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Evaluation of Peak-Flow Data Network of Small Streams in Missouri

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16. Abstract (Limit: 200 words)

Standard regression models were used as a tool to evaluate the transferability of streamflow characteristics for the small-streams network in Missouri. Tests for adequacy of record length and sample size were made. Results indicate that neither additional records nor sampling sites would substantially improve the standard error of the regression. Results also indicate a need for additional research to determine variables which could be used to predict floodflows and to determine other types of regression models applicable to flood frequency.

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 80-87

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1980

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

The following factors may be used to convert the inch-pound units published herein 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)
foot per mile (ft/mi)	0.189	meter per kilometer (m/km)
cubic foot per second (ft^3/s)	0.028	cubic meter per second (m^3/s)

EVALUATION OF PEAK-FLOW DATA NETWORK

OF SMALL STREAMS IN MISSOURI

By Leland D. Hauth

ABSTRACT

Linear multiple-regression models were used to evaluate the predictive adequacy of flood records from a rural, small-streams, flood-gaging network in Missouri. Station records were divided into temporal and sample-size subsets to test for effects of record length and sample size on defining flood-estimating relations in two physiographic regions. The standard error of estimate for each calibrated regression model using increasing record lengths was compared against the longest period of record in both tests.

Based on the assumption that the 1955-77 period of record is a representative temporal sample, that available flood records provide a representative areal and basin index sample, and that flood records are independent temporally and spatially, these tests indicate that an increase in length of small-area streamflow records or additional sampling sites in the data network will not substantially improve the standard error of estimate of the regression model.

The current crest-stage network could be reduced to a network large enough to measure the long-term trends in rural basins and provide information for future investigations in the field of small-streams hydrology. Additional research needs to be conducted to determine additional variables (quantitative and qualitative) that could be used to predict floodflows and to describe other types of regression or hydrologic models.

INTRODUCTION

The U.S. Geological Survey began collecting streamflow records in Missouri under cooperative arrangements with local, State, and other Federal agencies as early as 1921. For many years thereafter, data collection consisted of streamgaging at sites having drainage basins greater than 50 square miles.

As the need for highways increased, the value of hydrologic data for design of bridges and culverts at small-stream crossings was recognized. This led, during 1947, to a cooperative program between the Missouri State Highway Commission (now the Missouri Highway and Transportation Commission) and the U.S. Geological Survey. The primary objective of this program was to collect and analyze hydrologic data for use in estimating design floods for such structures as bridge openings, channel capacities, and roadbed elevations at ungaged sites with drainage areas less than 10 square miles. Data collection was to include only those rural basins unaffected by manmade changes. During the first year of the agreement, the collection of continuous-flow records began at 12 small-area sites (6 equipped with recording rain gages), and the collection of peak floodflow data was begun by the installation of crest-stage gages at 5 sites. During 1955 this program was expanded to 33 continuous-record sites (30 equipped with recording rain gages) and 88 peak-flow sites.

Five basin characteristics considered in the selection of drainage basins to be included in the network were: (1) Area; (2) topography; (3) shape factor (length/width); (4) land use (forest cover, cultivation, and open terrain); and (5) soil type. The distribution of drainage sizes included in the gaging-station network is shown in figure 1. The locations of continuous-recording gages are shown in figure 2, and crest-stage gages are shown in figure 3.

During the past decade, the data-collection program between the U.S. Geological Survey and its many cooperating agencies has evolved from a planned information-collection system to a system providing data to solve specific problems. Because of recent increases in cost of operation plus restraints on funds and manpower, it has become necessary to evaluate the planned information-collection system and to collect the least amount of data that can adequately fulfill the requirements for solving specific problems.

The purpose of this report is to present results from an evaluation of the small-streams information-collection network for adequacy of data, both for record length and spatial distribution. Results of this study were obtained from 2,361 station-years of record collected at 115 gaging stations with an average of 20.5 years of annual peak-flow data for each station.

NETWORK SUMMARY

Data Collection

The early data collection consisted of continuous records of stage and regular flow measurements so that mean daily discharges could be published annually as part of the statewide streamgaging program (U.S. Geological Survey, published annually). However, as the program was expanded, the greater part of the small-streams gaging-station network was directed toward collecting annual peak-flow data in order to meet the primary objective of the program. In addition to the continuous-recording gages established early in the program, temporary stilling-well structures, instrumented with continuous recorders, were erected at 14 crest-stage gage locations so that continuous records of stage and rainfall could be collected. These temporary structures, referred to as "roving recorders," were then moved to other crest-stage gage sites pending adequate information and adaptability of the site to the recording instrumentation. Stage-discharge relationships were

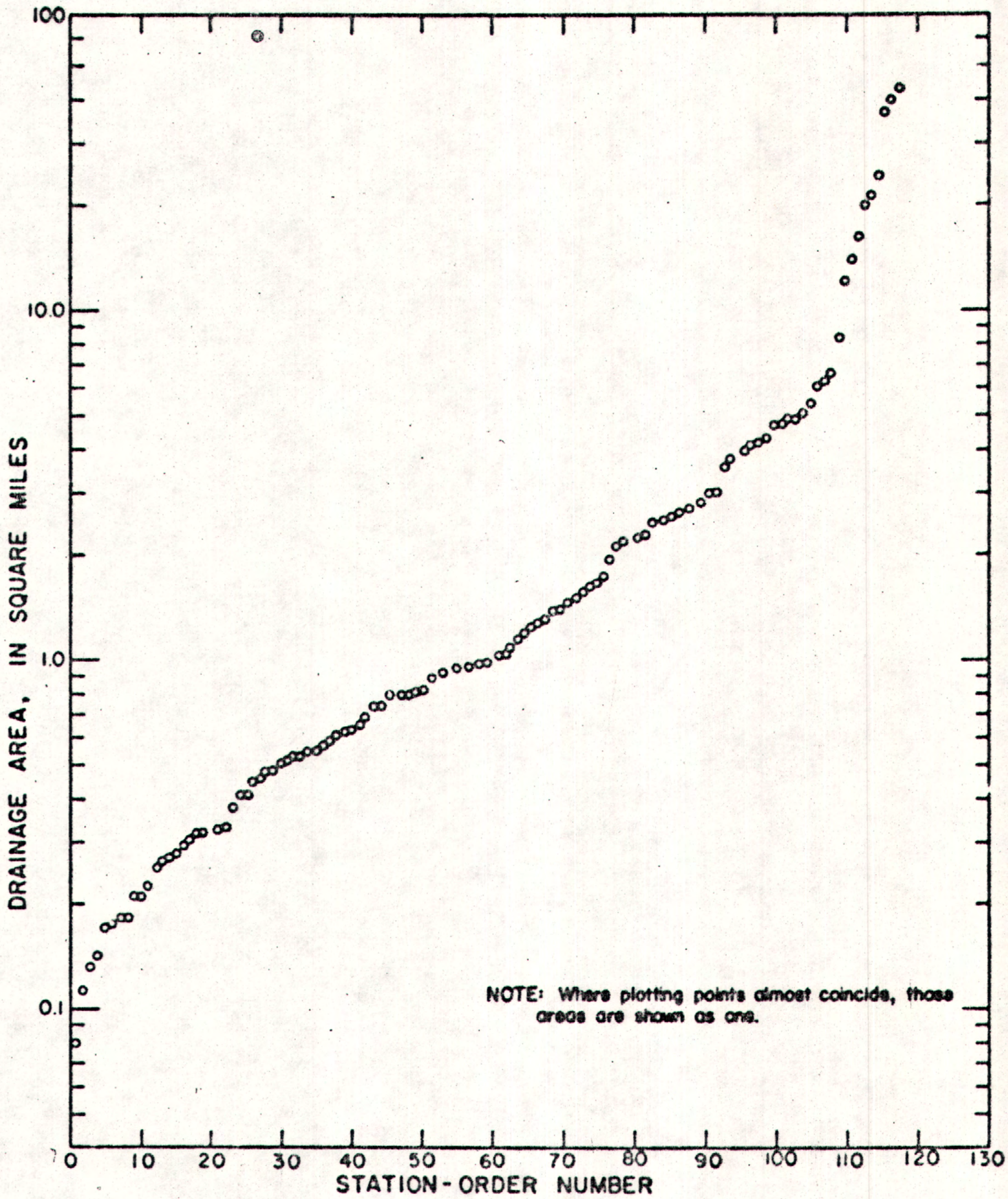


Figure 1.--Graphical representation of drainage-area distribution of small-streams network.

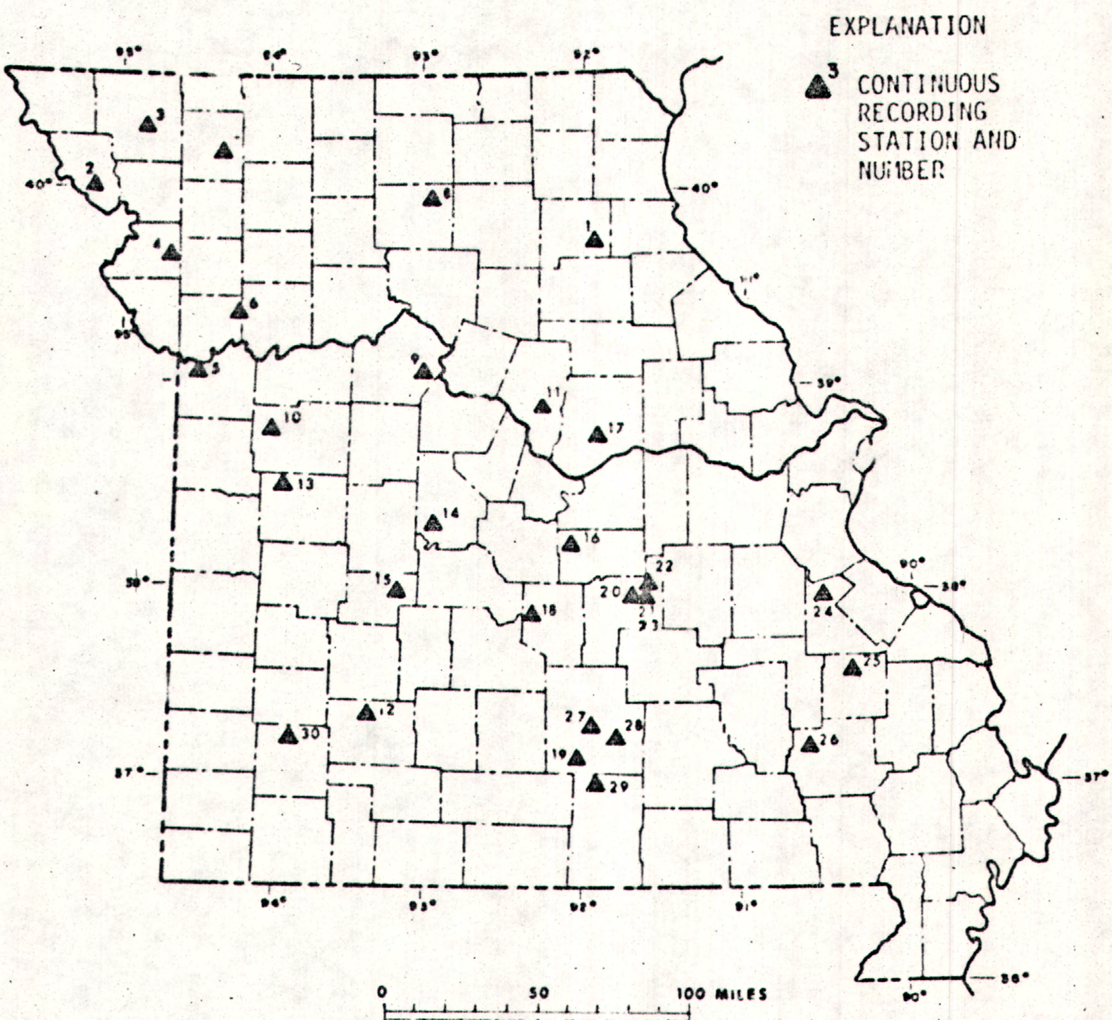
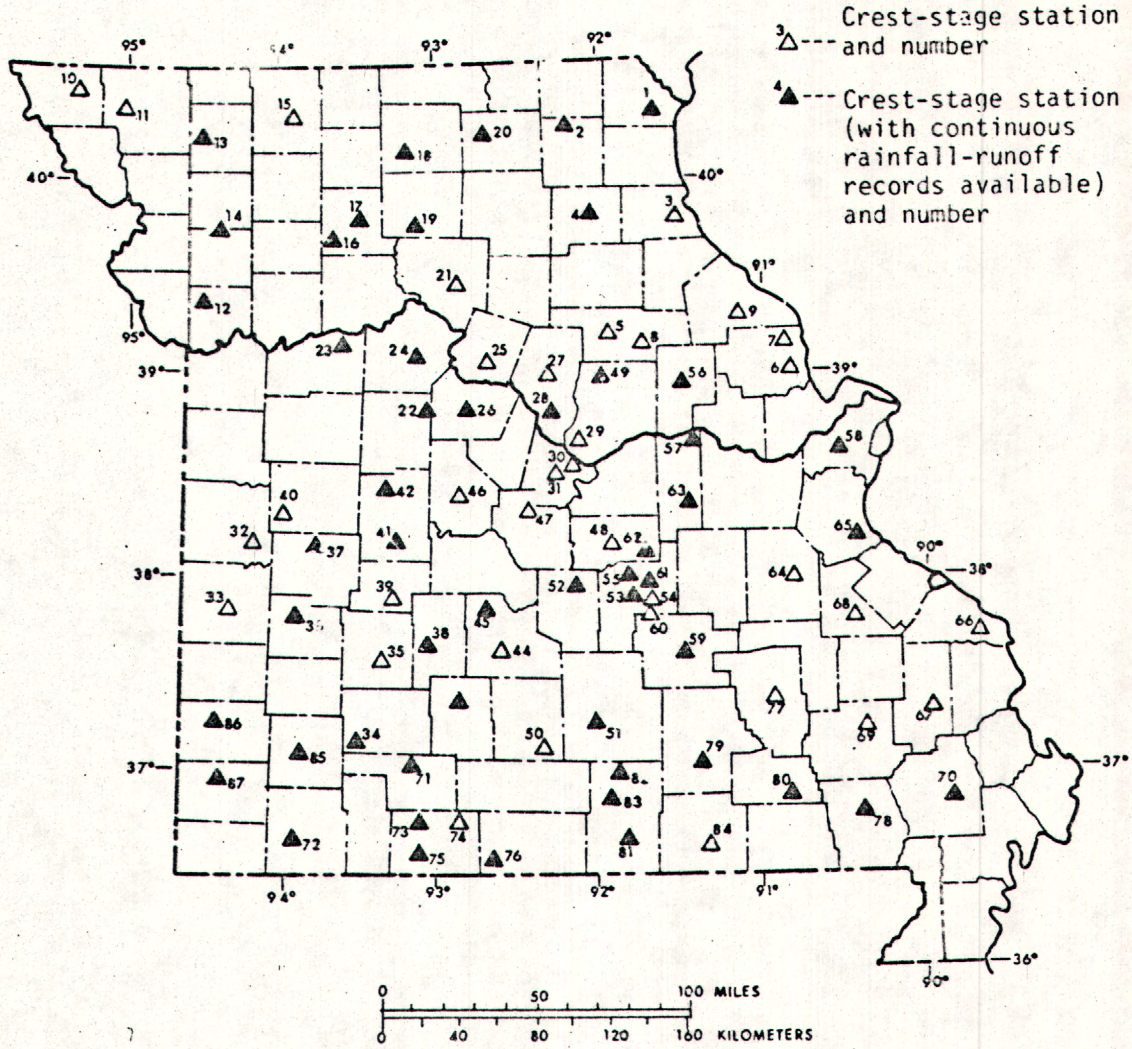


Figure 2.--Location of continuous-recording stations included in the mall-streams network.



3 △--- Crest-stage station and number

4 ▲--- Crest-stage station (with continuous rainfall-runoff records available) and number

Figure 3.--Location of crest-stage stations in the small-streams network.

established at all stations. Rainfall-runoff data were collected to provide a broader base to the analysis and ensure that the objective was met. These rainfall data also were later used in a rainfall-runoff model to synthesize peak-flow records.

The small-streams network evolved into a program that finally included 29 continuous-recording stations (fig. 2) and 87 crest-stage gages of which 52 sites included a sampling of continuous stage and rainfall (fig. 3). The continuous-record stations with their period of records are described in table 1 and crest-stage stations with their availability of rainfall-runoff data are described in table 2; all the data were available for analysis.

Previous Studies

There have been four studies conducted in Missouri where small-streams data have been included to determine design floods. Techniques used in these studies include the "Index Flood Method" (Searcy, 1955; Patterson, 1964, 1966; and Patterson and Gamble, 1968) and the "Multiple-Regression Method" (Sandhaus and Skelton, 1968; and Skelton and Homyk, 1970). The multiple-regression method (Benson, 1962) also was used by Hauth (1974a, 1974b) after synthesized records of peak-flow data were developed through a calibrated rainfall-runoff model (Lichty, Dawdy, and Bergmann, 1968) that used National Weather Service rainfall information. Streamflow characteristics used in the regression were determined from the log-Pearson Type III distribution of the annual peak discharge in conjunction with a generalized skew map developed by Hardison (1974). The number of samples used in a rainfall-runoff model is dependent on the number of stations having continuous stage and rainfall data. During the 1974 study, using the rainfall-runoff model, only 53 small-area sites were available for analysis.

ANALYSIS OF DATA

During recent years there have been many studies in which gaging-station networks have been evaluated to determine spatial and temporal adequacy as well as whether accuracy goals have been met. Among the current methods is a technique developed by Moss and Karlinger (1974), referred to as the "Big Basin-Meta-Nari" (Network Analysis of Regional Information). This analysis can incorporate impacts of serial correlation, cross correlation, nonrepresentative time and space samples, and linear-regression model errors. This analysis (NARI) is a complex, Bayesian approach to evaluating on a probability basis the changes in precision expected from additional years of record, additional gaging stations, or both. However, it also is relatively new and untested, and at present (1980) is confined to linear-regression relations, networks of less than 50 stations, and a narrow range in hydrologic limitations.

Table 1.--*Summary of continuous-record gaging stations in the small-streams network*

Map No. (fig. 2)	Station No.	Station name	Drainage area (square miles)	Period of continuous record
1	05503000	Oak Dale Branch near Emden--------------------------	2.64	1955-72
2	06816000	Mill Creek at Oregon--------------------------------	4.90	1950-77
3	06820000	White Cloud Creek near Maryville--------------------	6.06	1948-70
4	06821000	Jenkins Branch at Gower-----------------------------	2.72	1950-77
5	06893600	Rock Creek at Independence--------------------------	5.20	1967-
6	06894500	East Fork Fishing River at Excelsior Springs[1]--------	20.0	1951-72
7	06896500	Thompson Branch near Albany-------------------------	5.58	1955-73
8	06902500	Hamilton Branch near New Boston---------------------	2.51	1955-73
9	06906600	Burge Branch near Arrow Rock[1]-----------------------	.33	1959-73
10	06907500	South Fork Blackwater River near Elm[1]----------------	16.6	1954-
11	06910410	Cedar Creek near Columbia[1]--------------------------	44.8	1964-75
12	06918700	Oak Grove Branch near Brighton----------------------	1.30	1956-75
13	06921740	Brushy Creek near Blairstown------------------------	1.15	1960-75
14	06922800	Big Buffalo Creek near Stover[1]----------------------	24.2	1965-78
15	06925200	Starks Creek at Preston-----------------------------	4.18	1956-76
16	06926200	Van Cleve Branch near Meta--------------------------	.75	1956-73

Table 1.--Summary of continuous-record gaging stations in the small-streams network--continued

Map No. (fig. 2)	Station No.	Station name	Drainage area (square miles)	Period of continuous record
17	06927200	Big Hollow near Fulton----------------------------------	4.05	1957-73
18	06928200	Laquey Branch near Hazelgreen-----------------------	1.58	1958-72
19	06928700	Beeler Creek near Cabool----------------------------	7.78	1967-76
20	06931500	Little Beaver Creek near Rolla----------------------	6.41	1947-75
21	07011500	Green Acre Branch near Rolla------------------------	.62	1947-75
22	07015000	Bourbeuse River near St. James----------------------	21.3	1947-
23	07015500	Lanes Fork near Rolla-------------------------------	.22	1952-71
24	07017500	Dry Branch near Bonne Terre-------------------------	3.35	1955-75
25	07035500	Barnes Creek near Fredericktown---------------------	4.03	1955-75
26	07037700	Clark Creek near Piedmont---------------------------	4.39	1956-77
27	07064300	Fudge Hollow near Licking---------------------------	1.72	1956-77
28	07064500	Big Creek near Yukon--------------------------------	8.36	1949-74
29	07070000	Kings Creek near Willow Springs---------------------	4.91	1955-67
30	07185500	Stahl Creek near Miller-----------------------------	3.86	1950-76

[1] Stations used in small-streams network, but financed by other agencies.

Table 2.--Summary of crest-stage stations in the small-streams network

Map No. (fig. 3)	Station No.	Station name	Drainage area (square miles)	Period of rainfall-runoff record
1	05495100	Big Branch tributary near Wayland---------------	0.70	1964-69
2	05497700	Bridge Creek Branch near Baring-----------------	2.38	1960-64
3	05501200	Nichols Branch near Palmyra---------------------	2.58	----
4	05502700	Easdale Branch near Shelbyville-----------------	.71	1969-71
5	05504700	Bean Creek near Mexico--------------------------	3.02	----
6	05513600	Camp Creek near Elsberry------------------------	1.50	----
7	05513650	Hurricane Creek near Elsberry-------------------	3.06	----
8	05513700	Mams Slough Creek near Wellsville---------------	5.08	----
9	05514200	Reid Branch near Bowling Green------------------	.54	----
10	06815550	Staples Branch near Burlington Junction---------	.49	----
11	06820300	Big Slough near Wilcox--------------------------	1.30	----
12	06821130	First Creek near Nashua-------------------------	.55	1966-77
13	06896180	Demoss Branch near Stanberry--------------------	.38	1959-65
14	06896700	O'Neill Branch at Osborn------------------------	.80	1962-66
15	06897200	Simpson Branch near Bethany---------------------	4.72	----

Table 2.--Summary of crest-stage stations in the small-streams network--continued

Map No. (fig. 3)	Station No.	Station name	Drainage area (square miles)	Period of rainfall-runoff record
16	06897700	Grand River tributary near Utica	1.44	1966-72
17	06899600	West Fork Leakey Branch near Chillicothe	.21	1972-77
18	06901300	Moffet Branch near Reger	.13	1964-66
19	06902800	Onion Branch at St. Catherine	1.04	1961-66
20	06904700	Strop Branch near Novinger	.96	1971-77
21	06905700	Puzzle Creek near Salisbury	.80	----
22	06907200	Shaver Creek tributary near Clifton City	1.65	1961-66
23	06908300	Trent Branch near Waverly	.97	1959-62
24	06908500	Shiloh Branch near Marshall	2.87	1952-66
25	06909400	Cottonwood Creek tributary at Estill	.30	----
26	06909700	Petite Saline Creek tributary near Bellair	.49	1964-69
27	06910200	Cow Branch near Columbia	1.01	----
28	06910250	Traxler Branch near Columbia	.55	1960-64
29	06910300	Peden Branch near Jefferson City	.18	----
30	06910400	Baldwin Branch near Jefferson City	.60	----

Table 2.--Summary of crest-stage stations in the small-streams network--continued

Map No. (fig. 3)	Station No.	Station name	Drainage area (square miles)	Period of rainfall-runoff record
31	06910700	Hazel Branch tributary near Wardsville------------------	0.13	----
32	06918200	North Fork Panther Creek tributary near Appleton City---	.08	----
33	06918300	West Fork Clear Creek tributary near Nevada-------------	.51	----
34	06918400	Pickeral Creek tributary near Republic------------------	.57	1961-63
35	06918750	Franca Branch near Brighton-----------------------------	.59	----
36	06919200	Sac River tributary near Caplinger Mills----------------	.14	1962-70
37	06920800	Big Muddy Creek at Lowry City---------------------------	.36	1972-77
38	06921100	Olinger Creek near Buffalo------------------------------	1.96	1963-65
39	06921400	Ferguson Branch at Nemo---------------------------------	.18	----
40	06921800	Grandaddy Creek near Urich------------------------------	.92	----
41	06922600	Little Turkey Creek tributary near Warsaw---------------	.18	1970-77
42	06922700	Chub Creek near Lincoln---------------------------------	2.86	1964-70
43	06923000	Niangua Creek at Marshfield-----------------------------	.82	1950-59
44	06925270	Dry Auglaize Creek tributary near Lebanon---------------	.21	----
45	06925300	Prairie Branch near Decaturville------------------------	1.48	1969-72

Table 2.--Summary of crest-stage stations in the small-streams network--continued

Map No. (fig. 3)	Station No.	Station name	Drainage area (square miles)	Period of rainfall-runoff record
46	06925450	Little Gravois Creek near Versailles------------------	4.74	----
47	06926150	Jack Buster Creek at Eugene--------------------------	.17	----
48	06926800	Long Branch near Vienna------------------------------	.32	----
49	06927100	Doane Branch near Kingdom City-----------------------	.54	1959-62
50	06927600	Wheeler Branch near Mountain Grove-------------------	1.34	----
51	06929000	Coyle Branch at Houston------------------------------	1.10	1949-55
52	06930750	Prewett Hollow near Dixon----------------------------	.46	1964-66
53	06931000	Beaver Creek near Rolla------------------------------	13.7	1948-58
54	06931600	Paulsell Branch near Rolla---------------------------	2.33	----
55	06933700	Penzer Hollow near Rolla-----------------------------	.27	1964-67
56	06934600	Rumbo Branch near Danville---------------------------	1.40	1953-59
57	06934750	Little Berger Creek tributary near Hermann-----------	.25	1970-77
58	06935800	Shotwell Creek near Ellisville-----------------------	.81	1962-
59	07011200	Love Creek near Salem--------------------------------	.89	1959-64
60	07011300	Ragan Branch near Rolla------------------------------	6.58	----

Table 2.--Summary of crest-stage stations in the small-streams network--continued

Map No. (fig. 3)	Station No.	Station name	Drainage area (square miles)	Period of rainfall-runoff record
61	07012000	Behmke Branch near Rolla------------------------------	1.05	1948-59
62	07015700	Lanes Fork near Vichy---------------------------------	24.1	1950-59
63	07015800	Langenberg Branch near Rosebud------------------------	.64	1964-70
64	07017700	Fountain Farm Branch near Potosi----------------------	2.16	----
65	07019820	Murphy Branch near Crystal City-----------------------	.44	1960-64
66	07020700	Hochs Branch near Uniontown---------------------------	1.66	----
67	07021200	Sunnybrook Creek at Lesterville-----------------------	.52	----
68	07033000	Wolf Creek near Farmington----------------------------	40.3	----
69	07038000	Clark Creek at Patterson------------------------------	87.5	----
70	07040110	Delaware Creek tributary near Bloomfield--------------	.38	1971-77
71	07050800	Maple Grove Branch near Ozark-------------------------	1.50	1965-71
72	07052700	Brawley Hollow near Cassville-------------------------	2.61	1966-77
73	07053950	Ingenthron Hollow near Forsyth------------------------	.65	1962-66
74	07054100	Cedar Hollow at Bradleyville--------------------------	.83	----
75	07054200	Yandell Branch near Kirbyville------------------------	.33	1962-72

Table 2.--*Summary of crest-stage stations in the small-streams network*--*continued*

Map No. (fig. 3)	Station No.	Station name	Drainage area (square miles)	Period of rainfall-runoff record
76	07054300	Gray Branch at Lutie------------------------------------	0.23	1959-72
77	07061800	Brawley Hollow near Centerville------------------------	1.00	----
78	07063200	Pike Creek tributary near Poplar Bluff-----------------	.28	1959-74
79	07066800	Sycamore Creek near Winona-----------------------------	.88	1964-71
80	07068200	North Prong Little Black River at Hunter---------------	1.23	1964-71
81	07069100	Adams Branch near West Plains--------------------------	2.27	1971-77
82	07070000	Kings Creek near Willow Springs------------------------	4.91	1955-67
83	07070200	Burnham Branch near Willow Springs---------------------	1.27	1972-77
84	07071800	Williams Spring Branch near Alton----------------------	4.24	----
85	07185600	South Fork Stahl Creek near Miller---------------------	.94	1971-77
86	07185900	O'Possum Creek at Jasper-------------------------------	9.67	1970-77
87	07186950	North Fork Carver Branch at Diamond--------------------	.33	1960-66

For these reasons, a simpler approach of evaluating the adequacy of data collected through the Missouri small-streams program has been developed. Split-sampling techniques and regional-regression analysis were used to analyze the impact of the time-sampling and spatial-sampling errors on relationships developed from multiple-regression models already tested in Missouri. Regional-regression analysis (Benson and Matalas, 1967) uses the flow characteristics estimated from existing data for gaged sites. Because these estimates are based upon finite lengths of station record, they contain time-sampling errors. The foregoing procedure is based on the assumptions that the record period of 1948-77 is a representative temporal sample, that available flood records provide a representative areal and basin-index sample, and that the flood records are independent temporally and spatially as discussed by Matalas and Benson (1961).

Using methods recommended by the U.S. Water Resources Council (1977), flood-frequency curves were computed for 115 gaging records of streams draining less than 50 square miles. Regional skew values were selected for each of the 115 sites from a generalized skew map provided in the Water Resources Council report, and as recommended, the curves were adjusted for outliers, historic information, and generalized skew values. Flood magnitudes for the 2-, 10-, and 50-year recurrence intervals were defined as streamflow characteristics. The magnitude of floods for the given recurrence intervals at the small-streams network stations in the program is summarized in table 3.

Regression models have been tested using Missouri data by Sandhaus and Skelton (1968), Skelton and Homyk (1970), and Hauth (1974a, 1974b) where streamflow characteristics were used as dependent variables and basin characteristics as independent variables. Basin characteristics used in these regression models were contributing drainage area, main channel slope, mean basin elevation, forest cover, annual precipitation, the 2-year 24-hour rainfall magnitude, soils index, and main channel length. In each resulting computation, drainage area (A) and main channel slope (S) proved to be significant at the 1 percent level and therefore remained as variables in the relationships. Because of the experience gained in previous studies, only area and slope were used to calibrate and test models used in this analysis.

Regression models previously tested were recalibrated and examined to determine the best model to be used in the evaluation. Models used during 1965 and 1970 were linear ($\log Q = \log a + b \log A + c \log S$) and the model used in 1974 was curvilinear ($\log Q = \log a + b A^{-0.02} \log A + c \log S$), where a is the regression constant and b and c are coefficients obtained by regression. Both models were calibrated using all drainage areas (excluding lowland data) and resulting residuals plotted on semilog paper (fig. 4a-4b) to test linearity. The model used in figure 4a (linear) does not appear to fit the data, whereas the model used in figure 4b indicates the curvilinear relationship is more suitable, especially in the 10- to 100-square mile interval, and the standard error also is improved (see table 4). The two plots also indicate a need for more information between 10 and 100 square miles.

Table 3.--Summary of the magnitude of floods for selected recurrence intervals for drainage areas less than 50 square miles

Station No.	Station name	Drainage area (square miles)	Slope (feet per mile)	Skew coefficient: Systematic record	Skew coefficient: WRC[1] adjusted	Magnitude of flood (cubic feet per second) for indicated recurrence interval (years): 2	10	50
05495100	Big Branch tributary near Wayland	0.7	80.8	-0.20	-0.40	128	435	820
05497700	Bridge Creek Branch near Baring	2.38	43.2	-.16	-.40	374	771	1,120
05501200	Nichols Branch near Palmyra	2.58	52.5	1.05	-.32	514	1,240	2,000
05502700	Easdale Branch near Shelbyville	.71	76.1	-.37	-.40	338	714	1,050
05503000	Oakdale Branch near Emden	2.64	32.3	-.38	-.40	756	1,260	1,640
05504700	Bean Creek near Mexico	3.02	33.1	.42	-.40	682	1,660	2,630
05513600	Camp Creek near Elsberry	1.50	126	-.27	-.40	376	1,160	2,070
05513650	Hurricane Creek near Elsberry	3.06	86.3	-.90	-.40	740	2,020	3,390
05513700	Mams Slough Creek near Wellsville	5.08	14.3	-.46	-.40	694	1,460	2,160
05514200	Reid Branch near Bowling Green	.54	93.3	-.06	-.40	237	497	729
06815550	Staples Branch near Burlington Junction	.49	61.1	-.62	-.30	135	380	664
06816000	Mill Creek near Oregon	4.90	42.3	-.18	-.30	732	2,500	4,840
06820000	White Cloud Creek near Maryville	6.06	19.5	.21	-.28	701	2,700	5,620
06820300	Big Slough near Wilcox	1.30	35.5	-.24	-.30	478	981	1,440
06821000	Jenkins Branch at Gower	2.72	34	-.61	-.31	535	2,030	4,170
06821130	First Creek near Nashua	.55	59.5	.39	-.30	111	407	818
06894500	East Fork Fishing River at Excelsior Springs	20	21.9	.03	-.30	2,320	7,210	13,300
06896180	Demoss Branch near Stanberry	.38	106	-1.05	-.35	133	369	632
06896500	Thompson Branch near Albany	5.58	30.9	-.83	-.35	714	2,140	3,820
06896700	O'Neill Branch at Osborne	.80	50.9	-.02	-.35	225	867	1,770
06897200	Simpson Branch near Bethany	4.72	27.6	-.06	-.35	1,110	2,980	5,000
06897700	Grand River tributary near Utica	1.44	120	-.20	-.35	372	570	714
06899600	West Fork Leakey Branch near Chillicothe	.21	63.8	-.30	-.35	154	330	494
06901300	Moffet Branch near Reger	.13	150	.35	-.35	201	307	384
06902500	Hamilton Branch near New Boston	2.51	27	-.24	-.40	597	1,180	1,670
06902800	Onion Branch at St. Catherine	1.04	49.3	-.91	-.35	262	799	1,440
06904700	Strop Branch near Novinger	.96	94.7	-.66	-.40	497	1,670	3,140

Table 3.--Summary of the magnitude of floods for selected recurrence intervals for drainage areas less than 50 square miles--continued

Station No.	Station name	Drainage area (square miles)	Slope (feet per mile)	Skew coefficient: Systematic record	Skew coefficient: WRC[1] adjusted	Magnitude of flood (cubic feet per second) for indicated recurrence interval (years): 2	10	50
06905700	Puzzle Creek near Salisbury	0.80	55.6	-0.38	-0.40	169	528	953
06906600	Burge Branch near Arrow Rock	.33	76	-.03	-.35	66	165	268
06907200	Shaver Creek tributary near Clifton City	1.65	46.4	.08	-.35	473	1,120	1,760
06907500	South Fork Blackwater River near Elm	16.6	22.2	-.53	-.35	1,990	4,490	6,890
06908300	Trent Branch near Waverly	.97	69.2	-.42	-.35	245	705	1,230
06908500	Shiloh Branch near Marshall	2.87	40.1	.02	-.35	545	933	1,[illegible]40
06909400	Cottonwood Creek tributary at Estill	.30	87	-.09	-.35	65	153	239
06909700	Petite Saline Creek tributary near Bellair	.49	78.4	.62	-.35	187	517	885
06910200	Cow Branch near Columbia	1.01	57.3	-.95	-.35	302	724	1,150
06910250	Traxler Branch near Columbia	.55	119	-2.09	-.35	257	570	869
06910300	Peden Branch near Jefferson City	.18	220	-.66	-.35	68	172	282
06910400	Baldwin Branch near Jefferson City	.60	144	-1.03	-.35	144	1,320	2,880
06910410	Cedar Creek near Columbia	44.8	8.6	-.12	-.35	2,680	5,380	7,780
06910700	Hazel Branch tributary near Wardsville	.13	141	.38	-.35	86	161	222
06918200	North Fork Panther Creek tributary near Appleton City	.08	222	.11	-.30	50	75	93
06918300	West Fork Clear Creek tributary near Nevada	.51	36.2	.30	-.30	259	430	566
06918400	Pickerel Creek tributary near Republic	.57	68.8	-.49	-.30	110	229	341
06918700	Oak Grove Branch near Brighton	1.30	94.2	-.61	-.30	202	601	1,080
06918750	Franca Branch near Brighton	.59	109	-.96	-.30	141	501	993
06919200	Sac River tributary near Caplinger Mills	.14	149	.39	-.30	56	159	277
06920800	Big Muddy Creek near Lowry City	.31	48.7	-.16	-.30	125	196	250
06921100	Olinger Creek near Buffalo	1.96	47.8	2.30	-.30	478	1,240	2,090
06921400	Ferguson Branch at Nemo	.18	154	2.02	-.30	32	75	118
06921700	West Branch Crawford Creek near Lees Summit	.80	59.6	.25	-.30	343	825	1,330
06921740	Brushy Creek near Blairstown	1.15	70.8	.44	-.30	495	908	1,260
06921800	Grandaddy Creek near Urich	.92	36.2	.38	-.30	290	675	1,060
06922600	Little Turkey Creek tributary near Warsaw	.18	178	-.01	-.35	102	165	212

Table 3.--*Summary of the magnitude of floods for selected recurrence intervals for drainage areas less than 50 square miles*--continued

Station No.	Station name	Drainage area (square miles)	Slope (feet per mile)	Skew coefficient: Systematic record	Skew coefficient: WPC[1] adjusted	Magnitude of flood (cubic feet per second) for indicated recurrence interval (years): 2	10	50
06922700	Chub Creek near Lincoln------------------------------	2.86	40.3	-0.94	-0.35	754	924	1,030
06922800	Big Buffalo Creek near Stover------------------------	24.2	34.5	-.58	-.35	4,220	11,500	19,600
06923000	Niangua Branch at Marshfield-------------------------	.82	116	-1.13	-.35	204	426	629
06925200	Starks Creek at Preston------------------------------	4.18	31	-.15	-.35	761	1,460	2,060
06925270	Dry Auglaize Creek tributary near Lebanon------------	.21	115	.32	-.35	59	139	218
06925300	Prairie Branch near Decaturville---------------------	1.48	84.1	.22	-.35	456	1,650	3,260
06925450	Little Gravois Creek near Versailles-----------------	4.74	64.0	-.58	-.35	1,330	3,720	6,430
06926150	Jack Buster Creek near Eugene------------------------	.17	130	.43	-.35	102	233	360
06926200	Van Cleve Branch near Meta---------------------------	.75	95.4	.39	-.35	282	937	1,770
06926800	Long Branch near Vienna------------------------------	.32	112	.35	-.35	160	411	675
06927100	Doane Branch near Kingdom City-----------------------	.54	58.7	.85	-.40	160	221	368
06927200	Big Hollow near Fulton-------------------------------	4.05	34	.52	-.40	626	934	1,150
06927600	Wheeler Branch near Mountain Grove-------------------	1.34	48.8	-.40	-.30	362	803	1,230
06928200	Laquey Branch near Hazelgreen------------------------	1.56	87.4	.44	-.35	428	1,150	1,930
06929000	Coyle Branch at Houston------------------------------	1.10	95.9	-.16	-.40	204	562	949
06930750	Prewett Hollow near Dixon----------------------------	.46	87.5	.46	-.35	188	504	849
06931000	Beaver Creek near Rolla------------------------------	13.7	39.5	-1.12	-.38	1,980	4,800	7,600
06931500	Little Beaver Creek near Rolla-----------------------	6.41	65.6	.75	-.31	1,400	3,090	4,730
06931600	Paulsell Branch near Rolla---------------------------	2.33	75.5	-.08	-.34	930	2,530	4,300
06933700	Penzer Hollow near Rolla-----------------------------	.27	190	-.12	-.35	99	206	302
06934600	Rumbo Branch at Danville-----------------------------	1.40	44.9	.46	-.35	242	502	738
06934750	Little Berger Creek tributary near Hermann-----------	.25	178	.38	-.35	91	259	448
06935800	Shotwell Creek near Ellisville-----------------------	.81	79.5	-.28	-.35	382	803	1,190
07011200	Love Creek near Salem--------------------------------	.89	106	-.34	-.35	118	223	312
07011300	Ragan Branch near Rolla------------------------------	6.58	45.5	.52	-.34	631	2,380	4,820
07011500	Green Acre Branch near Rolla-------------------------	.62	82	-.06	-.34	257	691	1,170
07012000	Behmke Branch near Rolla-----------------------------	1.05	77	-1.70	-.41	454	876	1,240

Table 3.--Summary of the magnitude of floods for selected recurrence intervals for drainage areas less than 50 square miles--continued

Station No.	Station name	Drainage area (square miles)	Slope (feet per mile)	Skew coefficient: Systematic record	Skew coefficient: WRC[1] adjusted	Magnitude of flood (cubic feet per second) for indicated recurrence interval (years): 2	10	50
07015000	Bourbeuse River near St. James----------------------	21.3	34.0	-1.95	-0.38	3,440	5,970	7,960
07015500	Lanes Fork near Rolla------------------------------	.22	41.4	-.45	-.35	54	115	172
07015700	Lanes Fork near Vichy------------------------------	24.1	27	-.33	-.35	3,880	7,140	9,660
07015800	Langenberg Branch near Rosebud---------------------	.64	100	.52	-.35	105	294	507
07017500	Dry Branch near Bonne Terre------------------------	3.35	48.5	-1.19	-.35	655	1,080	1,410
07017700	Fountain Farm Branch near Potosi-------------------	2.16	71.8	.30	-.35	527	1,010	1,430
07019820	Murphy Branch near Crystal City--------------------	.44	108	.81	-.35	162	364	553
07020700	Hoehs Branch near Uniontown------------------------	1.66	59.4	-.94	-.35	822	1,610	2,290
07021200	Sunnybrook Creek at Lutesville---------------------	.54	196	.57	-.35	273	382	457
07033000	Wolf Creek near Farmington-------------------------	40.3	19.9	.37	-.35	3,260	6,700	9,820
07035500	Barnes Creek near Fredericktown--------------------	4.03	114	.36	-.35	1,280	3,740	6,590
07037700	Clark Creek near Piedmont--------------------------	4.39	63.9	-.89	-.35	754	1,370	1,880
07038000	Clark Creek at Patterson---------------------------	37.5	29.4	-.48	-.35	6,130	10,500	13,900
07040110	Delaware Creek tributary near Bloomfield-----------	.38	85.5	.31	-.35	404	652	838
07050800	Maple Grove Branch near Ozark----------------------	1.50	39.7	-.35	-.30	158	455	806
07052700	Brawley Hollow near Cassville----------------------	2.61	57.6	-.36	-.30	165	892	2,210
07053950	Ingenthron Hollow near Forsyth---------------------	.65	186	.38	-.30	191	561	996
07054100	Cedar Hollow at Bradleyville-----------------------	.83	204	-.36	-.30	314	755	1,210
07054200	Yandell Branch near Kirbyville---------------------	.33	116	-.42	-.30	59	242	513
07054300	Gray Branch at Lutie-------------------------------	.23	279	-.37	-.30	136	276	406
07061800	Brawley Hollow near Centerville--------------------	1.00	133	-.76	-.35	131	216	281
07063200	Pike Creek tributary near Poplar Bluff-------------	.28	111	-.51	-.30	274	273	426
07064300	Fudge Hollow near Licking--------------------------	1.72	68.1	.36	-.35	129	318	512
07064500	Big Creek near Yukon-------------------------------	8.36	53.3	-.30	-.35	1,910	4,790	7,790
07066800	Sycamore Creek near Winona-------------------------	.86	66.4	-.35	-.30	158	403	668
07068200	North Prong Little Black River at Hunter-----------	1.23	61.7	-.30	-.30	200	529	893
07069100	Adams Branch near West Plains----------------------	2.27	44.3	.48	-.30	346	570	745

Table 3.--Summary of the magnitude of floods for selected recurrence intervals for drainage areas less than 50 square miles--continued

Station No.	Station name	Drainage area (square miles)	Slope (feet per mile)	Skew coefficient: Systematic record	Skew coefficient: WRC[1] adjusted	Magnitude of flood (cubic feet per second) for indicated recurrence interval (years): 2	10	50
07070000	Kings Creek near Willow Springs	4.91	45.0	-0.85	-0.30	316	990	1,830
07070200	Burnham Branch near Willow Springs	1.27	58.6	.06	-.30	246	528	798
07071800	Williams Spring Branch near Alton	4.24	63.3	.81	-.30	371	960	1,600
07185500	Stahl Creek near Miller	3.86	41.3	.69	-.30	668	1,400	2,080
07185600	South Fork Stahl Creek near Miller	.94	66.7	.35	-.30	203	503	821
07185900	O'Possum Creek at Jasper	9.67	16	-.33	-.30	1,190	2,330	3,340
07186950	North Fork Carver Branch at Diamond	.33	100	-.71	-.30	79	212	360

[1]Water Resources Council.

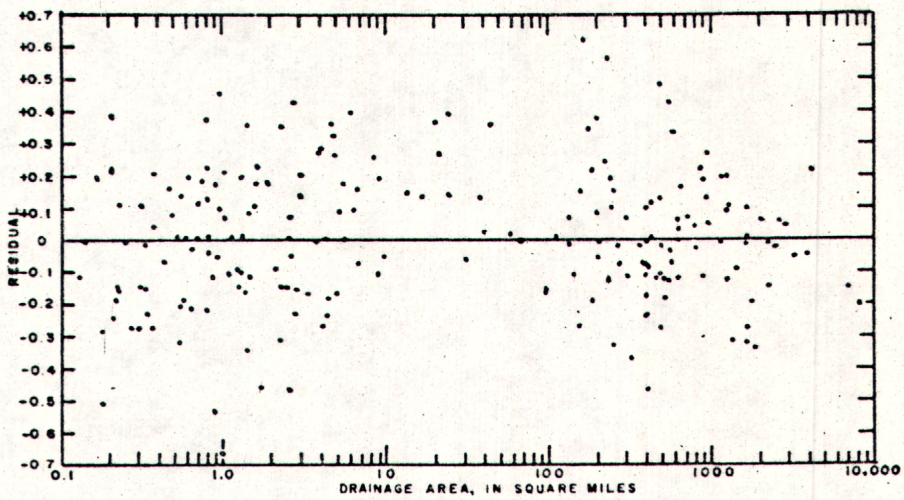


Figure 4a.--Fifty-year flood-magnitude residual distribution by area size for linear model $\log Q = \log a + b \log A + c \log S$.

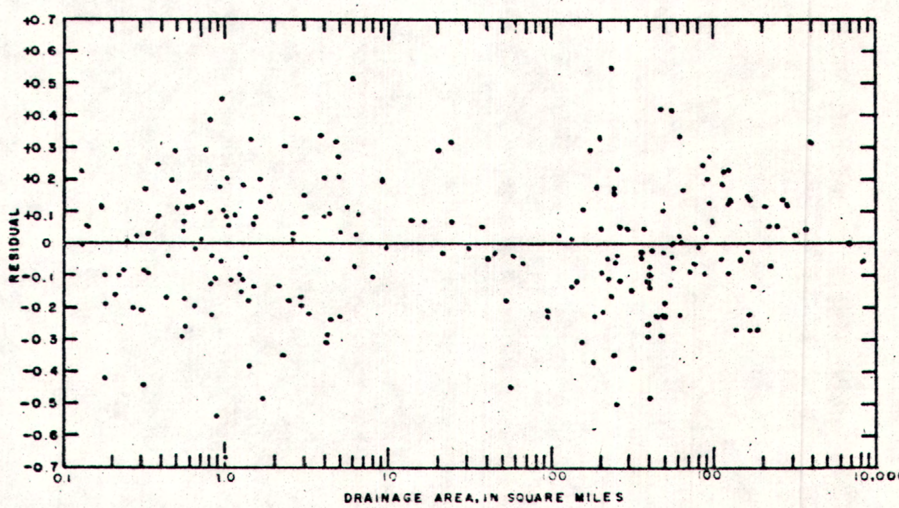


Figure 4b.--Fifty-year flood-magnitude residual distribution by area size using curvilinear model $\log Q = \log a + b A^{-0.02} \log A + c \log S$.

Table 4.--Summary of statewide regression models

Model	Standard error (percent) for indicated recurrence interval (years)		
	2	10	50
(1) $\log Q = \log a + b \log A + c \log S$	41.2	43.2	50.0
(2) $\log Q = \log a + b A^{-0.02} \log A + c \log S$	39.9	41.7	48.5

As a further linearity test, the magnitude of the 50-year flood was plotted against its respecitve drainage area, as shown in figure 5. Because regression results indicate a significant correlation between drainage area and main channel slope, slope was defined in terms of drainage area by linear regression and a plot is given in figure 6.

The scatter of points shown in figure 5 also indicate possible nonlinearity. Calibration of the linear model describing Q_{50} was made using the entire data matrix. Using the appropriate areas and slopes from figure 6, the relationship between Q_{50} and drainage area was developed and plotted as shown in figure 7. The model was again calibrated using only data from drainage areas less than 50 square miles. Using areas and slopes from figure 6 again, the Q_{50} versus drainage area was developed and plotted on figure 7. This example shows that if only data from the smaller basins are used, and the straight-line relationships are extended to larger areas, the 50-year flood magnitude will be overpredicted for drainage basins larger than 50 square miles. For this reason, a relationship based on the data shown in figure 5 would be curvilinear downward at the upper end. The curvilinear model, $\log Q = \log a + bA^{-0.02} \log A + c \log S$, was calibrated using all drainage areas and resulting accuracy of the fit of both models is shown in table 4.

During the plotting of figure 5, it was noted that stations in different regions were somewhat grouped, defining perhaps different relationships. For this reason and because of the apparent change in the relationships at about 50 square miles (fig. 5), the linear regression model was calibrated using area, slope, and the 50-year flood magnitude. Resulting residuals for just the small-area network were plotted on a State physiographic map (fig. 8) to determine regional trends in the small-streams network. Results show that positive residuals (observed minus computed lot units) are more numerous in the Dissected Till and Osage Plains thus indicating the relationship to be underpredictive in that area. The State was therefore divided into three physiographic regions, as described by Skelton (1976): The Dissected Till and Osage Plains to the north and west, Ozarks (Salem and Springfield Plateaus) to the south and central, and Southeastern Lowlands in the bootheel area). The Southeastern Lowlands were not considered in this analysis because small-area data are not available for that region and floodflow patterns have been altered by man.

Flood magnitudes having 2- and 50-year recurrence intervals were computed using calibrated models. The model was then recalibrated using data from the plains and again for data from the plateaus. Flood magnitudes of 2- and 50-year recurrence intervals were computed for each regional model and compared to those based on a statewide relationship by computing percentage bias. The bias between regional relationships and one statewide equation is summarized in table 5. Based on linearity tests and regional trends previously discussed, this evaluation analysis used the curvilinear regression model $\log Q = \log a + bA^{-0.02} \log A + c \log S$ calibrated for both the plains and plateaus regions.

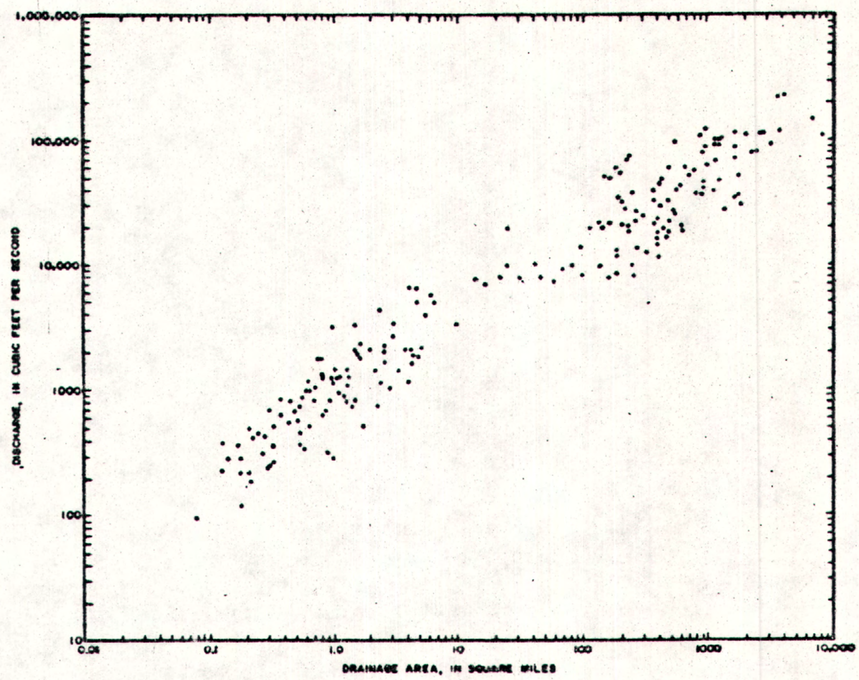


Figure 5.--Plot of flood magnitudes having 50-year recurrence interval versus drainage areas.

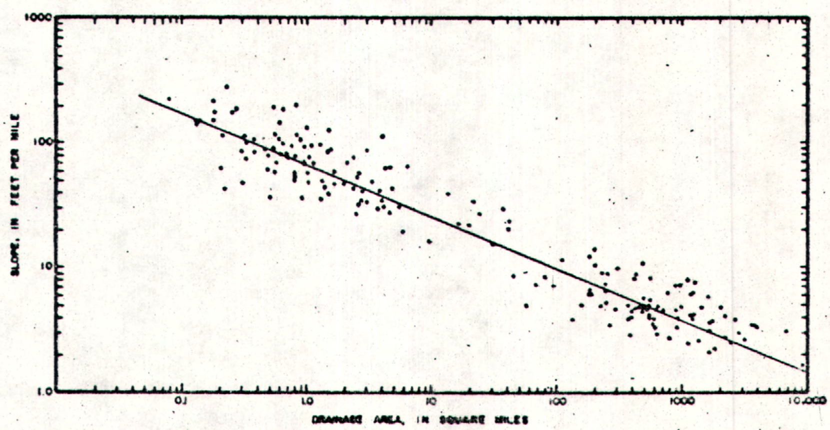


Figure 6.--Plot of drainage areas versus their respective main-channel slope between 10 and 85 percent points.

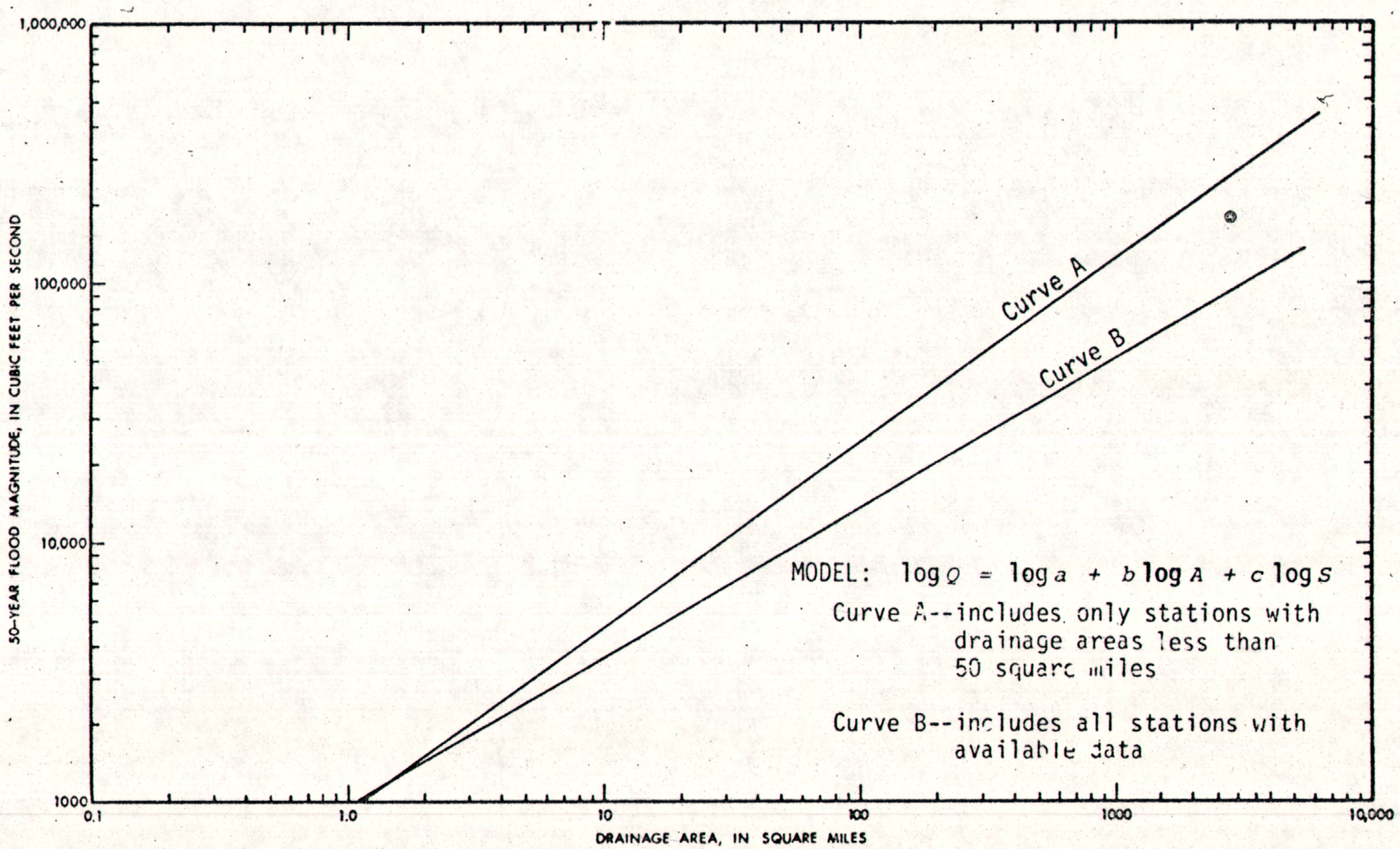


Figure 7.--Plot of flood magnitudes having 50-year recurrence intervals versus drainage area showing comparision between linear relationships using drainage areas less than 50 square miles and using all drainage areas.

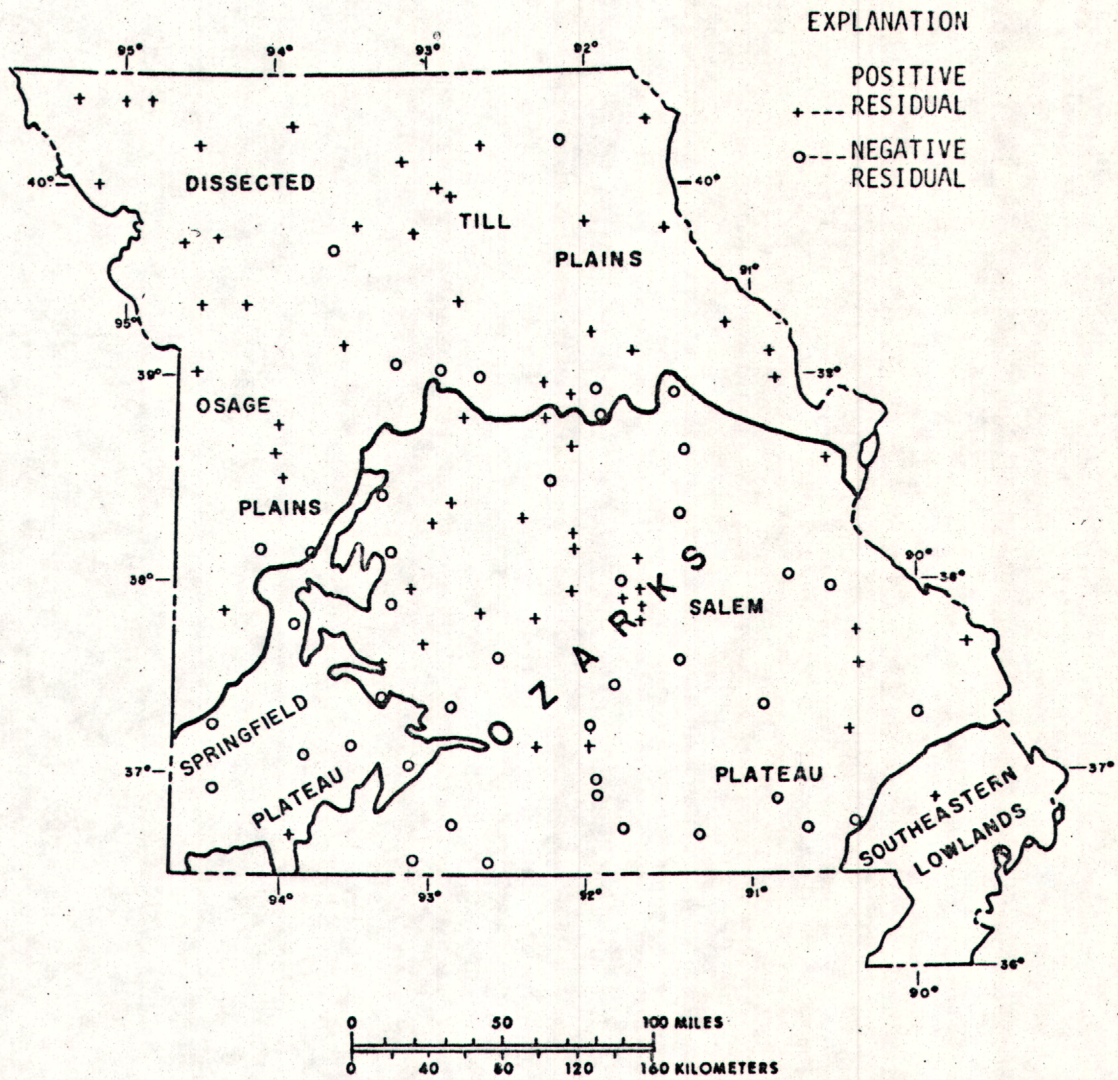


Figure 8.--Physiographic divisions showing residuals at small drainage-area locations.

Table 5.--Comparison of curvilinear model calibrated for the plains and plateaus region with calibration using a statewide data set

Physiographic regions (fig. 8)	Bias (percent) for indicated recurrence interval (years)			
	2		50	
	1 square mile	50 square miles	1 square mile	50 square miles
Plains-----	11.8	-3.7	10.6	-6.7
Plateaus---	0	4.3	-2.5	5.8

Test for Record Length

With physiographic regions defined and regression model determined, data from the large basins (areas greater than 50 square miles) were removed from the matrix so that results of the small-area network evaluation would not be affected by other data.

The period of record for each small-area station was divided into four segments, each segment beginning with the first year of record and ending with 1960, 1965, 1970, and 1977. The log-Pearson Type III distribution was used to define for each record segment the streamflow characteristics for the 2-, 10-, and 50-year recurrence interval based on the same guidelines as previously discussed. Recalibration was then made for each record segment for both physiographic regions. The results of calibration showing the standard error, standard deviation, and average record length for each record segment in each region are summarized in table 6.

Models thus calibrated were used to show precision bias by comparing flood magnitudes for 1- and 10-square mile drainage areas in both plains and plateaus regions for each time segment using flat and steep slopes and comparing it to the 1977 total record segment. Flat and steep slopes were determined in each region from figures 9a and 9b by lowering and raising the straight-line relationships to pass through the steepest and flattest slope in that region for drainage areas less than 50 square miles. Results are shown in table 7.

These test results show that although small improvements are shown by the deviation of the segmented data from the 1977 base, no substantial improvement in these regional regression models can be obtained by continuing to collect records of peak-flow data. However, when better analytical models (regression or nonregression) or additional basin characteristics that affect floodflows are determined, then additional peak-flow data may be needed to verify these models. These conclusions indicate a need for a model analysis whereby better estimating variables can be defined and a more thorough flood-frequency study made for Missouri.

Based upon the assumptions that the available 1955-77 flood peaks provide a representative sample in time, and that the available sample of gaged basins adequately represents Missouri drainage basins, these results indicate little likelihood of significant improvement in flood-estimating accuracy by collection of additional years of flood record to recalibrate this specific regression model. It is possible, however, that alternative model forms or different basin descriptions could lead to improved estimating capability and this avenue of investigation appears at present (1980) to offer more chance for improved accuracy than additional data collection.

Table 6.--Summary of results of tests for record length

Ending year of time segment	Average record length (years)	Standard deviation of logs of annual peaks	Standard error of estimate (percent) for indicated recurrence interval (years)		
			2	10	50
		PLAINS			
1960-----------	6	0.323	35.5	44.7	62.3
1965-----------	10	.318	40.4	58.2	55.1
1970-----------	14	.312	39.9	43.6	54.0
1977-----------	21	.323	38.1	47.4	45.6
		PLATEAUS			
1960-----------	7	0.312	66.2	73.2	83.2
1965-----------	11	.311	66.1	69.5	70.4
1970-----------	15	.307	63.5	60.3	64.3
1977-----------	21	.320	60.7	66.2	63.1

Table 7.--Summary of precision bias for flat, average, and steep slopes in the plains and plateaus regions of Missouri

[Bias, in percent, for 1.00-square mile drainage area]

Ending year of segment	Recurrence intervals (years)								
	Flat slopes 2	Flat slopes 10	Flat slopes 50	Mean slopes 2	Mean slopes 10	Mean slopes 50	Steep slopes 2	Steep slopes 10	Steep slopes 50
PLAINS									
1960------------------	16.8	-6.4	19.9	14.3	77.5	14.8	12.1	-27.6	9.7
1965------------------	5.4	-.5	5.6	7.0	-5.9	2.8	8.9	-10.8	-.7
1970------------------	8.4	-.2	-2.3	5.9	-1.4	.9	3.5	-2.7	4.5
1977------------------	0	0	0	0	0	0	0	0	0
PLATEAUS									
1960-----------------	-2.9	-6.9	-10.1	5.2	6.6	4.0	15.8	26.4	26.6
1965-----------------	4.1	2.0	1.9	4.8	3.2	2.0	5.3	4.6	2.4
1970-----------------	4.1	5.2	2.9	5.2	6.5	2.0	7.3	8.2	2.4
1977-----------------	0	0	0	0	0	0	0	0	0

Table 7.--Summary of precision bias for flat, average, and steep slopes in the plains and plateaus regions of Missouri--continued

[Bias, in percent, for 10.0-square mile drainage area]

Ending year of segment	Recurrence intervals (years) Flat slopes 2	10	50	Mean slopes 2	10	50	Steep slopes 2	10	50
PLAINS									
1960------------------	-6.6	-23.1	-.9	-8.2	-32.2	-5.1	-9.5	-40.6	-9.5
1965------------------	-3.3	-23.1	-.6	-2.2	-27.0	-3.7	.7	-31.4	-6.8
1970------------------	4.1	-9.2	-5.0	1.4	-10.6	-1.9	-.7	-11.8	1.6
1977------------------	0	0	0	0	0	0	0	0	0
PLATEAUS									
1960------------------	-8.3	-3.3	-11.5	-0.8	10.2	2.6	9.4	30.4	23.6
1965------------------	-5.0	-11.3	-7.1	-4.5	-10.0	-6.9	-4.6	-9.2	-6.7
1970------------------	0	9.2	.8	1.5	10.2	.2	3.3	12.0	.3
1977------------------	0	0	0	0	0	0	0	0	0

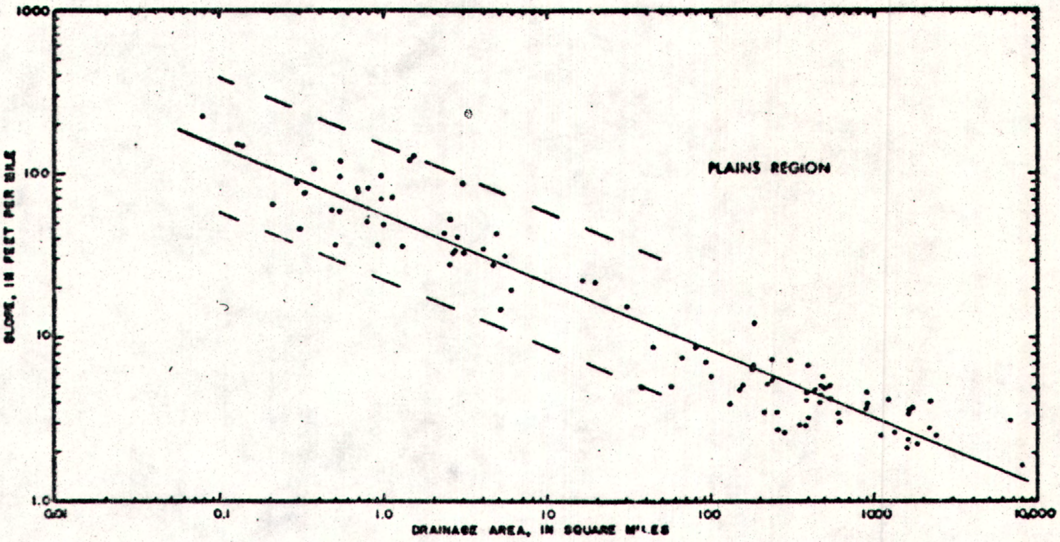


Figure 9a.--Plot of drainage areas versus their respective main-channel slope between the 10 and 85 percent points for the plains region.

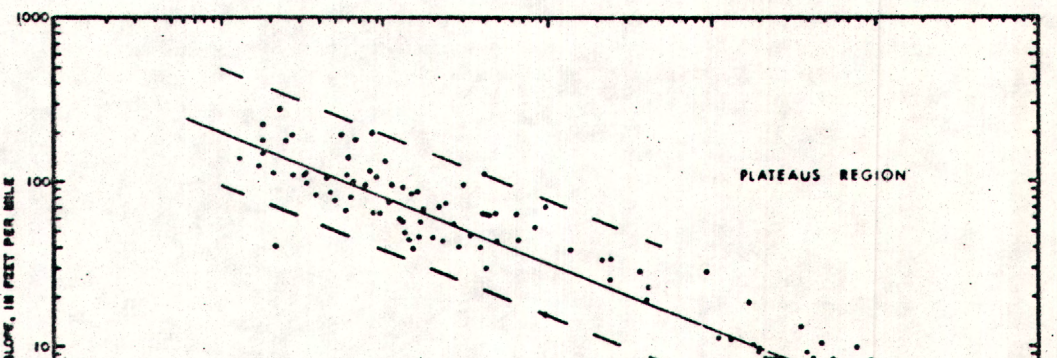


Figure 9b.--Plot of drainage areas versus their respective main-channel slope between the 10 and 85 percent points for the plateaus region.

Test for Spatial Distribution

In addition to long-term record at sampling points to define flood-frequency estimates, an adequate number of sampling sites are needed to define regional floodflow estimates. To analyze the effect of population size on the floodflow estimates, the sample population was again divided into data subsets by repetitively selecting every fourth station from a list of gaging stations arranged in downstream order from each physiographic region until all data points were included in a data set (each data set increasing until the last set included all the data). The model was recalibrated for each subset in the two physiographic regions with standard error and standard deviation computed for each regression. The magnitude of the 2- and 50-year floods for 1- and 10-square mile drainage areas using a mean slope was computed from relationships developed for each subset. Sample size bias is shown by comparing these results to those using the total sample. A summary of precision of regression estimates, bias, average record length, and average standard deviation of the data subset for each physiographic region is shown in table 8.

Results of these tests indicate that samples taken in Missouri for areas less than 10 square miles will fit a regression model with about the same precision regardless of the sample size. However, as the sample size is increased, computed floodflows become more representative of those basins which have thus far been sampled within a given region. It follows then that a much larger population is desirable because homoscidasticity is more probable (more totally representative sample and equally distributed about the mean for the complete range in drainage areas) even though the precision is not improved.

SUMMARY AND CONCLUSIONS

During the past 25 years, efforts have been made to include small drainage areas in flood-frequency analyses for Missouri. Techniques have included the flood-index method, multiple regression, and multiple regression in conjunction with a rainfall-runoff model. In each study, except that using a rainfall-runoff model, inadequate record lengths or perhaps small sample size prevented application of results to drainage areas less than about 50 square miles for floods with a 50-year recurrence interval or greater.

With nearly 25 years of record at most small-streams stations, recent increases in cost of operations, restraints on funds and manpower, public need for more kinds of hydrologic information, and success at using digital modeling techniques to estimate floodflows have made it necessary to evaluate the current small-streams data-collection program to determine if changes could be made.

Table 8.--Summary of results of test for spatial adequacy

Number of stations	Average record length (years)	Average standard deviation	Standard error of estimate (percent)		Bias (percent) for 1- and 10-square mile drainage areas and mean slope			
			(a)	(b)	(1 mi²) (a)	(10 mi²) (a)	(1 mi²) (b)	(10 mi²) (b)
				PLAINS REGION				
12	20	0.304	41.9	44.5	-17.5	9.0	-20.4	14.6
23	21	.306	32.4	40.5	-5.9	9.0	-14.3	.9
32	21	.326	35.8	43.4	-3.8	-.8	-1.8	4.4
44	21	.323	38.1	45.6	0	0	0	0
				PLATEAUS REGION				
18	21	0.328	40.7	31.1	4.8	19.7	12.0	22.7
35	21	.335	54.6	49.1	-7.1	-.8	8.0	5.4
55	20	.318	50.2	54.4	.7	7.6	4.0	6.9
71	21	.320	60.7	63.1	0	0	0	0

[a]2-year flood.
[b]50-year flood.

In order to evaluate the data collected thus far, the following assumptions need to be made:

1. The period 1948-77 is a representative temporal sample.

2. Available flood records provide a representative areal and basin index sample.

3. Flood records are independent temporally and spatially.

The approach for this analysis was to use all drainage-area sizes to establish the best current model (multiple-regression model with streamflow characteristics as dependent variable and basin characteristics as independent variable), then use that model to evaluate the small-streams area network. Station records were divided into subsets for both record length and spatial distribution analysis. The selected regression model ($\log Q = \log a + b\ A^{-0.02} \log A + c \log S$) was recalibrated for each data subset and tested for precision bias and accuracy using 1- and 10-square mile drainage areas with flat and steep slopes. Comparison of the results of each subset calibration allows evaluation of the effect of increasing record length or number of gaging stations.

The results of record-length tests (tables 6 and 7) show that the standard error of estimate was decreased by increasing the record length for both the plains and plateaus regions for 2- and 50-year floods but the increase in accuracy was not considered appreciable. When flood data for 1- and 10-square mile drainage areas with flat and steep slopes were compared for each subset model, bias was reduced as record length was increased in the plains region; however, with the exception of the steep slopes, bias using the plateaus region model was not generally changed as record length was increased. Results of test for spatial adequacy (table 8) indicated that subset data can be fit to the regression model with as much accuracy in both the plains and plateaus regions for the smaller subsets as the greater subsets, but bias will be reduced as the sample size is increased. Although some improvements have been shown, only about 10 percent reduction in bias was noted in the record length or spatial adequacy tests for the time sample (1948-77) of approximately 20 to 29 years.

Based on results of this analysis and the current need for more flood-frequency information in urban areas, much of the data-collection effort in the rural areas of the State could be shifted to the current urban rainfall-runoff network. However, a small network of crest-stage stations would need to be continued to sample long-term trends in rural basins and provide additional information for future model studies.

If improved accuracy is desired for estimating the magnitude and frequency of flooding for small drainage areas of Missouri, other alternatives such as the development of better regression models or evaluation of additional basin characteristics that affect floodflows for small drainage areas could be considered.

Results of this analysis indicate a need for additional research work in analyzing flood frequency, especially for small drainage areas. Types of studies needed include:

1. Nonlinear regression models.

2. Use of qualitative variables to predict floodflows.

3. Evaluation of variables which reflect storage attenutation and timing of flood peaks in tributaries (watershed shape factor).

4. Weighted least-squares regression.

The many different types of data collected during this project can provide the type of information needed to improve the estimating techniques of flood frequency and the understanding of small-streams hydrology.

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