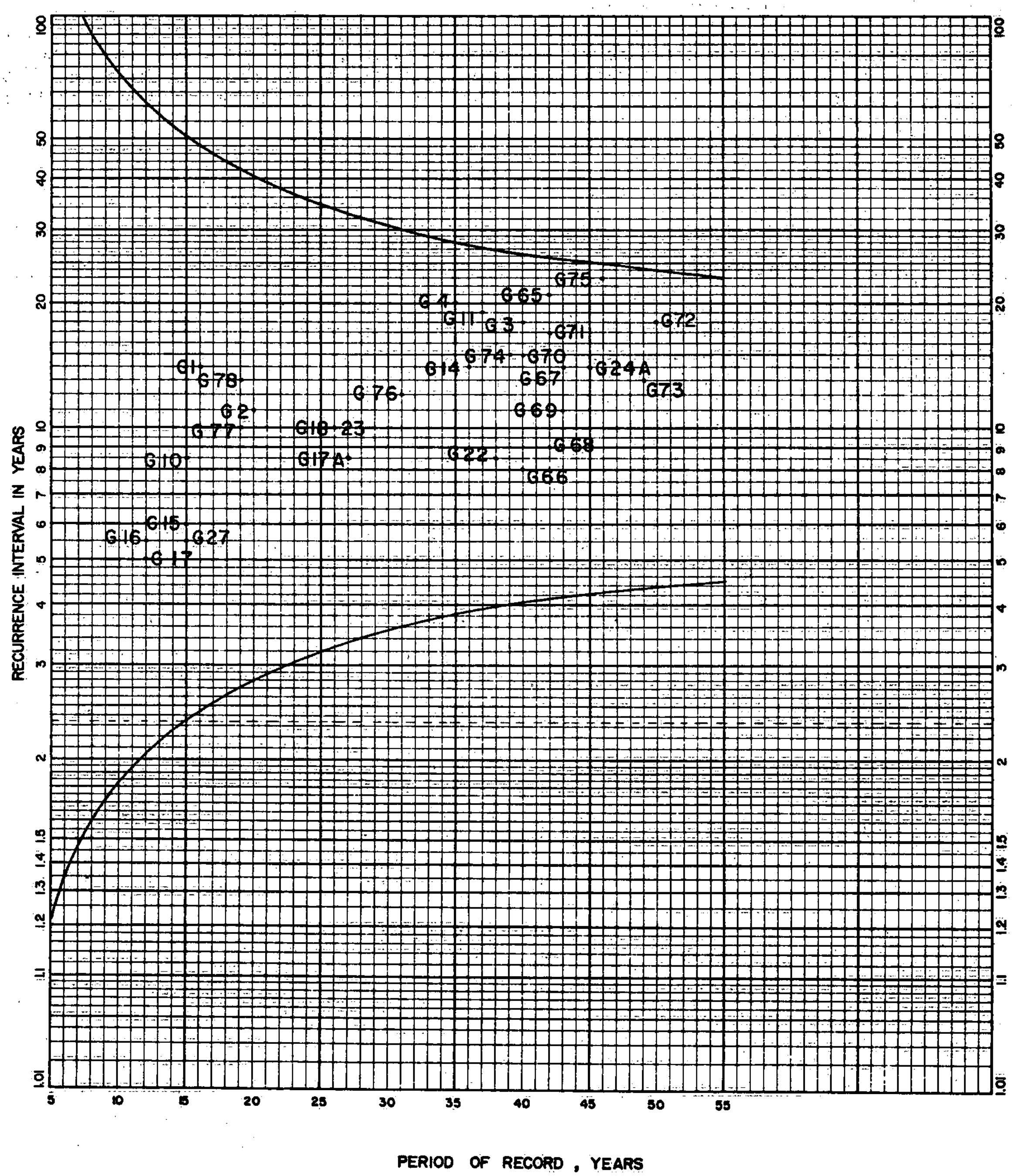

Figure 3. Homogeneity test chart.

REGIONAL FLOOD FREQUENCY CURVE

The regional flood frequency curve for a homogeneous region was assumed to be the mean of the individual frequency curves. The curves had to be reduced to dimensionless form before they were combined, to remove the effect of varying drainage areas. This was done by expressing the floods at given recurrence intervals as ratios to the mean annual flood at the site. The mean of the ratios for a given recurrence interval was taken as the equivalent ratio for the regional curve. This concept is based upon the assumption that the slope of the regional frequency curve is uniform throughout the region and variations between curves for individual stations are due only to sampling errors.

The regional curve for the area under consideration, which was developed by the method described, is shown in Figure 4. The data supporting the curve are listed in Table 3.

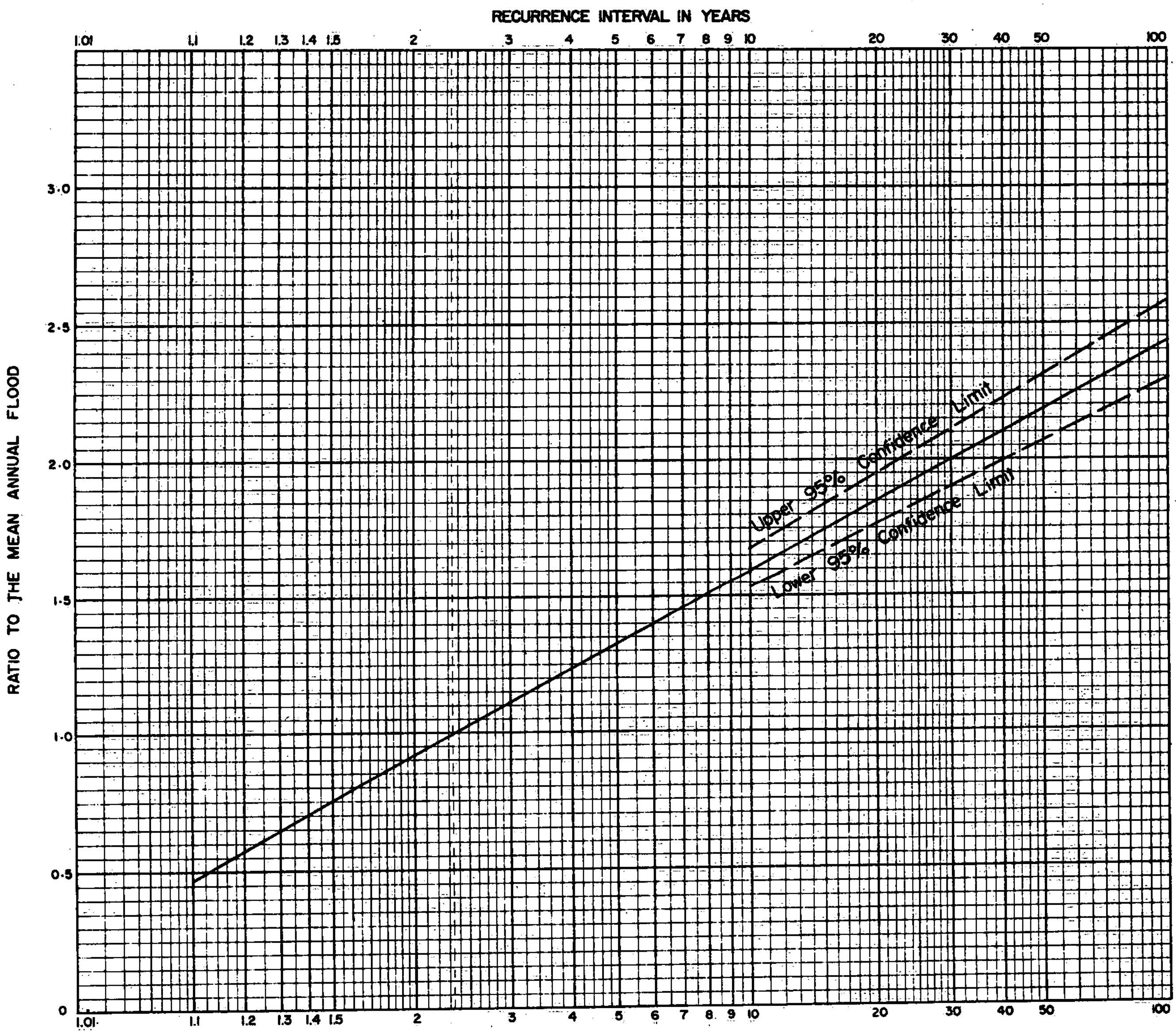

Figure 4. Regional flood frequency curve.

TABLE 3

Ratios to the Mean Annual Flood for Specified Recurrence Intervals

Station	Mean Annual Flood (cfs)	Recurrence Interval (years)				
		5	10	20	50	100
G1	19,838	1.29	1.51	1.72	1.99	2.19
G2	40,785	1.32	1.58	1.81	2.12	2.36
G3	77,167	1.24	1.45	1.64	1.89	2.08
G9	14,026	1.29	1.53	1.75	2.04	2.26
G10	6,298	1.38	1.67	1.96	2.32	2.59
G11	7,999	1.24	1.44	1.63	1.87	2.04
G14	22,382	1.28	1.51	1.72	2.00	2.21
G15	6,024	1.51	1.89	2.26	2.40	3.10
G16	8,227	1.57	2.02	2.45	3.00	3.41
G17	13,690	1.64	2.14	2.62	3.22	3.68
G17A	22,560	1.38	1.68	1.96	2.32	2.60
G18	3,310	1.32	1.60	1.87	2.20	2.46
G22	12,224	1.39	1.66	1.94	2.30	2.57
G23	2,642	1.36	1.64	1.90	2.24	2.49
G24A	9,310	1.28	1.51	1.73	2.01	2.22
G27	9,875	1.54	1.96	2.36	2.88	3.26
G65	12,634	1.23	1.42	1.60	1.83	2.00
G66	10,125	1.39	1.69	1.99	2.37	2.66
G67	5,301	1.29	1.54	1.76	2.06	2.28
G68	5,884	1.34	1.64	1.91	2.27	2.54
G69	7,360	1.32	1.57	1.81	2.12	2.36
G70	10,153	1.28	1.49	1.69	1.96	2.16
G71	8,512	1.25	1.46	1.65	1.90	2.09
G72	38,474	1.24	1.45	1.64	1.88	2.06
G73	6,104	1.29	1.54	1.76	2.06	2.28
G74	6,131	1.27	1.49	1.70	1.97	2.16
G75	8,878	1.22	1.41	1.58	1.81	1.98
G76	2,045	1.31	1.56	1.78	2.08	2.31
G77	8,774	1.35	1.60	1.85	2.17	2.42
G78	7,516	1.29	1.52	1.74	2.02	2.24
REGIONAL CURVE		1.34	1.61	1.86	2.18	2.44

CONFIDENCE LIMITS

The confidence limits for the regional frequency curve were computed by combining those of the individual station curves. The procedure may be described by reference to the frequency curve for the Rimouski River near Rimouski, illustrated in Figure 2.

At a recurrence interval of ten years, the flood and the confidence limits are:

Q_{10} = 15,093 cfs = 1.485 $Q_{2.33}$

Upper 95 per cent Confidence Limit = 17,393 cfs = 1.71 $Q_{2.33}$

Lower 95 per cent Confidence Limit = 12,793 cfs = 1.26 $Q_{2.33}$

The error, E_1(95 per cent), in the value of Q_{10} expressed as a ratio of the mean annual flood was defined as:

$$\begin{aligned} E_1(95 \text{ per cent}) &= 1.71 - 1.485 \\ &= 1.485 - 1.26 \\ &= 0.226 \end{aligned}$$

Similarly, the values of E_2(95 per cent), E_3(95 per cent)...E_{30}(95 per cent) for the remainder of the 30 individual frequency curves were computed.

The mean of all the individual station values of Q_{10}, expressed as ratios to $Q_{2.33}$, was taken as the value at Q_{10} for the regional curve; the error, E_R(95 per cent), in the regional curve was computed from the central limits theorem by the following expression:

$$E_R = \sqrt{\frac{E_1{}^2 + E_2{}^2 + \ldots E_N{}^2}{N}}$$

The computation gave the value for E_R (95 per cent), and thus the 95 per cent confidence limits for the regional curve at a recurrence interval of ten years. Confidence limits for other recurrence intervals were computed by the same method.

MEAN ANNUAL FLOOD

The magnitude in cfs of a flood of a given recurrence interval in a particular basin cannot be determined directly from the regional frequency curve but only the ratio to the mean annual flood at the site. It is necessary to compute the mean annual flood before the magnitude and frequency of other floods can be determined.

The mean annual flood, MAF, is dependent on many factors, including drainage area, stream slopes, elevations, land use, geology, natural storage in lakes, swamps and river channels, and the shape and position of the basin relative to the direction of travel of most storms. It is impracticable to assess accurately the effect of all these factors when estimating the mean annual flood. Numerical values may be derived for some of them, however, and their significance assessed by multiple correlation techniques. The mean annual flood may then be related to the more significant factors.

A series of stepwise linear regressions was run on a computer using mean annual flood (MAF) as the dependent variable and the following factors as independent variables:

(a) Drainage area

(b) Size and position of lakes and swamps

(c) Main channel slope

(d) Average basin elevation

(e) Mean barrier elevation

(f) Mean annual precipitation

Of these factors only the drainage area, the size and position of lakes and swamps, and the main channel slope proved to be significant.

The size and relative position of the lakes and swamps was taken into consideration by dividing the drainage area into two portions called the "controlled" and "uncontrolled" areas. These were combined to form a variable in a regression of the following form:

$$MAF = F(A_u + \lambda^K A_c)$$

where:

A_u = drainage area uncontrolled by major lakes and swamps, in sq. mi.

A_c = drainage area controlled by major lakes and swamps, i.e., total drainage area above the outlet of lowest lake or swamp, in sq.mi.

K = a constant

$$\lambda = \frac{A_c - A_L}{A_c}$$

where A_L = total surface area of major lakes and swamps.

Figure 5

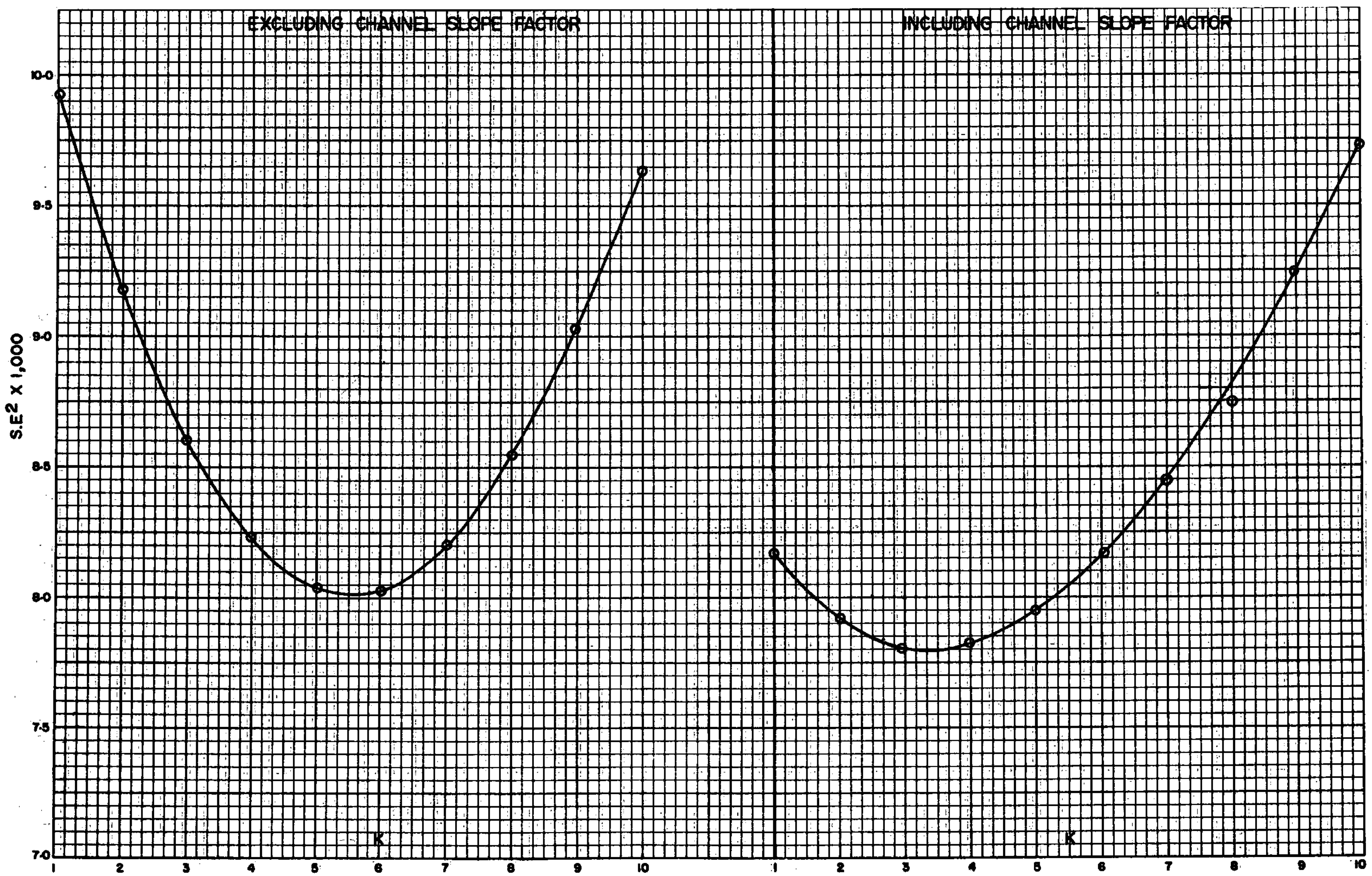

Figure 5. Graph for determination of best balue of K.

TABLE 4

Data Used in the Regression for Estimating the Mean Annual Flood

Station	D.A. sq. mi.	A_u sq. mi.	A_c sq. mi.	λ	Channel slope (ft/1,000 ft.)	Q (cfs)	Estimated Q (cfs)	Error %
G1	1,290	880.5	409.5	.944	0.96	19,838	19,055	- 3.9
G2	2,700	1,838.7	861.3	.957	1.04	40,785	36,150	-11.4
G3	5,690	2,391.1	3,298.9	.926	1.00	77,167	59,074	-23.4
G9	1,250	146.8	1,103.2	.914	0.68	14,026	13,671	- 2.5
G10	520	0	520.0	.968	1.27	6,298	8,183	+29.9
G11	860	76.3	783.7	.882	0.62	7,999	8,449	+ 5.6
G14	1,650	190.9	1,459.1	.985	0.83	22,382	18,664	-16.6
G15	330	69.8	260.2	.930	2.23	6,024	4,763	-21.0
G16	860	541.5	318.5	.943	1.59	8,227	13,327	+62.0
G17	1,210	864.8	345.2	.940	1.33	13,690	18,139	+32.5
G17A	1,600	1,232.8	367.2	.940	1.01	22,560	23,330	+ 3.4
G18	175	60.3	134.7	.896	2.72	3,310	2,987	- 9.8
G22	877	835.9	41.1	.970	2.29	12,224	14,852	+21.5
G23	140	72.8	67.2	.993	4.55	2,642	3,130	+19.3
G24A	712	597.3	114.7	.973	2.80	9,310	12,280	+31.9
G27	518	341.5	176.5	.950	4.47	9,875	8,847	-10.2
G65	640	507.7	132.3	.978	3.15	12,634	11,212	-11.3
G66	739	385.9	353.1	.949	3.80	10,125	11,500	+13.6
G67	311	252.8	58.2	.922	6.23	5,301	5,861	+10.6
G68	404	265.8	138.2	.936	2.62	5,884	7,034	+19.6
G69	387	314.1	72.9	.940	5.48	7,360	7,127	- 3.2
G70	800	464.5	335.5	.934	3.76	10,153	12,182	+19.8
G71	311	294.6	16.4	.924	6.15	8,512	6,133	-27.9
G72	2,261	1,774.4	486.6	.931	1.63	38,474	31,103	-19.2
G73	448	73.8	374.2	.936	5.15	6,104	6,495	+ 6.4
G74	274	257.6	16.4	.564	4.24	6,131	5,332	-13.0
G75	443	412.1	30.9	.932	3.28	8,878	8,238	- 7.2
G76	85	47.0	38.0	.960	4.14	2,045	1,917	- 6.3
G77	288	275.9	12.1	.966	5.64	8,774	5,809	-33.8
G78	389	351.6	37.4	.963	4.79	7,516	7,411	- 1.4

Different values of K were assumed in successive regression analyses, and the value which gave the least standard error of estimate (S_e) for the MAF was selected. The result of these trials is shown in the graph of S_e^2 against K in Figure 5.

The following regression equation using K = 6 and the data shown in Table 4, arose out of the series of regressions:

$$\text{Log MAF} = 0.8429 \text{ Log } (A_u + \lambda^6 A_c) + 1.694 \qquad (1)$$

Equation 1 may be used to estimate the mean annual flood with a standard error of estimate of 0.0895 log units or +23 per cent and -19 per cent.

The main channel slope was then introduced in another series of regressions, using different values for K. The equation giving the best estimate for MAF was the following:

$$\text{Log MAF} = 0.9154 \text{ Log } (A_u+\lambda^3 A_c) + 0.140 \text{ Log } S + 1.415 \qquad (2)$$

where S = main channel slope in feet per thousand feet computed as the mean slope between points at 10 per cent and 85 per cent of stream length above the station (Benson, 1962).

The standard error of estimate was 0.883 log units or +22.5 per cent and -18.5 per cent.

As Equation 2 represents only very small improvement over Equation 1, it is a matter for personal judgement as to whether the factor for channel slope should be considered in any specific application.

APPLICATION OF THE REGRESSION EQUATION FOR MEAN ANNUAL FLOOD

The mean annual flood at a point of interest may be determined either from regression Equations 1 or 2 or from the curve in Figure 6. In any case, a necessary first step is the computation of the value of $(A_u+\lambda^6 A_c)$.

Swamps are considered to have the same effect as lakes on the mean annual flood, and are considered as lakes for the purpose of the analysis.

The value of $(A_u+\lambda^6 A_c)$ is determined by first measuring the total drainage area of the basin under study, the total surface area of major lakes and the area controlled by the major lakes. The controlled area is defined as the area of watershed upstream of the outlet of the lake or, where more than one lake is involved, the total area above the outlet of the lowest.

A somewhat arbitrary decision must be made as to what constitutes a major lake. A rule of thumb which may be adopted defines a major lake as one whose area is at least one per cent of the area it controls.

Values for the drainage area (A), the area controlled (A_c) and the surface area of the lakes (A_L) are then substituted in Equations 3 and 4:

$$A_u = A - A_c \qquad (3)$$

$$\lambda = \frac{A_c - A_L}{A_c} \qquad (4)$$

The value of $(A_u+\lambda^6 A_c)$ can then be computed. Figure 7 gives a convenient method for determining λ^6.

APPLICATION OF THE REGIONAL FLOOD FREQUENCY CURVE AT GAUGING STATION SITES

Using the computed mean annual flood and the regional frequency curve, a frequency curve of annual floods may be derived for any specific site.

There are two types of error inherent in the estimated frequency curve, the error in the mean annual flood and the error in the regional frequency curve. As the error in the mean annual flood far outweighs that in the regional frequency curve, it is desirable, where possible, to estimate the mean annual flood from streamflow records rather than by Equations 1 or 2.

Where streamflow records are available at the point of interest and the flood frequency curve based on the actual records is close to the regional curve, the latter is usually preferable. Where there is a significant difference between the two curves, it is a matter of judgement as to which of the two is the better definition of flood potential at the site. In some cases it may be desirable to select some intermediate curve.

An example is shown in Figure 8 in which the preliminary curve (plotted from streamflow records) with its confidence limits is compared with the estimated curve. Here the estimated mean annual flood was in close agreement with that based on the records, but there is a significant difference between the preliminary frequency curve and the curve derived by the regional approach. This difference may be attributable to some physical factors in the basin which are not common to the region. Or it may be

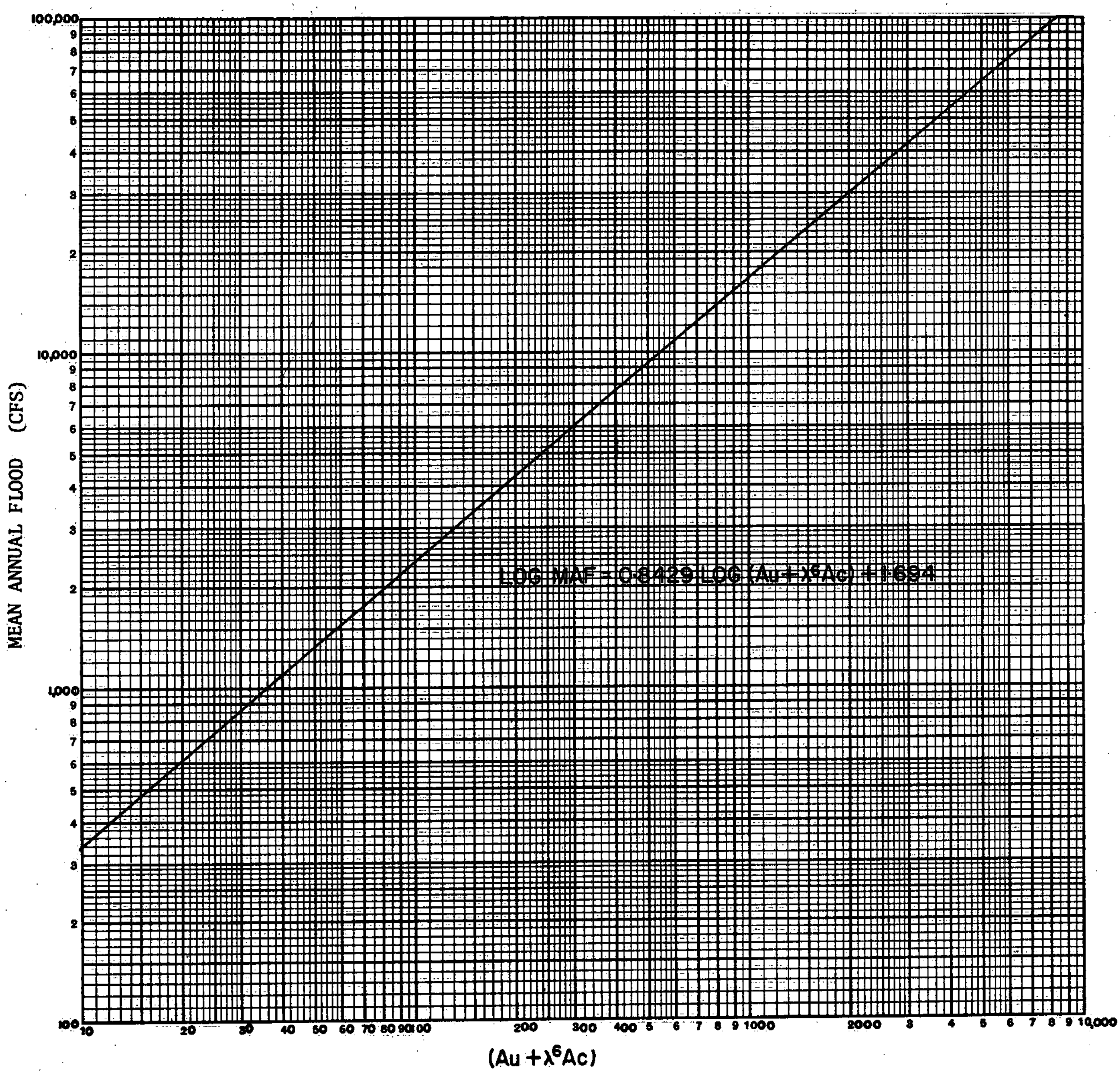

Figure 6. Curve for determination of Mean Annual Flood

that precipitation during the period of record was not representative of the long-term condition. In the latter case, the regional curve may prove to be better in the long run.

In this basin, the surface area of the lakes is about 11 per cent of the total area of the drainage basin. It might be concluded that the flood ratios at higher recurrence intervals in basins with relatively large lake areas tend to be lower than indicated by the regional curve. This is not supported, however, by data in some other basins such as G15 Machias River and G18 Meduxnekeag River. The difference between the two curves in Figure 8 may be attributable to other physical factors or to sampling effects in the distribution of precipitation.

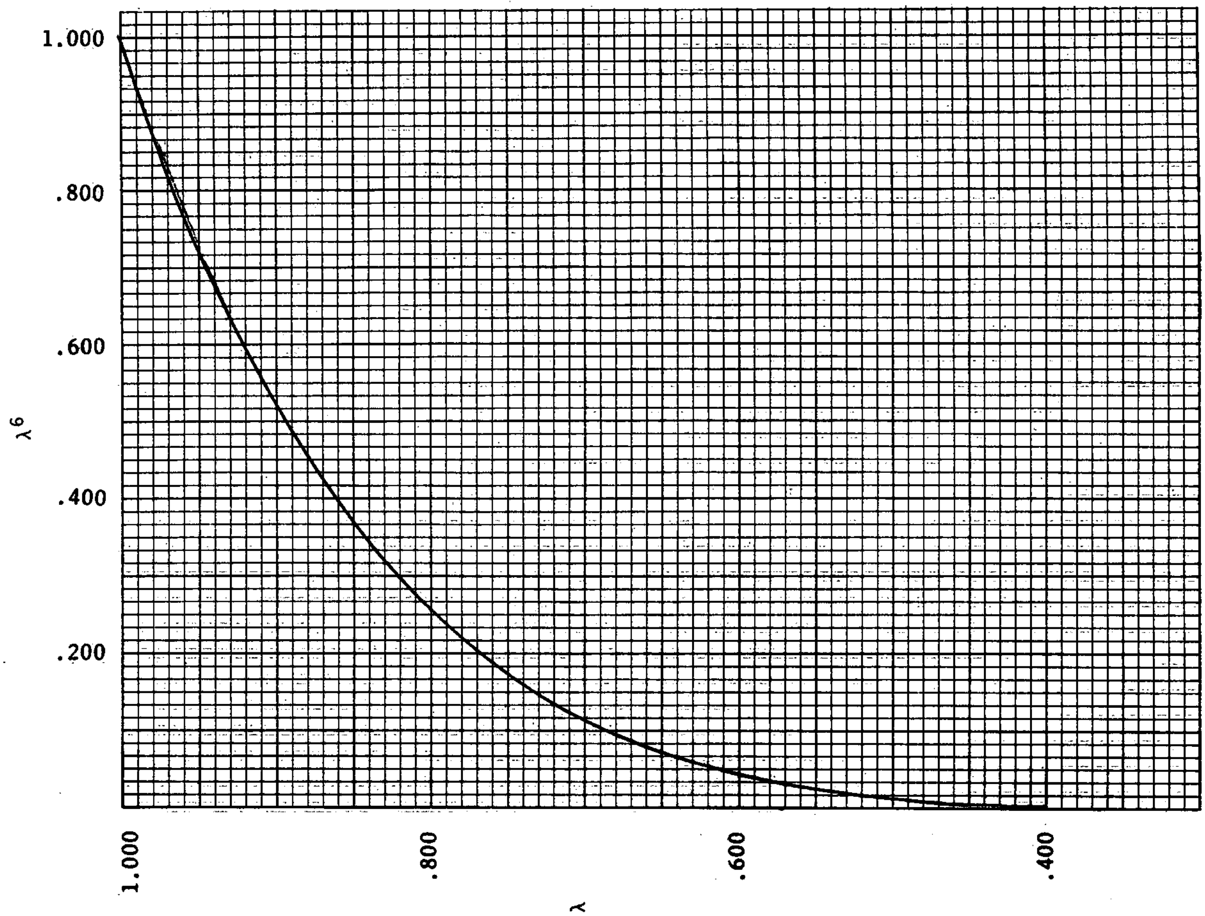

Figure 7. Curve for the determination of λ^6

Although personal judgement cannot be eliminated in the construction of frequency curves for gauging station sites, the following generalities may be of some assistance:

(a) The shorter the period of streamflow records, the more weight should be given to the regional approach, providing there are no obvious peculiarities in the drainage basin under study.

(b) Where some adjustment to the curve derived by the regional approach is advisable, an adjustment to the mean annual flood obtained from the regression equation may provide a satisfactory solution. An example of this is shown in Figure 9, where the adjusted curve is obtained by adjusting the mean annual flood to that derived from the station data and then applying the regional frequency curve.

(c) Where there is significant natural or artificial regulation of flow above the gauging station, the curve based on the recorded data should be given more weight, particularly if the period of record is relatively long.

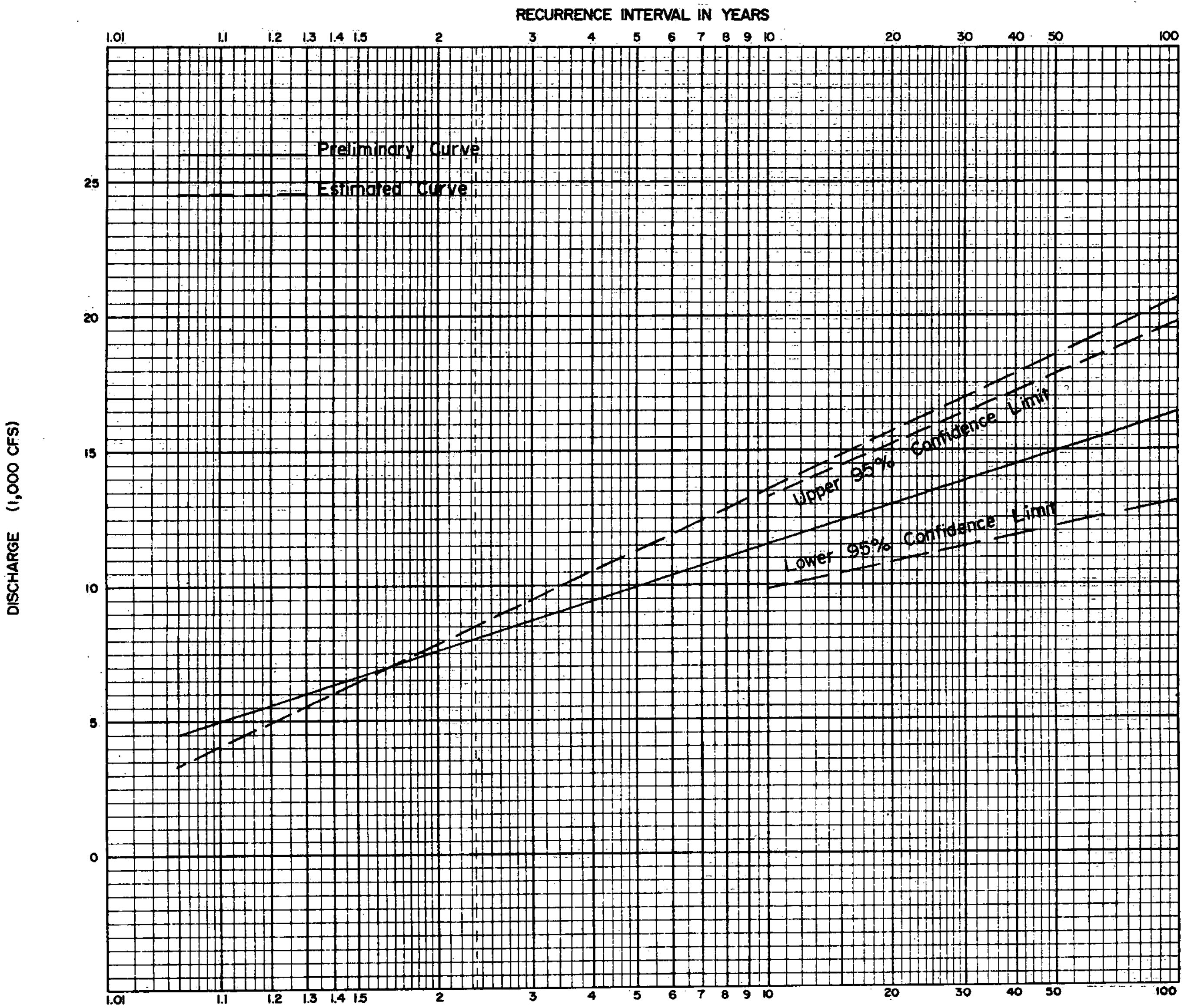

Figure 8. Flood frequency curve for Fish River near Fort Kent.

APPLICATION OF THE REGIONAL FLOOD FREQUENCY CURVE TO UNGAUGED DRAINAGE BASINS

The problems associated with the application of the regional flood frequency curve to ungauged drainage basins will usually fall into one of the following three categories:

(a) A recurrence interval having been selected, it is required to know the magnitude of the flood with that recurrence interval.

(b) A flood of specified magnitude is known, and the recurrence interval of such a flood is required.

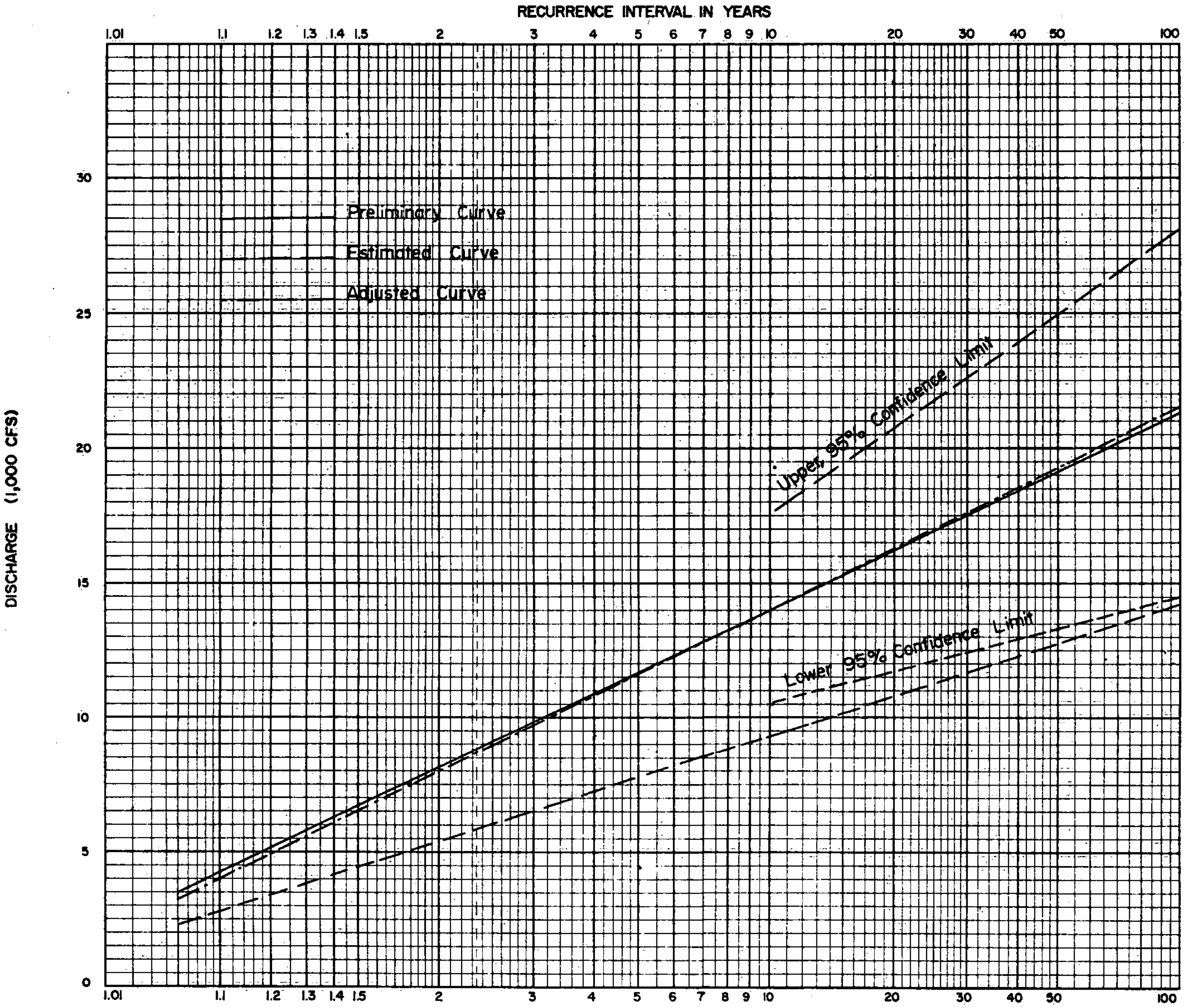

Figure 9. Flood frequency curves for Darmouth River near Cortéréal.

(c) A flood frequency curve for a full range of recurrence intervals up to 100 years is required.

To solve a type (a) problem, the following steps are carried out:

(1) The desired recurrence interval is selected and the equivalent flood ratio is read from the regional flood frequency curve shown in Figure 4. It must be stressed that extrapolation of the regional flood frequency curve beyond the 100-year recurrence interval is not recommended. Studies of floods of such a magnitude require special treatment and are beyond the scope of this report.

(2) The mean annual flood is computed from regression Equations 1 or 2.

(3) The mean annual flood is multiplied by the equivalent flood ratio obtained in Step 1 to give the magnitude of the flood with the selected recurrence interval.

The solution of a type (b) problem is carried out in the following manner:

(1) The mean annual flood for the basin is computed.

(2) The known flood is divided by the mean annual flood to give the flood ratio.

(3) The desired recurrence is read from the regional flood frequency curve.

To solve a type (c) problem, the following steps are carried out:

(1) The mean annual flood is computed.

(2) Flood ratios for a series of recurrence intervals covering the required range are read from the regional frequency curve.

(3) The mean annual flood is multiplied by the flood ratios to give the magnitudes of the appropriate floods.

(4) The floods are plotted at their corresponding recurrence intervals and a curve is drawn through the points to produce the required frequency curve.

COMMENTS ON THE APPLICATION OF THE REGIONAL FREQUENCY CURVE

1. The frequency curve derived from the regional curve by the application of the procedure described in this report, appears to delineate satisfactorily the distribution of recorded annual floods at 19 of the 30 stations considered.

At four of the stations, G11, G65, G70 and G75, the regression equation appears to give a satisfactory solution for the mean annual flood, but the regional frequency curve appears to be too steep. These basins do not form a contiguous area within the region, nor do they appear to have any topographical features in common that do not apply to the rest of the region. Thus there is no apparent reason for the difference in slopes, and it is not clear if they are attributable to unknown parameters peculiar to these basins or to sampling errors.

At four of the stations, G3, G24A, G71 and G77, the regression equation gives a value for the mean annual flood that is significantly different from that indicated by the recorded data. The computed mean annual flood is appreciably higher at one station, G24A, and lower at the other three. These basins do not appear to have physical features peculiar to them, and there is no obvious reason for the apparent anomalies.

At three stations, G10, G15 and G16, the derived frequency curve is not a good representation of the recorded data. The period of record at these stations is short, however, and it is possible that the regional curve is a reasonable definition of the long-term characteristics of the basins. Or again it is possible that there are unknown parameters peculiar to these basins.

2. A thorough discussion of all the aspects of regional flood frequency analysis is beyond the scope of this report but one more example might be mentioned. The highest flood on record for station G27, Little Southwest Miramichi River at Lyttleton, plots so far from the curve derived by the regional approach as to cast some doubt on the validity of the curve. This can be clearly seen in Figure 10.

The flood in question occurred in the latter part of May 1961 and was caused by very severe rain on a saturated watershed, in which the flow in the drainage channels was receding from the peak of the snowmelt runoff about two weeks previously. The snow cover of the preceding winter had been appreciably above normal, and the rainstorm was the heaviest experienced in New Brunswick in the forty-five years of record from 1922 to 1966. One of the principal storm centres, where a total of 10-inches of rain fell in 72 hours, lay directly over the Little Southwest Miramichi basin and less than five miles above the gauging station.

The frequency curve shown in Figure 10 indicates that the resulting flood may have been one of 0.33 per cent probability or the flood with a 300-year recurrence interval.

The combination of the heaviest rainstorm in 45 years, occurring only two weeks after the peak runoff from the melt of an above normal snow cover, and the storm lying directly over the basin and centred only a few miles upstream of the gauging station, was obviously an occurrence of very low probability. A 0.33 per cent probability for the resulting flood peak does not seem unreasonable under the circumstances.

The period of record at the station was short, only 15 years, and thus the low-probability flood had a significant influence on the slope of the frequency curve based on the recorded data. The rainstorm had a similar effect on the curves for two stations on the Tobique River, G16 and G17, whose periods of record were also short. The Tobique River basin is adjacent to the Little Southwest Miramichi basin, as are the Nepisiguit and Upsalquitch River basins. The severe rainstorm covered all these basins, but its effect on the frequency curve was less at stations G17A - Tobique River at Narrows, G22 - Upsalquitch River at Upsalquitch, and G24A Nepisiguit River at Nepisiguit Falls, where the periods of record were longer.

3. Figure 11 shows the regional frequency curve and the individual curves for the 30 stations considered. It can be seen that the curves for the three stations with short periods of record affected by the severe rainstorm in 1961 are relatively steep and lie farthest from the regional curve. It is possible that had the records been longer at G16, G17 and G27, their frequency curves would be closer to the regional curve.

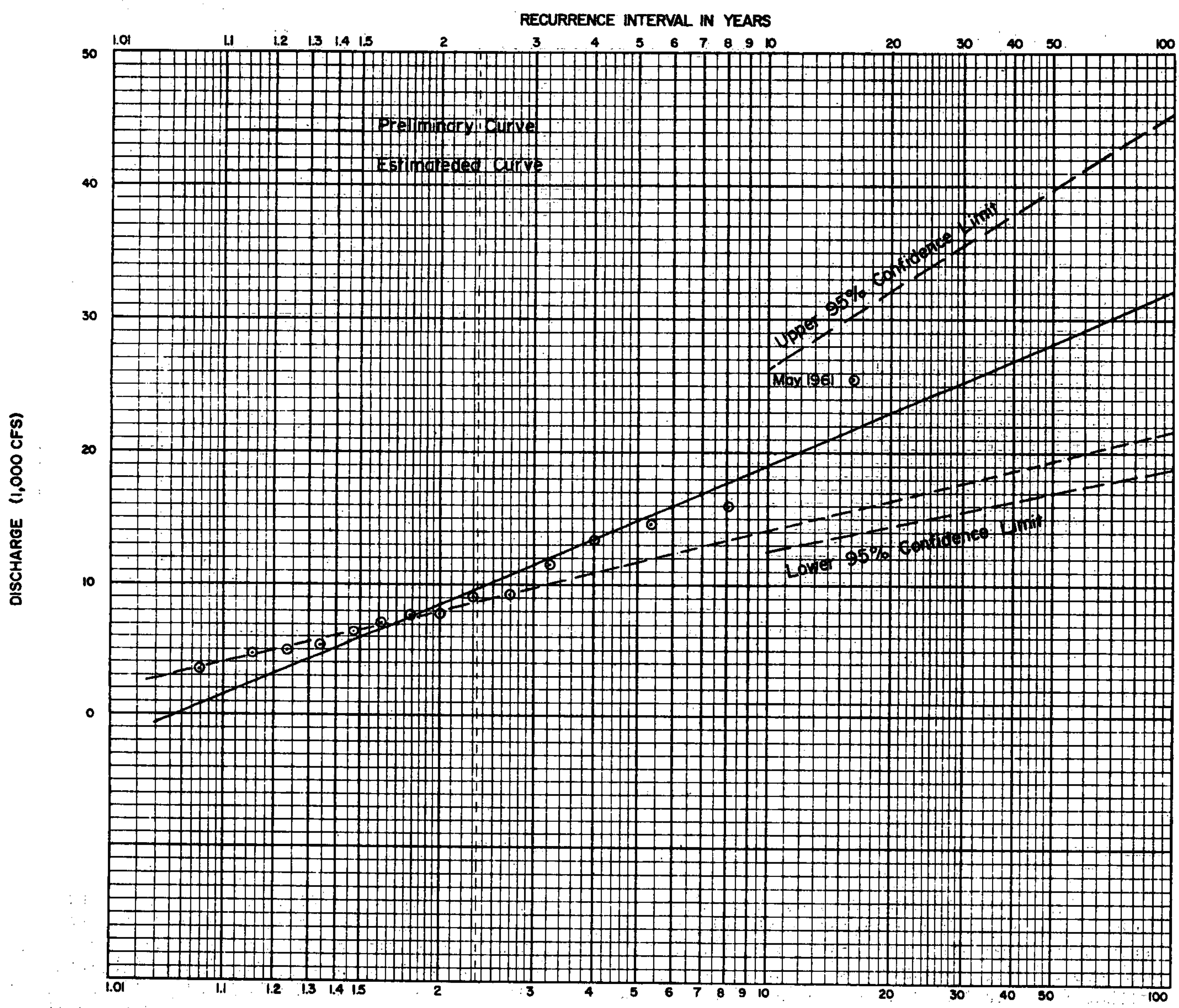

Figure 10. Flood frequency curves for Little Southwest Miramichi River at Lyttleton.

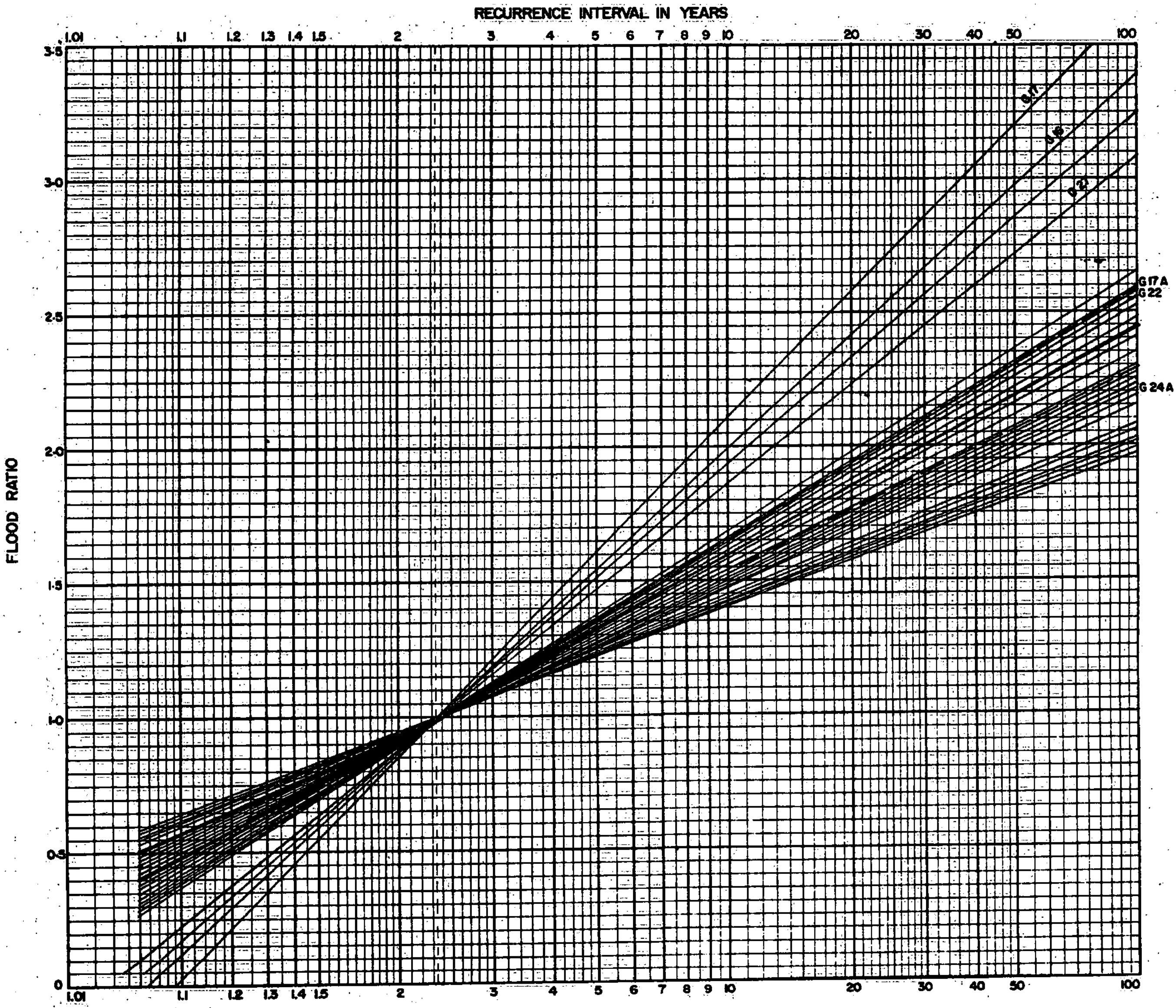

Figure 11. Single-station flood-frequency curves and regional curve

Thus a better definition of the regional curve might have been obtained if the preliminary curves had been weighted according to the periods of record before computation of their mean. A method for weighting the curves is not suggested in this report but it is mentioned as a possibility for future study.

4. The regional frequency curve in Figure 3 has been compared to those developed for the State of New York by the U.S. Geological Survey in co-operation with New York State (Robison, 1961). Curve "A" in the USGS study is applicable over almost all but the southeast corner of the State. It is almost identical to the curve

developed quite independently in this study, as shown in Figure 12. It can be seen that the curve for the New Brunswick region was developed by the Gumbel Method, which produces a straight line, yet it is in close agreement with the New York curve, which was developed according to methods described by Dalrymple (1960).

When the two areas are studied in a broader context, it is noted that they lie on a line which strikes northeast in a direction parallel to the usual path of the extra tropical storms common to that part of the continent. It is possible, therefore, that the regional curve may be applicable to a strip about 150 miles wide, south of the St. Lawrence River, reaching from Lake Erie to the Gaspé Peninsula.

A general equation for the mean annual flood was not developed in the New York study, and the basic data were not available in the preparation of this report with which to test the applicability of the mean annual flood equation over the broader area.

The similarity between the two regional curves is mentioned as a matter of interest and as a suggestion for possible future investigation. In the meantime, the mean annual flood equation and the regional frequency curve cannot be recommended for use outside the region considered in this report.

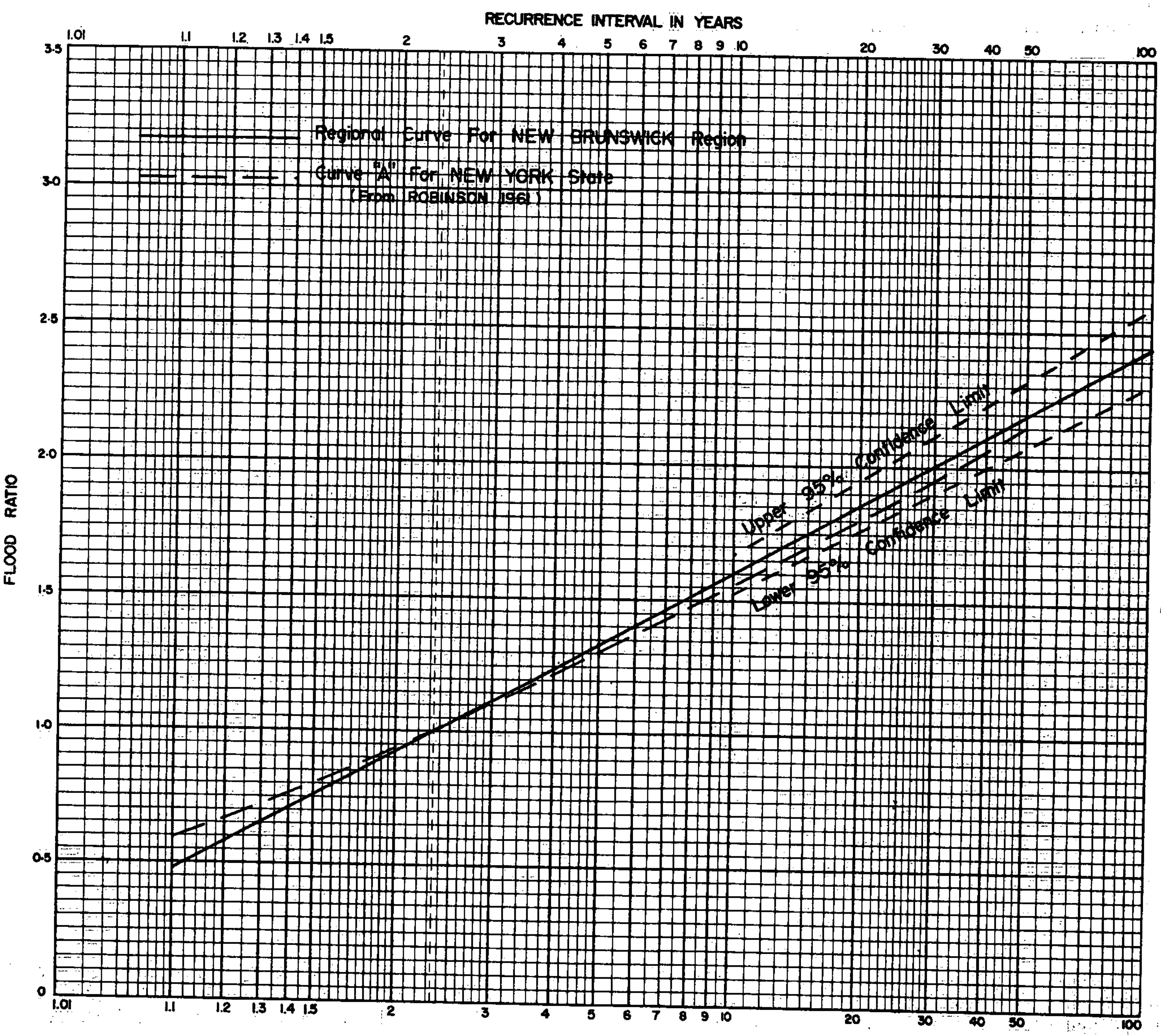

Figure 12. Regional flood frequency curves compared.

CONCLUSIONS

1. A flood frequency curve can be derived by the methods described in this report for an ungauged drainage basin in the region shown on Figure 1. Minor adjustments to the curve for characteristics peculiar to the basin may be necessary. Experience at gauging station sites may help the user to employ his judgement in this respect.

2. A flood frequency curve may also be constructed for a gauging station site without reference to the records available. This curve should be compared to that derived from the records, and the final curve selected from the comparison of the two results. The judgement of the user will have to be employed in weighing the alternatives. It will be found that the curve derived by the regional approach will be most useful when the period of record at the site is short.

3. The methods described are not recommended for drainage basins outside the range 80 to 6,000 square miles. Nor are they recommended for assessing frequency of floods having a recurrence interval of more than 100 years.

At this time it is not recommended that the regional curve be used outside the region indicated on Figure 1 although further investigation might demonstrate its validity over a broader region.

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No. 1 E. P. Collier and A. Coulson, October 1965. Natural flow of North Saskatchewan River at Alberta - Saskatchewan boundary by the rim station method. (OUT OF PRINT)

No. 2 R. O'N. Lyons, November 1965. LACOR - Program for streamflow correlation. (OUT OF PRINT)

No. 3 A. Coulson, 1966. Tables for computing and plotting flood frequency curves.

No. 4 A. Coulson, 1967. Flood frequencies of Nova Scotia streams.

Recorded flood flows have been analysed on a regional basis and a method for estimating the flood frequency curve for any stream in Nova Scotia is outlined.

No. 5 A. Coulson and P. N. Gross, 1967. Measurement of the physical characteristics of drainage basins.

Methods of obtaining quantitative descriptions of certain physical characteristics of drainage basins are outlined using as examples Marmot Creek and Streeter Creek, two of the experimental basins of the East Slopes (Alberta) Watershed Research Program.

No. 6 D. A. Davis and A. Coulson, 1967. Hydrologic zones in the headwaters of the Saskatchewan River.

The Saskatchewan River headwaters area of Alberta has been divided into seven by hydrologically similar zones, based on correlations of mean monthly recorded stream discharge.

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Methods of estimating the runoff and its distribution in ungauged streams or in streams with short periods of record in the area of Southern Ontario south of the Canadian shield.

No. 8 W. Q. Chin, 1967. Tables for computing and plotting drought frequency curves.

A compilation of tables for the computation and plotting of low flow frequency curves by both the third asymptotic distribution and the Pearson Type III distribution. Worked examples are included.

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