Progress report on

FLOOD MAGNITUDE AND FREQUENCY OF MASSACHUSETTS STREAMS

by

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ABSTRACT

A technique is presented for estimating the magnitude and frequency of floods on streams in Massachusetts with drainage areas between 0.25 and 497 square miles. Multiple regression techniques are used to define the relation between flood peaks, collected at a network of gaging stations maintained by the U.S. Geological Survey, and a set of basin characteristics. Results indicate that flood peaks may be estimated from knowledge of the drainage area, main channel slope, and mean annual precipitation of the basin. The relations are presented graphically for user convenience.

INTRODUCTION

The purpose of this investigation is to develop a useful technique for estimating the magnitude and frequency of floods on streams where flood flows are virtually natural. Flood magnitude is expressed in terms of a volume rate of flow (discharge) and in units of cubic feet per second (ft^3/s). Flood frequency is expressed in terms of recurrence interval, which is the average interval of time, in years, within which the given flood magnitude will be exceeded once. The relationship between flood recurrence interval and chance that the flood will be exceeded in a given period of years is discussed in Supplemental Data, p. 41.

This is the second status report on the study of flood frequency of small Massachusetts watersheds. An earlier report, "Flood magnitude and frequency of small Massachusetts streams, preliminary estimating relations" by Carl G. Johnson and G. Alan Laraway, was dated September 16, 1971. The investigation has been in progress since 1962 in cooperation with the Massachusetts Department of Public Works and the Federal Highway Administration.

Previous reports, Benson (1962), Green (1964), Knox and Johnson (1965), and Johnson (1970), have presented methods for estimating flood magnitude for various recurrence intervals. However, each of these methods was developed from data collected on large streams and is applicable only to streams draining more than 10 square miles (mi^2). The estimating relations in this report were developed from data collected on small streams (drainage area less than 10 square miles) over the past 10 years in addition to data collected on larger streams. Therefore, the relations presented herein apply to all streams in Massachusetts, except as noted in the section on ACCURACY AND LIMITATIONS.

ESTIMATING PROCEDURE

In general, the most reliable estimates of future flood flow magnitudes are obtained by frequency analysis of gaging records. Locations of gaging sites where flood records are of adequate length for frequency analysis are identified in table 3, p. 27; and the 2-, 5-, 10-, and 25-year flow magnitudes, as defined for each site, are shown in table 2, p. 26.

For ungaged sites, peak discharges P_2, P_5, P_{10}, P_{25}, P_{50}, and P_{100}: for recurrence intervals of 2, 5, 10, 25, 50, and 100, respectively, can be estimated by the following equations:

$$P_2 = 0.0645A^{0.816}S^{0.091}p^{4.59}$$

$$P_5 = 0.0795A^{0.831}S^{0.116}p^{4.67}$$

$$P_{10} = 0.102A^{0.852}S^{0.132}p^{4.60}$$

$$P_{25} = 0.144A^{0.885}S^{0.155}p^{4.43}$$

$$P_{50} = 0.193A^{0.911}S^{0.171}p^{4.27}$$

$$P_{100} = 0.260A^{0.940}S^{0.187}p^{4.08}$$

in which,

A is drainage area, in square miles,

p is mean annual precipitation, in feet of water, and S is main channel slope, in feet per mile.

Detailed explanation of how these characteristics are evaluated is given in table 5, p. 37-38.

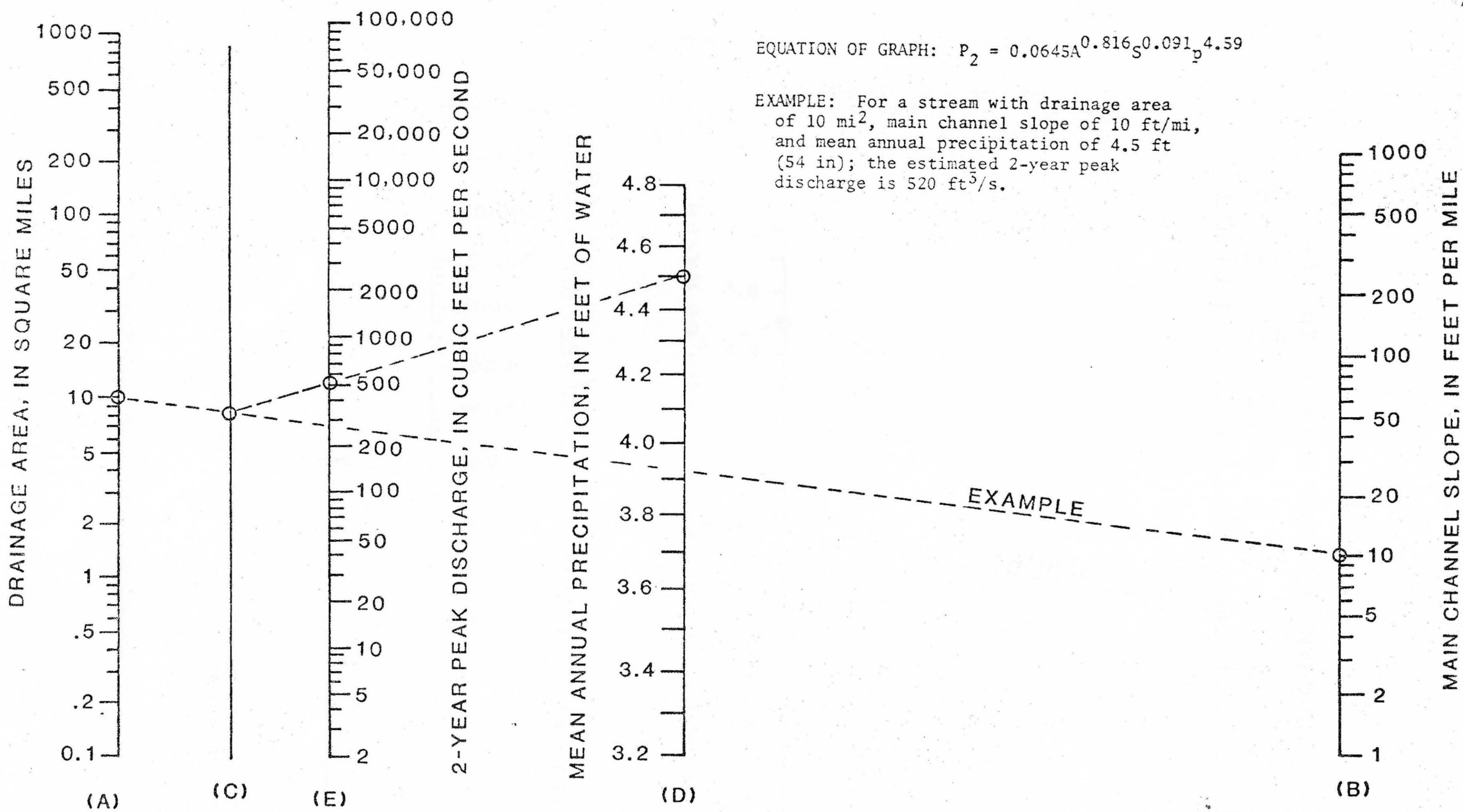
These estimating relations can also be presented graphically. The 2-, 5-, 10-, 25-, 50-, and 100-year peak discharges can be estimated from the nomographs, or alignment charts, shown in figures 1 through 6, respectively. The procedure for estimating peaks from nomographs is as follows:

(1) Locate the value of the appropriate basin characteristic on scales (a), (b), and (d). For a detailed explanation of how these characteristics are determined, see table 5, p. 37.

(2) Draw a straight line between the values on scales (a) and (b).

(3) From the intersection of this line (step 2) with scale (c), draw a straight line to the value of the basin characteristic on scale (d).

(4) The estimated peak discharge is determined at the point of intersection of this line (step 3) with scale (e).



EQUATION OF GRAPH: $P_2 = 0.0645A^{0.816}S^{0.091}P^{4.59}$

EXAMPLE: For a stream with drainage area of 10 mi^2, main channel slope of 10 ft/mi, and mean annual precipitation of 4.5 ft (54 in); the estimated 2-year peak discharge is 520 ft^3/s.

FIGURE 1. -- NOMOGRAPH FOR ESTIMATING P_2

EQUATION OF GRAPH: $P_5 = 0.0795A^{0.831}S^{0.116}P^{4.67}$

EXAMPLE: For a stream with drainage area of 10 sq mi, main channel slope of 10 ft/mi, and mean annual precipitation of 4.5 ft (54 in), the estimated 5-year peak discharge is 790 ft^3/s.

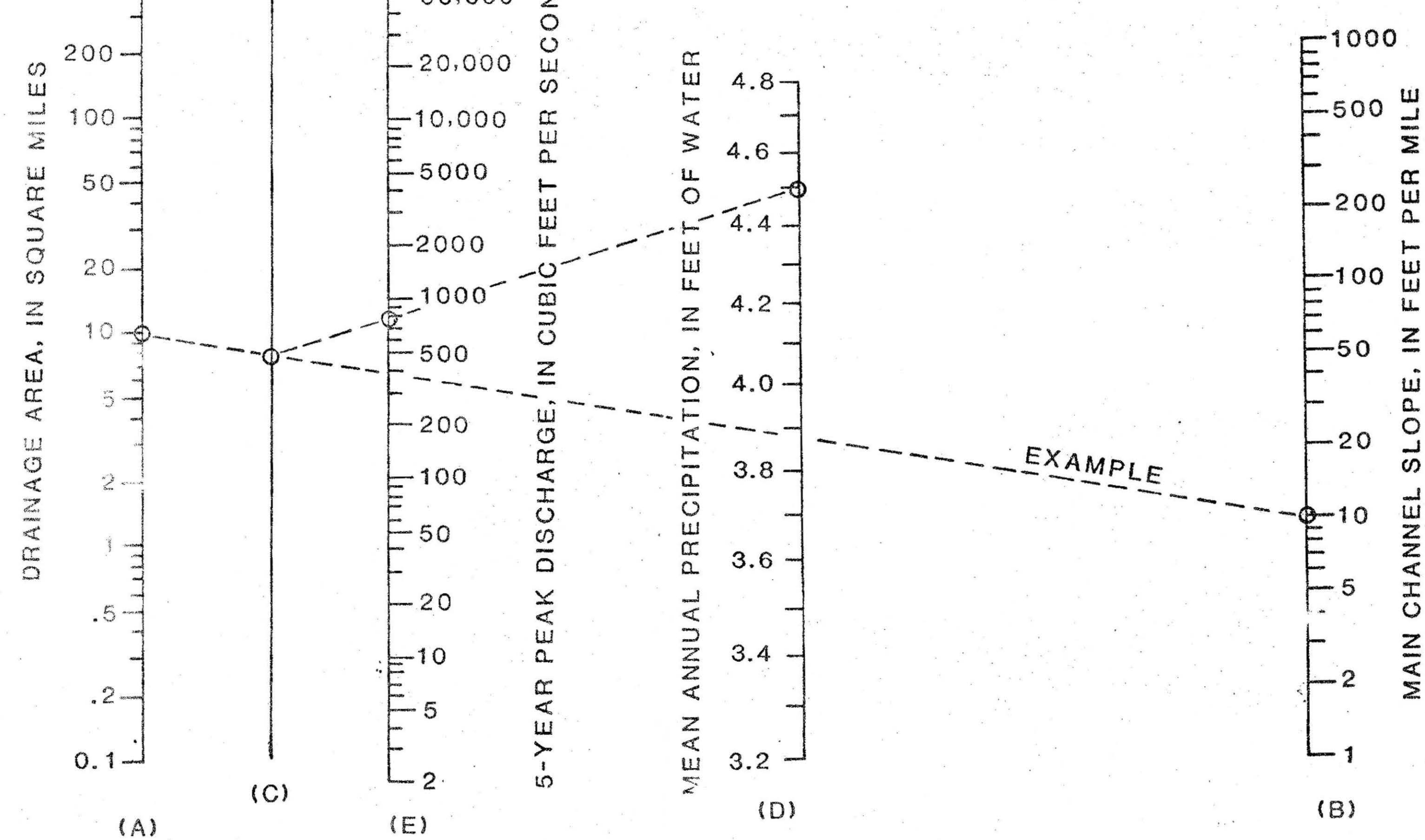


FIGURE 2. -- NOMOGRAPH FOR ESTIMATING P_5

EQUATION OF GRAPH: $P_{10} = 0.102A^{0.852}S^{0.132}P^{4.60}$

EXAMPLE: For a stream with drainage area of 10 sq mi, main channel slope of 10 ft/mi, and mean annual precipitation of 4.5 ft (54 in), the estimated 10-year peak discharge is 990 ft^3/s.

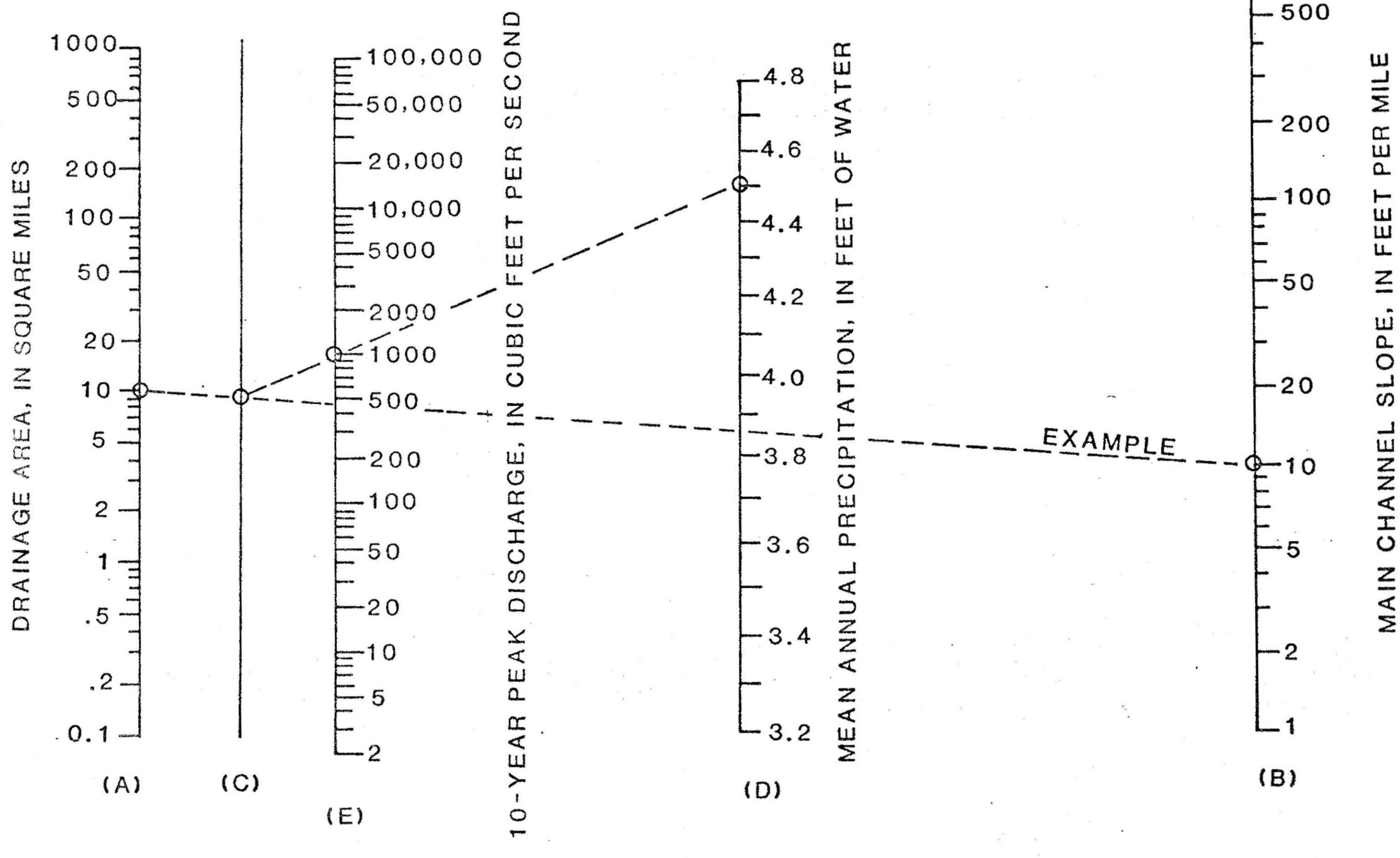


FIGURE 3. -- NOMOGRAPH FOR ESTIMATING P_{10}

EQUATION OF GRAPH: $P_{25} = 0.144 A^{0.885} S^{0.155} P^{4.43}$

EXAMPLE: For a stream with drainage area of 10 sq mi, main channel slope of 10 ft/mi, and mean annual precipitation of 4.5 ft (54 in), the estimated 25-year peak discharge is 1,200 ft^3/s.

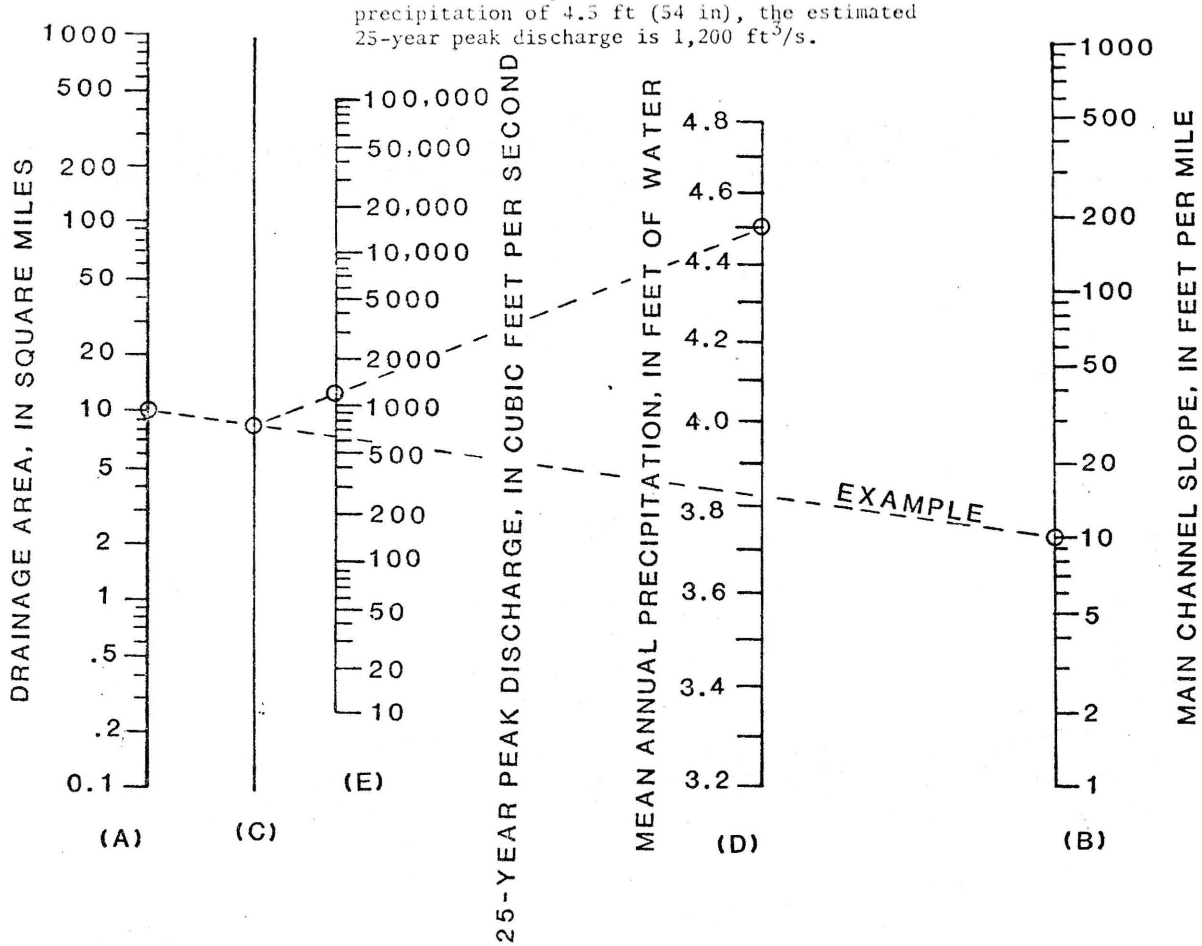


FIGURE 4. -- NOMOGRAPH FOR ESTIMATING P_{25}

EQUATION OF GRAPH: $P_{50} = 0.193A^{0.911}S^{0.171}P^{4.27}$

EXAMPLE: For a stream with drainage area of 10 sq mi, main channel slope of 10 ft/mi, and mean annual precipitation of 4.5 ft (54 in), the estimated 50-year peak discharge is 1,400 ft^3/s.

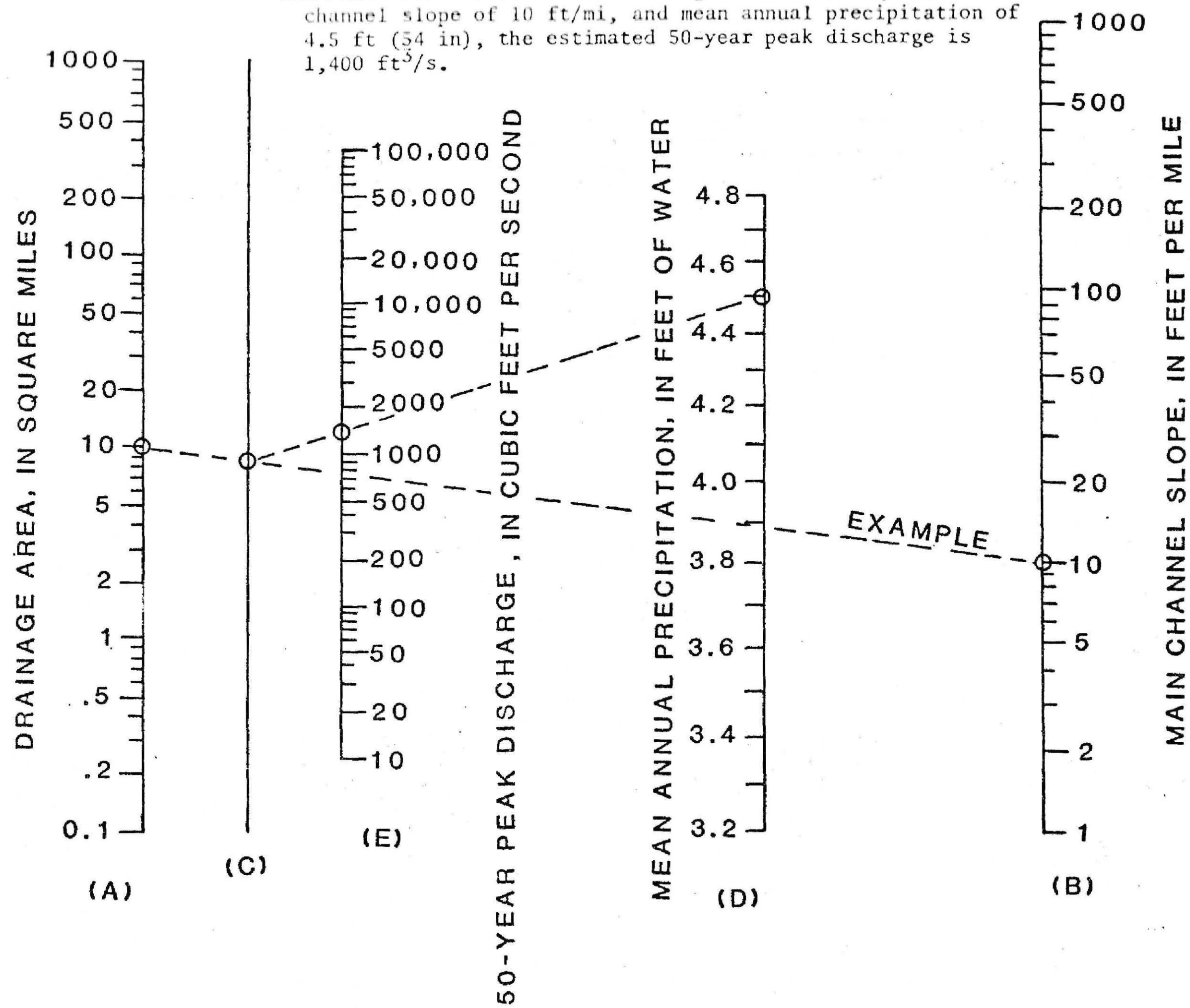


FIGURE 5. -- NOMOGRAPH FOR ESTIMATING P_{50}

EQUATION OF GRAPH: $P_{100} = 0.260A^{0.940}S^{0.187}P^{4.08}$

EXAMPLE: For a stream with drainage area of 10 mi^2, main channel slope of 10 ft/mi, and mean annual precipitation of 4.5 ft (54 in), the estimated 100-year peak discharge is 1,600 ft^3/s.

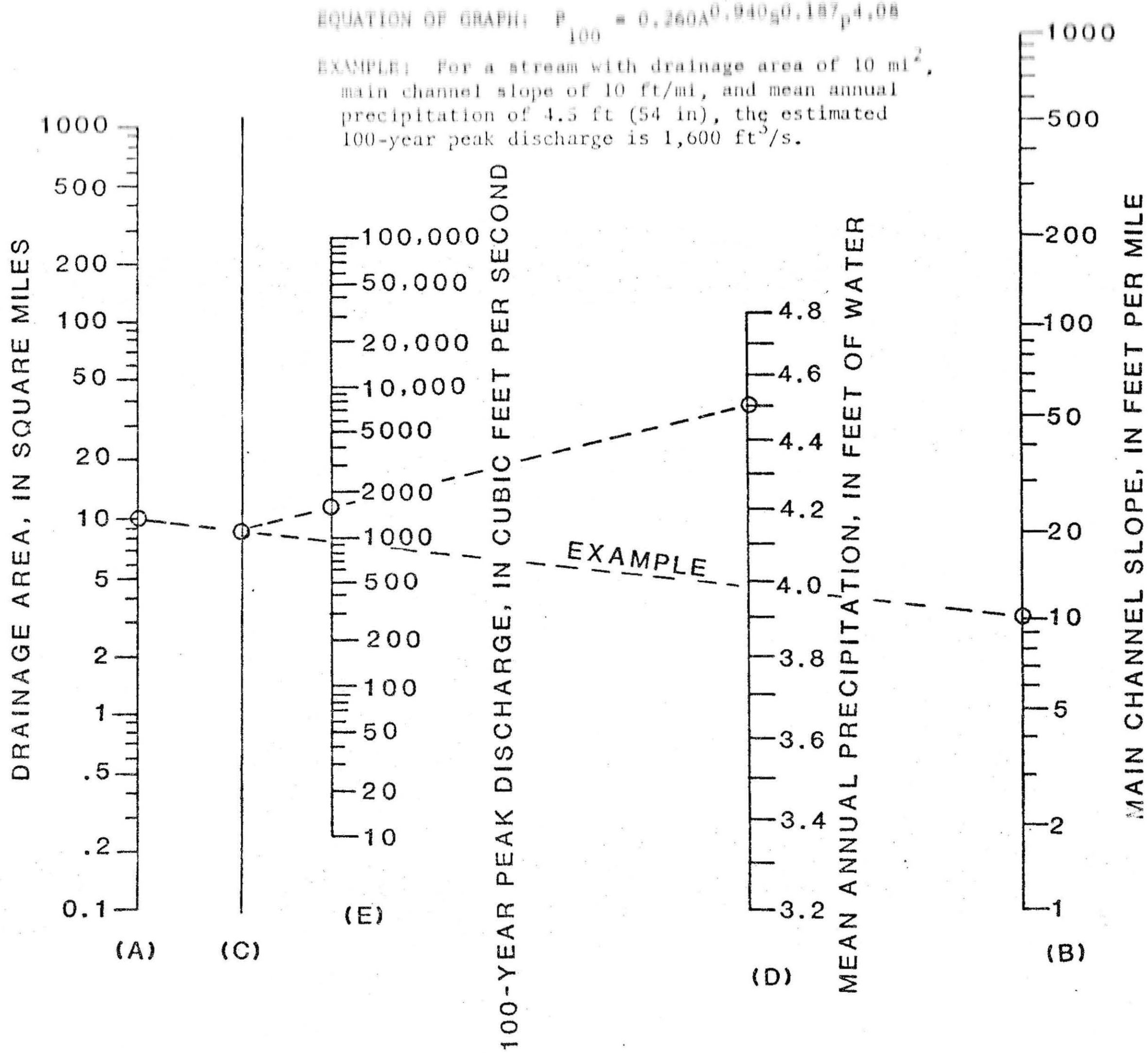


FIGURE 6. -- NOMOGRAPH FOR ESTIMATING P_{100}

ACCURACY AND LIMITATIONS

Standard error of estimate (table 1) is a measure of how well the flood peaks experienced agree with those computed by the estimating relations. Approximately two out of three sites with flood records had estimated peak discharge values within one standard error of estimate of the observed value, and approximately 19 out of 20 had values within two standard errors of estimate. Peak discharges determined from the frequency curves at each site for the 50- and 100-year recurrence intervals plotted against those determined from the estimating relations are shown in figures 7 and 8, respectively.

Table 1.--Standard error of estimate of equations on page 3 for given flood peak.

Flood peak	Standard error of estimate, in percent
P_2	45
P_5	47
P_{10}	51
P_{25}	59
P_{50}	65
P_{100}	73

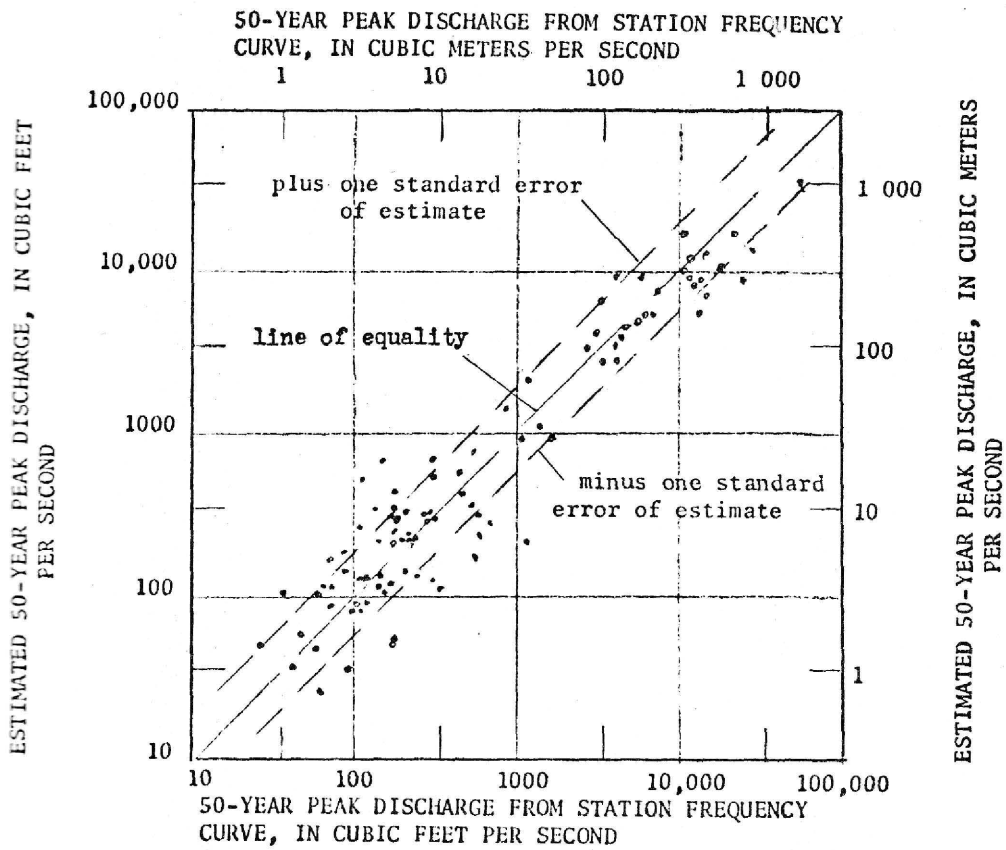


Figure 7. -- Graph of observed and estimated 50-year peak discharges

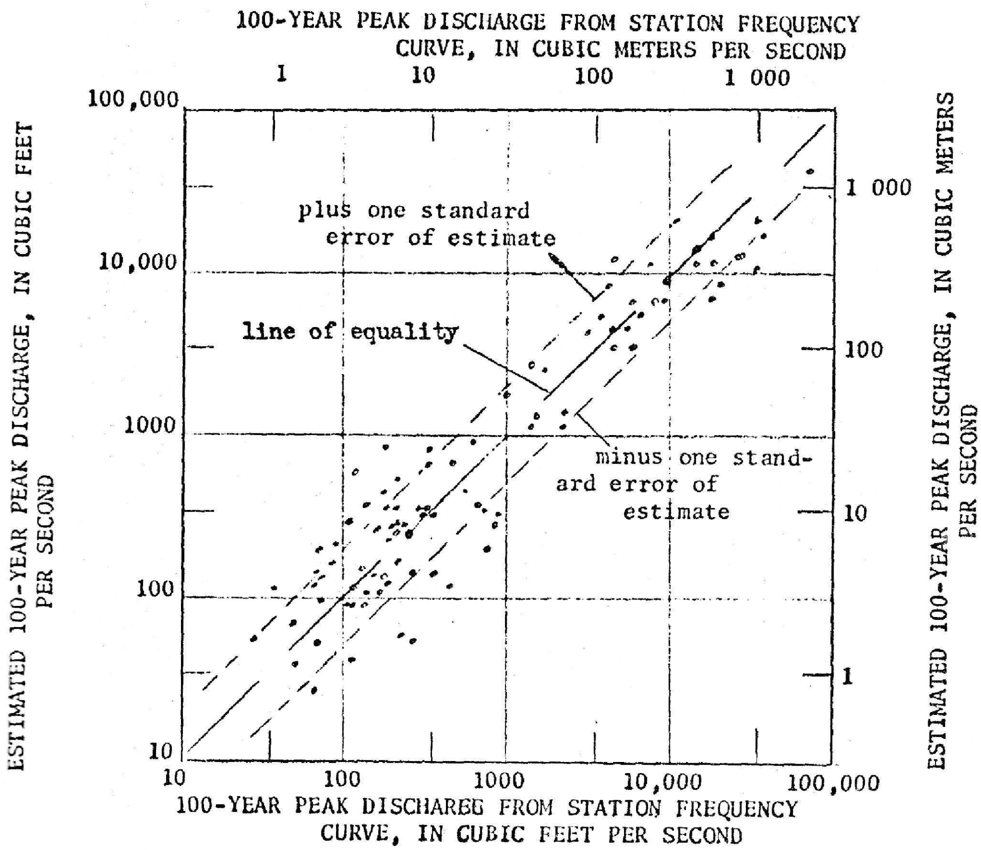


Figure 8. -- Graph of observed and estimated 100-year peak discharges

Applicability of empirical relations of this type to a site is dependent on similarity of the basin characteristics above the site to those of the basins on which the relations are based. Consequently, the relationships developed apply only to those largely rural, unregulated streams in Massachusetts whose basin characteristics fall within the range of values given in table 2. (The highest and lowest values of each basin characteristic in table 2 are underscored.) For example, the relationships do not apply to streams with drainage areas less than 0.25 mi^2 or more than 500 mi^2.

In addition, the estimating relations do not apply to streams on Cape Cod or in the eastern part of Plymouth County. Because the relatively high infiltration and storage capacities of these basins are not adequately represented in the data collection network, it is expected that the estimating relations would significantly over estimate the peak discharges in that area.

ANALYTICAL TECHNIQUE

Data-collection Network

Annual maximum discharges determined for at least 7 consecutive years at 92 stations in Massachusetts and in Vermont and Rhode Island near the Massachusetts border were used in this analysis (figure 9 and table 3). The drainage area above 60 of these stations is less than 10 square miles. The remaining 32 stations were selected from the network of gaging stations maintained by the U.S. Geological Survey in Massachusetts. Only those stations where the effect of regulation on the annual peak was considered to be minimal (Johnson, 1970, p. A2-A6) were selected for this analysis.

Determination of Flood Frequency at Data-collection Stations

A flood-frequency curve for each gaging station was prepared using methods recommended by the Hydrology Committee, Water Resources Council (1967). A sample curve is shown in figure 10. From these curves, peak discharges P_2, P_5, P_{10}, P_{25}, P_{50}, and P_{100} were determined for recurrence intervals of 2, 5, 10, 25, 50, and 100 years, respectively.

Determination of Basin Characteristics

Multiple regression techniques were used to develop estimating relations by relating each peak discharge (P_2, P_5, P_{10}, P_{25}, P_{50}, and P_{100}) to a set of physical and meteorological characteristics of the stream's drainage basin. Twelve basin characteristics which logically could have at least an indirect effect on peak discharges were selected for use as independent variables. The basin characteristics selected were:

A, drainage area, in square miles,

S, slope of stream, in feet per mile,

L, length of stream, in miles,

St, area of lakes and ponds, in percent of drainage area,

E, mean basin elevation, in thousands of feet above mean sea level,

F, forested area, in percent of drainage area,

P, mean annual precipitation, in feet of water,

$I_{24,2}$, precipitation intensity for 24 hours at 2-year recurrence interval in inches,

T, mean minimum January temperature, in °F,

Sn, mean annual snowfall, in inches,

Si, soils index, in inches,

and Sh, shape factor, ratio of average basin width to length.

For a more detailed explanation of how these characteristics are determined, see table 6, p. 40.

Determination of Estimating Relations

The relation between each peak discharge (dependent variable) and the set of basin characteristics (independent variables) was developed by step-forward multiple-regression techniques. In step-forward multiple regression, a sequence of multiple linear regression equations are computed by adding one independent variable at each step. The variable added is the one which makes the greatest reduction in standard error of estimate of the regression equation. Objective statistical tests in the regression techniques are helpful in determining which basin characteristics should be retained in the final estimating relations and provide insight as to their relative importance to the relations.

These multiple-regression techniques require linearity between the dependent and independent variables. Previous studies relating flood peaks to basin characteristics, Benson (1962), Knox and Johnson (1965), Thomas and Benson (1970), and Johnson (1970), have shown that the logarithms of flood peaks are linearly related to the logarithms of basin characteristics. Therefore, all data were transformed into logarithms to satisfy the requisite of linearity before the regression analysis was performed.

The results of this type analysis are summarized by the following equations, in which the basin characteristics listed are the only ones that were shown to be statistically significant.

	Standard error of estimate, in percent
$P_2 = 0.197A^{0.831}St^{0.198}p^{4.71}Si^{0.642}$	43
$P_5 = 0.290A^{0.857}S^{0.098}St^{-0.134}p^{4.37}Si^{0.577}$	46
$P_{10} = 0.102A^{0.852}S^{0.132}p^{4.60}$	51
$P_{25} = 0.144A^{0.855}S^{0.155}p^{4.43}$	59
$P_{50} = 0.193A^{0.911}S^{0.171}p^{4.27}$	65
$P_{100} = 0.260A^{0.940}S^{0.187}p^{4.08}$	73

For the final estimating relations, the regressions for P_2 and P_5 were re-run with only independent variables A, S, and p so that all equations would contain common variables. In these regressions, all three independent variables were found to be statistically significant at greater than the 95 percent level. The resulting equations (page 3) show a slightly higher standard error of estimate (45 percent and 47 percent, respectively) than that computed using all of the independent variables. However, the added convenience for the user of the relations was judged to outweigh the slight increase in error.

DISCUSSION

The period of record of annual peaks on most of the small streams necessarily is relatively short (about 10 years). Therefore, it contains time sampling errors, or errors that result from estimating future events (especially the less frequently occuring flood peaks, P_{25}, P_{50}, and P_{100}) from a past record that is not representative of future occurrences. Some errors of this type are preserved in the estimating relations and, in general, mask the underlying relation between flood peaks and basin characteristics. Consequently, improvement in the estimating relations would be expected by obtaining a more representative sample.

One means of obtaining a more representative sample is by relating rainfall, for which there is a longer period of record, to flood peaks by a watershed model incorporating the physics of the process by which rainfall and floods are related. Another means is to observe annual peaks for an additional period of time.

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_____1959, Rainfall intensity-frequency regime, northeastern United States: U.S. Weather Bureau Technical Paper no. 29, 35 p.

SUPPLEMENTAL DATA

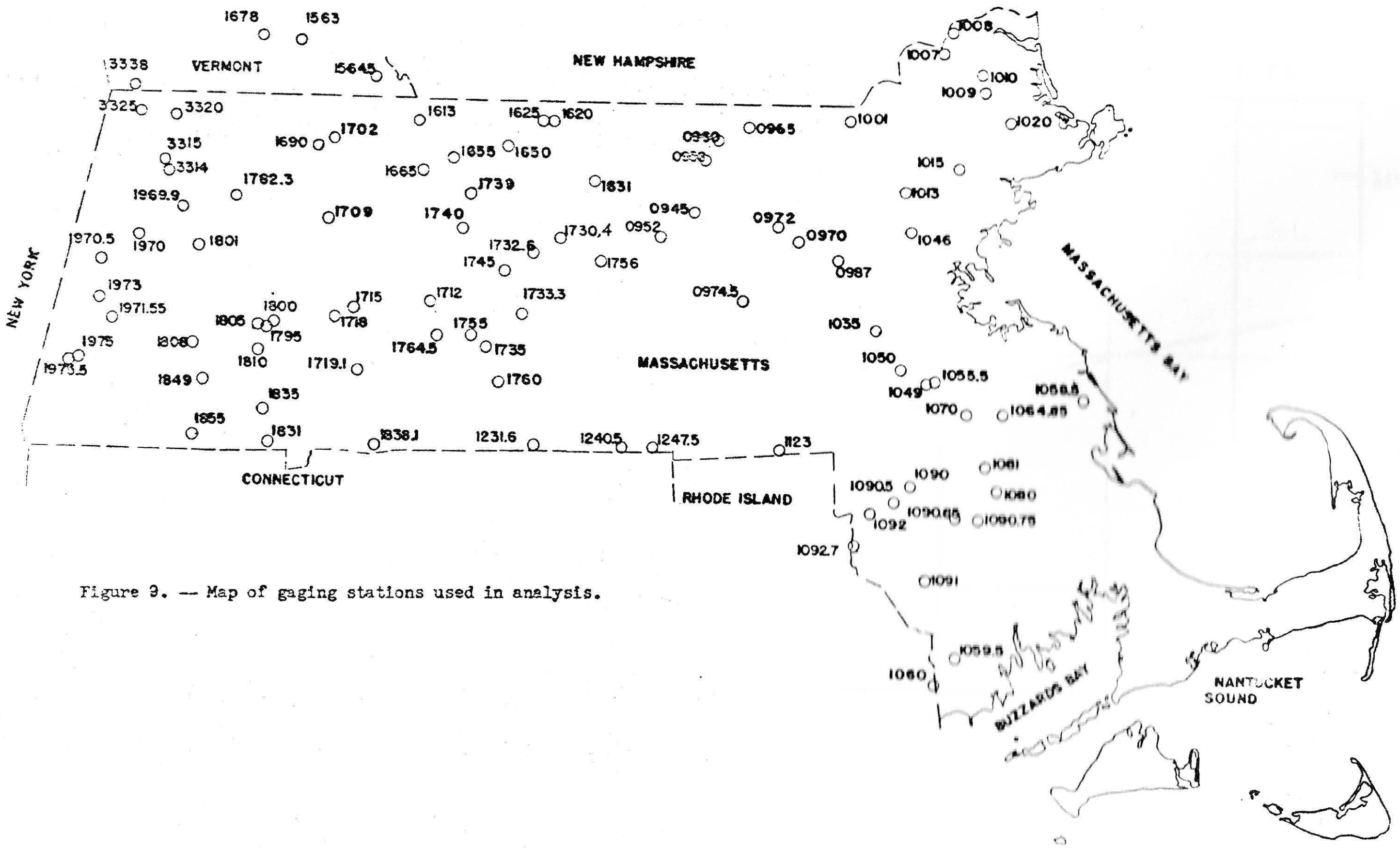

Figure 9. -- Map of gaging stations used in analysis.

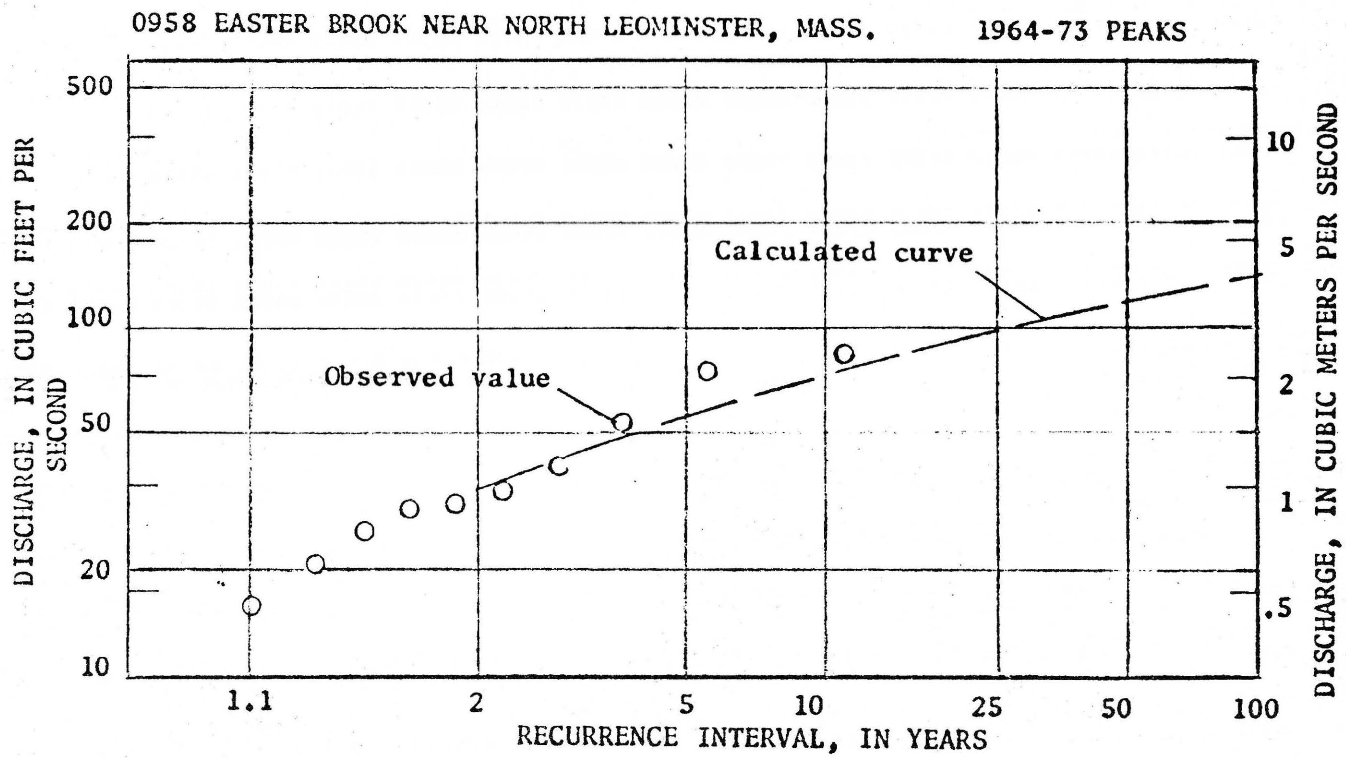

FIGURE 10 -- SAMPLE FLOOD FREQUENCY CURVE.

Table 2.--Hydrologic and basin characteristics
(Maximum and minimum values of each basin characteristic are underscored.)

Station number	Drainage area (mi²)	Slope (ft/mi)	Length (mi)	Area of ponds (percent +0.5)	Basin elevation (thousands of feet above msl)	Forest cover (percent +1)	Mean annual precipitation (feet of water)	Maximum 24-hour rainfall at 2-year recurrence interval (inches)	Mean minimum January temperature (°F+1)	Average seasonal snowfall (inches)	Soils index (inches)	Shape factor	Peak discharges for indicated recurrence interval (cubic feet per second): 2-year	5-year	10-year	25-year	Maximum discharge for period of record (ft³/s)	Date	Period of record
945.00	107	40.7	22.7	3.60	0.87	73	3.74	3.20	15	65	5.20	0.21	2,100	4,190	6,430	10,700	16,300	3-18-36	1935-72
957.00	.69	27.8	1.20	.50	.55	66	3.67	3.00	17	60	5.30	.48	18.9	29.1	35.2	42.1	34.0	3-18-68	1964-73
958.00	.92	114.3	1.40	.50	.47	51	3.50	3.00	17	60	5.70	.47	35.2	56.3	73.0	97.5	85.0	3-18-68	1964-73
960.00	62.8	43.55	15.0	1.70	.65	90	3.58	3.00	14	63	6.00	.28	1,230	2,070	2,680	3,470	4,010	10-16-55	1945-72
965.00	316	10.0	49.5	4.21	.65	76	3.63	3.00	15	62	5.40	.13	3,220	5,300	7,300	10,800	20,900	3-26-36	1935-72
970.00	116	5.86	24.1	2.27	.35	77	3.52	2.90	18	55	4.40	.20	1,010	1,460	1,880	2,530	4,250	8-20-55	1941-72
972.00	3.89	12.1	5.50	1.50	.29	75	3.50	3.00	18	55	4.40	.13	46.6	79.3	105	141	156	3-18-68	1964-73
974.50	1.11	133.3	2.40	.50	.50	62	3.67	3.25	18	50	4.20	.19	26.4	37.6	46.0	57.6	53.0	3-23-72	1964-73
987.00	2.32	19.7	1.10	.94	.18	62	3.50	3.00	19	50	4.20	1.92	33.8	[illegible]	62.1	75.6	74.0	3-18-68	1964-73
1001.00	4.32	50.0	2.80	.51	.17	59	3.33	3.00	18	60	3.80	.55	134	175	191	203	186	3-18-68	1963-73
1007.00	4.93	18.4	2.90	1.33	.14	75	3.33	3.00	18	55	3.80	.59	99.5	174	264	429	480	4- 2-73	1963-73
1008.00	.77	64.8	1.40	.50	.21	82	3.33	3.00	18	55	4.20	.39	49.7	77.4	102	144	117	3-18-68	1963-73
1009.00	.65	11.1	1.20	19.9	.10	86	3.42	3.00	20	55	3.90	.45	18.8	36.1	50.8	73.2	76.0	3-18-68	1964-73
1010.00	21.6	6.23	10.9	3.19	.12	71	3.39	3.20	20	55	3.90	.18	203	302	374	474	489	3-19-68	1945-72
1013.00	3.99	23.5	3.70	1.75	.14	64	3.42	3.00	20	60	4.00	.29	54.6	83.1	102	127	119	3-19-68	1963-73
1015.00	43.4	5.10	11.5	1.49	.11	72	3.40	3.20	21	60	4.00	.33	360	513	623	770	833	3-19-68	1938-72
1020.00	124	2.50	27.2	1.86	.13	75	3.40	2.90	21	55	4.00	.17	1,010	1,510	1,870	2,320	2,680	3-20,21-68	1930-72
1035.00	184	4.47	41.2	2.16	.23	73	3.58	3.20	19	50	4.60	.11	1,100	1,640	2,170	2,800	3,220	8-23-55	1937-72
1046.00	4.09	21.0	3.80	.99	.23	20	3.50	3.00	20	50	3.40	.28	141	182	203	223	212	3-18-68	1963-73
1049.00	1.52	53.50	2.50	1.21	.28	15	3.58	3.25	19	45	4.00	.24	30.5	50.7	66.8	90.4	96.0	3-18-68	1964-73
1050.00	35.2	23.8	11.0	3.88	.21	73	3.63	3.30	20	46	4.30	.29	292	460	629	932	1,490	8-19-55	1939-72
1055.50	1.52	88.1	2.60	1.18	.17	35	3.58	3.25	18	45	4.00	.22	131	160	176	194	178	3-18-68	1964-73
1058.50	1.61	2.50	2.70	.50	.16	96	3.67	3.25	22	40	5.60	.22	40.3	62.7	76.6	92.7	75.0	9- 3-72	1964-73
1059.50	3.69	38.1	3.20	.50	.14	71	3.58	3.25	24	30	3.80	.36	139	264	374	548	378	3-18-68	1964-73
1060.00	7.91	32.2	6.00	.62	.14	86	3.58	3.40	22	30	3.80	.24	152	206	240	281	316	12-27-69	1940-72
1064.85	1.04	49.4	1.22	.50	.11	54	3.58	3.25	21	40	3.60	.69	49.4	61.0	66.0	70.4	64.0	3-25-69	1967-73
1070.00	4.67	33.3	5.80	2.20	.19	69	3.58	3.25	20	40	3.60	.14	107	193	272	401	359	3-18-68	1963-73
1080.00	260	4.84	28.7	4.70	.10	73	3.63	3.30	21	37	4.30	.32	2,250	2,920	3,350	3,890	4,980	3-20-68	1929-73
1081.00	1.41	30.3	2.20	.89	.08	89	3.58	3.25	21	40	4.00	.29	45.8	102	159	257	153	3-18-68	1964-73
1090.00	42.4	10.7	16.3	1.11	.20	85	3.63	3.20	19	40	4.50	.16	436	634	793	1,030	1,460	3-19-68	1925-73
1090.50	.50	13.5	.99	.50	.09	81	3.58	3.25	20	40	4.50	.51	14.5	21.0	26.4	34.7	31.0	12-27-69	1964-73
1090.75	1.16	33.3	2.00	3.69	.14	85	3.58	3.25	20	36	3.30	.29	51.7	74.1	89.8	111	86.0	3-18-68	1967-73
1090.85	1.94	16.4	2.43	.52	.09	79	3.58	3.25	20	37	4.41	.33	128	177	202	229	190	3-18-68	1967-73
1091.00	.25	69.6	1.10	.50	.18	44	3.58	3.25	22	35	4.40	.21	44.9	52.5	56.2	60.0	55.0	3-25-68	1964-73
1092.00	4.96	17.5	3.40	.91	.15	82	3.58	3.25	20	35	4.70	.43	148	246	331	463	441	3-18-68	1963-73
1092.70	4.24	11.1	4.20	.74	.09	54	3.58	3.50	21	39	4.15	.24	101	123	140	164	155	3-18-68	1967-73
1123.00	2.66	36.3	2.60	2.00	.33	66	3.75	3.50	19	50	5.90	.39	90.0	134	162	194	188	3-18-68	1964-73
1231.60	.71	179	1.20	.70	.92	94	3.83	3.25	15	55	5.20	.49	24.8	36.1	44.0	54.2	52.0	2- 4-70	1964-73
1240.50	1.06	169	1.10	.50	.69	56	3.50	3.25	16	50	4.60	.88	49.2	76.3	96.5	125	106	2- 4-70	1963-73
1247.50	.49	182	.99	.65	.78	95	3.50	3.50	17	50	5.20	.50	13.1	33.7	59.2	114	125	3-18-68	1963-73
1563.00	1.05	66.7	1.60	.50	1.62	76	3.83	3.00	12	80	4.80	.41	88.7	152	199	266	230	7-29-69	1963-73
1564.50	1.12	122	2.40	.50	.60	83	3.58	3.00	13	70	5.10	.19	44.8	70.5	90.6	120	128	4-25-70	1964-73
1613.00	2.33	330	2.70	.83	.90	89	3.67	3.00	13	60	4.40	.32	87.3	134	174	235	218	4-25-68	1964-73
1620.00	83.0	19.6	14.2	4.99	1.11	82	3.71	2.90	12	65	5.30	.41	975	1,620	2,280	3,500	8,500	9-22-38	1916-72
1625.00	19.4	27.2	11.8	1.84	1.11	86	3.60	3.00	12	65	5.30	.14	353	626	884	1,330	3,000	9-21-38	1916-72
1631.00	2.50	38.5	4.00	.71	1.10	94	3.50	3.25	14	65	4.60	.16	42.6	53.1	58.8	64.9	56.0	3-23-72	1964-73
1650.00	50.4	51.9	12.8	2.31	1.06	82	3.51	3.00	12	62	6.40	.31	715	1,200	1,630	2,500	5,140	9-21-38	1915-72
1655.00	17.3	58.1	7.20	1.56	.87	95	3.71	3.00	13	60	4.80	.24	255	443	604	857	1,540	3-19-36	1916-72
1665.00	375	17.7	42.8	2.83	.99	81	3.59	2.80	12	58	5.30	.20	4,230	6,980	10,100	16,300	29,000	9-22-38	1914-72
1678.00	6.38	88.9	4.60	.50	1.94	87	4.17	3.00	11	90	4.70	.30	407	702	963	1,380	1,130	6-30-73	1964-73
1690.00	88.4	65.6	21.0	.67	1.44	82	4.06	3.10	12	82	4.30	.20	3,480	5,490	7,230	9,980	13,200	10-15-55	1939-72
1702.00	.73	81.1	.99	.50	.88	66	3.75	3.25	13	70	4.30	.74	25.2	46.4	62.6	84.8	89.0	4-25-68	1964-73
1709.00	6.37	134	7.00	.63	.55	69	3.75	3.25	15	60	4.50	.13	140	208	245	284	300	4- 3-70	1963-73
1712.00	2.92	266	2.70	.70	.83	94	3.67	3.50	16	55	4.60	.40	71.6	92.7	105	119	125	2- 3-73	1963-73
1715.00	52.8	94.8	16.4	1.31	.87	77	3.90	3.20	16	55	3.60	.20	1,930	3,100	3,870	4,780	6,300	8-19-55	1938-72
1718.00	5.56	39.9	4.20	.77	.40	74	3.83	3.50	16	50	5.40	.32	65.5	85.2	95.7	107	98.0	6-30-73	1963-73
1719.00	2.26	80.6	4.60	1.02	.46	54	3.83	3.50	17	50	4.30	.11	67.3	83.1	91.4	100	88.0	4- 3-70	1965-73
1730.40	1.11	102	2.30	.64	.94	64	3.67	3.25	14	60	4.20	.21	36.4	49.0	56.0	63.7	62.0	6-30-73	1965-73
1732.60	4.54	67.9	1.80	1.43	1.04	72	3.58	3.25	14	60	4.20	1.40	75.9	109	130	155	140	6-30-73	1963-73
1733.30	1.01	122	2.10	.50	.88	37	3.58	3.50	14	55	4.20	.23	37.3	56.9	71.3	90.9	79.0	6-30-73	1963-73
1735.00	199	15.5	38.9	1.71	.91	61	3.62	3.20	15	57	4.60	.13	1,990	3,480	5,230	8,880	22,700	9-21-38	1912-72
1739.00	4.73	118	4.00	.60	.91	86	3.67	3.00	14	55	5.30	.30	89.9	123	145	173	160	4- 3-70	1964-73
1740.00	3.39	68.2	5.85	.50	1.02	85	3.71	3.20	14	60	5.30	.10	144	208	241	274	289	10-24-59	1947-72
1745.00	43.7	38.2	14.3	2.83	.91	75	3.67	3.20	15	60	5.30	.21	584	1,090	1,660	2,800	6,780	9-21-38	1937-72
1755.00	183	11.8	26.0	1.60	.80	70	3.70	2.90	14	58	5.30	.28	1,660	2,530	3,350	4,730	7,590	3-19-36	1912-72
1756.00	2.35	72.7	2.20	.50	1.00	89	3.67	3.00	16	60	4.10	.49	84.4	123	151	191	163	3-18-68	1964-73
1760.00	151	8.62	28.3	3.27	.84	60	3.46	3.20	16	55	4.10	.19	1,020	1,640	2,420	4,130	12,800	8-19-55	1912-72
1764.50	2.77	77.9	2.70	.50	.55	67	3.83	3.50	16	55	5.00	.38	99.2	145	169	193	185	4- 3-70	1963-73
1782.30	4.47	56.4	2.60	.54	1.68	89	4.00	3.25	12	65	4.00	.66	158	260	320	385	292	6- 1-72	1964-73
1795.00	162	41.7	32.6	.77	1.47	70	3.97	3.20	12	65	4.00	.15	6,330	11,000	15,400	22,900	37,900	9-21-38	1909-72
1800.00	1.64	118	3.82	.93	1.11	80	3.67	3.70	12	65	4.00	.11	53	114	186	341	680	8-19-55	1945-72
1801.00	2.07	40.6	2.13	.50	1.97	89	4.17	3.25	12	65	3.96	.46	117	167	201	246	230	4-23-69	1967-73
1805.00	52.6	79	19.5	.51	1.42	66	4.01	3.20	12	65	4.00	.14	2,760	4,900	7,030	10,800	19,900	9-21-38	1910-72
1808.00	3.01	138	3.30	.59	1.57	95	3.92	3.25	12	65	3.80	.28	115	192	257	359	299	6- 1-72	1963-73
1810.00	93.7	54.9	21	1.02	1.42	87	3.96	3.20	12	65	4.00	.21	4,070	7,820	11,600	18,400	26,100	8-19-55	1935-72
1831.00	.66	311	1.40	.50	.96	62	4.00	3.50	16	55	5.50	.34	34.8	64.5	86.6	116	105	2- 3-73	1964-73
1835.00	497	28.8	53.9	1.14	1.20	79	3.98	3.40	12	62	4.20	.17	13,800	23,000	31,500	45,300	70,300	8-19-55	1914-72
1838.10	4.15	43.8	4.40	.99	.15	68	3.58	3.50	18	50	5.60	.21	65.7	91.5	112	141	130	2- 3-73	1963-73
1849.00	.26	64.8	.72	11.4	1.61	83	4.17	3.50	12	65	3.80	.50	11.5	17.6	20.8	24.0	19.0	6- 1-72	1964-73
1855.00	97	67.9	16.0	3.85	1.51	94	4.13	3.60	12	65	4.50	.36	2,260	4,440	6,990	12,300	34,300	8-19-55	1913-72
1969.90	.29	138	1.10	.50	1.90	29	3.92	3.00	12	70	4.00	.24	22.6	32.0	39.1	49.5	48.0	4-23-69	1964-73
1970.00	57.1	47.7	14.7	1.71	1.68	66	4.01	3.00	12	65	4.50	.26	1,520	2,650	3,630	5,170	6,400	9-21-38	1936-72
1970.50	1.16	432	2.70	.50	1.66	89	3.83	3.00	14	70	3.90	.16	29.7	51.7	64.7	78.4	69.0	6-30-73	1964-73
1971.55	.73	449	1.40	.50	1.32	62	3.83	3.50	12	65	3.40	.37	34.1	58.5	76.6	101	69.0	4- 3-70	1965-73
1973.00	2.19	161	2.80	1.19	1.24	61	3.83	3.25	13	65	3.70	.28	81.8	122	160	221	250	6-30-73	1963-73
1975.00	280	16.5	49.7	2.44	1.43	66	3.89	2.80	13	65	3.80	.11	3,720	5,470	6,810	8,750	12,200	1- 1-49	1913-72
1975.50	.69	474	2.00	.50	1.19	90	3.67	3.50	13	65	4.10	.17	16.2	24.2	28.7	33.6	30.0	4-26-72	1963-73
3314.00	7.53	188	4.80	.77	1.76	61	4.00	3.00	13	70	3.70	.33	603	912	1,090	1,300	1,150	6-30-73	1963-73
3315.00	46.3	12.6	12.5	2.38	1.58	72	4.00	3.00	13	68	3.70	.30	1,080	[illegible]	2,260	3,200	5,080	9-21-38	1931-72
3370.00	39.0	77.4	10.6	.72	1.84	83	4.61	3.00	12	95	4.40	.35	2,030	3,290	4,400	6,200	8,950	[illegible]	1931-72
3375.00	137	19.2	24.0	1.37	1.66	68	4.13	2.90	14	78	3.70	.23	3,390	5,[illegible]	6,860	9,500	13,000	[illegible]	1940-72
3318.00	7.70	85.9	5.60	2.04	1.48	68	3.67	3.00	12	60	5.20	.25	73.6	103	121	143	166	6-30-73	1963-73

Table 3.--Stations used in this analysis

Station number	Station name	Location
0945	North Nashua River near Leominster, Mass.	Lat 42°30'06", long 71°43'23", Worcester County, on right bank 1.3 miles upstream from Wekepeke Brook, 2.5 miles southeast of Leominster, and 6.1 miles upstream from confluence with South Branch Nashua River.
0952	Houghton Brook near Oakdale, Mass.	Lat 42°24'57", long 71°48'12", Worcester County, at culvert on State Highway 140, 2 miles north of Oakdale.
0958	Easter Brook near North Leominster, Mass.	Lat 42°32'46", long 71°42'45", Worcester County, at culvert on Lancaster Ave., 1.5 miles east of North Leominster.
0960	Squannacook River near West Groton, Mass.	Lat 42°38'03", long 71°39'30", Middlesex County, on left bank 0.7 mile downstream from Trout Brook and 2.7 miles northwest of West Groton.
0965	Nashua River at East Pepperell, Mass.	Lat 42°40'03", long 71°34'32", Middlesex County, on right bank 200 ft downstream from powerplant of St. Regis Paper Co. at East Pepperell, and 0.8 mile upstream from Nissitissit River.
0970	Assabet River at Maynard, Mass.	Lat 42°25'55", long 71°27'01", Middlesex County, 150 ft upstream from bridge on State Highway 27, 1.7 miles downstream from Assabet Brook, and 7.1 miles upstream from confluence with Sudbury River.
0972	Heath Hen Meadow Brook at Stow, Mass.	Lat 42°26'44", long 71°30'02", Middlesex County, at culvert on West Acton Rd., 0.7 mile northeast of Stow.
0974.5	Jackstraw Brook at Westborough, Mass.	Lat 42°15'14", long 71°36'14", Worcester County, at culvert on Upton Rd., 1.1 miles southeast of Westborough.
0987	Hayward Brook at Wayland, Mass.	Lat 42°21'40", long 71°20'51", Middlesex County, at culvert on U.S. Highway 20, 0.7 mile east of Wayland.
1001	Richardson Brook near Lowell, Mass.	Lat 42°39'48", long 71°16'02", Middlesex County, at culvert on Methuen St., 2 miles northeast of Lowell.

Table 3.--Stations used in this analysis (Continued)

Station number	Station name	Location
1007	East Meadow River near Haverhill, Mass.	Lat 42°48'41", long 71°01'59", Essex County, on left bank 10 ft downstream from culvert on State Highway 110 and 3.5 miles northeast of Haverhill.
1008	Cobbler Brook near Merrimac, Mass.	Lat 42°50'55", long 71°01'10", Essex County, at culvert on Highland St., 1.3 miles northwest of Merrimac.
1009	Parker River tributary near Georgetown, Mass.	Lat 42°44'03", long 70°58'22", Essex County, at culvert on North St., 1.2 miles northeast of Georgetown.
1010	Parker River at Byfield, Mass.	Lat 42°45'10", long 70°56'46", Essex County, on left bank 1,400 ft downstream from dam, 0.5 mile south of Byfield, 0.7 mile upstream from Wheeler Brook, and 5.5 miles southwest of Newburyport.
1013	Maple Meadow Brook at Wilmington, Mass.	Lat 42°32'15", long 71°09'41", Middlesex County, on right bank 10 ft upstream from culvert on State Highway 38 and 0.9 mile southeast of Wilmington.
1015	Ipswich River at South Middleton, Mass.	Lat 42°34'10", long 71°01'39", Essex County, on right bank 700 ft downstream from Boston Street Bridge at South Middleton, 1.3 miles downstream from Wills Brook, and 2 miles south of Middleton.
1020	Ipswich River near Ipswich, Mass.	Lat 42°39'35", long 70°53'39", Essex County, on left bank 200 ft downstream from Willowdale Dam, 1.5 miles downstream from Howlett Brook, and 4 miles upstream from Ipswich.
1035	Charles River at Charles River Village, Mass.	Lat 42°15'23", long 71°15'42", Norfolk County, on right bank 0.3 mile downstream from highway bridge at Charles River Village, 0.8 mile downstream from Moanet Brook, and 1.3 miles northeast of Dover.
1046	Beaver Brook at Belmont, Mass.	Lat 42°23'26", long 71°11'51", Middlesex County, at culvert on State Highway 60 (Trapelo Rd.), 1 mile southwest of Belmont.
1049	Mill Brook at Westwood, Mass.	Lat 42°12'21", long 71°14'26", Norfolk County, at culvert on State Highway 109, at Westwood.

Table 3.--Stations used in this analysis (Continued)

Station number	Station name	Location
1050	Neponset River at Norwood, Mass.	Lat 42°10'39", long 71°12'05", Norfolk County, on left bank 200 ft upstream from Pleasant Street Bridge, 200 ft downstream from Penn. Central Railroad bridge, 0.45 mile downstream from Hawes Brook, and 0.5 mile south of Norwood.
1055.5	Plantingfield Brook at Norwood, Mass.	Lat 42°12'17", long 71°11'13", Norfolk County, at culvert on State Highway 1, 1.0 mile northeast of Norwood.
1058.5	Furnace Brook near Marshfield, Mass.	Lat 42°06'30", long 70°43'53", Plymouth County, at culvert on Furnace St., 1.7 miles northwest of Marshfield.
1059.5	Kirby Brook near Head of Westport, Mass.	Lat 41°36'02", long 71°04'25", Bristol County, at culvert on Drift Rd., 1.5 miles south of Head of Westport.
1060	Adamsville Brook at Adamsville, R.I.	Lat 41°33'30", long 71°07'47", Newport County, on right bank 0.2 mile upstream from mill dam at Adamsville, and 0.7 mile upstream from mouth.
1064.85	Meadow Brook tributary near Whitman, Mass.	Lat 42°04'11", long 70°57'34", Plymouth County, at culvert on Auburn St., 1.3 miles southwest of Whitman.
1070	Dorchester Brook near Brockton, Mass.	Lat 42°03'41", long 71°03'59", Plymouth County, on right bank 20 ft upstream from bridge on Pearl St. and 3 miles southwest of Brockton.
1080	Taunton River at State Farm, near Bridgewater, Mass.	Lat 41°56'05", long 70°57'18", Plymouth County, on right bank at State Farm, 1 mile upstream from Sawmill Brook, 3.5 miles northwest of Middleboro, and 4 miles southeast of Bridgewater.
1081	Snows Brook near Bridgewater, Mass.	Lat 41°56'53", long 70°59'37", Plymouth County, at culvert on Cross St., 3 miles south of Bridgewater.
1090	Wading River near Norton, Mass.	Lat 41°56'51", long 71°10'38", Bristol County, on left bank 200 ft downstream from bridge on State Highway 140, 0.9 mile upstream from confluence with Rumford River, and 1.5 miles southeast of Norton.
1090.5	Threemile River tributary near Oakland, Mass.	Lat 41°55'38", long 71°09'17", Bristol County, at culvert on State Highway 140, 1.3 miles northwest of Oakland.

Table 3.--Stations used in this analysis (Continued)

Station number	Station name	Location
1090.75	Holloway Brook near Myricks, Mass.	Lat 41°49'34", long 70°59'25", Plymouth County, at culvert on Pickens St., 2.0 miles east of Myricks.
1090.85	Quaker Brook near Myricks, Mass.	Lat 41°49'29", long 71°03'18", Bristol County, at culvert on Bryant St., 1.5 miles southwest of Myricks.
1091	Taunton River tributary near Fall River, Mass.	Lat 41°45'31", long 71°07'01", Bristol County, at culvert on State Highway 79, 4 miles northeast of Fall River.
1092	West Branch Palmer River near Rehoboth, Mass.	Lat 41°52'46", long 71°15'18", Bristol County, on left bank 20 ft downstream from culvert on Homestead Ave. and 2.6 miles north of Rehoboth.
1092.7	Runnins River at Seekonk, Mass.	Lat 41°49'25", long 71°20'00", Bristol County, at culvert on Pleasant St., 1.0 mile north of Seekonk.
1123	Bungay Brook near Sheldonville, Mass.	Lat 42°01'29", long 71°27'24", Bristol County, at culvert on Wrentham St., 3.5 miles west of Sheldonville.
1231.6	Wales Brook tributary near Wales, Mass.	Lat 42°04'48", long 72°11'51", Hampden County, at culvert on Holland Rd., 1.5 miles northeast of Wales.
1240.5	Tufts Branch at Dudley, Mass.	Lat 42°03'11", long 71°56'22", Worcester County, at culvert on Dudley-Southbridge Rd., 0.7 mile northwest of Dudley.
1247.5	Browns Brook near Webster, Mass.	Lat 42°03'24", long 71°49'51", Worcester County, on left bank 15 ft downstream from culvert on State Highway 16 and 1.8 miles east of Webster.
1563	Whetstone Brook tributary near Marlboro, Vt.	Lat 42°52'42", long 72°42'30", Windham County, at culvert on State Highway 9, 1.5 miles northeast of Marlboro.
1564.5	Connecticut River tributary near Vernon, Vt.	Lat 42°47'01", long 72°31'57", Windham County, at culvert on macadam road, 1.5 miles northwest of Vernon.
1613	Millers Brook at Northfield, Mass.	Lat 42°41'07", long 72°27'11", Franklin County, at culvert on Beers Plain Rd., 0.8 mile south of Northfield.

Table 3.--Stations used in this analysis (Continued)

Station number	Station name	Location
1620	Millers River near Winchendon, Mass.	Lat 42°41'03", long 7°05'02", Worcester County, on right bank 10 ft downstream from Nolan Bridge, 0.3 mile downstream from Tarbell Brook, 2 miles west of Winchendon, and at mile 32.8.
1625	Priest Brook near Winchendon, Mass.	Lat 42°40'57", long 72°06'56", Worcester County, on right bank 100 ft downstream from highway bridge, 3 miles upstream from mouth, and 3.5 miles west of Winchendon.
1631	Wilder Brook near Gardner, Mass.	Lat 42°35'42", long 72°00'53", Worcester County, at culvert on Clark St., 1.5 miles northwest of Gardner.
1650	East Branch Tully River near Athol, Mass.	Lat 42°38'32", long 72°13'34", Worcester County, on right bank 300 ft downstream from Tully Dam, 1.3 miles downstream from Lawrence Brook, and 3.5 miles north of Athol.
1655	Moss Brook at Wendell Depot, Mass.	Lat 42°36'10", long 72°21'36", Franklin County, on left bank 0.2 mile upstream from mouth, 0.2 mile north of Wendell Depot, and 2.5 miles west of Orange.
1665	Millers River at Erving, Mass.	Lat 42°35'51", long 72°26'19", Franklin County, on right bank 75 ft downstream from bridge at Farley, 0.6 mile upstream from Mormon Hollow Brook, 2.4 miles downstream from Erving, and 5.5 miles upstream from mouth.
1678	Beaver Brook at Wilmington, Vt.	Lat 42°51'38", long 72°51'04", Windham County, on right bank 20 ft downstream from bridge on State Highway 9, 1.0 mile south-east of Wilmington, and 1.7 miles upstream from mouth.
1690	North River at Shattuckville, Mass.	Lat 42°38'18", long 72°43'32", Franklin County, on right bank in Shattuckville, 1.2 miles south of Griswoldville and 1.3 miles upstream from mouth.
1702	Allen Brook near Shelburne Falls, Mass.	Lat 42°36'46", long 72°40'02", Franklin County, at culvert on Peckville Rd., 3.5 miles east of Shelburne Falls.
1709	Mill River near South Deerfield, Mass.	Lat 42°28'09", long 72°38'31", Franklin County, at culvert on North St., 2 miles southwest of South Deerfield.

Table 3.--Stations used in this analysis (Continued)

Station number	Station name	Location
1712	Scarboro Brook at Dwight, Mass.	Lat 42°19'44", long 72°26'47", Hampshire County, at culvert on State Highway 9, at Dwight.
1715	Mill River at Northampton, Mass.	Lat 42°19'05", long 72°39'21", Hampshire County, on right bank at Northampton, 3.5 miles upstream from mouth.
1718	Bassett Brook near Northampton, Mass.	Lat 42°18'09", long 72°41'16", Hampshire County, on right bank 20 ft upstream from bridge on State Highway 66 and 3 miles southwest of Northampton.
1719.1	Broad Brook near Holyoke, Mass.	Lat 42°11'59", long 72°41'11", Hampden County, at culvert on Keys Rd., 3.5 miles west of Holyoke.
1730.4	Pleasant Brook near Barre, Mass.	Lat 42°25'44", long 72°04'35", Worcester County, at culvert on State Highway 62, 1.5 miles east of Barre.
1732.6	Moose Brook near Barre, Mass.	Lat 42°23'52", long 72°08'51", Worcester County, on right bank 20 ft upstream from culvert on Hardwick Rd., and 2.8 miles southwest of Barre.
1733.3	Fish Brook near Gilbertville, Mass.	Lat 42°19'24", long 72°11'11", Worcester County, at culvert on Goddard Rd., 1.2 miles northwest of Gilbertville.
1735	Ware River at Gibbs Crossing, Mass.	Lat 42°14'07", long 72°16'45", Hampshire County, on right bank 0.5 mile upstream from Gibbs Crossing, 1.8 miles upstream from Beaver Brook, 2.5 miles southwest of Ware, and 8.8 miles upstream from mouth.
1739	Middle Branch Swift River at North New Salem, Mass.	Lat 42°32'45", long 72°19'10", Franklin County, at culvert on Elm St., at North New Salem.
1740	Hop Brook near New Salem, Mass.	Lat 42°28'42", long 72°20'05", Franklin County, on right bank 1.5 miles upstream from mouth and 1.5 miles south of New Salem.
1745	East Branch Swift River near Hardwick, Mass.	Lat 42°23'36", long 72°14'21", Worcester County, on left bank 100 ft above spillway of regulating dam and 4.6 miles northwest of Hardwick.

Table 3.--Stations used in this analysis (Continued)

Station number	Station name	Location
1755	Swift River at West Ware, Mass.	Lat 42°16'04", long 72°19'59", Hampshire County, on left bank at West Ware, 1.4 miles downstream from Quabbin Reservoir, 3.5 miles east of Belchertown, and 8.0 miles upstream from mouth.
1756	Caruth Brook near Paxton, Mass.	Lat 42°19'00", long 71°58'16", Worcester County, at culvert on Spring St., 2.2 miles west of Paxton.
1760	Quaboag River at West Brimfield, Mass.	Lat 42°10'56", long 72°15'51", Hampden County, on right bank 10 ft upstream from abandoned highway bridge at West Brimfield, 0.9 mile upstream from Blodgett Mill Brook, 3.5 miles northeast of Palmer, and 9.9 miles upstream from mouth.
1764.5	Roaring Brook near Belchertown, Mass.	Lat 42°14'07", long 72°24'28", Hampshire County, at culvert on State Highway 21, 4 miles south of Belchertown.
1782.3	Mill Brook at Plainfield, Mass.	Lat 42°30'57", long 72°55'30", Hampshire County, at culvert on High St., 0.4 mile west of Plainfield.
1795	Westfield River at Knightville, Mass.	Lat 42°17'16", long 72°51'53", Hampshire County, on left bank at Knightville, 0.2 mile downstream from Knightville Dam, 0.2 mile upstream from Sykes Brook, 2.4 miles upstream from Middle Branch, 3.5 miles north of Huntington, and at mile 29.7.
1800	Sykes Brook at Knightville, Mass.	Lat 42°17'27", long 72°52'15", Hampshire County, on right bank 200 ft downstream from bridge on State Highway 112 at Knightville, 0.4 mile upstream from mouth, 0.4 mile west of Knightville Dam, and 3.5 miles north of Huntington.
1801	Fuller Brook near Peru, Mass.	Lat 42°25'59", long 73°01'19", Hampshire County, at culvert on State Highway 143, 1.3 miles southeast of Peru.
1805	Middle Branch Westfield River at Goss Heights, Mass.	Lat 42°15'31", long 72°52'23", Hampshire County, on right bank at upstream side of highway bridge at Goss Heights, 0.3 mile upstream from mouth, 0.7 mile downstream from Littleville Dam, and 1.7 miles north of Huntington.

Table 3.--Stations used in this analysis (Continued)

Station number	Station name	Location
1808	Walker Brook near Becket Center, Mass.	Lat 42°15'49", long 73°02'48", Berkshire County, on right bank 20 ft upstream from culvert on U.S. Highway 20, 0.2 mile east of Bonny Rigg Corners, 1.7 miles southeast of Becket Center, and 3.5 miles west of Chester.
1810	West Branch Westfield River at Huntington, Mass.	Lat 42°14'14", long 72°53'46", Hampshire County, on left bank at Huntington, 0.4 mile downstream from Roaring Brook and 1.5 miles upstream from mouth.
1831	Seymour Brook tributary at Granville, Mass.	Lat 42°03'53", long 72°51'42", Hampden County, at culvert on State Highway 189 at Granville.
1835	Westfield River near Westfield, Mass.	Lat 42°06'24", long 72°41'58", Hampden County, on left bank 0.7 mile downstream from Great Brook 3 miles east of Westfield, and 8.1 miles upstream from mouth.
1838.1	Longmeadow Brook at Pondside Road, near Longmeadow, Mass.	Lat 42°02'22", long 72°35'32", Hampden County, at culvert on Pondside Rd., 2 miles southwest of Longmeadow.
1849	Haley Pond outlet near Otis, Mass.	Lat 42°12'15", long 73°01'56", Berkshire County, at culvert on Algerie Rd., 3 miles northeast of Otis.
1855	West Branch Farmington River near New Boston, Mass.	Lat 42°04'45", long 73°04'24", Berkshire County, on left bank and 5 ft downstream from highway bridge, 0.3 mile downstream from Clam River, 1 mile south of New Boston, and at mile 65.0.
1969.9	Windsor Brook tributary at Windsor, Mass.	Lat 42°30'41", long 73°04'37", Berkshire County, at culvert on State Highway 9, 0.9 mile west of Windsor.
1970	East Branch Housatonic River at Coltsville, Mass.	Lat 42°28'10", long 73°11'49", Berkshire County, on right bank 40 ft downstream from Hubbard Avenue Bridge at Coltsville, 1.2 miles upstream from Unkamet Brook and 2 miles northeast of Pittsfield.
1970.5	Churchill Brook at Pittsfield, Mass.	Lat 42°29'28", long 73°16'56", Berkshire County, at culvert on Churchill St., at north limits of Pittsfield.
1971.55	Housatonic River tributary No. 2 at Lee, Mass.	Lat 42°18'21", long 73°13'49", Berkshire County, at culvert on East St., 1.0 mile east of Lee.

Table 3.--Stations used in this analysis (Continued)

Station number	Station name	Location
1973	Marsh Brook at Lenox, Mass.	Lat 42°20'59", long 73°17'56", Berkshire County, on left bank 15 ft downstream from culvert on Hawthorne St. and 1.0 mile southwest of Lenox.
1975	Housatonic River near Great Barrington, Mass.	Lat 42°13'55", long 73°21'19", Berkshire County, on left bank at upstream side of highway bridge at Van Deusenville, 0.5 mile upstream from Williams River and 2 miles north of Great Barrington.
1975.5	Housatonic River tributary at Risingdale, Mass.	Lat 42°13'57", long 73°20'47", Berkshire County, at culvert on State Highway 183, 0.7 mile southeast of Risingdale.
3314	Dry Brook near Adams, Mass.	Lat 42°35'20", long 73°06'48", Berkshire County, on right bank 20 ft upstream from bridge on State Highway 116, just south of junction of Wells Road and State Highway 116, and 2.5 miles south of Adams.
3315	Hoosic River at Adams, Mass.	Lat 42°36'37", long 73°07'32", Berkshire County, on right bank just downstream from Dry Brook, at Adams, 0.5 mile upstream from Pecks Brook.
3320	North Branch Hoosic River at North Adams, Mass.	Lat 42°42'08", long 73°05'37", Berkshire County, on left bank at North Adams, 0.4 mile downstream from Hudson Brook, and 1.5 miles upstream from mouth.
3325	Hoosic River near Williamstown, Mass.	Lat 42°42'21", long 73°10'50", Berkshire County, on left bank 1.0 mile upstream from Green River and 1.2 miles east of Williamstown.
3338	South Stream near Bennington, Vt.	Lat 42°49'53", long 73°10'04", Bennington County, at culvert on South Stream Rd., 3.5 miles southeast of Bennington.

Table 4.--Table of conversion factors

The following factors may be used to convert English units published herein to the International System of units (SI).

Multiply English units	by	to obtain SI units
Square miles (mi^2)	2.590	square kilometers (km^2)
Cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)
Feet (ft)	.3048	meters (m)
Inches (in)	25.4	millimeters (mm)
Feet per mile (ft/mi)	.1894	meters per kilometer (m/km)

Convert temperature in degrees Fahrenheit (°F) to degrees Celsius (°C) by the following equation:

$$°C = (5/9)*(°F-32).$$

Table 5.--Method of computing independent variables used in estimating relations

Basin characteristics drainage area, main channel slope, and mean annual precipitation should be determined by the following methods or by methods of equivalent accuracy.

(1) Drainage area. Trace drainage area boundary lines on topographic maps along divides indicated by contour elevations, starting at the point on the stream for which the drainage area is desired. Interpolation between contours may be indicated by reference to trails, old roads, or firebreaks in forested areas, all of which frequently follow drainage divides. Also, detailed information may be obtained from highway or street profiles, from examination of aerial photographs, and from ground reconnaissance. Trace drainage area boundaries on uncontoured maps midway between streams only when more accurate indications of correct boundaries cannot be obtained practically. Planimeter the outlined drainage area to obtain the drainage area in square miles.

(2) Main channel slope. Outline the main channel on a map of the basin. Upstream from each stream junction point, choose the main channel as the stream that drains the most area. Continue the main channel to the ridge beyond the upstream end of the stream line on the map by drawing flow lines indicated by contours. Measure the total length by a map measurer or set of dividers set to one-tenth of a mile, locate the points 85 and 10 percent of the total length above the point of interest on the stream, and determine the altitude of these points. The main channel slope is computed as the difference in altitude in feet divided by the length in miles between the two points.

(3) <u>Mean annual precipitation</u>. Locate the basin of interest on the map given in figure 11. By interpolation determine the mean annual precipitation for the basin to the nearest inch. Convert mean annual precipitation in inches to feet.

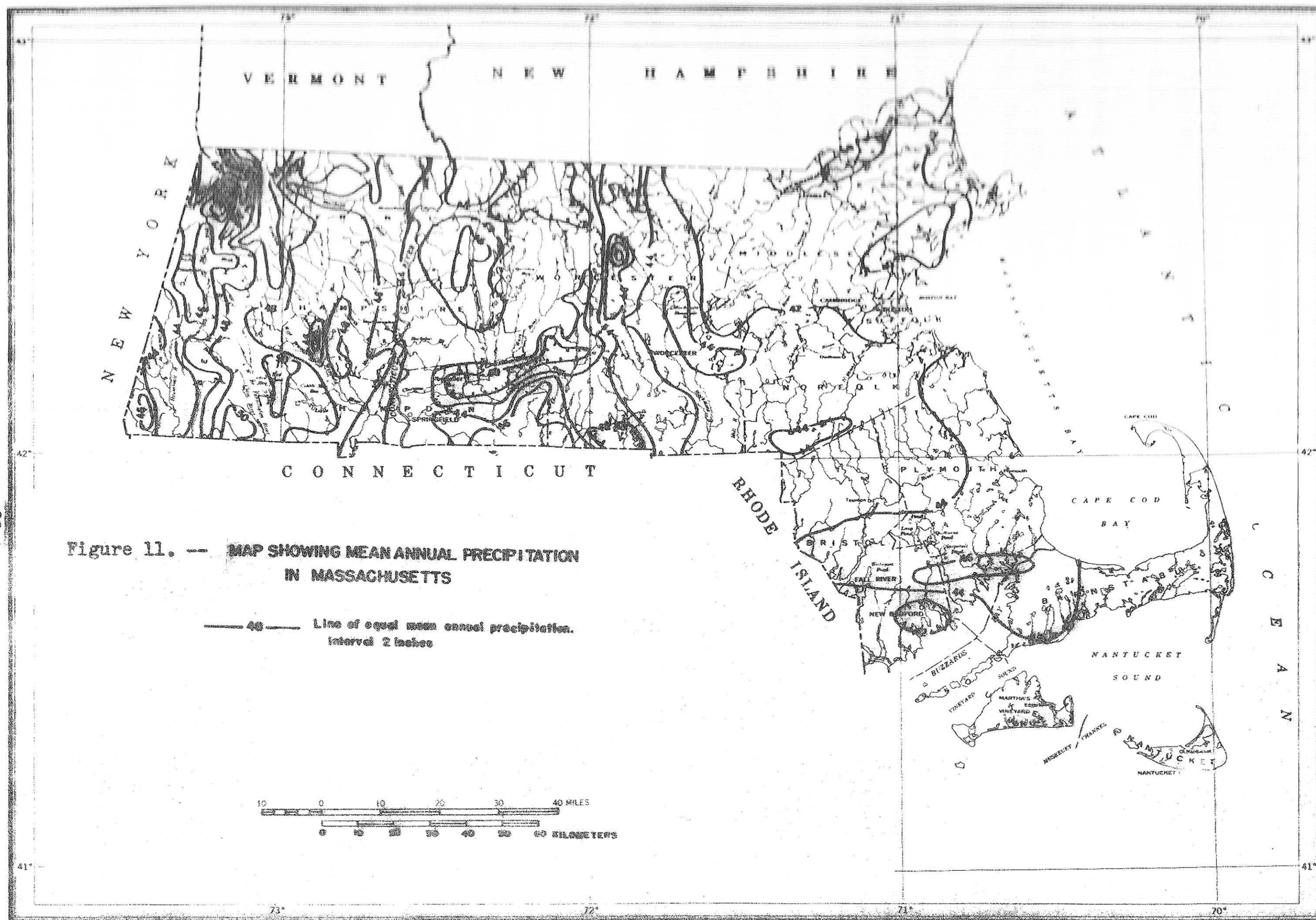

Figure 11. — MAP SHOWING MEAN ANNUAL PRECIPITATION IN MASSACHUSETTS

after Knox and Nordenson, 1955

Table 6.--List of independent variables used in regression analysis

a. Drainage area (A), in square miles, as taken from the latest Geological Survey streamflow reports.

b. Main-channel length (L), in miles, from the gaging station to the basin divide, as measured with dividers set to 0.1 mile or with a map measurer.

c. Main-channel slope (S), in feet per mile, determined from elevations at points 10 percent and 85 percent of the distance along the channel from the gaging station to the divide. This index was described and used by Benson (1962, 1964).

d. Mean basin elevation (E), in thousands of feet above mean sea level, measured on topographic maps by laying a grid over the map, determining the elevation at each grid intersection, and averaging those elevations. The grid spacing was selected to give at least 25 intersections within the basin boundary.

e. Forest cover (F), in a decimal fraction of the drainage area covered by forests as shown on the topographic map, determined by the grid method, and increased by 0.01.

f. Mean annual precipitation (p), in inches, determined from an isohyetal map (Knox and Nordenson, 1955).

g. Area of lakes and ponds (St), expressed as percentage of the drainage area, determined by the grid method, and increased by 0.5 percent.

h. The maximum 24-hour rainfall having a recurrence interval of 2 years ($I_{24,2}$), expressed in inches. This characteristic was determined from U.S. Weather Bureau Technical Paper No. 29.

i. Minimum January temperature (T), in degree Fahrenheit, was determined from the U.S. Weather Bureau publication series "Climates of the States" and increased by 1 degree.

j. Snowfall (Sn), in inches, is the average total seasonal snowfall and was determined from an isohyetal map provided by the U.S. Weather Bureau.

k. Soils index represents values of potential maximum infiltration, in inches, during an annual flood, under average soil moisture conditions (Si). This characteristic was provided by the Soil Conservation Service.

l. Shape factor was determined by dividing A by L^2.

Relationship between recurrence interval and chance that a flood will be exceeded at least once in a given period of years

Some important problems in hydrology are concerned with the chance that a flood of certain size will be exceeded within a given period. Let p equal the probability of exceeding an annual flood of given magnitude. Assume the magnitude-frequency relationship is known without error and that annual peaks are randomly distributed in time. Then recurrence interval, RI, is equal to 1/p. The probability of not exceeding the discharge for a given recurrence interval is 1 -p, and the probability that it will not be exceeded in the next n years is:

$$(1 - p)^n.$$

Therefore, the probability that the flood will be exceeded at least once in the next n years is:

$$1 - (1 - p)^n.$$

This relationship is summarized in table 5. For example, the chance that a 50-year flood will be exceeded in any 20-year period is 33 percent.

Table 7.--Chance, in percent, that a flood of indicated recurrence interval, RI, will be exceeded at least once in any n year period.

RI	n=10	n=20	n=50	n=100
5	89	99	99+	99+
10	65	88	99	99+
25	34	56	87	98
50	18	33	64	87
100	10	18	39	63