ESTIMATING GENERALIZED FLOOD SKEW COEFFICIENTS FOR MICHIGAN

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CONVERSION FACTORS

The following factors may be used to convert the inch-pound unit published in this report to the International System of Units (SI).

Multiply inch-pound units	By	To obtain SI units
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

ACKNOWLEDGMENTS

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ABSTRACT

Current estimates of station skew indicate that estimates of generalized skew obtained from the skew map of the United States prepared by the U.S. Water Resources Council have a -0.27 bias for Michigan. Station skew was recomputed using currently recommended statistical procedures of the Water Resources Council, and available data through 1982. Generalized skew is combined with station skew in order to improve estimates of flood-flow frequencies. As a result of this study, the mean station skew for each of three designated regions can be used to estimate generalized skew in Michigan. The Upper Peninsula has a skew of 0.12; the southwest part of the Lower Peninsula has a skew of 0.081; the remainder of the Lower Peninsula has a skew of -0.17. The mean-square error associated with generalized skew determined on the basis of designated regions is 0.2.

INTRODUCTION

To obtain consistent and accurate estimates of flood-flow frequencies, the U. S. Water Resources Council has published guidelines containing methods for computing station skew and estimating generalized skew. Bulletin 17, (1976) "Guidelines for Determining Flood Flow Frequencies," discussed recommended procedures and contained an isoline map of the United States which showed generalized skew. Bulletin 17B (1981) updated the statistical procedures recommended in Bulletin 17; however, the generalized skew map was not revised.

The generalized skew map of the United States was developed using 2,972 stream gaging stations with drainage areas equal to or less than 3,000 mi^2. These stations had 25 or more years of unregulated annual maximum streamflow data through water year 1973. Station skew was computed by use of low-outlier test criteria that rejected low-outliers at the one percent rather than the currently used 10-percent confidence level of significance. No attempt was made to identify and treat high outliers, to use historic flood information, or to make a detailed evaluation of each frequency curve.

Purpose and Scope

The purpose of this report is to compare and evaluate four methods of estimating flood-frequency skew coefficients for Michigan. These methods are based on use of (1) the generalized skew map of the United States, (2) maps showing lines of equal mean skew of Michigan, (3) mean regional station skews, and (4) skew-prediction equations.

Skew coefficients were computed by use of annual maximum discharge values for 100 gaging stations in Michigan and 31 gaging stations in adjoining states having at least 25 years of record and for 99 additional stations in Michigan having from 10 to 24 years of record.

ESTIMATING FLOOD-FLOW FREQUENCY

Flood-flow frequency is estimated by fitting observed annual maximum discharge values to a log-Pearson type III distribution using a weighted skew. The weighted skew is a function of station and generalized skew and their mean-square errors, and is

assumed to be the best estimate of true station skew. Estimates of flood-flow frequencies with longer recurrence intervals are more sensitive to skew.

Computing Station Statistics

Mean, standard deviation, and skew were computed with logarithms of annual maximum discharge values for 100 stations in Michigan and 31 stations in adjacent parts of Indiana, Ohio, and Wisconsin where flow is unregulated and record length is 25 or more years (table 1, at the end of the report, and fig. 1). In addition, annual maximum streamflow statistics were computed for 99 Michigan stations having record lengths between 10 and 24 years (table 2, at the end of the report). True station skew estimated by use of station skew from stations with record lengths less than 24 years has a high degree of uncertainty. The addition of one relatively high or low annual maximum streamflow value can change station skew by more than ± 0.2. Following detailed evaluation of each frequency curve, adjustments were made for high and low outliers (U.S. Water Resoures Council, 1981). When low outliers were dropped, the remaining record was retested for additional outliers.

Estimating Generalized Skew

Estimates of generalized skew for Michigan from the generalized skew map of the United States were compared to mean skew computed from station records. In addition, three methods of estimating generalized skew were developed and evaluated, including (1) maps showing lines of equal mean skew of Michigan, (2) means of station skew within homogeneous hydrologic regions,

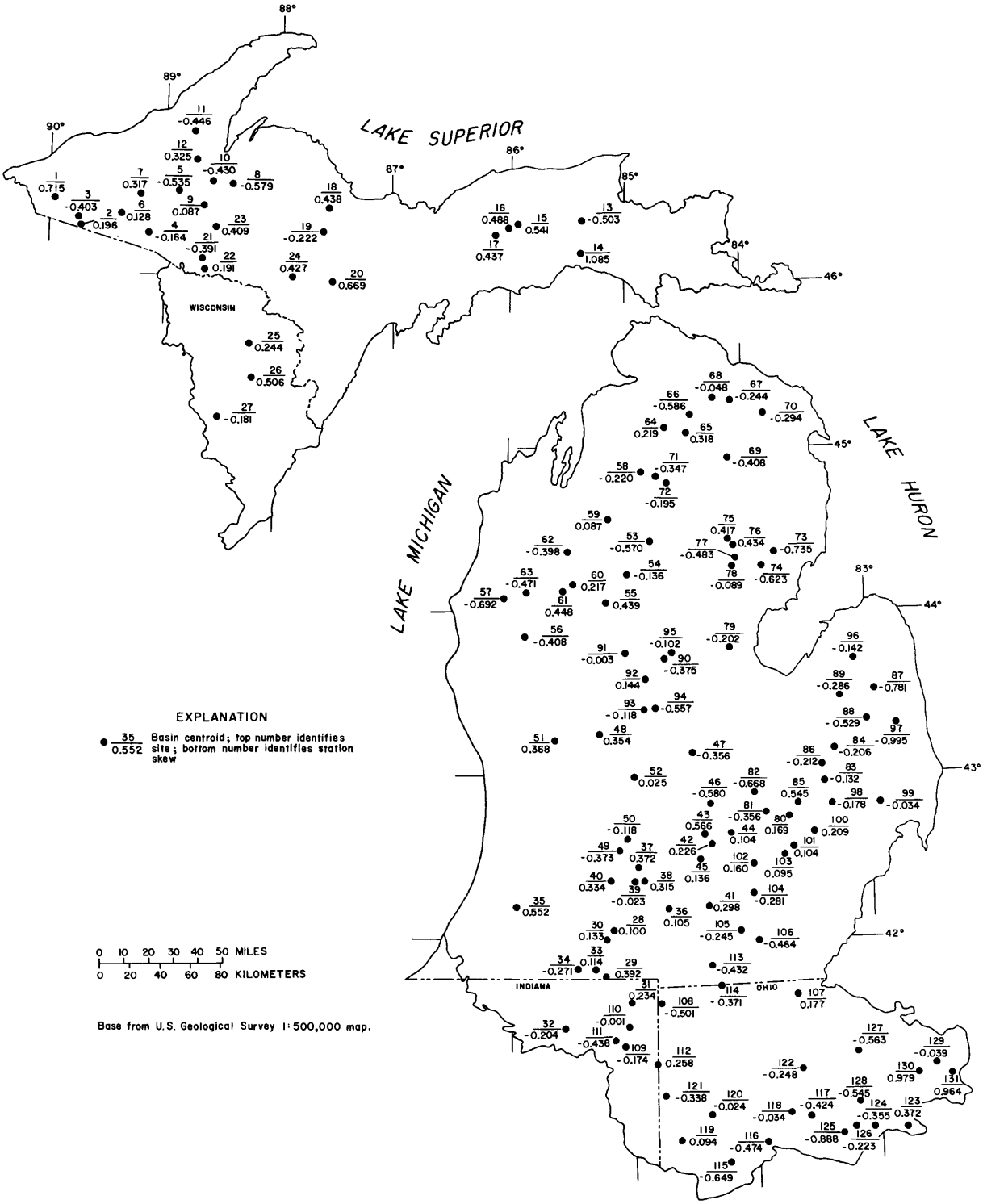

Figure 1.--Computed station skews at basin centroids.

and (3) generalized skew prediction equations. Evaluation criteria for the three estimating techniques included (1) minimum bias and mean-square error (MSE), and (2) potential for uniform application by various users.

Use of Generalized Skew Map of United States

The mean and mean-square error of differences between generalized skew estimated from the skew map of the United States (U.S. Water Resources Council, 1976) and station skew for 100 stations in Michigan is -0.27 and 0.16, respectively. The effect of a -0.27 bias in the estimate of generalized skew is to underestimate higher recurrence interval flood discharges. In addition, the MSE of 0.16 is considerably lower than the MSE associated with the generalized skew map of the United States which is 0.30. The lower MSE value indicates that generalized skew should have a greater affect on weighted skew.

Use of Maps Showing Lines of Equal Mean Skew

Skew maps were drawn based on a grid with mean skew computed for all stations within 50-mi and 100-mi radii of grid points (figs. 2 and 3). Grid points were located at the intersection of every 12 minutes of latitude and longitude across Michigan. The accuracy of this method was estimated by computing the difference between the mean skew of all stations within 50-mi and 100-mi radii of each stations' basin centroid and the station skew. The mean and MSE of the differences between 50-mi radius mean skew and station skews were 0.00 and 0.13, respectively. The mean number of stations within a 50-mi radius of each station was 15. In comparison, the mean and MSE of the differences

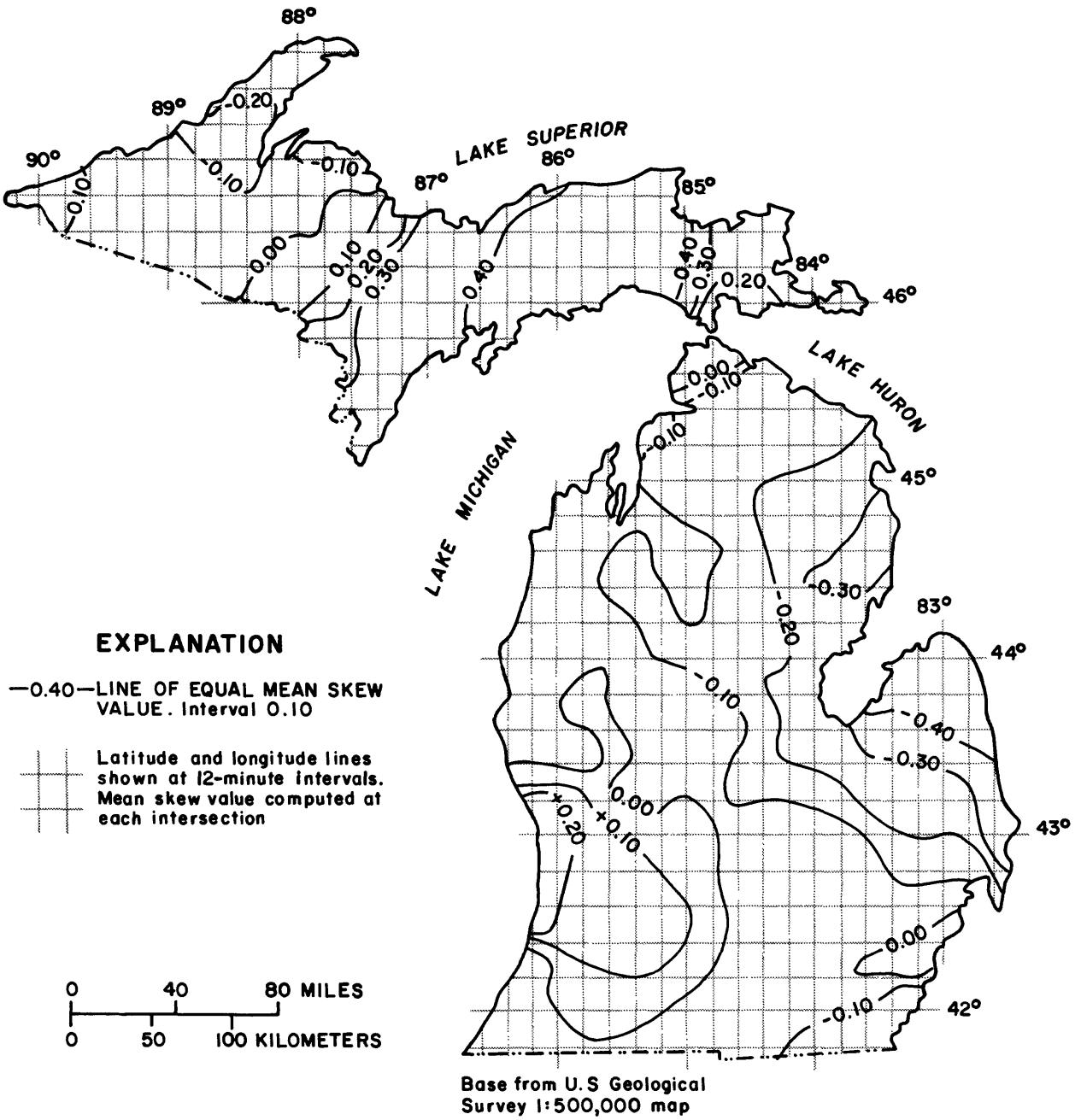

Figure 2.--Lines of equal mean skew at stations within a 50-mile radius of grid points.

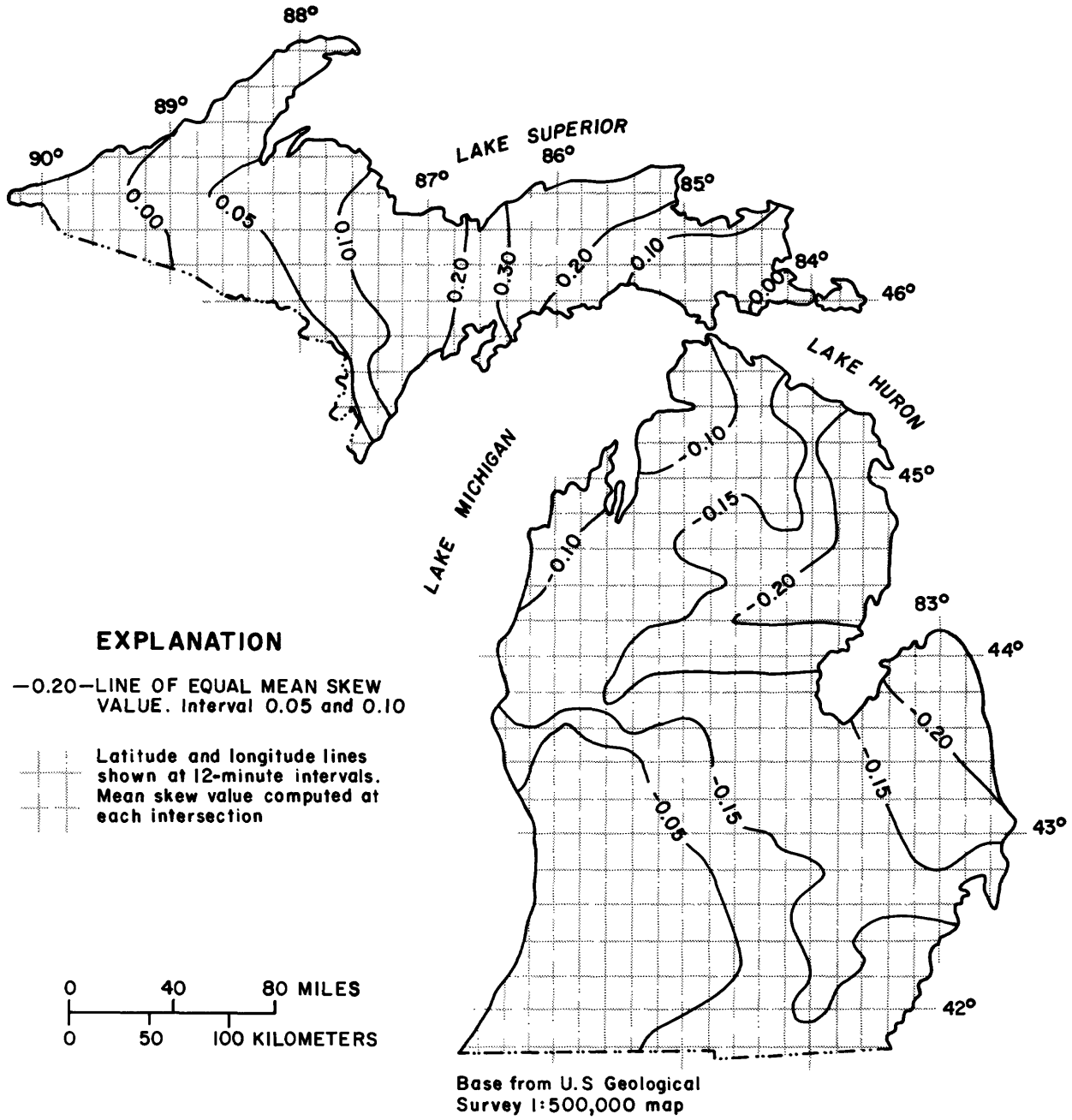

Figure 3.--Lines of equal mean skew at stations within a 100-mile radius of grid points.

between 100-mi radius mean skew and station skews were 0.01 and 0.14, respectively. The mean number of stations within a 100-mi radius of each station was 41.

Use of Mean of Station Skew

Mean skew and MSE were computed using station skew for each of nine major hydrologic unit areas (U.S. Geological Survey, 1974) which encompass Michigan (fig. 4 and table 3). Thirty-one of the 131 sites used were located in the adjoining states of Indiana, Ohio, and Wisconsin (table 1). Stepwise t-tests were used to combine adjacent unit areas, where appropriate. In order to meet the 20 station minimum criteria for defining generalized skew, (U.S. Water Resources Council, 1981), the three unit areas A, B, and C in the Upper Peninsula were combined, even though significant differences were found among unit area station means at the 5 percent confidence level.

Three skew regions were defined (fig. 4). Region 1 includes all of Michigan's Upper Peninsula and has a mean skew of 0.12. Region 2 encompasses hydrologic unit area D in the southwestern part of the Lower Peninsula and has a mean skew of 0.081. The remainder of the Lower Peninsula is referred to as region 3 and has a mean skew of -0.17.

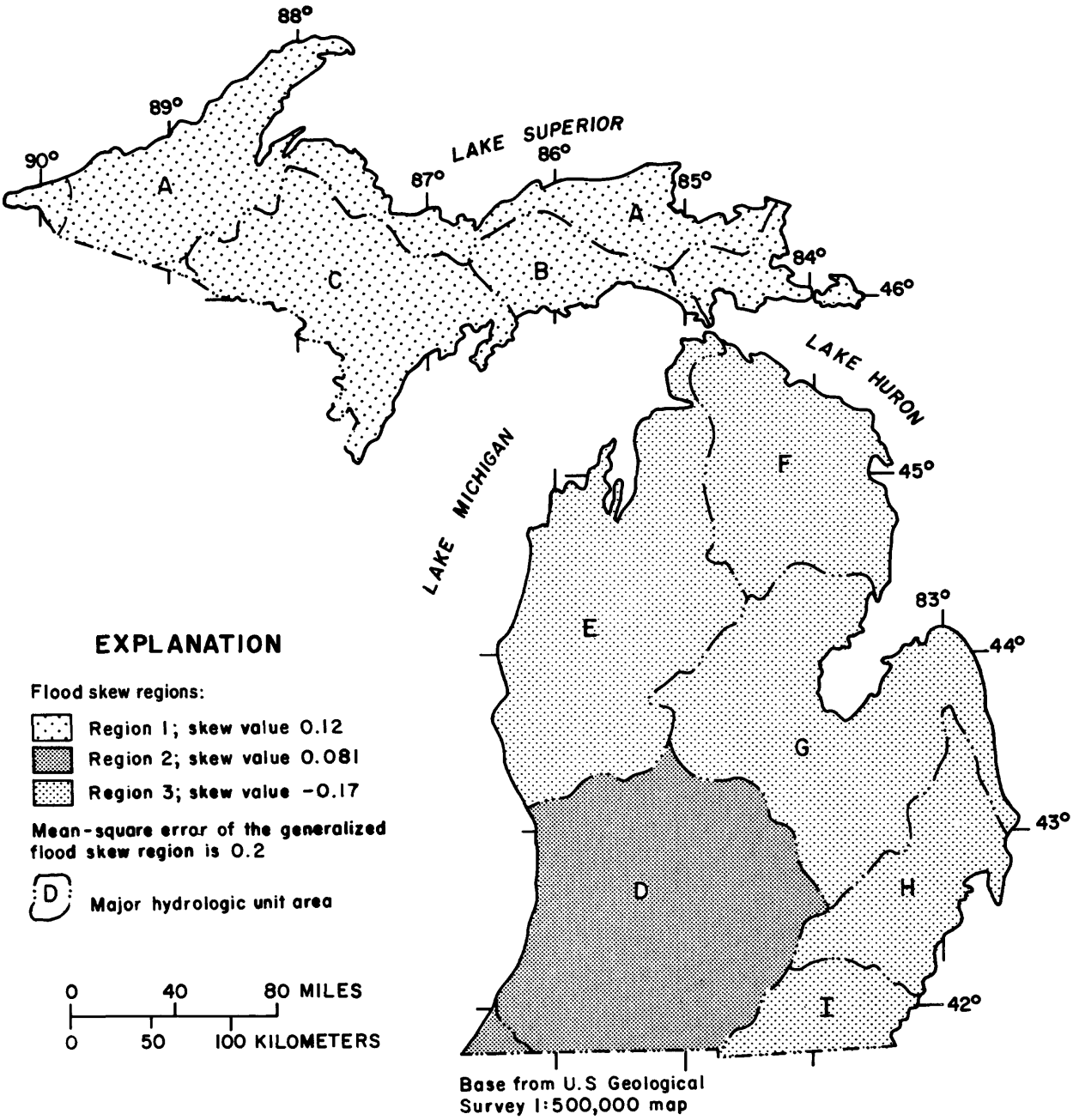

Figure 4.--Major hydrologic unit areas and flood skew regions.

Table 3.--Regional determination of generalized skew based on stepwise t-tests of mean station skew between major hydrologic unit areas

Region	Hydrologic unit area	Mean skew	Standard deviation of skew	Site number	Number of stations	Adjacent group	Probability of > t
	A	-0.10	0.42	1-13	13	B	0.01
	B	.64	.30	14-17	4	C	.06
	C	.21	.36	18-27	10	A	.07
1	A,B,C	.12	.45	1-27	27		
2	D	.08	.31	28-52	25	E	.08
						G	.00
	E	-.16	.40	53-63	11	F	.78
	F	-.18	.29	64-72	9	G	[1].83
	G	-.20	.37	73-96	24	E	.59
	H	-.16	.39	97-104	8	D	.15
						G	.57
	I	-.17	.44	105-131	27	D	.15
						H	[2].73
	F,G	-.20	.34	64-96	33	D	.00
						E	.60
	H,I	-.16	.42	97-131	35	D	.02
						F,G	[3].71
	F,G,H,I	-.18	.38	64-131	68	D	.00
						E	[4].70
3	E,F,G,H,I	-.17	.38	53-131	79	D	.00

[1] Areas F and G were combined based on probability of t >0.50.
[2] Areas H and I were combined based on probability of t > .50.
[3] Areas F,G and H,I were combined based on probability of t > .50.
[4] Areas E and F,G,H,I were combined based on probability of t > .50.

Use of Skew Prediction Equations

Regression analyses were used to determine the correlation between selected basin characteristics and station skew. Two multiple linear regression equations were developed by the stepwise procedure to select basin characteristics, significant at the ten percent level (Helwig and Council, 1979).

Equation 1 relates selected basin characteristics to station skew at 100 Michigan stations with 25 or more years of record.

$$skew = 0.0206 - 0.276X1 + 0.00574S \qquad (1)$$

In this analysis, basin characteristics include contributing drainage area, main channel slope, stream length (L), mean basin elevation, percent lake, pond, and swamp area (S), percentage of forested area, mean annual precipitation, precipitation intensity for 24-hour rainfall, for the 2-year and 100-year storm, mean annual snowfall, mean minimum January temperature, and the ratio of stream length squared to contributing drainage area. Contributing drainage area was not available for stations having drainage areas greater than 200 mi^2 and was, therefore, set equal to drainage area. In addition, indicator variables, X1 and X2, were defined as follows:

Region 1: X1 = 0, X2 = 0

Region 2: X1 = 0, X2 = 1

Region 3: X1 = 1, X2 = 0

Equation 2 relates a second set of basin characteristics to computed skew at 122 selected Michigan stations having less than 200 mi^2 drainage areas and 10 or more years of record.

$$skew = -0.0605 + 0.193X2 - 0.0107L + 0.00827S + 0.00336CS \quad (2)$$

Additional basin characteristic available on the smaller basins include: percentage of stream length that is swamp or lake (CS), and percentages of areas that are moraine, ground moraine, waterlaid moraine, outwash and glacial channel, ponded water, lakebed clay, lakebed sand, and surface rock (Martin, 1955). To compensate for shorter record lengths, the least squares analysis was weighted by the number of years of record.

The mean of residuals, or bias, for equations 1 and 2 was 0.00. The MSE's of equations 1 and 2 were 0.137 and 0.172, respectively. Both equation 1 and 2 have overall F statistics significant at the 1 percent confidence level. However, relatively low r^2 values of 0.15 and 0.19 for equations 1 and 2, respectively, and the significance of region variables X1 or X2, indicate that the regression equations may not appreciably improve estimates of generalized skew from those based on means of computed station skew within defined regions.

Evaluation of Methods for Estimating Generalized Skew

Biased estimates of generalized skew for Michigan result from use of the generalized skew map of the United States because of changes in recommended procedures for computing station skew. The three other methods of estimating generalized skew--(1) maps

showing lines of equal mean skew of Michigan, (2) skew regionalization, and (3) skew prediction equations--are unbiased and result in similar MSE values. Method 2, skew regionalization, may provide more accurate estimates of generalized skew because of its ease of application and potential for uniform application by various users.

Estimating Mean-Square Error of Generalized Skew from Skew Regions

Mean-square error using generalized skew was computed for each skew region, and a combined MSE was determined which is applicable to all regions (table 4). Because of the limited

Table 4. Mean and mean-square error of skew regions

	Number of observations	Minimum record length (years)	Mean	Mean square error
Region 1				
Station	27	25	0.12	0.21
Residual[1]	41	10	.012	.17
Region 2				
Station	25	25	.081	.097
Residual[1]	42	10	.013	.097
Region 3				
Station	79	25	-.17	.15
Residual[1]	147	10	.045	.19
Combined				
Station	131	25	-.063	.17
Residual[1]	230	10	.045	.19

[1] Difference between station skew and mean skew including Michigan stations having 10 or more years of record.

number of stations in regions 1 and 2, the combined MSE is favored. In addition, 99 Michigan stations with 10 or more years of record (table 2) were included in a second estimate of combined MSE. The combined MSE is the MSE of residuals formed from the difference between station skew and generalized skew. Expressed to one significant figure, the estimated MSE associated with generalized skew determined on the basis of designated regions is 0.2.

CONCLUSIONS

Skew estimated from the generalized skew map of the United States in Bulletin 17 (U.S. Water Resources Council, 1976) is a biased estimate of generalized skew for Michigan. This is based on station statistics computed following recommended methods (U.S. Water Resources Council, 1981). Maps showing lines of equal mean skew, mean station skew within homogeneous regions, and regression equations all produce unbiased estimates of generalized skew. Mean-square error does not vary appreciably among the four methods evaluated. To ensure uniform estimation of generalized skew, use of the mean of station skews within designated regions 1, 2, and 3 is favored. The estimated MSE associated with generalized skew determined on the basis of designated regions is 0.2.

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TABLES

Table 1.--Annual maximum streamflow statistics for selected stations with 25 or more years of record.

Site	USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence: High outlier	Year of occurrence: Low outlier	Year of occurrence: Historic event	Systematic and adjusted: Mean	Systematic and adjusted: Standard deviation	Systematic and adjusted: Skew
1	04031000	Black River near Bessemer, Mich.	200	1955-81	27	____	____	____	3.540	0.216	0.881
					44	1960	____	____	3.531	.201	.715
2	04031500	Presque Isle River at Marenisco, Mich.	171	1945-81	37	____	____	____	3.078	.186	.196
3	04032000	Presque Isle River near Tula, Mich.	261	1945-81	37	____	____	____	3.375	.159	- .403
4	04033000	Middle Branch Ontonagon River near Paulding, Mich.	164	1943-81	39	____	____	____	2.941	.180	- .164
5	04035000	East Branch Ontonagon River near Mass, Mich.	272	1943-79	37	____	____	____	3.427	.145	- .535
6	04039500	South Branch Ontonagon River at Ewen, Mich.	348	1939-81	43	1960	____	____	3.585	.186	.128
7	04040000	Ontonagon River near Rockland, Mich.	1,340	1942-81	40	____	____	____	4.143	.149	.365
					44	1942	____	____	4.142	.147	.317
8	04040500	Sturgeon River near Sidnaw, Mich.	171	1913-15, 1943-81	42	____	____	____	3.344	.164	- .579
9	04041000	Perch River near Sidnaw, Mich.	63.1	1957-81	25	____	____	____	2.662	.168	.087
10	04041500	Sturgeon River near Alston, Mich.	346	1932-81	50	____	____	____	3.540	.142	- .430
11	04042500	Otter River near Elo, Mich.	167	1943-79	37	____	____	____	3.434	.153	- .446
12	04043000	Sturgeon River near Arnheim, Mich.	705	1943-74	32	____	____	____	3.784	.186	.325
13	04045500	Tahquamenon River near Tahquamenon Paradise, Mich.	790	1954-81	28	____	____	____	3.650	.107	- .503
14	04046000	Black River near Garnet, Mich.	33.1	1952-81	30	____	____	____	2.425	.187	1.126
					43	1960	____	____	2.419	.179	1.085
15	04049500	Manistique River at Germfask, Mich.	341	1938-81	44	____	____	____	3.103	.099	.541
16	04055000	Manistique River near Blaney, Mich.	704	1938-79	42	____	____	____	3.581	.147	.488
17	04056500	Manistique River near Manistique, Mich.	1,100	1938-81	44	____	____	____	3.848	.150	.437
18	04058500	East Branch Escanaba River at Gwinn, Mich.	124	1955-80	26	____	____	____	2.974	.167	.438
19	04059000	Escanaba River at Cornell, Mich.	870	1906-08, 1911-12, 1951-81	36	____	____	____	3.799	.142	- .222
20	04059500	Ford River near Hyde, Mich.	450	1955-81	27	____	____	____	3.477	.142	.819
					44	1960	____	____	3.471	.133	.669
21	04060500	Iron River at Caspian, Mich.	92.1	1948-80	33	____	____	____	2.697	.230	- .391
22	04061000	Brule River near Florence, Wisc.	389	1914-15, 1945-81	39	1953	____	____	3.189	.180	.191
23	04061500	Paint River at Crystal Falls, Mich.	597	1945-81	37	____	____	____	3.620	.176	.409
24	04065500	Sturgeon River near Foster City, Mich.	237	1955-78, 1980	25	____	____	____	3.081	.143	.427
25	04066500	Pike River at Amberg, Wisc.	255	1914-70	57	____	____	____	3.009	.163	.244
26	04069500	Peshtigo River at Pehstigo, Wisc.	1,080	1954-78	25	____	____	____	3.670	.145	.506
27	04071000	Oconto River near Gillet, Wisc.	705	1907-08, 1912, 1914-79	69	____	____	____	3.407	.189	- .181

Table 1.--Annual maximum streamflow statistics for selected stations with 25 or more years of record--Continued.

Site	USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence			Systematic and adjusted		
						High outlier	Low outlier	Historic event	Mean	Standard deviation	Skew
28	04097500	St. Joseph River at Three Rivers, Mich.	1,350	1952-82	31	___	___	___	3.556	0.149	-0.089
					33	___	___	1950	3.567	.160	.100
29	04098500	Fawn River near White Pigeon, Mich.	192	1958-82	25	___	___	___	2.601	.143	- .458
					78	___	___	1904	2.604	.143	- .392
30	04099000	St. Joseph River at Mottville, Mich.	1,870	1924-82	59	___	___	___	3.688	.138	.133
31	04099510	Pigeon Creek near Angola, Ind.	106	1946-82	37	___	___	___	2.533	.191	- .722
						___	1953,64	___	2.549	.157	.234
32	04100500	Elkhart River at Goshen, Ind.	594	1925-28, 1932-82	55	___	___	___	3.428	.198	- .685
						___	1941,64	___	3.439	.175	- .204
33	04101000	St. Joseph River at Elkhart, Ind.	3,370	1903-27, 1948-82	61	___	___	___	3.982	.153	.179
					80	1908	___	___	3.980	.150	.114
34	04101500	St. Joseph River at Niles, Mich.	3,670	1931-82	52	___	___	___	3.999	.152	- .717
						___	1931	___	4.005	.138	- .271
35	04102500	Paw Paw River at Riverside, Mich.	390	1952-82	31	___	___	___	3.133	.140	.552
36	04103500	Kalamazoo River at Marshall, Mich.	449	1948-81	34	___	___	___	3.003	.143	.105
37	04105000	Battle Creek at Battle Creek, Mich.	241	1933-81	49	___	___	___	3.098	.218	- .357
						___	1964	___	3.107	.196	.372
38	04105500	Kalamazoo River near Battle Creek, Mich.	824	1938-81	44	___	___	___	3.402	.174	.315
39	04106000	Kalamazoo River at Comstock, Mich.	1,010	1933-79	47	___	___	___	3.448	.167	- .023
40	04108500	Kalamazoo River near Fennville,	1,600	1931-36, 1938-8	50	___	___	___	3.635	.153	.299
					53	___	___	1929	3.630	.151	.334
41	04109000	Grand River at Jackson, Mich.	174	1936-81	46	___	___	___	2.786	.116	.298
42	04111500	Deer Creek near Dansville, Mich.	16.3	1955-81	27	___	___	___	2.382	.301	- .946
						___	1964	___	2.405	.245	.226
43	04112000	Sloan Creek near Williamston, Mich.	9.34	1955-81	27	___	___	___	2.332	.362	- .446
						___	1964	___	2.357	.308	.566
44	04112500	Red Cedar River at East Lansing, Mich.	355	1903-4, 1911-81	73	___	___	___	3.300	.261	- .766
						___	1931,64	___	3.316	.225	.104
45	04113000	Grand River at Lansing, Mich.	1,230	1901-81	81	___	___	___	3.722	.230	.136
46	04114500	Looking Glass River near Eagle, Mich.	281	1945-81	37	___	___	___	3.049	.243	- .827
						___	1964	___	3.059	.224	- .580
47	04115000	Maple River at Maple Rapids, Mich.	434	1945-81	37	___	___	___	3.289	.300	- .356
48	04116500	Flat River near Smyrna, Mich.	528	1951-81	31	___	___	___	3.186	.138	.354
49	04117000	Quaker Brook near Nashville, Mich.	7.60	1955-81	27	___	___	___	2.097	.275	- .373
50	04117500	Thornapple River at Hastings, Mich.	385	1945-81	37	___	___	___	3.315	.239	- .424
						___	1964	___	3.324	.221	- .118
51	04118500	Rouge River near Rockford, Mich.	234	1952-81	30	___	___	___	3.103	.182	.368
52	04119000	Grand River at Grand Rapids, Mich.	1,900	1901-81	81	___	___	___	4.239	.219	- .345
						___	1931	___	4.244	.205	.025

Table 1.--Annual maximum streamflow statistics for selected stations with 25 or more years of record--Continued.

Site	USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence			Systematic and adjusted		
						High outlier	Low outlier	Historic event	Mean	Standard deviation	Skew
53	04121000	Muskegon River near Merritt, Mich.	355	1947-78	32				2.888	0.135	-0.570
54	04121500	Muskegon River at Evart, Mich.	1,450	1934-81	48				3.617	.156	- .136
55	04122000	Muskegon River at Newaygo, Mich.	2,350	1910-15, 1932-81	56				3.802	.143	.439
56	04122500	Pere Marquette River at Scottville, Mich.	681	1940-81	42				3.249	.150	- .408
57	04123000	Big Sable River near Freesoil, Mich.	127	1943-75	33				2.534	.123	- .692
58	04123500	Manistee River near Grayling, Mich.	123	1943-81	39				2.464	.055	- .220
59	04124000	Manistee River near Sherman, Mich.	900	1904-16, 1934-81	61				3.373	.084	.087
60	04124500	East Branch Pine River near Tustin, Mich.	63.0	1953-65, 1968-76, 1978-81	26				2.557	.267	.217
61	04125500	Pine River near Hoxeyville, Mich.	251	1953-81	29				3.022	.158	.448
62	04126000	Manistee River near Manistee, Mich.	1,780	1952-81	30				3.704	.103	- .398
63	04126200	Little Manistee River near Freesoil, Mich.	178	19 7-81	25				2.591	.124	- .471
64	04128000	Sturgeon River near Wolverine, Mich.	198	1943-81	39				2.834	.124	- .231
							1958		2.839	.114	.219
65	04129000	Pigeon River near Vanderbilt, Mich.	62.6	1951-56, 1958-81	30				2.619	.172	.318
66	04129500	Pigeon River at Afton, Mich.	139	1943-81	39				2.805	.150	- .586
67	04131500	Rainy River near Ocqueoc, Mich.	85.0	1953-81	29				2.604	.225	- .542
							1958		2.614	.207	- .244
68	04132000	Black River near Cheboygan, Mich.	597	1943-74, 1976,78	34				3.180	.143	- .048
69	04132500	Thunder Bay River near Hillman, Mich.	232	1946-81	36				2.917	.148	- .727
							1958		2.923	.135	- .408
70	04134000	North Branch Thunder Bay River near Bolton, Mich.	184	1946-80	35				3.152	.200	- .624
							1958		3.160	.183	- .294
71	04135500	Au Sable River at Grayling, Mich.	93.4	1943-81	39				2.214	.106	- .347
72	04135600	East Branch Au Sable River at Grayling, Mich.	69.4	1958-82	25				2.036	.144	- .195
73	04138000	East Branch Au Gres River at McIvor, Mich.	91.0	1951-81	31				2.668	.240	- .909
							1964		2.678	.221	- .735
74	04138500	Au Gres River near National City, Mich.	154	1951-81	31				3.059	.286	-1.904
							1964,77		3.094	.201	- .623
75	04139000	Houghton Creek near Lupton, Mich.	30.2	1951-81	31				2.499	.184	- .024
					100	1959	1964		2.498	.147	.417
76	04140500	Rifle River at Selkirk, Mich.	117	1951-81	31				2.947	.190	- .151
						1959	1964		2.956	.171	.434
77	04141000	South Branch Shepards Creek near Selkirk, Mich.	1.15	1952-81	30				1.728	.383	-1.861
							1964		1.763	.287	- .483
78	04142000	Rifle River near Sterling, Mich.	320	1937-81	45				3.332	.184	- .841
							1964		3.342	.161	- .089
79	04143500	North Branch Kawkawlin River near Kawkawlin, Mich.	101	1951-81	31				2.827	.291	-1.317
							1964,67		2.862	.214	- .202

Table 1.--Annual maximum streamflow statistics for selected stations with 25 or more years of record--Continued.

Site	USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence			Systematic and adjusted		
						High outlier	Low outlier	Historic event	Mean	Standard deviation	Skew
80	04144000	Shiawassee River at Byron, Mich.	368	1948-81	34	___	___	___	3.149	0.214	-0.284
						___	1964	___	3.158	.195	.169
81	04144500	Shiawassee River at Owosso, Mich.	538	1931-81	51	___	___	___	3.371	.249	-1.043
						___	1931	___	3.383	.218	- .356
82	04145000	Shiawassee River near Fergus, Mich.	637	1940-80	41	___	___	___	3.522	.220	- .668
83	04146000	Farmers Creek near Lapeer, Mich.	51.9	1933-81	49	___	___	___	2.468	.295	- .132
84	04147500	Flint River near Otisville, Mich.	530	1953-81	29	___	___	___	3.308	.289	- .518
						___	1964	___	3.320	.265	- .206
85	04148200	Swartz Creek near Holly, Mich.	12.1	1956-81	26	1975	___	___	1.720	.204	.545
						___	___	___			
86	04148500	Flint River near Flint, Mich.	956	1933-81	49	___	___	___	3.678	.213	- .212
87	04150000	South Branch Cass River near Cass City, Mich.	238	1949-80	32	___	___	___	3.424	.312	-2.090
						___	1964	___	3.452	.232	- .781
88	04150500	Cass River at Cass City, Mich.	359	1948-81	34	___	___	___	3.544	.298	-1.941
						___	1964	___	3.570	.225	- .529
89	04151500	Cass River at Frankenmuth, Mich.	841	1940-81	42	___	___	___	3.831	.273	-1.379
						___	1964	___	3.849	.224	- .286
90	04153500	Salt River near North Bradley, Mich.	138	1935-81	47	___	___	___	3.318	.350	- .375
91	04154000	Chippewa River near Mt. Pleasant, Mich.	416	1933-81	49	___	___	___	3.263	.212	- .003
92	04154500	Chippewa River near Midland, Mich.	597	1948-78	31	___	___	___	3.546	.194	- .217
					78	___	___	1904	3.554	.205	.144
93	04155000	Pine River at Alma, Mich.	288	1931-38, 1942-81	48	___	___	___	3.162	.251	- .118
						___	___	___			
94	04155500	Pine River near Midland, Mich.	390	1935-38, 1948-81	38	___	___	___	3.386	.214	- .557
						___	___	___			
95	04156000	Tittabawassee River at Midland, Mich.	2,400	1910-81	72	___	___	___	4.098	.260	- .321
						___	1931	___	4.104	.248	- .102
96	04158500	Pigeon River near Owendale, Mich.	53.2	1953-81	29	___	___	___	2.901	.340	-1.985
						___	1961,64	___	2.951	.217	- .142
97	04159500	Black River near Fargo, Mich.	480	1944-81	38	___	___	___	3.720	.294	-1.637
						___	1964	___	3.739	.247	- .995
98	04161500	Paint Creek near Lake Orion, Mich.	38.5	1956-81	26	___	___	___	2.206	.247	- .178
99	04164500	North Branch Clinton River near Mt. Clemens, Mich.	199	1948-81	34	___	___	___	3.365	.265	- .034
100	04169500	Huron River at Commerce, Mich.	57.3	1946-77, 1979	33	___	___	___	2.046	.167	.209
						___	___	___			
101	04172000	Huron River near Hamburg, Mich.	308	1952-81	30	___	___	___	2.794	.168	.104
102	04172500	Portage River near Pinckney, Mich.	79.1	1945-79	35	___	___	___	2.247	.193	.160
103	04173000	Huron River near Dexter, Mich.	522	1946-79	34	___	___	___	3.075	.198	.095
104	04173500	Mill Creek near Dexter, Mich.	133	1952-81	30	___	___	___	2.888	.160	- .702
						___	1964	___	2.896	.144	- .281
105	04176000	River Raisin near Adrian, Mich.	463	1933-38, 1954-81	34	___	___	___	3.372	.192	- .515
						___	1964	___	3.379	.178	- .245

Table 1.--Annual maximum streamflow statistics for selected stations with 25 or more years of record--Continued.

Site	USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence			Systematic and adjusted		
						High outlier	Low outlier	Historic event	Mean	Standard deviation	Skew
106	04176500	River Raisin near Monroe, Mich.	1,042	1938-81	44	____	_____	_____	3.769	0.218	-0.464
107	04176900	Hill Drain near Richards, Ohio	3.35	1947-79	33	____	_____	_____	1.875	.340	.177
108	04177400	Eagle Creek Trail near Montpelier, Ohio	1.84	1950-75	26	____	_____	_____	1.804	.313	-1.040
						____	1964	_____	1.825	.269	- .501
109	04178000	St. Joseph River near Newville, Ind.	610	1947-82	36	____	_____	_____	3.609	.202	- .174
110	04179500	Cedar Creek at Auburn, Ind.	87.3	1943-78, 1980-82	39	____	_____	_____	2.944	.146	- .001
111	04180000	Cedar Creek near Cedarville, Ind.	270	1947-82	36	____	_____	_____	3.458	.154	- .438
112	04183500	Maumee River at Antwerp, Ohio	1,180	1912-79	68	____	_____	_____	4.137	.166	- .965
					97	1913	1931,41	_____	4.147	.131	.258
113	04184500	Bean Creek at Powers, Ohio	203	1941-79	39	____	_____	_____	3.300	.216	- .822
						____	1964	_____	3.310	.195	- .432
114	04185000	Tiffin River at Stryker, Ohio	410	1922-28, 1941-79	46	____	_____	_____	3.481	.217	- .991
					68	____	1964	1913,37	3.497	.196	- .371
115	04186500	AuGlaze River near Fort Jennings, Ohio	332	1922-36, 1941-79	54	____	_____	_____	3.678	.202	- .649
116	04187500	Ottawa River at Allentown, Ohio	160	1924-35, 1943-79	49	____	_____	_____	3.473	.187	- .483
					57	____	_____	1939	3.478	.189	- .474
117	04189000	Blanchard River near Findlay, Ohio	346	1924-36, 1941-80	53	____	_____	_____	3.690	.224	-1.007
					97	____	1941	1913	3.704	.214	- .424
118	04189100	Tiderishi Creek near Jenera, Ohio	4.65	1947-77	31	____	_____	_____	2.274	.252	- .871
					68	1959	_____	_____	2.471	.274	- .034
119	04190500	Roller Creek at Ohio City, Ohio	5.14	1947-77	31	____	_____	_____	2.336	.216	.386
					68	1959	_____	_____	2.325	.199	.094
120	04191500	AuGlaze River near Defiance, Ohio	2,320	1916-79	64	____	_____	_____	4.386	.197	- .998
					68	____	1941	1913	4.402	.199	- .024
121	04192500	Maumee River near Defiance, Ohio	1,280	1925-36, 1939-75, 1979	50	____	_____	_____	4.619	.192	-1.417
						____	1931,41	_____	4.636	.150	- .338
122	04195500	Portage River at Woodville, Ohio	428	1929-35, 1940-79	47	____	_____	_____	3.780	.169	- .705
					68	____	1931	1913	3.791	.166	- .248
123	04196000	Sandusky River near Bucyrus, Ohio	88.8	1926-35, 1939-51, 1964-79	39	____	_____	_____	3.402	.178	- .346
					68	____	_____	1959	3.413	.196	.372
124	04196500	Sandusky River near Upper Sandusky, Ohio	298	1922-36, 1938-79	57	____	_____	_____	3.669	.189	- .355
125	04196700	St. James River near Upper Sandusky, Ohio	5.29	1947-77	31	____	_____	_____	2.279	.256	-1.449
						____	1954	_____	2.296	.216	- .888
126	04197000	Sandusky River near Mexico, Ohio	774	1922-37, 1939-79	57	____	_____	_____	3.926	.186	- .223
127	04197500	Havens Creek at Havens, Ohio	4.28	1947-77	31	____	_____	_____	2.127	.220	- .563
128	04198000	Sandusky River near Fremont, Ohio	1,250	1924-36, 1939-80	55	____	_____	_____	4.172	.162	- .545
129	04198100	Norwalk Creek at Norwalk, Ohio	4.92	1947-79	33	____	_____	_____	2.544	.318	.069
					68	1969	_____	_____	2.532	.303	- .039
130	04199000	Huron River at Milan, Ohio	371	1950-79	30	____	_____	_____	3.961	.218	1.512
					149	1969	_____	_____	3.940	.179	.979
131	04199500	Vermillion River near Vermillion, Ohio	262	1950-79	30	____	_____	_____	3.847	.301	1.054
					149	1969	_____	_____	3.852	.272	.964

Table 2.--Annual maximum streamflow statistics for selected stations with 10 to 24 years of record.

USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence			Systematic and adjusted		
					High outlier	Low outlier	Historic event	Mean	Standard deviation	Skew
04042300	Sturgeon River near Pelkie, Mich.	506	1958-68	11				3.640	0.151	0.366
04043050	Trap Rock River near Lake Linden, Mich.	28.0	1967-81	15				2.892	.144	.340
04056000	West Branch Manistique River near Manistique, Mich.	322	1938-56	19				3.415	.161	.098
04057510	Sturgeon River near Nahma Junction, Mich.	183	1967-81	15				3.053	.098	.235
04057800	Middle Branch Escanaba River at Humbolt, Mich.	46	1960-81	22				2.831	.162	.602
04057900	Black River near Republic, Mich.	34.4	1962-68, 1970-81	19				2.496	.167	- .097
04058000	Middle Branch Escanaba River near Ishpeming, Mich.	128	1955-72	18				3.067	.162	.185
04058100	Middle Branch Escanaba River near Princeton, Mich.	210	1962-81	20				3.143	.165	- .087
04058400	Goose Lake Outlet near Sands Station, Mich.	37.5	1966-80	15				2.487	.140	- .501
04059400	Tenmile Creek at Perronville, Mich.	43.9	1971-81	11				2.613	.163	.869
04062200	Peshekee River near Champion, Mich.	133	1962-81	20				3.388	.102	- .111
04062230	Michigamme River near Michigamme, Mich.	194	1969-81	13				3.300	.136	.140
04062400	Michigamme River near Witch Lake, Mich.	316	1965-80	16				3.442	.143	- .169
04065300	West Branch Sturgeon River near Randville, Mich.	56.1	1959-81	23				2.523	.132	.407
04096400	St. Joseph River near Burlington, Mich.	201	1963-82	20				2.805	.177	- .171
04096515	Hog Creek near Allen, Mich.	48.7	1970-82	13				2.376	.181	.175
04096600	Coldwater River near Hodunk, Mich.	293	1963-82	20				3.031	.231	-1.172
						1964		3.051	.186	- .332
04096900	Nottawa Creek near Athens, Mich.	162	1967-82	16				2.736	.141	.800
				50	1978			2.722	.123	.667
04097060	Little Portage Creek near Fulton, Mich.	28.3	1965-67, 1972-79	11				2.404	.248	.836
				50	1978			2.361	.189	.294
04097170	Portage River near Vicksburg, Mich.	68.2	1947-51, 1965-70 1972-82	22				2.304	.146	- .019
04097370	Flowerfield Creek at Flowerfield, Mich.	37.6	1964-79	16				1.835	.133	- .963
						1964		1.847	.109	- .334
04097540	Prairie River near Nottawa, Mich.	106	1963-82	20				2.505	.197	- .762
						1964		2.518	.171	- .280
04101800	Dowagiac River at Sumnerville, Mich.	255	1961-82	22				2.941	.089	- .003
04102700	Black River near Bangor, Mich.	83.6	1967-82	16				2.900	.173	.358
04105800	Gull Creek near Galesburg, Mich.	38.1	1965-74	10				1.919	.144	.565
04106300	Portage Creek near Kalamazoo, Mich.	19.5	1965-82	18				2.154	.147	.614
04106400	West Fork Portage Creek at Kalamazoo, Mich.	25.0	1960-81	22				1.354	.124	.075
04108600	Rabbit River near Hopkins, Mich.	68.5	1966-81	16				2.767	.170	.207

Table 2.--Annual maximum streamflow statistics for selected stations with 10 to 24 years of record--Continued

USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence			Systematic and adjusted		
					High outlier	Low outlier	Historic event	Mean	Standard deviation	Skew
04108800	Macatawa River near Zeeland, Mich.	65.8	1961-81	21	____	_____	____	3.307	0.257	-0.008
04109500	Portage River below Little Portage Lake near Munith, Mich.	54	1945-56	12	____	_____	____	2.449	.219	.242
04110000	Orchard Creek at Munith, Mich.	49	1945-56	12	____	_____	____	2.663	.269	- .159
04121300	Clam River at Vogel Center, Mich.	243	1967-81	15	____	_____	____	2.737	.163	.450
04121900	Little Muskegon River near Morley, Mich.	138	1967-81	15	____	_____	____	2.721	.138	.771
04122100	Bear Creek near Muskegon, Mich.	14.8	1966-81	16	____	_____	____	2.396	.245	.781
04122200	White River near Whitehall, Mich.	406	1958-81	24	____	_____	____	3.211	.237	.494
04125000	Pine River near Le Roy, Mich.	118	1953-63	11	____	_____	____	2.786	.173	1.274
				50	1956	_____	____	2.754	.126	.874
04127800	Jordan River near East Jordan, Mich.	67.6	1967-81	15	____	_____	____	2.846	.137	.764
04135700	South Branch Au Sable River, near Luzerne, Mich.	401	1967-81	15	____	_____	____	2.767	.138	.304
04138600	Gamble Creek at Lupton, Mich.	9.47	1953-56, 1961-78	22	____	_____	____	1.885	.154	- .234
					____	1977	____	1.897	.131	.798
04141500	West Branch Rifle River near Selkirk, Mich.	64.5	1952-63	12	____	_____	____	2.838	.160	- .066
04143900	Shiawassee River at Linden, Mich.	81.2	1968-82	15	____	_____	____	2.350	.148	.718
04144180	Jones Creek near Gaines, Mich.	7.60	1970-82	13	____	_____	____	2.027	.227	- .306
04144200	Porter Drain near Gaines, Mich.	4.68	1970-82	13	____	_____	____	1.814	.262	- .598
					____	1977	____	1.838	.216	.192
04144220	Jones Creek at Duffield, Mich.	23.4	1970-77, 1979-82	12	____	_____	____	2.530	.212	- .927
04145500	Bad River near Brant, Mich.	89.0	1949-59, 1961-65, 1967-68	18	____	_____	____	3.079	.253	- .529
04147800	Powers-Cullen Drain near Genesee, Mich.	9.17	1970-82	13	____	_____	____	2.323	.305	- .280
04147900	Lefler-Scothan Drain near Otisville, Mich.	4.69	1970-82	13	____	_____	____	1.862	.273	- .573
04147990	Butternut Creek near Genesee, Mich.	34.5	1970-82	13	____	_____	____	2.779	.359	- .915
04148120	Kearsley Creek near Atlas, Mich.	55.6	1970-82	13	____	_____	____	2.499	.245	1.158
				50	1975	_____	____	2.462	.190	.761
04148139	Black Creek near Davison, Mich.	22.8	1970-82	13	____	_____	____	2.382	.206	- .578
04148140	Kearsley Creek near Davison, Mich.	99.4	1966-82	17	____	_____	____	2.783	.212	- .182
04148160	Gilkey Creek near Flint, Mich.	6.43	1970-82	13	____	_____	____	2.235	.211	- .160
04148255	Swartz Creek near Grand Blanc, Mich.	36.0	1970-82	13	____	_____	____	2.092	.242	.872
04148260	Swartz Creek near Swartz Creek, Mich.	67.3	1970-82	13	____	_____	____	2.805	.296	- .828
04148265	Kimball Drain near Swartz Creek, Mich.	10.6	1970-82	13	____	_____	____	2.298	.211	- .413
04148270	West Branch Swartz Creek near Swartz Creek, Mich.	40.6	1970-82	13	____	_____	____	2.866	.271	- .771
					____	1977	____	2.891	.225	- .171
04148300	Swartz Creek at Flint, Mich.	115	1970-82	13	____	_____	____	3.115	.257	- .863
					____	1977	____	3.137	.219	- .501

Table 2.--Annual maximum streamflow statistics for selected stations with 10 to 24 years of record--Continued

USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence			Systematic and adjusted		
					High outlier	Low outlier	Historic event	Mean	Standard deviation	Skew
04148410	Thread Creek near Goodrich, Mich.	28.8	1970-82	13				2.243	0.168	-0.073
04148440	Thread Creek near Flint, Mich.	54.4	1970-82	13				2.687	.242	- .148
04148610	Cole Creek near Flushing, Mich.	8.51	1970-82	13		1977		2.217 2.227	.205 .193	- .755 - .872
04148620	Freeman Drain near Montrose, Mich.	8.21	1970-82	13		1970,77		2.251 2.318	.264 .140	-1.351 .294
04148640	Armstrong Creek near Montrose, Mich.	11.9	1970-82	13		1970		2.324 2.343	.177 .141	-1.149 - .588
04148740	Central-Stadler Drain near Montrose, Mich.	14.1	1970-82	13				2.230	.212	- .503
04148800	Pine Run near Montrose, Mich.	28.2	1970-82	13				2.668	.226	-1.291
04148900	Silver Creek near Clio, Mich.	3.70	1970-82	13		1977		1.871 1.889	.148 .111	-1.219 - .259
04149300	Misteguay Creek near Flushing, Mich.	17.3	1970-82	13		1970,77		2.752 2.825	.331 .201	-1.111 .257
04152500	Tobacco River at Beaverton, Mich.	487	1961-81	21				3.498	.181	.169
04157500	Sebewaing River near Sebewaing, Mich.	67.3	1940-54	15		1941		3.215 3.234	.188 .151	-1.394 - .991
04158000	East Fork Sebewaing River near Sebewaing, Mich.	33.9	1940-54	15		1941		2.867 2.910	.280 .176	-1.772 .394
04160000	Mill Creek near Abbotsford, Mich.	208	1948-64	17		1964		3.107 3.157	.395 .275	-1.817 - .639
04160050	Black River near Port Huron, Mich.	684	1933-43	11				3.761	.235	.111
04160570	North Branch Belle River at Imlay City, Mich.	18	1966-81	16				2.154	.195	- .538
04160600	Belle River at Memphis, Mich.	151	1963-81	19		1964		3.127 3.165	.377 .292	-1.285 - .279
04160800	Sashabaw Creek near Drayton Plains, Mich.	20.9	1960-81	22				1.882	.180	.296
04160900	Clinton River near Drayton Plains, Mich.	79.2	1960-81	22				2.128	.132	.674
04161100	Galloway Creek near Auburn Heights, Mich.	17.9	1960-81	22				2.072	.195	.619
04161540	Paint Creek at Rochester, Mich.	70.9	1960-81	22				2.561	.259	- .162
04161580	Stony Creek near Romeo, Mich.	25.6	1965-81	17				2.108	.221	- .215
04161760	West Branch Stony Creek near Washington, Mich.	22.5	1967-81	15		1970		2.105 2.128	.285 .244	- .057 .852
04163500	Plum Brook near Utica, Mich.	22.9	1954-66	13				2.564	.287	- .423
04164010	North Branch Clinton River at Almont, Mich.	9.56	1959-81	23				2.294	.277	- .419
04164050	North Branch Clinton River near Romeo, Mich.	49.7	1959-81	23				2.838	.347	.014
04164100	East Pond Creek at Romeo, Mich.	21.8	1959-81	23				2.129	.280	- .125
04164150	North Branch Clinton River near Meade, Mich.	89.6	1959-81	23				3.064	.306	- .151
04164200	Coon Creek near Armada, Mich.	10.0	1959-82	24				2.291	.304	- .556

Table 2.--Annual maximum streamflow statistics for selected stations with 10 to 24 years of record--Continued

USGS station number	Station name	Drainage area (square miles)	Period of record	Systematic and historic record length	Year of occurrence			Systematic and adjusted		
					High outlier	Low outlier	Historic event	Mean	Standard deviation	Skew
04164250	Tupper Brook at Ray Center, Mich.	8.62	1959-80	22	___	_____	___	2.235	0.268	0.277
04164300	East Branch Coon Creek at Armada, Mich.	13.0	1959-81	23	___	_____	___	2.494	.326	- .904
04164350	Highbank Creek near Armada, Mich.	14.9	1959-81	23	___	_____	___	2.649	.316	- .010
04164360	East Branch Coon Creek near New Haven, Mich.	36.1	1959-81	23	___	_____	___	2.899	.251	- .131
04164400	Deer Creek near Meade, Mich.	12.7	1959-81	23	___	_____	___	2.566	.157	- .133
04164450	McBride Drain near Macomb, Mich.	5.79	1960-81	22	___	_____	___	2.100	.115	- .082
04164600	Middle Branch Clinton River near Macomb, Mich.	22.2	1959-69, 1971-81	22	___	_____	___	2.704	.222	.223
04164800	Middle Branch Clinton River at Macomb, Mich.	41.0	1959-81	23	___ ___	_____ 1963	___ ___	2.908 2.918	.200 .183	- .867 - .719
04165200	Gloede Ditch near Waldenburg, Mich.	16.0	1959-81	23	___ ___	_____ 1964	___ ___	2.425 2.437	.192 .166	- .659 - .026
04171500	Ore Creek near Brighton, Mich.	31.0	1952-68	17	___	_____	___	1.914	.167	.200
04175340	Stony Creek at Oakville, Mich.	69.3	1970-81	12	___	_____	___	2.791	.129	- .336
04175600	River Raisin near Manchester, Mich.	132	1970-81	12	1976	_____	___	2.569	.081	.640
04175700	River Raisin near Tecumseh, Mich.	267	1957-80	24	___ 1968	_____ 1964	___ ___	3.046 3.059	.166 .138	- .391 .813
04176400	Saline River near Saline, Mich.	93.5	1966-81	16	1968	_____	___	3.041	.204	.878

DEFINITION OF TERMS

Bias. Mean difference between station and generalized skew.

F statistic. Ratio between two variances or mean-square errors. The computed F statistic is compared to a Fisher's F distribution to estimate probability.

Flood-flow frequency. The probability that a given flow is equaled or exceeded in a given year. It is equal to 1 divided by the recurrence interval.

Generalized skew. Skew derived by a procedure which integrates skew obtained at many locations.

Mean-square error (MSE). Sum of the squared differences between the station skew and generalized skew divided by the number of observations. It can also be defined as the bias squared plus the variance of the quantity.

Outlier. Data points of extreme events which depart from the trend of other data points.

r^2 coefficient. Coefficient of linear determination which measures the closeness of the relationship. It is the square of the correlation coefficient.

Skew. Numerical measure or index of the lack of symmetry in a frequency distibution. It is a function of the third moment of magnitudes about their mean, which is a measure of asymmetry.

Station skew. Skew of the logarithms of annual maximum discharge values available for the period of record at a streamflow gaging station.

t-test. Statistical test based on "student's" t-distribution. A value of t is computed as $(x-\mu)/(s/\sqrt{n})$, where x is the sample mean, μ is the population mean, s is the sample standard deviation and n is the number of observations. Computed t is compared to the theoretical t-distribution to estimate probability.

True station skew. Skew of the logarithms of annual maximum discharge at a station having a very long period of homogeneous record.

Weighted skew. Skew computed by combining the generalized skew and station skew in inverse proportion to their individual mean-square errors. It is an estimate of true station skew.