Generalized Skew Coefficients for Flood-Frequency Analysis in Minnesota

By D.L. Lorenz

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Bruce Babbitt, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
2280 Woodale Drive
Mounds View, MN 55112

Copies of this report can be purchased from:

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Conversion Factors

Multiply	By	To obtain
square mile (mi^2)	2.590	square kilometer

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Abstract

This report presents an evaluation of generalized skew coefficients used in flood-frequency analysis. Station skew coefficients were computed for 267 long-term stream-gaging stations in Minnesota and the surrounding states of Iowa, North and South Dakota, Wisconsin, and the provinces of Manitoba and Ontario, Canada. Generalized skew coefficients were computed from station skew coefficients using a locally weighted regression technique. The resulting regression trend surface was the generalized skew coefficient map, except for the North Shore area, and has a mean square error of 0.182.

Introduction

Reliable peak streamflow information is needed for water-resources regulation, planning, and design of dams, bridges, and culverts. In 1995, the U.S. Geological Survey, in cooperation with the Minnesota Department of Transportation, began to update previous flood investigation reports in Minnesota. This report presents an evaluation of generalized skew coefficients, which are used in flood-frequency analysis to modify the station skew coefficient, because station skew coefficients computed for stations with short records can have significant error.

The Water Resources Council (WRC), Hydrology Committee (1982), recommends the use of weighted skew coefficients for the computation of flood-frequency statistics. The use of both the generalized skew and the station skew results in a better estimate of the skew coefficient for a given station. A generalized skew coefficient map of the United States, prepared for a previous report (Water Resources Council, Hydrology Committee, 1976) and not based on the 1982 standards, was included in that report. That generalized skew map was intended to be used to determine the generalized skew coefficient in the absence of a detailed study.

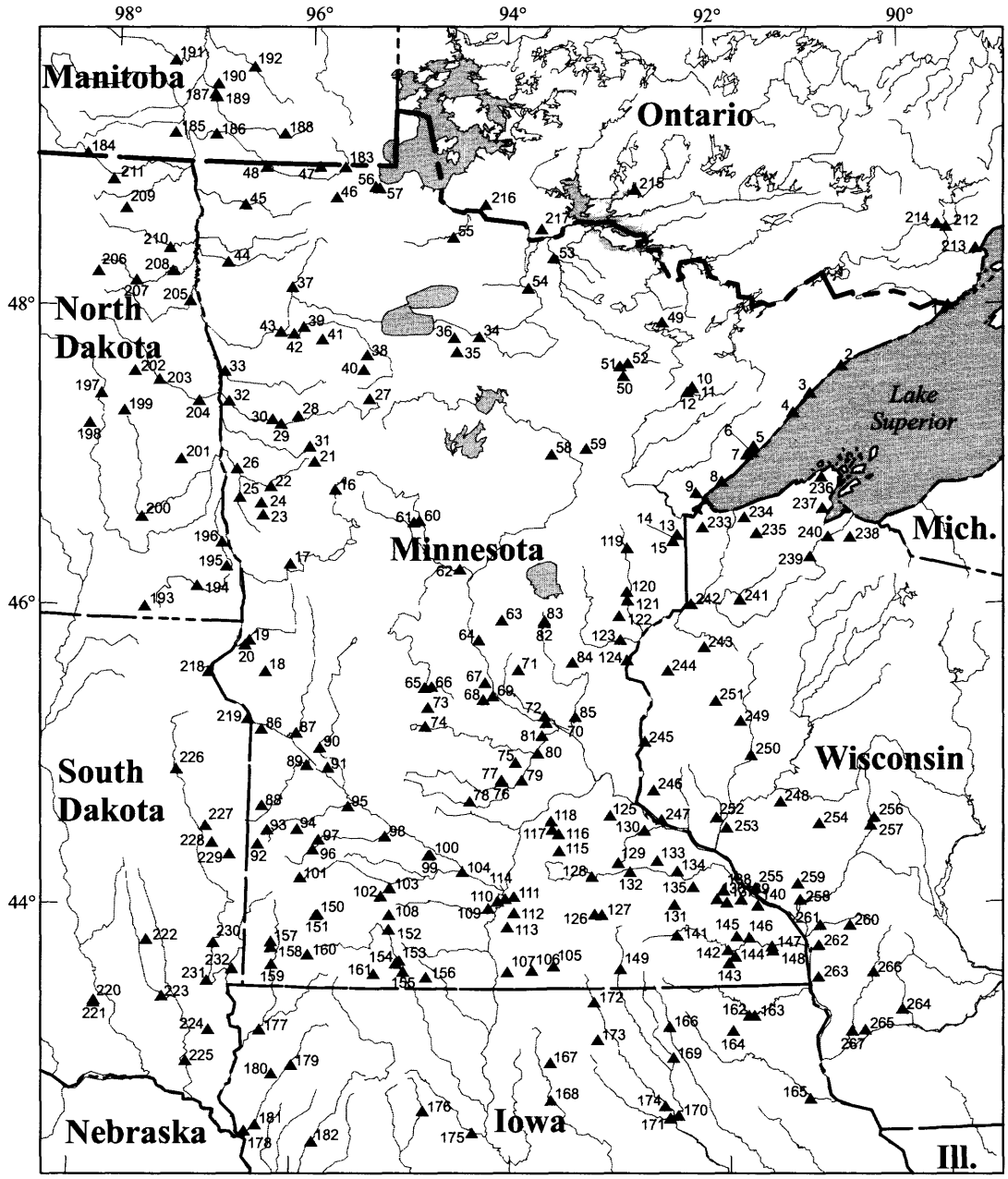
The author thanks Sue Saunders and Carol Walker, both of Environment Canada, for their timely assistance in providing peak-flow data for this study. George Carlson of the U.S. Geological Survey provided assistance in computing the peak-flow-frequency statistics.

Methods

Stream-gaging stations used in this analysis were selected on the basis of having a minimum of 25 years of unregulated peak-flow records and drainage areas less than 6,000 square miles. To reduce redundancy in the data, stations in the same river basin were selected if the drainage area at least doubled between the two stations, or if they had no more than 5 years of concurrent record. The peak-flow data were obtained from the files of the U.S. Geological Survey or Environment Canada. The analysis used 267 stations (fig. 1; table 1, at the back of report) selected from Minnesota and the surrounding states of Iowa, North and South Dakota, Wisconsin, and the provinces of Manitoba and Ontario, Canada. In addition to 162 stations in Minnesota, 105 stations were selected from the surrounding states and Canada to improve estimation of skew coefficients near the border of the State. Of these stations, the 162 in Minnesota and 2 in South Dakota were used to compute statistics for this report. These stations are referred to as the 164 Minnesota stations.

The station skew coefficients were computed using a computer program that conforms to the WRC (1982) guidelines. Adjustments were made for historical data and for low-value outliers. A historical peak is the highest known streamflow outside the period of record. Other historical data include the time period since a previous peak, or the time period until present for a discontinued station.

No Canadian stream-gaging records had complete instantaneous peak-flow data. Instantaneous and daily peak-flow data were correlated, and daily peak-flow data were used to compute station skew coefficients if there were at least 10 years of data that comprised the same relative range in peak flow and the Pearson correlation coefficient was at least 0.99. The high correlation coefficient criterion was used to ensure that the station skew was valid. Instantaneous peaks were used to compute station skew if there were at least 25 years of data and the correlation did not meet the criteria.



EXPLANATION

▲88 Location of gaging station
(number is map number from table 1).

Figure 1. Location of stations used in this analysis.

Tasker and Stedinger (1986) discussed the use of a bias-correction factor for station skew coefficients. The bias in skew coefficients results from two factors—relatively short-term records and use of the method of moments to compute the station skew. The bias-correction factor was not used because there is no correction factor in the WRC (1982) guidelines.

The WRC (1982) recommended three procedures for estimating generalized skew coefficients: (1) compute the mean station skew for a region, (2) develop a prediction equation based on watershed and climatologic variables, and (3) plot station skews and develop an isoline map. The mean square error (MSE) was used to compare and evaluate each of the methods.

A weighting factor was used to give more weight to stations with longer periods of record and historical periods than to stations with shorter periods of record (G.D. Tasker, U.S. Geological Survey, written commun., 1996). This weighting factor was used for all procedures to determine the generalized skew coefficients. The period of record for stations used in this analysis ranges from 25 to 84 years. Historical record, up to 141 years, was available for some stations.

The mean station skew was computed using the weighted station skew coefficient for the 164 Minnesota stations. This value formed the basis for evaluating other procedures.

A regression procedure used watershed and climatic variables: drainage area, percent storage, percent lake area, channel slope, and mean annual runoff determined from Gebert and others (1985) to estimate the generalized skew coefficient. Linear regression techniques were used for untransformed and log-transformed independent variables.

To develop an isoline map, the WRC (1982) recommends plotting each station skew coefficient at the centroid of each basin and examining the data for areal trends. That procedure was modified for this analysis by using the gage location, and a locally weighted regression technique was used to determine the trend surface. The gage location was used instead of the basin centroid because those data were available for all stations, and the gage location has been used for determining the generalized skew coefficient from the WRC (1982) map.

Cleveland and Devlin (1988) described a locally weighted regression technique, a procedure for estimating regression surfaces by the local fitting of linear or quadratic functions of the independent variables in a moving fashion. That technique was chosen for this analysis because it is a robust method for interpolating a trend surface without distortion in data containing a large amount of scatter.

This technique basically required only the selection of either a first-order or second-order (quadratic) regression model and the number of data points, expressed as the proportion of the data, used at each location. The second-order model is selected if there are local minima or maxima in the regression surface. The selection of the proportion of the data requires some judgment, but is based on finding an acceptable variance with minimal bias. That is, by choosing the proportion too small, we introduce bias by having too great an influence from each observation and, by choosing the proportion too large, we can introduce bias by inducing too much smoothing.

Generalized Skew Coefficients

The MSE for the 164 Minnesota stations (0.233), computed using the mean skew coefficient for the State (–0.170), was the basis for evaluating WRC (1982) procedures 2 and 3. The WRC (1982) generalized skew map had a MSE of 0.254 for the 164 Minnesota stations. Because the MSE of the WRC (1982) generalized skew map was larger than 0.233, that map was considered not adequate for the State of Minnesota.

The regression analyses of the skew data and watershed and climatic variables were based on 159 stations in Minnesota. Two equations were derived; both had a MSE of 0.205, and the significant independent variables were runoff and channel slope in one equation and runoff and the logarithm of channel slope in the other. The regression equations were

$$\hat{G} = -0.461 + 0.0401 * \text{runoff} + 0.00352 * \text{slope},$$

and

$$\hat{G} = -0.621 + 0.0404 * \text{runoff} + 0.953 * \log(\text{slope}),$$

where

$\hat{G}$ is the estimated generalized skew coefficient.

This procedure was not pursued because the MSE was substantially larger than the isoline map and because both runoff and slope vary regionally across Minnesota, implying that generalized skew is dependent on the general factors at a location rather than specific basin characteristics.

The second-order model was appropriate for the locally weighted regression analysis because the surface appears to have several undulations. There were no rules to select the proportion of data; however, Cleveland and Devlin (1988) imply that the proportion should be near the largest value in the acceptable range of proportions. Using too small a proportion would allow the interpolated surface to fluctuate too much in response to the data; using all of the data could make the regression ignore real local trends. A proportion of 0.562, or 150 stations, was used for

this analysis because an analysis of variance indicated that the model was significantly different from the full data model, and an analysis of the residuals indicated that the residuals were well distributed (fig. 2), except in the North Shore area (fig. 3). Figure 2 shows a coplot of the residuals in a north-south swath that includes the North Shore area of Minnesota. Superimposed on figure 2 is a locally weighted scatterplot smoothing (LOWESS) (Cleveland, 1979) curve that indicates the amount of bias in the North Shore area. The generalized skew coefficient for the North Shore area was computed separately from the rest of the State rather than reduce the proportion of data and possibly introduce local bias.

An F-test statistic based only on the 164 Minnesota stations indicated that the locally weighted regression trend surface was significant at the 0.0002 level. The MSE of the regression trend surface was 0.182, which is 22 percent lower than the MSE computed from the mean of the 164 Minnesota stations. Because of the relatively low MSE of this technique, this method was chosen as the procedure to estimate the generalized skew coefficient for Minnesota.

Figure 3 shows the generalized skew coefficient map developed by locally weighted regression. The North Shore area was treated separately from the rest of the State. The weighted mean station skew of the eight stations in the North Shore area (0.500) was considered applicable to that area. Although treating that area differently reduced the actual MSE for the State, the value of the MSE for generalized skew coefficients used to determine the WRC (1982) weighted skew coefficient remained 0.182. The generalized skew coefficient for any specific station of interest is available from the U.S. Geological Survey, Mounds View, Minnesota.

Summary

This report presents an evaluation of generalized skew coefficients, which are used in flood-frequency analysis. Skew coefficients are used to estimate peak-flood-frequency statistics. The Water Resources Council, Hydrology Committee, recommended using a weighted skew coefficient based on the generalized skew coefficient because station skew coefficients computed for stations with short records can have significant error. However, a statistical analysis of the original generalized skew coefficient map indicated that it was not adequate for use in Minnesota.

Station skew coefficients were computed for 267 long-term stream-gaging stations in Minnesota and the surrounding states of Iowa, North and South Dakota, Wisconsin, and the provinces of Manitoba and Ontario, Canada. Generalized skew coefficients were estimated using a locally weighted regression technique. The regression trend surface had a mean square error of 0.182. The North Shore area of Minnesota was treated separately from the rest of the State for the purpose of determining the generalized skew. That area is considered to have a generalized skew coefficient of 0.500.

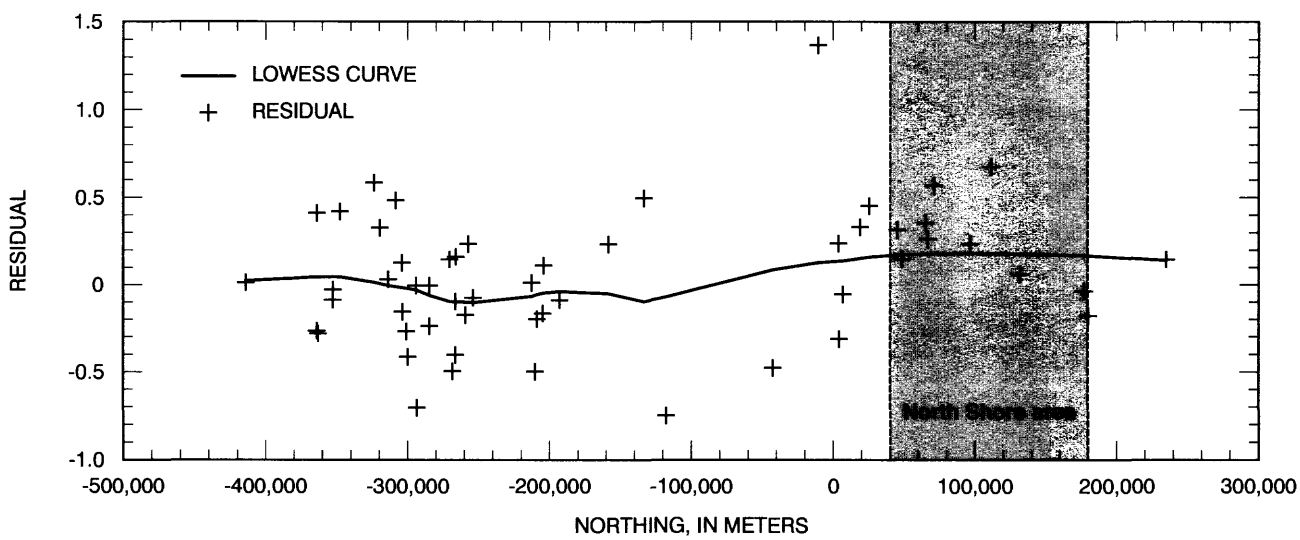


Figure 2. Residual coplot in the north-south swath that includes the North Shore area of Minnesota.

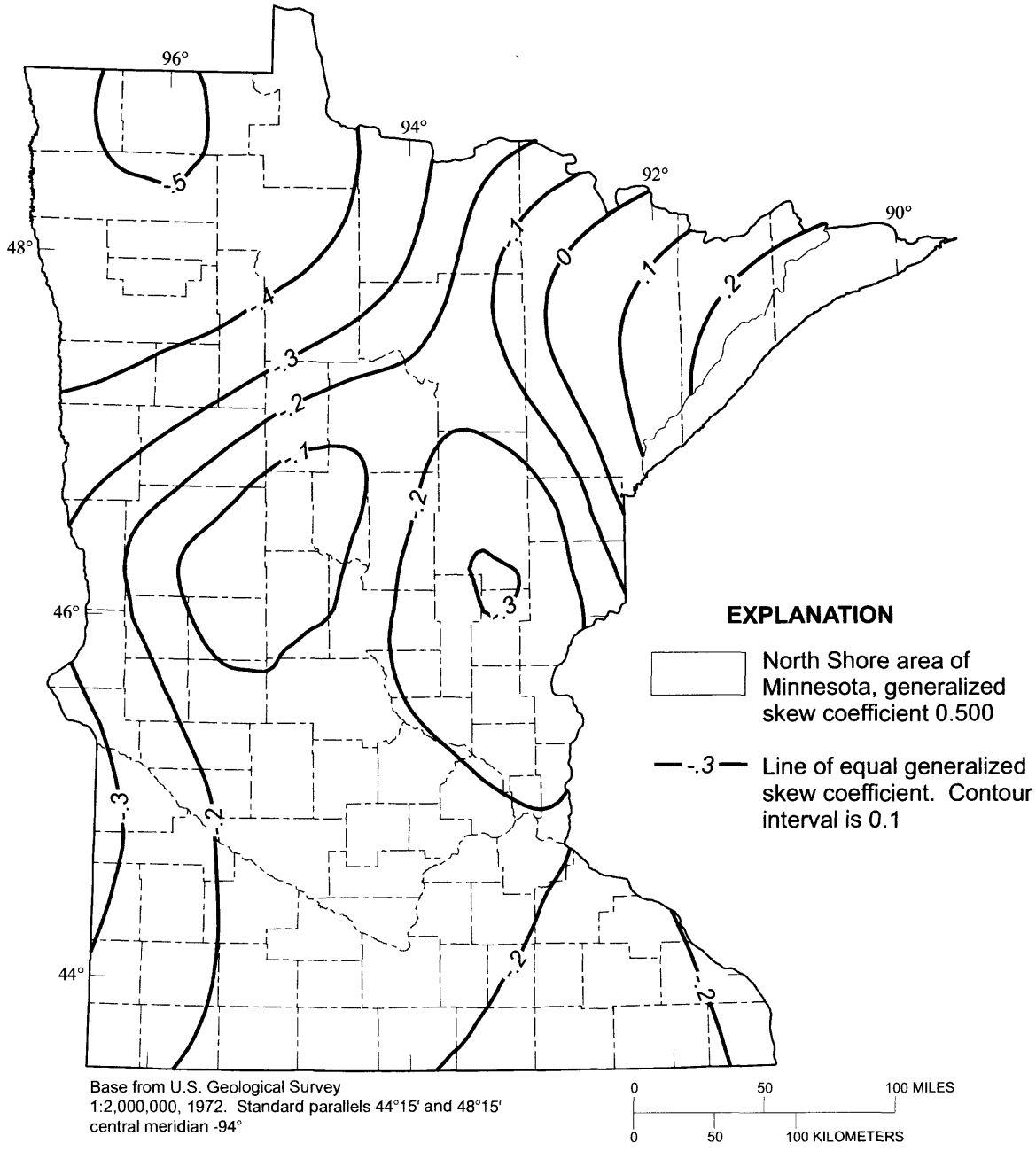


Figure 3. Generalized skew coefficient isolines for Minnesota.

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———1982, Guidelines for determining flood-flow frequency: Washington, D.C., Bulletin 17B, 190 p., 1 sheet. [Revised September 1981, editorial corrections March 1982].

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
1	04010500	Pigeon River at Middle Falls near Grand Portage, Minnesota	480044	893658	71	71	71	0.202	0.500
2	04012500	Poplar River at Lutsen, Minnesota	473823	904231	43	43	43	0.373	0.500
3	04013200	Caribou River near Little Marais, Minnesota	472751	910150	25	25	25	0.980	0.500
4	04014500	Baptism River near Beaver Bay, Minnesota	472007	911206	63	63	63	0.529	0.500
5	04015200	Encampment River tributary at Silver Creek, Minnesota	470701	913604	31	31	31	0.816	0.500
6	04015250	Silver Creek tributary near Two Harbors, Minnesota	470440	913649	31	31	31	0.508	0.500
7	04015300	Little Stewart River near Two Harbors, Minnesota	470352	914003	36	36	36	0.591	0.500
8	04015370	Talmadge River at Duluth, Minnesota	465320	915521	32	32	32	0.495	0.500
9	04015400	Miller Creek at Duluth, Minnesota	464901	921042	26	26	26	–0.130	0.080
10	04015500	Second Creek near Aurora, Minnesota	473125	921135	26	26	26	0.755	0.116
11	04016000	Partridge River near Aurora, Minnesota	473102	921124	40	40	40	–0.334	0.116
12	04016500	St. Louis River near Aurora, Minnesota	472930	921420	53	53	53	0.341	0.109
13	04024100	Rock Creek near Blackhoof, Minnesota	463210	922212	26	26	26	–0.022	–0.036
14	04024110	Rock Creek tributary near Blackhoof, Minnesota	463214	922205	26	26	26	0.132	–0.034
15	04024200	South Fork Nemadji River near Holyoke, Minnesota	462938	922436	25	25	25	–0.162	–0.063
16	05030000	Otter Tail River near Detroit Lakes, Minnesota	465012	954157	35	35	35	–0.785	–0.208
17	05040500	Pelican River near Fergus Falls, Minnesota	462010	960710	40	40	40	0.217	–0.167
18	05047700	West Branch Mustinka River tributary near Graceville, Minnesota	453653	961947	26	26	26	0.235	–0.267
19	05049000	Mustinka River above Wheaton, Minnesota	454915	962925	47	47	47	–0.373	–0.271
20	05049200	Eighteen Mile Creek near Wheaton, Minnesota	454718	963152	31	31	31	–0.247	–0.280
21	05060800	Buffalo River near Callaway, Minnesota	470117	955443	36	36	36	–0.449	–0.297
22	05061000	Buffalo River near Hawley, Minnesota	465100	961945	51	75	60	–0.453	–0.308
23	05061200	Whisky Creek at Barnesville, Minnesota	463935	962354	35	35	35	0.143	–0.273
24	05061400	Spring Creek above Downer, Minnesota	464437	962512	35	35	35	0.937	–0.296
25	05061500	South Branch Buffalo River at Sabin, Minnesota	464620	963740	51	75	61	–0.191	–0.329
26	05062000	Buffalo River near Dilworth, Minnesota	465740	963940	65	75	69	0.016	–0.361
27	05062280	Mosquito Creek near Bagley, Minnesota	472702	952255	25	25	25	–0.729	–0.354
28	05062470	Marsh Creek tributary near Mahnomen, Minnesota	471931	960441	25	25	25	–0.521	–0.382
29	05062500	Wild Rice River at Twin Valley, Minnesota	471600	961440	74	87	79	–0.347	–0.383
30	05062700	Wild Rice River tributary near Twin Valley, Minnesota	471747	961942	25	25	25	–0.694	–0.392

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota--(Continued)

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
31	05063200	Spring Creek tributary near Ogema, Minnesota	470722	955735	27	27	27	−0.671	−0.329
32	05067500	Marsh River near Shelly, Minnesota	472445	964550	52	52	52	−0.804	−0.422
33	05069000	Sand Hill River at Climax, Minnesota	473643	964852	53	53	53	−0.276	−0.439
34	05073600	South Branch Battle River at Northome, Minnesota	475220	941750	26	26	26	−0.030	−0.332
35	05073750	Spring Creek near Blackduck, Minnesota	474623	943122	26	26	26	0.641	−0.343
36	05073800	Perry Creek near Shooks, Minnesota	475200	943250	26	26	26	−0.148	−0.363
37	05076000	Thief River near Thief River Falls, Minnesota	481108	961011	84	84	84	−1.124	−0.487
38	05077700	Ruffy Brook near Gonvick, Minnesota	474450	952445	34	34	34	−0.685	−0.415
39	05078000	Clearwater River at Plummer, Minnesota	475524	960246	57	57	57	−0.032	−0.463
40	05078180	Silver Creek near Clearbrook, Minnesota	473843	952633	26	26	26	−1.299	−0.401
41	05078230	Lost River at Oklee, Minnesota	475035	955130	35	46	40	−0.624	−0.451
42	05078400	Clearwater River tributary near Plummer, Minnesota	475234	960835	30	30	30	0.240	−0.463
43	05078500	Clearwater River at Red Lake Falls, Minnesota	475315	961625	70	70	70	−0.249	−0.466
44	05087500	Middle River at Argyle, Minnesota	482027	964902	47	47	47	−0.869	−0.481
45	05094000	South Branch Two Rivers at Lake Bronson, Minnesota	484350	963950	58	58	58	−0.346	−0.498
46	05104500	Roseau River below South Fork near Malung, Minnesota	484730	954440	66	66	66	−0.759	−0.502
47	05107000	Pine Creek near Pine Creek, Minnesota	485935	955504	25	25	25	−0.838	−0.505
48	05112000	Roseau River below State Ditch 51 near Caribou, Minnesota	485854	962746	77	77	77	−0.782	−0.505
49	05129000	Vermilion River below Vermilion Lake near Tower, Minnesota	475741	922833	59	59	59	−0.177	0.039
50	05130300	Boriin Creek near Chisholm, Minnesota	473614	925158	34	34	34	0.053	0.006
51	05130500	Sturgeon River near Chisholm, Minnesota	474025	925400	53	53	53	0.227	−0.001
52	05131000	Dark River near Chisholm, Minnesota	474127	924915	33	33	33	0.448	0.015
53	05131500	Little Fork River at Littlefork, Minnesota	482345	933257	75	75	75	−0.090	−0.232
54	05132000	Big Fork River at Big Falls, Minnesota	481145	934825	69	69	69	−0.219	−0.276
55	05134200	Rapid River near Baudette, Minnesota	483210	943345	29	36	32	−0.539	−0.415
56	05139500	Warroad River near Warroad, Minnesota	485200	952120	35	35	35	−0.522	−0.480
57	05140500	East Branch Warroad River near Warroad, Minnesota	485130	951840	26	26	26	−0.531	−0.477
58	05210200	Smith Creek near Hill City, Minnesota	470458	933459	35	35	35	−0.065	−0.194
59	05216980	Swan River tributary at Warba, Minnesota	470711	931500	25	25	25	−0.593	−0.166
60	05244000	Crow Wing River at Nimrod, Minnesota	463825	945244	65	65	65	−0.071	−0.026

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota--(Continued)

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
61	05244200	Cat River near Nimrod, Minnesota	463749	945551	35	35	35	–0.137	–0.020
62	05246000	Crow Wing River at Pillager, Minnesota	461858	942852	27	27	27	–0.473	–0.110
63	05267900	Hillman Creek near Pierz, Minnesota	455827	940421	32	32	32	–0.571	–0.213
64	05268000	Platte River at Royalton, Minnesota	455043	941740	31	31	31	–0.626	–0.181
65	05270300	Sauk River tributary at Spring Hill, Minnesota	453122	944831	36	77	51	1.289	–0.129
66	05270310	Sauk River tributary #2 near St. Martin, Minnesota	453144	944450	25	67	40	1.193	–0.135
67	05270500	Sauk River near St. Cloud, Minnesota	453335	941400	60	86	69	–0.068	–0.182
68	05271800	Johnson Creek tributary at Luxemburg, Minnesota	452630	941446	26	26	26	0.507	–0.174
69	05272300	Johnson Creek near St. Augusta, Minnesota	452749	940919	32	32	32	–0.020	–0.184
70	05273700	Otsego Creek near Otsego, Minnesota	451719	933859	26	26	26	–0.290	–0.205
71	05274200	Stony Brook tributary near Foley, Minnesota	453842	935454	30	30	30	–0.266	–0.220
72	05275000	Elk River near Big Lake, Minnesota	452002	934000	69	86	76	–0.693	–0.209
73	05276100	North Fork Crow River tributary near Paynesville, Minnesota	452329	944656	26	26	26	–0.008	–0.138
74	05278000	Middle Fork Crow River near Spicer, Minnesota	451545	944810	39	39	39	–0.840	–0.143
75	05278350	Fountain Creek near Montrose, Minnesota	450120	935629	25	34	29	0.760	–0.166
76	05278700	Otter Creek near Lester Prairie, Minnesota	445423	940424	29	29	29	0.011	–0.152
77	05278750	Otter Creek tributary near Lester Prairie, Minnesota	445334	940424	29	29	29	–0.442	–0.150
78	05278850	Buffalo Creek tributary near Brownton, Minnesota	444555	942233	28	34	31	–0.224	–0.134
79	05279000	South Fork Crow River near Mayer, Minnesota	445420	935305	57	77	65	–0.230	–0.161
80	05280000	Crow River at Rockford, Minnesota	450512	934402	74	86	79	–0.455	–0.181
81	05280300	School Lake Creek tributary near St. Michael, Minnesota	451209	934131	27	27	27	0.735	–0.192
82	05284600	Robinson Brook near Onamia, Minnesota	455822	933942	26	26	26	–0.905	–0.273
83	05284620	Rum River tributary near Onamia, Minnesota	455729	933943	26	26	26	0.609	–0.271
84	05284920	Stanchfield Creek tributary Near Day, Minnesota	454129	932345	25	25	25	–0.238	–0.270
85	05286000	Rum River near St. Francis, Minnesota	451940	932220	66	80	72	–0.675	–0.231
86	05293000	Yellow Bank River near Odessa, Minnesota	451335	962112	56	77	65	–0.655	–0.301
87	05294000	Pomme De Terre River at Appleton, Minnesota	451210	960120	65	77	70	–0.152	–0.254
88	05299100	Lazarus Creek tributary near Canby, Minnesota	444304	961942	31	31	31	–0.827	–0.310
89	05300000	Lac Qui Parle River near Lac Qui Parle, Minnesota	445942	955509	68	77	72	–0.090	–0.252
90	05304500	Chippewa River near Milan, Minnesota	450639	954757	58	77	66	–0.233	–0.229

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota--(Continued)

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
91	05305200	Spring Creek near Montevideo, Minnesota	445841	954257	37	37	37	–0.368	–0.222
92	05311200	North Branch Yellow Medicine River near Ivanhoe, Minnesota	442732	962127	26	26	26	–0.406	–0.307
93	05311250	North Branch Yellow Medicine River tributary near Wilno, Minnesota	443312	961633	26	26	26	–0.625	–0.300
94	05311400	South Branch Yellow Medicine River at Minneota, Minnesota	443350	955950	28	28	28	–0.370	–0.261
95	05313500	Yellow Medicine River near Granite Falls, Minnesota	444318	953107	64	115	83	–0.594	–0.201
96	05315000	Redwood River near Marshall, Minnesota	442549	955043	55	77	64	–0.311	–0.239
97	05315200	Prairie Ravine near Marshall, Minnesota	442944	954748	27	27	27	–0.318	–0.233
98	05316500	Redwood River near Redwood Falls, Minnesota	443125	951020	69	77	72	–0.429	–0.170
99	05316690	Spring Creek tributary near Sleepy Eye, Minnesota	442354	944535	25	25	25	–0.563	–0.141
100	05316700	Spring Creek near Sleepy Eye, Minnesota	442412	944441	37	37	37	–0.249	–0.140
101	05316800	Cottonwood River tributary near Balaton, Minnesota	441424	955722	27	27	27	–0.424	–0.248
102	05316900	Dry Creek near Jeffers, Minnesota	440721	951213	25	25	25	–0.151	–0.173
103	05316920	Cottonwood River tributary near Sanborn, Minnesota	441034	950715	27	27	27	–0.292	–0.166
104	05317000	Cottonwood River near New Ulm, Minnesota	441729	942624	67	77	71	0.103	–0.123
105	05317850	Foster Creek near Alden, Minnesota	433931	933530	26	26	26	–1.190	–0.201
106	05318000	East Branch Blue Earth River near Bricelyn, Minnesota	433750	934725	35	35	35	–0.587	–0.182
107	05318100	East Branch Blue Earth River tributary near Blue Earth, Minnesota	433709	940103	26	26	26	–0.178	–0.165
108	05318300	Watonwan River near Delft, Minnesota	435955	950711	36	36	36	0.247	–0.165
109	05319500	Watonwan River near Garden City, Minnesota	440247	941143	25	77	47	0.173	–0.130
110	05320000	Blue Earth River near Rapidan, Minnesota	440544	940633	82	115	93	–0.271	–0.127
111	05320200	Le Sueur River tributary near Mankato, Minnesota	440729	935733	27	27	27	1.103	–0.132
112	05320300	Cobb River tributary near Mapleton, Minnesota	440105	935730	27	27	27	0.313	–0.137
113	05320400	Maple River tributary near Mapleton, Minnesota	435518	940117	27	27	27	0.450	–0.142
114	05320500	Le Sueur River near Rapidan, Minnesota	440640	940228	52	56	54	–0.029	–0.126
115	05330200	Rice Lake tributary near Montgomery, Minnesota	442542	933210	25	36	29	–0.281	–0.157
116	05330300	Sand Creek near New Prague, Minnesota	443237	933216	35	77	51	–0.116	–0.160
117	05330550	East Branch Raven stream near New Prague, Minnesota	443421	933558	25	36	29	0.703	–0.157
118	05330600	Sand Creek tributary #2 near Jordan, Minnesota	443745	933633	25	36	29	0.564	–0.159
119	05336200	Glaisby Brook near Kettle River, Minnesota	462719	925134	36	36	36	–0.084	–0.229
120	05336550	Wolf Creek tributary near Sandstone, Minnesota	460945	925158	30	30	30	–0.471	–0.245

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota--(Continued)

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
121	05336700	Kettle River below Sandstone, Minnesota	460620	925150	29	82	48	–0.349	–0.254
122	05338200	Mission Creek near Hinckley, Minnesota	455952	925644	26	26	26	–0.179	–0.260
123	05338500	Snake River near Pine City, Minnesota	455030	925600	43	108	70	–0.472	–0.266
124	05339500	St. Croix River near Rush City, Minnesota	454215	925220	39	108	66	–0.605	–0.253
125	05345000	Vermillion River near Empire, Minnesota	444000	930317	27	54	38	0.168	–0.190
126	05352700	Turtle Creek tributary #2 near Pratt, Minnesota	440002	930830	26	26	26	–0.446	–0.214
127	05352800	Turtle Creek tributary near Steele Center, Minnesota	440026	931220	26	26	26	–0.193	–0.206
128	05353800	Straight River near Faribault, Minnesota	441529	931351	30	30	30	–0.549	–0.185
129	05355100	Little Cannon River tributary near Kenyon, Minnesota	442050	925850	27	27	27	–0.137	–0.205
130	05355200	Cannon River at Welch, Minnesota	443350	924355	64	108	81	0.205	–0.207
131	05372995	South Fork Zumbro River at Rochester, Minnesota	440342	922758	44	141	81	0.184	–0.240
132	05373700	Spring Creek near Wanamingo, Minnesota	441713	925217	27	27	27	–0.117	–0.215
133	05373900	Trout Brook tributary near Goodhue, Minnesota	442130	923658	27	99	52	0.659	–0.222
134	05374000	Zumbro River at Zumbro Falls, Minnesota	441712	922556	69	137	94	–0.643	–0.229
135	05374400	Long Creek near Potsdam, Minnesota	441048	921723	25	25	25	0.082	–0.232
136	05376000	North Fork Whitewater River near Elba, Minnesota	440530	920357	29	56	40	–0.037	–0.225
137	05376500	South Fork Whitewater River near Altura, Minnesota	440410	915849	48	48	48	–0.689	–0.219
138	05376800	Whitewater River near Beaver, Minnesota	440903	920017	34	58	44	–0.362	–0.216
139	05378300	Straight Valley Creek near Rollingstone, Minnesota	440509	915034	27	27	27	–0.577	–0.202
140	05379000	Gilmore Creek at Winona, Minnesota	440240	914125	24	57	38	–0.006	–0.183
141	05383600	North Branch Root River tributary near Stewartville, Minnesota	435120	922650	28	28	28	0.095	–0.254
142	05384000	Root River near Lanesboro, Minnesota	434458	915843	63	63	63	–0.380	–0.239
143	05384100	Duschee Creek near Lanesboro, Minnesota	433940	915810	26	26	26	–0.201	–0.243
144	05384200	Gribben Creek near Whalen, Minnesota	434226	915450	27	27	27	0.262	–0.235
145	05384400	Pine Creek near Arendahl, Minnesota	435027	915339	27	27	27	–0.910	–0.224
146	05384500	Rush Creek near Rushford, Minnesota	435000	914640	54	54	54	–0.194	–0.211
147	05385000	Root River near Houston, Minnesota	434607	913411	73	86	79	–0.430	–0.183
148	05385500	South Fork Root River near Houston, Minnesota	434419	913350	43	43	43	–0.036	–0.184
149	05457000	Cedar River near Austin, Minnesota	433811	925826	56	56	56	–0.919	–0.269
150	05474750	Beaver Creek tributary #2 near Slayton, Minnesota	435935	954801	25	25	25	0.264	–0.228

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota--(Continued)

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
151	05474760	Beaver Creek tributary above Slayton, Minnesota	435935	954712	25	25	25	–0.445	–0.227
152	05475400	Warren Lake tributary near Windom, Minnesota	435405	950720	28	28	28	0.654	–0.165
153	05475800	Des Moines River tributary near Jackson, Minnesota	434136	950126	26	26	26	–0.467	–0.159
154	05475900	Des Moines River tributary #2 near Lakefield, Minnesota	434028	950315	26	26	26	–0.460	–0.160
155	05476000	Des Moines River at Jackson, Minnesota	433710	945910	70	70	70	–0.082	–0.158
156	05476900	Fourmile Creek near Dunnell, Minnesota	433457	944626	36	36	36	–0.011	–0.154
157	06482950	Mound Creek near Hardwick, Minnesota	434818	961247	27	27	27	0.118	–0.255
158	06482960	Mound Creek tributary at Hardwick, Minnesota	434605	961244	27	27	27	–0.788	–0.251
159	06483000	Rock River at Luverne, Minnesota	433915	961203	28	85	50	0.236	–0.241
160	06483210	Kanaranzi Creek tributary #2 near Wilmont, Minnesota	434332	955220	26	26	26	–0.760	–0.221
161	06603530	Little Sioux River near Spafford, Minnesota	433608	951527	34	34	34	0.192	–0.171
162	05387500	Upper Iowa River at Decorah, Iowa	431819	914748	39	77	53	–0.336	–0.248
163	05388000	Upper Iowa River near Decorah, Iowa	431820	914500	30	77	47	–0.270	–0.241
164	05411600	Turkey River at Spillville, Iowa	431228	915656	33	33	33	–0.550	–0.284
165	05412500	Turkey River at Garber, Iowa	424424	911542	76	106	89	–0.155	–0.168
166	05420560	Wapsipinicon River near Elma, Iowa	431434	923148	34	34	34	–0.385	–0.337
167	05449000	East Branch Iowa River near Klemme, Iowa	430031	933742	47	47	47	0.030	–0.353
168	05449500	Iowa River near Rowan, Iowa	424536	933723	54	54	54	–0.311	–0.431
169	05458000	Little Cedar River near Ionia, Iowa	430205	923005	42	42	42	–0.427	–0.381
170	05458500	Cedar River at Janesville, Iowa	423854	922754	74	91	81	–0.545	–0.474
171	05458900	West Fork Cedar River at Finchford, Iowa	423750	923224	50	67	58	–0.591	–0.486
172	05459000	Shell Rock River near Northwood, Iowa	432451	931314	41	41	41	–0.598	–0.288
173	05459500	Winnebago River at Mason City, Iowa	430954	931133	63	63	63	–0.205	–0.357
174	05462000	Shell Rock River at Shell Rock, Iowa	424243	923458	42	140	75	–0.503	–0.468
175	05480000	Lizard Creek near Clare, Iowa	423235	942045	42	42	42	–0.684	–0.371
176	05482170	Big Cedar Creek near Varina, Iowa	424116	944752	32	32	32	–0.737	–0.279
177	06483500	Rock River near Rock Valley, Iowa	431252	961739	48	99	66	–0.369	–0.208
178	06600000	Perry Creek at 38th Street, Sioux City, Iowa	423208	962439	46	46	46	–0.772	–0.133
179	06600100	Floyd River at Alton, Iowa	425855	960003	41	120	68	–0.176	–0.192
180	06600300	West Branch Floyd River near Struble, Iowa	425526	961036	39	39	39	–0.674	–0.182

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota--(Continued)

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
181	06600500	Floyd River at James, Iowa	423436	961843	61	120	81	0.010	–0.148
182	06606600	Little Sioux River at Correctionville, Iowa	422820	954749	70	105	82	0.052	–0.206
183	05106000	Sprague Creek near Sprague, Manitoba[1]	485933	953943	52	52	52	–0.858	–0.496
184	05OB007	Pembina River near Windygates, Manitoba	490153	981640	33	33	33	–0.060	–0.231
185	05OC019	Buffalo Creek near Rosenfeld, Manitoba	491130	972400	26	26	26	–0.285	–0.387
186	05OD001	Roseau River near Dominion City, Manitoba	491133	965904	77	77	77	–0.307	–0.435
187	05OE001	Rat River near Otterburne, Manitoba	492742	970026	67	67	67	–0.025	–0.410
188	05OE004	Rat River near Sundown, Manitoba	491235	961700	35	35	35	–0.315	–0.465
189	05OE007	Joubert Creek at St. Pierre-Jolys, Manitoba	492626	965923	29	29	29	–0.300	–0.413
190	05OE009	Tourond Creek near Tourond, Manitoba	493150	965850	26	26	26	0.006	–0.403
191	05OG001	La Salle River near Sanford, Manitoba	494045	972546	35	35	35	–0.642	–0.338
192	05OH007	Seine River near Ste. Anne, Manitoba	493910	963700	31	31	31	–0.199	–0.412
193	05051600	Wild Rice River near Rutland, North Dakota	460120	973040	35	35	35	–0.619	–0.354
194	05052000	Wild Rice River near Mantador, North Dakota	461021	970037	32	32	32	0.237	–0.325
195	05052500	Antelope Creek at Dwight, North Dakota	461841	964403	31	31	31	–0.481	–0.284
196	05053000	Wild Rice River near Abercrombie, North Dakota	462805	964700	64	64	64	–0.564	–0.301
197	05057000	Sheyenne River near Cooperstown, North Dakota	472558	980138	51	51	51	–0.447	–0.395
198	05057200	Baldhill Creek near Dazey, North Dakota	471345	980728	41	41	41	–0.041	–0.407
199	05059600	Maple River near Hope, North Dakota	471930	974725	30	30	30	–1.205	–0.403
200	05059700	Maple River near Enderlin, North Dakota	463718	973425	40	40	40	–0.471	–0.405
201	05060500	Rush River at Amenia, North Dakota	470100	971250	49	49	49	–0.180	–0.388
202	05064900	Beaver Creek near Finley, North Dakota	473540	974218	31	31	31	–1.008	–0.392
203	05065500	Goose River near Portland, North Dakota	473220	972720	44	44	44	–0.191	–0.399
204	05066500	Goose River at Hillsboro, North Dakota	472434	970339	65	114	86	–0.694	–0.399
205	05083000	Turtle River at Manvel, North Dakota	480443	971103	28	28	28	0.407	–0.424
206	05083600	Middle Branch Forest River near Whitman, North Dakota	481450	980700	30	30	30	–0.604	–0.325
207	05084000	Forest River near Fordville, North Dakota	481150	974349	56	56	56	–0.565	–0.376
208	05085000	Forest River at Minto, North Dakota	481610	972210	52	52	52	–0.125	–0.413
209	05089500	Cart Creek at Mountain, North Dakota	484037	975141	31	31	31	–0.432	–0.342
210	05090000	Park River at Grafton, North Dakota	482524	972430	64	114	83	–0.640	–0.410

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota--(Continued)

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
211	05099400	Little South Pembina River near Walhalla, North Dakota	485155	980020	27	27	27	−0.173	−0.306
212	02AB006	Kaministiqua River at Kaministiquia, Ontario	483158	893539	26	26	26	0.151	0.006
213	02AB008	Neebing River near Thunder Bay, Ontario	482256	891828	27	27	27	−0.353	0.066
214	02AB009	Shebandowan River at Sunshine, Ontario	483320	894055	37	37	37	0.056	0.234
215	05PB014	Turtle River near Mine Centre, Ontario	485100	924330	78	78	78	−0.260	−0.262
216	05PC011	Pinewood River near Pinewood, Ontario	484510	941400	43	43	43	−0.340	−0.342
217	05PC016	La Vallee River near Devlin, Ontario	483525	934022	27	27	27	−0.228	−0.259
218	05290000	Little Minnesota River near Peever, South Dakota[2]	453605	965218	48	77	60	−0.032	−0.321
219	05291000	Whetstone River near Big Stone City, South Dakota[2]	451732	962914	68	86	74	−0.513	−0.300
220	06478280	South Branch Dry Creek near Parkston, South Dakota	432122	974935	25	25	25	0.299	−0.187
221	06478300	Dry Creek near Parkston, South Dakota	432218	974923	32	32	32	−0.166	−0.190
222	06478540	Little Vermillion River near Salem, South Dakota	434739	972202	29	29	29	−0.856	−0.294
223	06478690	West Fork Vermillion River near Parker, South Dakota	432455	971218	34	34	34	−0.092	−0.241
224	06478820	Saddlerock Creek tributary near Beresford, South Dakota	431221	964551	25	25	25	−0.032	−0.209
225	06479000	Vermillion River near Wakonda, South Dakota	425927	965749	50	50	50	−0.060	−0.163
226	06479500	Big Sioux River at Watertown, South Dakota	445633	970845	27	27	27	−1.195	−0.347
227	06479750	Peg Munky Run near Estelline, South Dakota	443422	965115	25	25	25	−0.536	−0.334
228	06479800	North Deer Creek near Estelline, South Dakota	442744	964713	25	25	25	0.320	−0.329
229	06479950	Deer Creek near Brookings, South Dakota	442303	963719	25	25	25	−0.523	−0.311
230	06481000	Big Sioux River near Dell Rapids, South Dakota	434725	964442	47	47	47	−0.294	−0.288
231	06481500	Skunk Creek at Sioux Falls, South Dakota	433201	964726	47	47	47	−0.193	−0.259
232	06482610	Split Rock Creek at Corson, South Dakota	433659	963354	30	30	30	0.200	−0.260
233	04024400	Stoney Brook near Superior, Wisconsin	463501	920710	36	36	36	−0.782	0.091
234	04025200	Pearson Creek near Maple, Wisconsin	463851	914255	38	38	38	0.534	0.204
235	04025500	Bois Brule River at Brule, Wisconsin	463216	913543	51	51	51	0.161	0.218
236	04026200	Sand River tributary near Red Cliff, Wisconsin	465353	905647	36	36	36	0.483	0.335
237	04026300	Sioux River near Washburn, Wisconsin	464120	905702	36	36	36	0.778	0.328
238	04027000	Bad River near Odanah, Wisconsin	462915	904145	54	54	54	0.573	0.335
239	04027200	Pearl Creek at Grandview, Wisconsin	462205	910527	35	35	35	1.654	0.286
240	04027500	White River near Ashland, Wisconsin	462950	905415	47	47	47	0.004	0.318

Table 1.--Stations used for estimating the generalized skew coefficient in Minnesota--(Continued)

[ddmmss; d, degrees, m, minutes, s, seconds]

Map number (fig. 1)	Station identification	Station name	Latitude (ddmmss)	Longitude (ddmmss)	Period of record in years	Historical record in years	Weight factor	Station skew	Generalized skew
241	05333100	Little Frog Creek near Minong, Wisconsin	460548	914639	32	32	32	–0.379	0.101
242	05333500	St. Croix River near Danbury, Wisconsin	460428	921450	78	78	78	0.018	–0.061
243	05335380	Bashaw Brook near Shell Lake, Wisconsin	454702	920751	35	35	35	0.416	–0.060
244	05340300	Trade River near Fredric, Wisconsin	453741	922919	37	37	37	0.978	–0.144
245	05341500	Apple River near Somerset, Wisconsin	450927	924259	75	75	75	–0.234	–0.148
246	05341900	Kinnickinnic River tributary at River Falls, Wisconsin	444957	923823	35	35	35	–0.480	–0.149
247	05346600	Little Trimbelle Creek near Bay City, Wisconsin	443801	923405	20	20	20	0.449	–0.168
248	05367030	Willow Creek near Eau Claire, Wisconsin	444411	912648	37	37	37	–0.102	–0.013
249	05367480	East Branch Pine Creek tributary near Dallas, Wisconsin	451650	914830	34	34	34	0.458	–0.037
250	05367500	Red Cedar River near Colfax, Wisconsin	450311	914243	67	67	67	0.192	–0.040
251	05367700	Lightning Creek at Almena, Wisconsin	452517	920157	36	36	36	–0.822	–0.070
252	05370600	Arkansaw Creek tributary near Arkansaw, Wisconsin	443831	920309	35	35	35	–0.310	–0.145
253	05370900	Spring Creek near Durand, Wisconsin	443413	915748	33	33	33	–0.130	–0.141
254	05371800	Buffalo River tributary near Osseo, Wisconsin	443501	910540	35	35	35	–0.128	0.070
255	05378200	Eagle Creek near Fountain City, Wisconsin	440949	914228	31	31	31	0.093	–0.142
256	05380970	Cawley Creek near Neillsville, Wisconsin	443642	903431	34	34	34	0.364	0.253
257	05381000	Black River at Neillsville, Wisconsin	443334	903652	84	135	101	–0.263	0.236
258	05382000	Black River near Galesville, Wisconsin	440422	911741	64	64	64	–0.154	–0.058
259	05382200	French Creek near Ettrick, Wisconsin	441104	911849	18	18	18	–0.125	–0.050
260	05382500	Little La Crosse River near Leon, Wisconsin	435345	905025	47	47	47	–0.173	0.068
261	05383000	La Crosse River near West Salem, Wisconsin	435405	910705	58	58	58	–0.032	–0.027
262	05386300	Morman Creek near La Crosse, Wisconsin	434600	910827	33	33	33	–0.466	–0.051
263	05387100	North Fork Bad Axe River near Genoa, Wisconsin	433310	910858	35	35	35	0.507	–0.076
264	05406800	Rocky Branch near Richland Center, Wisconsin	431852	902322	34	34	34	0.627	0.209
265	05407100	Richland Creek near Plugtown, Wisconsin	431112	904423	36	36	36	–0.239	0.043
266	05408000	Kickapoo River at La Farge, Wisconsin	433427	903835	57	57	57	0.435	0.109
267	05410490	Kickapoo River at Steuben, Wisconsin	431058	905130	62	62	62	0.408	–0.002

[1]Actually located in Minnesota.

[2]Included as a Minnesota station.