ESTIMATION OF FLOODS OF VARIOUS FREQUENCIES FOR THE SMALL EPHEMERAL STREAMS IN EASTERN WASHINGTON



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations

Open-File Report 79-81

Prepared in Cooperation With
State of Washington Department of Transportation

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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By W.L. Haushild

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1979

UNITED STATES DEPARTMENT OF THE INTERIOR
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Multiply	By	To obtain
inch	25.4	millimeter (mm)
	2.54	centimeter (cm)
	.0254	meter (m)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
cubic foot per second per square mile $(ft^3/s)/mi^2$	.01093	cubic meter per second per square kilometer $(m^3/s)/km^2$

ESTIMATION OF FLOODS OF VARIOUS FREQUENCIES FOR THE SMALL EPHEMERAL STREAMS IN EASTERN WASHINGTON

By W. L. Haushild

ABSTRACT

Equations were developed to estimate the magnitude of floods for various occurence frequencies at ungaged sites on ephemeral streams that drain small, relatively undeveloped basins in the semiarid part of eastern Washington. The equations were developed from regression analyses that used the logarithms of the longitude indexes of gaged sites, forest cover, and drainage areas of the upstream basins as independent variables. Logarithms of the discharges for selected exceedance-probabilities at the gaged sites were used as dependent variables. These equations may be used to estimate floodflows with probabilities of being exceeded in any year of 50, 20, 10, 4, 2, and 1 percent in natural flow ephemeral streams that drain relatively undeveloped basins with areas and forest covers less than about 40 mi^2 and 30 percent, respectively. The standard errors of estimate for the equations range from 57 to 100 percent. Equations that use longitude index as a surrogate for a precipitation index more accurately estimate floods than do equations that use mean annual precipitation, which, in turn, are better than the equations that use the 24-hour precipitation with an exceedance probability of 50 percent.

INTRODUCTION

Since the early 1950's the U.S. Geological Survey has cooperated with the State of Washington Department of Transportation in determining the annual peak flows at stations on many small ephemeral streams in the semiarid parts of eastern Washington. The two agencies agreed to do a study during 1977-1978 that would: (1) use the annual peak-flow data to compute magnitudes and frequencies of peak flows at the stations; and (2) develop regression equations that can be used to estimate the magnitude of floods for specific probabilities of exceedance in any year at any site on the small, natural flow, ephemeral streams located in relatively undeveloped basins of eastern Washington. This report presents the magnitudes and frequencies of peak flows and the regression equations. It also describes the development of these equations.

PREVIOUS STUDIES

Previous studies have provided methods for estimating floods in eastern Washington streams. The methods described by Bodhaine and Thomas (1964) are applicable only to streams with drainage areas larger than 20 square miles in the Columbia River basin upstream of the Snake River. This area-limitation excludes use of their methods for most of the streams used in this study.

Cummans, Collings, and Nassar (1975) also provide equations that can be used to estimate magnitudes and frequencies of floods in Washington streams. They used seven regions for eastern Washington and give estimating equations for each region. They report that "they [the equations] can be used with least confidence in arid areas." In evaluating the results of their study, they state: "The errors of estimate were generally greater, on the average, in eastern Washington. This is believed attributable to less average total precipitation, more variability of precipitation in the semiarid parts, and generally shorter streamflow records and sparser coverage of the area with streamflow data than in western Washington. The precipitation index is from widely separated data in eastern Washington and its use, where not accurately measured, could be a source of the larger errors of estimates."

The area of this study is the same as that classified as a separate region (the Columbia Plateau and contiguous areas) by Moss and Haushild (1978) for purposes of evaluating and designing a streamflow-data network in Washington. They excluded the region from the design analyses because the flow data for the ephemeral streams and the few perennial streams of the region did not fulfill the criteria established for inclusion. Their recommendations for future operation of stations in the region were: "no station on natural-flow streams of Washington could be justifiably operated for the sole purpose of collecting data for regionalization of streamflow characteristics. The only exceptions to this statement are stations in the small stream basins on the Columbia Plateau, where the paucity of data and the variation of the runoff regime from those examined herein might over-extend the generality of this conclusion. The continuation of the collection of annual peak-flow data at existing stations in this ephemeral-stream part of Washington (Columbia Plateau) is recommended in the interim until further analysis can determine if and when they should be terminated. Continual-record stations on the few perennial streams in the ephemeral-stream area should be either continued or discontinued for the same reasons as those for the other five runoff regimes."

The results of the previous studies indicate either a nonapplicability of, or some lack of confidence in, the equations and methods developed to estimate floods in the small ephemeral streams of eastern Washington. These deficiencies emphasize the need for the re-analyses and re-evaluation done in this study. The estimating equations described herein may be better than those of the previous studies, because additional data are now available and the small ephemeral streams are included in a separate, homogenous region instead of being included with the perennial streams of one or several regions.

THE STUDY AREA AND CLIMATE

The study area (fig. 1) is semiarid and includes all of the Columbia Plateau and some of the northern border mountains and highlands, Blue Mountains and foothills of the Cascade Range (fig. 2). The area is drained by several large perennial streams flowing from the mountains and by the Columbia and Snake Rivers which cross the area. There are also numerous ephemeral streams that flow only following periods of heavy rainfall or snowmelt. The drainage area of the study streams ranged from 0.21 to 50.3 mi^2.

The summers in the study area are hot and dry and the winters are cold and snowy. Average annual precipitation is less than 10 inches over much of the area. Earl L. Phillips, in the report by Gifford, Ashcraft and Magnuson (1967), describes the precipitation patterns of Washington, including that of the study area as follows:

"Washington's climate varies from a marine-type in the western section to one which combines both marine and continental characteristics in the eastern area. Some of the factors influencing the climate are: terrain, the Pacific Ocean, and the prevailing direction of the wind. The combined effects of these produce entirely different rainfall patterns within short distances* * *. In late fall and winter a prevailing southwesterly flow of moist air results in a wet season beginning in October, reaching a peak in December, then decreasing in the spring. Approximately 75 percent of the annual precipitation falls in the 6-month period, October through March * * *. In late spring and summer, a prevailing westerly and northwesterly flow of air into the State results in a dry season beginning in May and reaching a peak in midsummer. The total rainfall for the two driest months, July and August, accounts for approximately 5 percent of the annual precipitation * * *.

"The second area of heavy precipitation is along the western slope of the Cascade Mountains. Annual amounts increase from 60 inches in the foothills to 100 inches in the higher elevations, reaching 150 or more in the wettest localities. In eastern Washington, precipitation decreases from the summit of the Cascades to less than 10 inches in the driest portion of the Central Basin. There is a gradual increase in precipitation in an easterly and northerly direction from the lowest elevation of the Central Basin to 20 inches near the Idaho border and 20 to 40 inches over the Okanogan Highlands northern border mountains."

The data of the U.S. Weather Bureau (1965) presented in table 1 for stations listed in order along east-to-west and north-to-south directions indicate the spatial and temporal variations of precipitation in the study area. Locations and elevations of the stations are those given by the U.S. Weather Bureau (1960). In the eastern part of the study area, precipitation increases north and south from the dry lowland part of the area; however, in the western part of the study area, the dry area extends to the State's southern border. (See data in table 1 for stations located along about 118° and about 119.6° longitude.)

The runoff from short periods of intense rain causes many of the peak flows in streams located in semiarid regions. Data taken from Miller, Frederick, and Tracey (1973), which are illustrated in figure 3, indicate that the 6-hour precipitation with chances of 1-in-25 of being exceeded in any year is about 1 inch in the drier central part of the study area and increases to about 1.5 inches along its eastern and western borders.

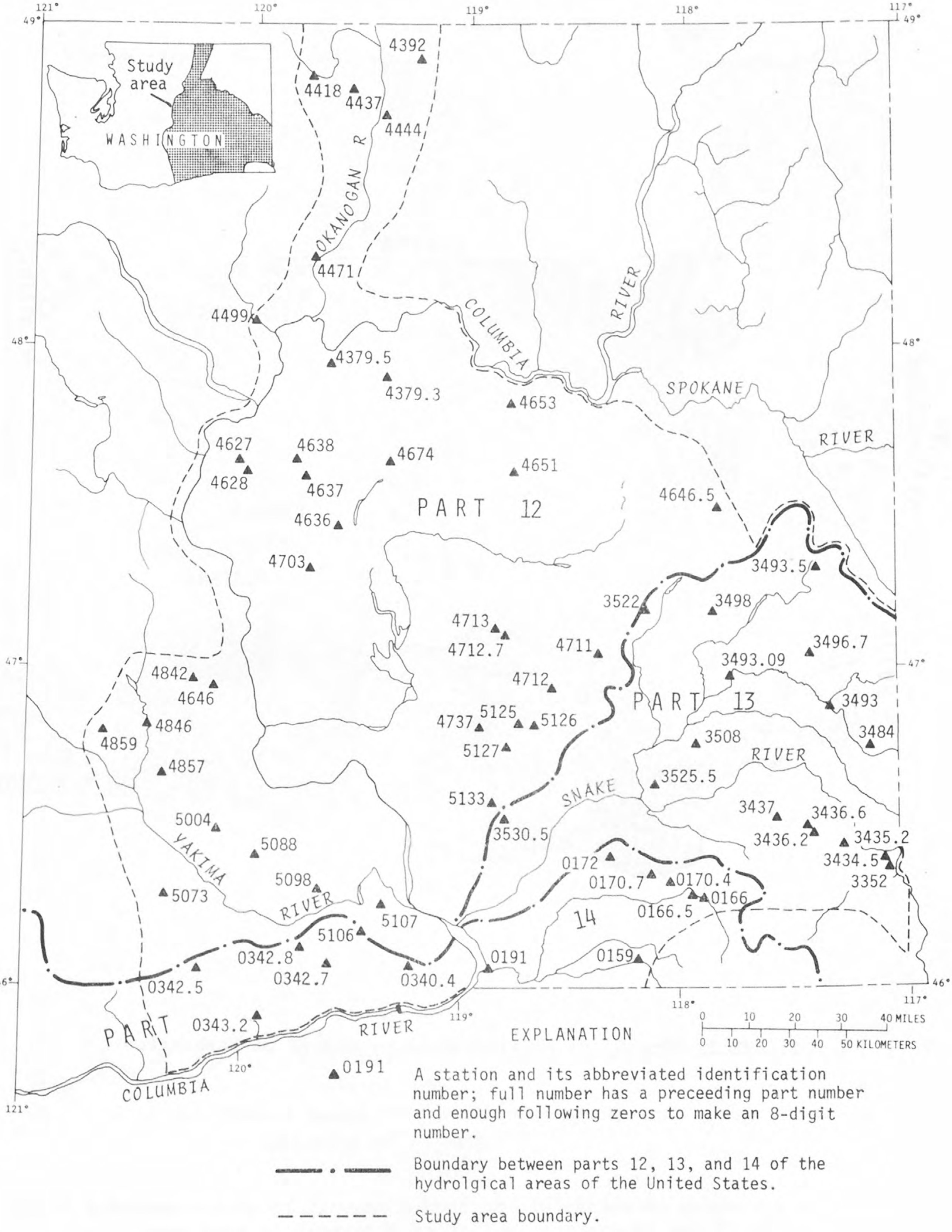

FIGURE 1.--Location of data-collection stations in eastern Washington.

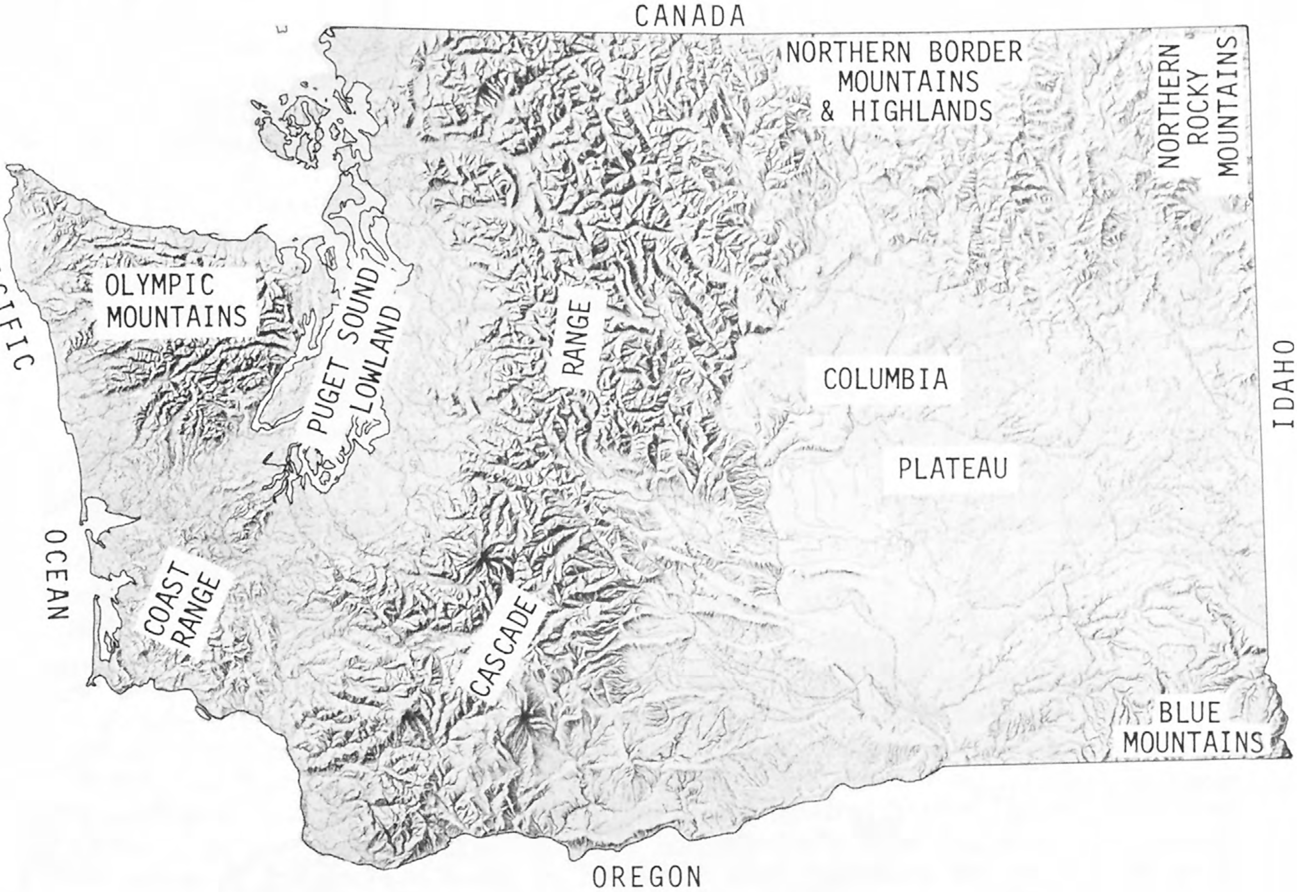

FIGURE 2.--Principal physiographic provinces of Washington.

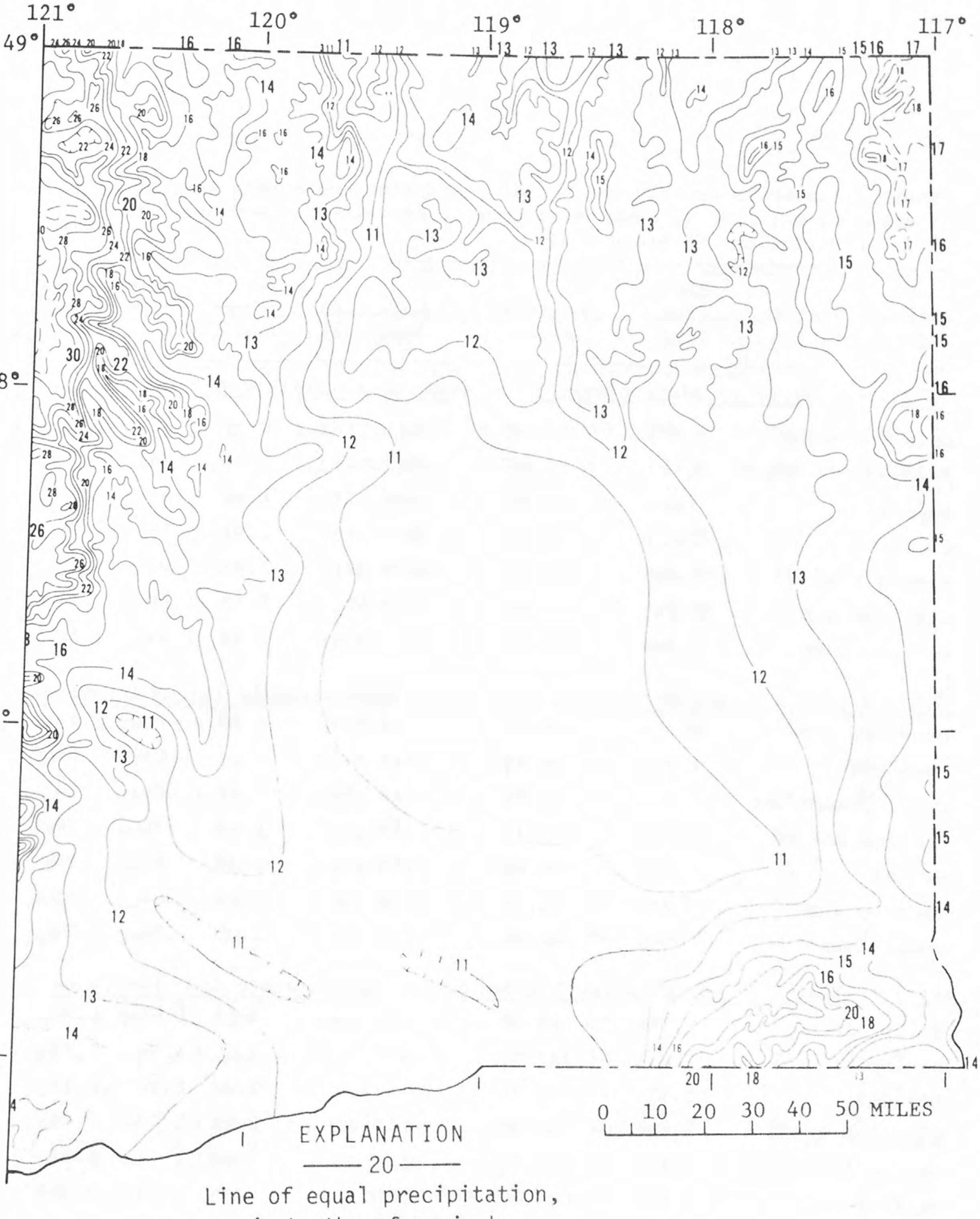

FIGURE 3.--Isopluvials of 25-year 6-hour precipitation in eastern Washington from part of figure 22 by Miller, Frederick, and Tracy (1973).

TABLE 1.--Average monthly and annual precipitations during 1951-60 at stations selected to show variations in east-to-west and north-to-south directions in study area

National Weather Service station	Elevation (ft)	Latitude (degrees)	Longitude (degrees)	Average Jan.	Average Feb.	Average Mar.
Stations listed in east-to-west order along approximately 47° latitude						
Lake Keechelus	2,475	47.32	121.33	10.39	7.82	6.15
Ellensburg, FAA AP	1,727	47.03	120.52	1.67	.74	.88
Smyrna	560	46.83	119.67	1.44	.87	.69
Othello	1,110	46.83	119.17	1.41	.76	.56
Hatton 8 E	1,428	46.77	118.67	1.63	.82	.73
LaCrosse 3 ESE	1,546	46.80	117.82	2.12	1.00	1.04
Pullman 2 NW	2,545	46.77	117.20	2.95	2.44	2.30
Stations listed in north-to-south order along approximately 119.6° longitude						
Oroville 3 NW	1,060	48.97	119.50	1.78	.98	.92
Omak 2NW	1,228	48.43	119.53	1.94	1.04	.85
Chief Joseph Dam	822	48.00	119.65	1.50	.84	.64
Ephrata FAA AP	1,259	47.30	119.53	1.34	.78	.70
Smyrna	560	46.83	119.67	1.44	.87	.69
Prosser 4 NE	840	46.25	119.75	1.24	.62	.55
McNary Dam	348	45.95	119.30	1.31	.81	.84
Stations listed in north-to-south order along approximately 118° longitude						
Wellpinit	2,450	47.88	117.98	3.16	1.68	1.61
Davenport	2,450	47.65	118.15	2.66	1.54	1.53
Sprague	1,925	47.30	117.98	2.49	1.26	1.12
LaCrosse 3 ESE	1,546	46.80	117.82	2.12	1.00	1.04
Dayton 1 WSW	1,557	46.32	118.00	2.84	1.71	1.81
Mill Creek	2,000	46.02	118.12	5.85	3.98	4.35

precipitation, in inches									
Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
4.26	2.52	2.23	0.78	0.90	3.09	7.30	10.77	11.83	68.04
.49	.67	.68	.13	.44	.51	.61	1.08	1.12	9.02
.59	.52	.66	.13	.13	.37	.59	.97	1.14	8.10
.39	.68	.62	.16	.16	.40	.64	.72	.89	7.39
.68	.91	.68	.18	.38	.42	.98	1.00	1.28	9.69
.84	.91	1.05	.22	.64	.55	1.35	1.48	1.92	13.12
1.68	1.62	1.59	.43	.94	1.00	2.50	3.43	3.15	24.03
.80	1.25	1.56	.60	.90	.45	.97	1.07	1.21	12.49
.83	1.07	.93	.50	.70	.60	.96	1.47	1.35	12.24
.52	.76	1.14	.18	.55	.36	.68	1.26	1.16	9.59
.64	.64	.77	.20	.24	.43	.64	.91	.82	8.11
.59	.52	.66	.13	.13	.37	.59	.97	1.14	8.10
.58	.65	.62	.19	.18	.41	.83	.94	.92	7.73
.46	.74	.42	.17	.22	.47	1.04	.85	.93	8.26
1.56	1.91	1.34	.68	1.15	1.00	1.53	2.39	2.58	20.59
1.20	1.49	1.14	.64	.97	1.09	1.30	2.01	2.03	17.60
.87	1.28	.87	.35	.68	.73	1.44	1.85	1.90	14.84
.84	.91	1.05	.22	.64	.55	1.35	1.48	1.92	13.12
1.59	1.48	1.60	.24	.75	.77	1.86	2.15	2.77	19.57
3.75	3.27	2.76	.42	1.03	1.74	3.83	4.60	5.41	40.99

FLOOD-FREQUENCY ANALYSES

Data-Collection Stations

The study stations are shown in figure 1 and also are listed in table 2 along with some data about their location, basin size, record period, and maximum observed runoff. Only annual peak-flows were determined at the stations. The stations are located on main or tributary channels of the coulees, draws, canyons, creeks, and rivers that are part of the drainage basin of the Columbia River.

The frequency distributions of annual peak flows at 51 of the 66 study stations were determined by using the guidelines recommended by the U.S. Water Resources Council (1976). The data at the other 15 stations are too few to apply these guidelines; therefore, the available data were used to compute the probability of the annual peak flow exceeding either zero or some small value at these stations. At 5 of the 15 stations, enough data were available to graphically determine the annual peak flow for several exceedance probabilities. The annual peak flows with probabilities of exceedance in any year of 50, 20, 10, 4, 2, and 1 percent are designated within this report as the P50%, P20%, P10%, P4%, P2% and P1% floods. The flood flows determined for these six probabilities of exceedance in any year are given for all stations in table 3.

The frequency distributions calculated for Cow Creek tributary near Ritzville (fig. 4) are examples of fitting distributions according to the guidelines of the U.S. Water Resources Council (1976). Available for many stations was either a historical peak flow or the historical period during which the maximum-observed, annual, peak-flow had not been exceeded. (Historical refers to time prior to starting operation of a station.) In figure 4 the two curves for the Cow Creek tributary show the difference between frequencies determined from using the 1955-73 annual peak flows and those obtained by adding the 1951 historical peak flow of 200 ft^3/s to the 1955-73 data. For example, the floodflow that has a 1-in-10 chance of being exceeded in any year is about 100 ft^3/s with the historical peak flow in the analysis and about 80 ft^3/s without it.

TABLE 2.--Drainage areas, latitudes, longitudes, periods of record, and maximum observed peak runoffs at ephemeral-stream stations in study area of eastern Washington

[Stations listed in west-to-east order]

Station number and name		Drainage area (mi^2)	Latitude (degrees)	Longitude (degrees)	Period of record	Maximum observed peak runoff[1] ($ft^3/s/mi^2$)
12485900	Pine Canyon near Naches	2.26	46.820	120.671	1961-76	61
12484600	McPherson Canyon at Wymer	5.48	46.834	120.453	1952, 1955-76	56
12485700	Selah Creek Tributary near Yakima	.68	46.676	120.389	1955-74	150
12507300	Toppenish Creek Tributary near Toppenish	1.24	46.289	120.358	1955-74	27
12484200	Johnson Canyon Tributary near Kittitas	.65	46.978	120.240	1956-75	66
14034250	Glade Creek Tributary near Bickleton	.50	46.069	120.206	1961-76	86
12462800	Moses Creek at Douglas	15.4	47.614	120.167	1955-76	17
12464600	Schnebly Coulee Tributary near Vantage	.82	46.962	120.146	1955-74	200
12500400	Firewater Canyon near Maxee City	7.30	46.504	120.144	1963-76	75
12462700	Moses Creek at Waterville	3.48	47.647	120.053	1954-73	34
12449900	Methow River Tributary near Methow	.77	48.074	120.003	1954-69	23
12508800	Yakima River Tributary near Sunnyside	1.91	46.422	119.940	1954-73	140
14034320	Dead Canyon Tributary near Alderdale	.62	45.920	119.908	1955-74	27
12463800	Pine Canyon Tributary near Farmer	1.10	47.648	119.814	1960, 1962-76	27
12463700	McCarteney Creek Tributary near Farmer	.4	47.630	119.744	1960, 1962-76	280
12441800	Olie Creek near Loomis	1.42	48.850	119.732	1961-75	6
14034280	East Branch Glade Creek Tributary near Prosser	.77	46.128	119.719	1962-75	390
12470300	Iron Springs Creek near Winchester	1.57	47.333	119.703	1959-76	81
12447100	Okanogan River Tributary at Malott	2.66	48.281	119.700	1959-75	19
12509800	Snipes Creek Tributary near Benton City	5.18	46.338	119.658	1965, 1967-76	64
12437950	East Foster Creek Tributary near Bridgeport	4.75	47.950	119.631	1957-76	210
14034270	East Branch Glade Creek near Prosser	50.3	46.076	119.603	1962-76	10
12463600	Rattlesnake Creek Tributary near Soap Lake	2.22	47.442	119.596	1959, 1961-76	58
12443700	Spectacle Lake Tributary near Loomis	4.59	48.810	119.553	1961-76	24
12510600	Weber Canyon near Kiona	2.88	46.187	119.456	1955-74	73
12510700	Yakima River Tributary near Kiona	3.35	46.265	119.388	1955-74	1
12437930	East Fork Foster Creek at Leahy	35.4	47.914	119.383	1959, 1963-76	10
12444400	Siwash Creek Tributary near Tonasket	.66	48.720	119.370	1957, 1959-76	79
12467400	Haynes Canyon near Coulee City	2.7	47.646	119.356	1959-76	57
14034040	Bofer Canyon Tributary near Kennewick	1.53	46.062	119.223	1965, 1967-76	50
12439200	Dry Creek Tributary near Molson	1.68	48.915	119.212	1958-76	28

TABLE 2.--Drainage areas, latitudes, longitudes, periods of record, and maximum observed peak runoffs at ephemeral-stream stations in study area of eastern Washington--continued

[Stations listed in west-to-east order]

Station number and name		Drainage area (mi^2)	Latitude (degrees)	Longitude (degrees)	Period of record	Maximum observed peak runoff[1] ($ft^3/s/mi^2$)
12473700	Kansas No. 2 near Cunningham	6.06	46.824	118.926	1955-70	29
14019100	Walla Walla River Tributary near Wallula	.80	46.053	118.883	1955-76	400
12471300	Weber Coulee Tributary near Ruff	.95	47.140	118.872	1959-72	250
12513300	Dunnigan Coulee near Connell	27.1	46.578	118.857	1956, 1963-76	17
12471270	Farrier Coulee near Schrag	42.0	47.126	118.838	1963-76	34
13353050	Smith Canyon Tributary near Connell	1.80	46.541	118.815	1955-76	26
12512500	Providence Coulee at Cummingham	27.8	46.822	118.810	1953-75	78
12465300	Broadax Draw Tributary near Wilburn	1.12	47.840	118.807	1955-74	180
12512700	Hatton Coulee Tributary near Hatton	3.71	46.764	118.799	1956-75	50
12465100	Connawai Creek Tributary near Govan	.25	47.616	118.761	1958-76	660
12512600	Hatton Coulee Tributary No. 2 near Cunningham	2.44	46.823	118.697	1961-76	35
12471200	Lind Coulee Tributary near Lind	.21	46.956	118.600	1956, 1961-76	290
12471100	Paha Coulee Tributary near Ritzville	8.52	47.051	118.424	1962-76	31
14017200	Badger Hollow near Clyde	4.16	46.416	118.338	1955-74	380
13352200	Cow Creek Tributary near Ritzville	1.51	47.177	118.192	1951, 1955-73	130
14015900	Spring Creek Tributary near Walla Walla	1.94	46.104	118.189	1955-74	120
14017070	East Fork McKay Creek near Huntsville	4.92	46.363	118.132	1963-76	150
13352550	Stewart Canyon Tributary near Riparia	1.27	46.639	118.128	1958-75	220
14017040	Thorn Hollow near Dayton	2.68	46.347	118.065	1962-76	81
14016650	Davis Hollow near Dayton	3.01	46.300	117.953	1956-75	100
13350800	Willow Creek Tributary near LaCrosse	.95	46.758	117.919	1967-76	46
14016600	Hatley Creek near Dayton	4.12	46.281	117.893	1955-74	61
13349800	Imbler Creek Tributary near Lamont	1.33	47.164	117.882	1967-76	150
12464650	South Fork Crab Creek Tributary at Waukon	.68	47.537	117.853	1954-73	160
13349309	Palouse River Tributary at Winona	2.94	46.960	117.803	1967-76	26
13343700	Ben Day Gulch Tributary near Pomeroy	.78	46.538	117.591	1961-69	90
13343660	Smith Gulch Tributary near Pataha	1.85	46.490	117.445	1955-74	360
13349670	Pleasant Valley Creek Tributary near Thorton	.77	47.042	117.439	1967-76	82
13343620	South Fork Deadman Creek Tributary near Pataha	.54	46.479	117.413	1961-76	360
13349350	Hardman Draw Tributary at Plaza	1.64	47.310	117.387	1955-74	1100
13349300	Palouse River Tributary at Colfax	2.1	46.889	117.383	1955-76	87
13343520	Clayton Gulch near Alpowa	5.60	46.448	117.293	1961-76	53
13348400	Missouri Flat Creek Tributary near Pullman	.88	46.764	117.167	1955-74	260
13343450	Dry Creek at mouth near Clarkston	6.83	46.408	117.106	1963-76	1200
13335200	Critchfield Draw near Clarkston	1.80	46.374	117.085	1959-76	390

[1] Computed by dividing maximum peak flow by drainage area.

TABLE 3.--Flood-frequency data for ephemeral-stream stations in study area of eastern Washington

Station number and name		Drain-age area (mi^2)	Flood discharge (ft^3/s) for indicated probability of exceedance in any year, in percent					
			50	20	10	4	2	1
12437930	East Fork Foster Creek at Leahy	35.4	80	180	260	390	500	630
12437950	East Foster Creek Tributary near Bridgeport	4.75	30	70	110	200	290	410
12439200	Dry Creek Tributary near Molson	1.68	20	30	40	60	70	90
12441800	Olie Creek near Loomis	1.42	0	(a)	(a)	(a)	(a)	(a)
12443700	Spectacle Lake Tributary near Loomis	4.59	4	20	40	90	150	240
12444400	Siwash Creek Tributary near Tonasket	.66	8	20	30	50	70	90
12447100	Okanogan River Tributary at Malott	2.66	1	6	20	40	80	130
12449900	Methow River Tributary near Methow	.77	0	0	(a)	(a)	(a)	(a)
12462700	Moses Creek at Waterville	3.48	10	40	70	130	190	280
12462800	Moses Creek at Douglas	15.4	60	130	200	300	390	490
12463600	Rattlesnake Creek Tributary near Soap Lake	2.22	10	40	70	140	220	320
12463700	McCarteney Creek Tributary near Farmer	.4	5	20	40	80	130	200
12463800	Pine Canyon Tributary near Farmer	1.10	2	10	30	60	100	170
12464600	Schnebly Coulee Tributary near Vantage	.82	7	20	40	70	110	160
12464650	South Fork Crab Creek Tributary at Waukon	.68	20	40	50	70	80	100
12465100	Connawai Creek Tributary near Govan	.25	5	20	30	50	80	110
12465300	Broadax Draw Tributary near Wilburn	1.12	20	60	90	140	180	240
12467400	Haynes Canyon near Coulee City	2.7	8	20	40	60	90	130
12470300	Iron Springs Creek near Winchester	1.57	20	40	60	90	130	160
12471100	Paha Coulee Tributary near Ritzville	8.52	110	200	270	380	460	550
12471200	Lind Coulee Tributary near Lind	.21	7	20	30	50	70	100
12471270	Farrier Coulee near Schrag	42.	130	490	970	2000	3000	4500
12471300	Weber Coulee Tributary near Ruff	.95	2	[b]30	[b]90	[b]170	(a)	(a)
12473700	Kansas No. 2 near Cunningham	6.01	0	0	(a)	(a)	(a)	(a)
12484200	Johnson Canyon Tributary near Kittitas	.65	2	9	20	40	60	100
12484600	McPherson Canyon at Wymer	5.48	40	80	110	160	200	240
12485700	Selah Creek Tributary near Yakima	.68	2	10	30	70	140	240
12485900	Pine Canyon near Naches	2.26	10	30	50	100	140	200
12500400	Firewater Canyon near Moxee City	7.30	10	60	150	400	760	1300
12507300	Toppenish Creek Tributary near Toppenish	1.24	0	[b]20	[b]30	[b]40	(a)	(a)
			4					
12508800	Yakima River Tributary near Sunnyside	1.91	6	30	60	140	240	390
12509800	Snipes Creek Tributary near Benton City	5.18	20	[b]170	[b]360	(a)	(a)	(a)
12510600	Weber Canyon near Kiona	2.88	0	[b]20	[b]90	[b]200	(a)	(a)
12510700	Yakima River Tributary near Kiona	3.35	0	(a)	(a)	(a)	(a)	(a)
12512500	Providence Coulee at Cunningham	27.8	70	310	640	1400	2200	3400

TABLE 3.--Flood-frequency data for ephemeral-stream stations in study area of eastern Washington--Continued

Station number and name		Drainage area (mi^2)	Flood discharge (ft^3/s) for indicated probability of exceedance in any year, in percent					
			50	20	10	4	2	1
12512600	Hatton Coulee Tributary No. 2 near Cunningham	2.44	4	20	60	140	260	430
12512700	Hatton Coulee Tributary near Hatton	3.71	4	20	30	70	110	180
12513300	Dunnigan Coulee near Connell	27.1	0	[b]60	[b]180	[b]390	(a)	(a)
13335200	Critchfield Draw near Clarkston	1.80	20	100	240	570	980	1600
13343450	Dry Creek at Mouth near Clarkston	6.83	60	210	440	1000	1900	3500
13343520	Clayton Gulch near Alpowa	5.60	100	190	260	360	440	530
13343620	South Fork Deadman Creek Tributary near Pataha	.54	30	60	100	160	200	260
13343660	Smith Gulch Tributary near Pataha	1.85	50	150	250	420	590	780
13343700	Ben Day Gulch Tributary near Pomeroy	.78	20	40	60	80	110	130
13348400	Missouri Flat Creek Tributary near Pullman	.88	30	80	120	190	250	320
13349300	Palouse River Tributary at Colfax	2.1	30	70	110	160	200	240
13349309	Palouse River Tributary at Winona	2.94	40	60	80	100	120	130
13349350	Hardman Draw Tributary at Plaza	1.64	30	70	120	220	330	500
13349670	Pleasant Valley Creek Tributary near Thornton	.77	30	40	60	70	80	80
13349800	Imbler Creek Tributary near Lamont	1.33	60	100	130	160	180	200
13350800	Willow Creek Tributary near LaCrosse	.95	20	30	40	60	70	80
13352200	Cow Creek Tributary near Ritzville	1.51	20	60	100	170	240	320
13352550	Stewart Canyon Tributary near Riparia	1.27	20	70	130	250	380	540
13353050	Smith Canyon Tributary near Connell	1.80	0	(a)	(a)	(a)	(a)	(a)
14015900	Spring Creek Tributary near Walla Walla	1.94	20	80	130	240	350	490
14016600	Hatley Creek near Dayton	4.12	70	180	280	440	590	760
14016650	Davis Hollow near Dayton	3.01	10	40	80	180	300	490
14017040	Thorn Hollow near Dayton	2.68	30	110	190	340	500	690
14017070	East Fork McKay Creek near Huntsville	4.92	70	220	380	690	990	1400
14017200	Badger Hollow near Clyde	4.16	50	170	320	630	960	1400
14019100	Walla Walla Tributary near Wallula	.80	(a)	(a)	(a)	(a)	(a)	(a)
14034040	Bofer Canyon Tributary near Kennewick	1.53	0	(a)	(a)	(a)	(a)	(a)
14034250	Glade Creek Tributary near Bickleton	.50	8	20	20	40	50	60
14034270	East Branch Glade Creek near Prosser	50.3	0	(a)	(a)	(a)	(a)	(a)
14034280	East Branch Glade Creek Tributary near Prosser	.77	0	0	(a)	(a)	(a)	(a)
14034320	Dead Canyon Tributary near Alderdale	.62	0	0	(a)	(a)	(a)	(a)

[a] Floodflow greater than zero but undeterminable from the few available data.

[b] Floodflow determined from graphical analysis of annual peak flows greater than zero and with exceedance probabilities adjusted for number of zero-flow years.

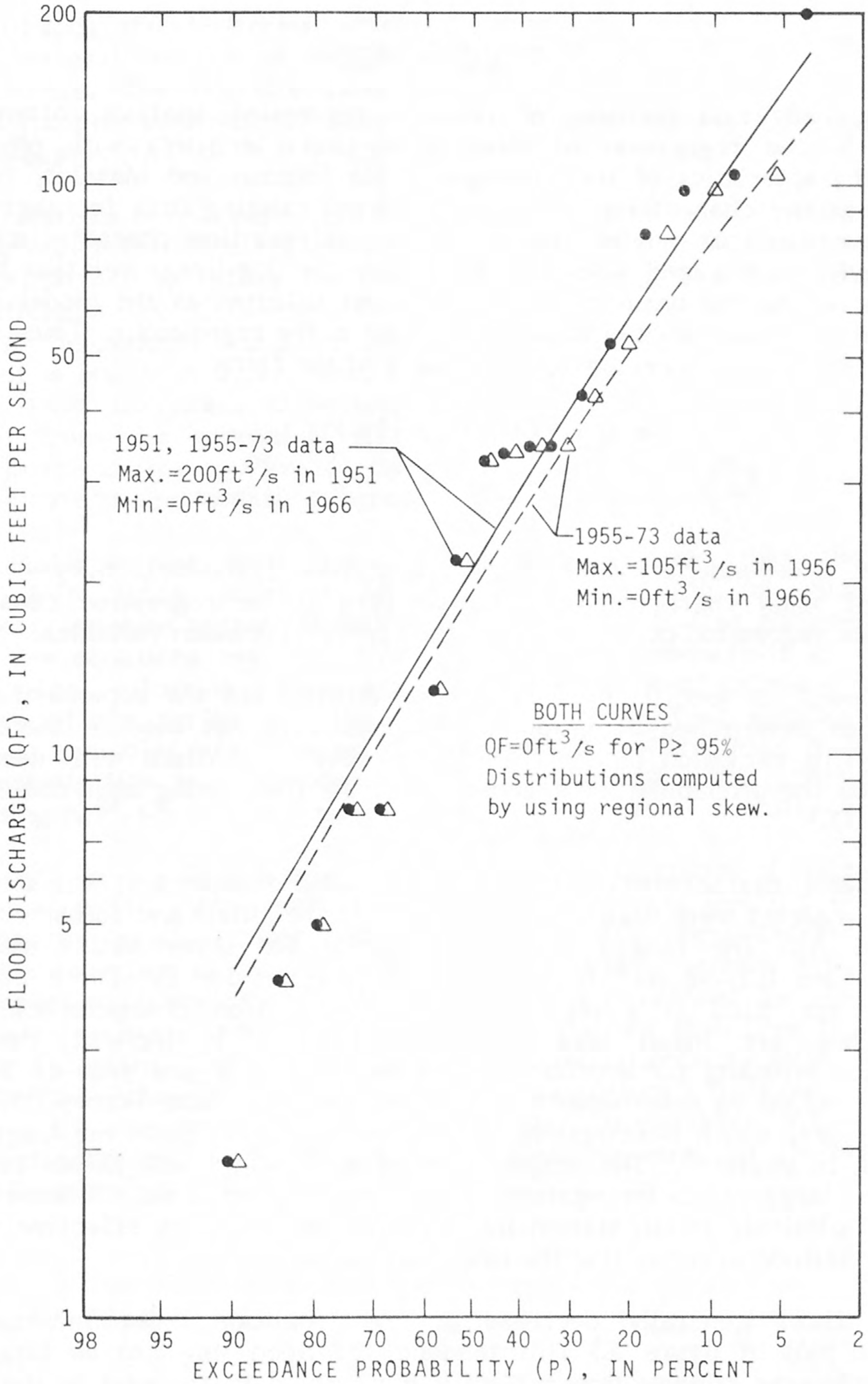

FIGURE 4.--Flood-frequency curves, Cow Creek tributary near Ritzville, station no. 13352200.

Regionalization

A regionalization method, or regional regression analysis, often used in hydrology is the regression of streamflow characterisitics with physical and climatic characteristics of the drainage basins (Benson and Matalas, 1967). The analysis uses the characteristics estimated from existing data for gaged sites to develop equations that may be used to estimate streamflow characteristics (floods in this study) at ungaged sites. In this study the log-linear relation between a specific flood and the basin characteristics was selected as the model form, and the logarithms of all variable values were used in the regressions. Thus, the model is one commonly used in regionalization and is of the form:

$$\log y = \log a + b_1 \log x_1 + b_2 \log x_2 \text{ --- } b_n \log x_n$$

or

$$y = a x_1^{b_1} x_2^{b_2} \text{------} x_n^{b_n}$$

where y is a dependent streamflow characteristic (variable), x_1, x_2 ----- x_n are independent basin characteristics (variables), $\underline{a}$ is the regression constant, and b_1, b_2--b_n are regression coefficients for the appropriate basin variables.

The floods for specific exceedance probabilities are the dependent variables. Those floods determined by graphical methods were not used in the regression analyses. This exclusion meant that the number of stations with useable data depended on the probability of exceedance of the flood being analyzed and varied from 51 to 53.

Two basin characteristics found to be useful independent variables in the regression analyses were drainage area (A, in square miles) and forest cover (F, in percent of A). The ranges in these variables for study basins used in the regressions are 0.21-42 mi^2 for A and 0-28 percent for F. Three independent variables were tried as a representative precipitation characteristic for the basins. They are mean annual precipitation (P, in inches), the 24-hour precipitation intensity for a probability of exceedance in any year of 50 percent (I24, 2, in inches) as determined from Miller, Frederick and Tracey (1973), and a longitude index, which is computed by subtracting 117.00° from the longitude of a station (LI, in degrees). The longitude index will have small values for eastern stations and large values for western stations in the study area. Because the study basins are relatively small, station longitude is considered an effective substitute for basin longitude in computing the longitude index.

Flood flows generally decrease as the longitude index increases. (See logarithmic plot in figure 5.) This tendency of flood flows to be larger in the eastern study-area streams may reflect a diminishing to the east in the shielding effects of the Cascade Range on precipitation. Monthly and annual average precipitation do increase in an easterly direction as is indicated by the increase from Smyrna-Othello to Pullman shown in table 1. Also, the intensity and duration of local thunderstorms, which usually cause many of the flows that occur in the ephemeral streams of semiarid regions, may increase easterly from the Cascade Range. The longitude index was selected as a surrogate that may better represent the precipitation that causes floods in the study-area streams than does mean annual precipitation or a specific precipitation-intentsity.

The relations of the dependent variables to each set of independent variables were determined from the regression analyses. The estimating equations accepted for evaluation had to satisfy the following criteria: (1) the regression constants and coefficients are significant at a 95-percent-confidence level, and (2) the significant independent variables are essentially uncorrelated--their correlation coefficient is less than 0.50. Also, the residual errors, which are the differences between flood discharges determined from the frequency curves and those estimated from the regression equations, were determined for each station included in the analyses. Plots of these residual errors on maps of the area (not shown) indicated no systematic geographic bias.

An evaluation of the regression analyses indicated that the equations resulting from using drainage area, forest cover, and longitude index as independent variables better estimate floods in the study-area ephemeral streams than do the equations resulting from using other combinations of independent variables. The evaluation criteria are the standard error of estimate (SE) and the percentage of the variance in the dependent variable that is explained by the independent variables (r^2). The set of estimating equations using A, F, and mean annual precipitation as independent variables had less SE and higher r^2 than did the set using A, F, and the 24-hour, 50-percent precipitation intensity.

The data for the P4% flood shown in the two lower graphs of figure 6 indicate the improvement by using longitude index instead of mean annual precipitation as an independent variable to represent the characteristic precipitation of the study basins. A comparison of the data shown in the two lower graphs with that shown in the upper graph indicates that both equations developed for only the study region better estimate P4% floods at the study stations than does the use of the applicable Cummans, Collings, and Nassar (1975) equations--the study stations are located in six of their seven eastern Washington regions. Because the foregoing conclusions are also valid for the other 5 floods, the equations that use drainage area, forest cover and longitude index as independent variables are recommended for use. These equations are given in table 4.

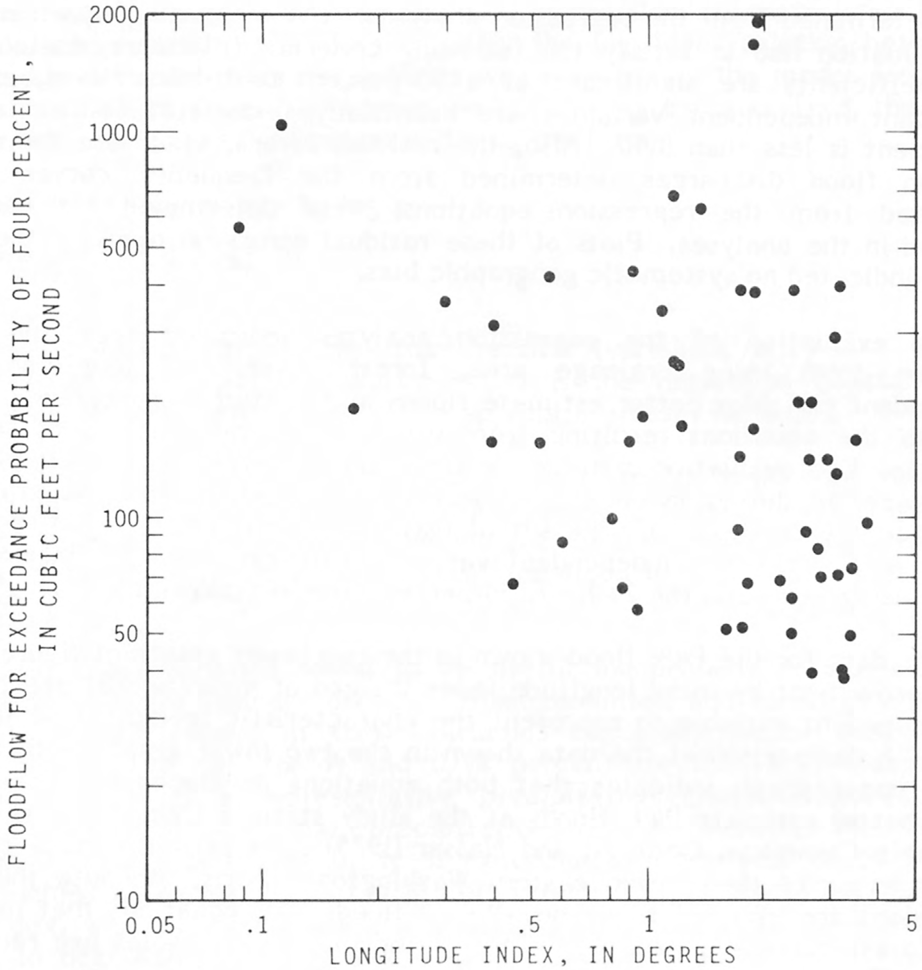

FIGURE 5.--Relation of 4-percent floods to longitude indexes (station longitude - 117.00°) of stations on small ephemeral streams in study area of eastern Washington.

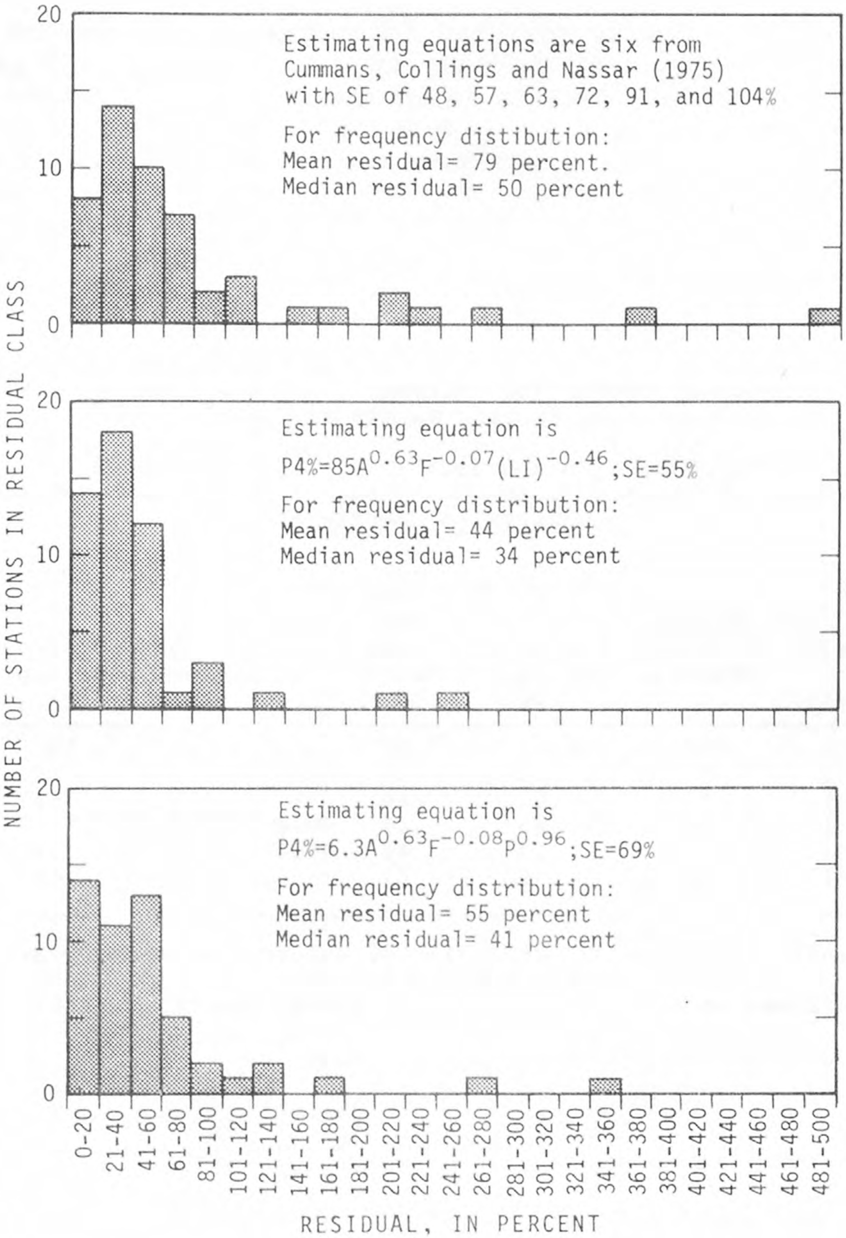

FIGURE 6.--Frequency distributions of residuals determined for the P4% floods, which are the floods with a 4-percent probability of exceedance in any year. A residual is the difference between the P4% flood determined from annual-peak data and the estimated P4% flood at a study station and is expressed as a relative percentage of the annual-peak data flood. See text for explanation of symbols.

TABLE 4.--Summary of regression analyses of floods of small ephemeral streams in study area of eastern Washington

[The regression equation is $y = aA^{b_1} (LI)^{b_2} F^{b_3}$]

			Regression coefficient for:					
Flood y[1]	Number of basins	Regression constant a	Drainage area (A) b_1	Longitude index (LI)[2] b_2	Forest cover (F) b_3	Standard error (log units)	Standard error (percent)	Multiple correlation coefficient, r
P50%	53	13	0.59	-0.63	--	0.363	100	0.72
P20%	52	38	.60	- .51	--	.257	65	.81
P10%	51	64	.62	- .46	--	.235	58	.83
P4%	51	85	.63	- .46	-0.07	.222	55	.85
P2%	51	110	.64	- .44	- .10	.236	58	.85
P1%	51	139	.66	- .42	- .12	.257	65	.83

[1]The percentages are the probabilities of exceedance in any year.

[2]Longitude index is computed from: LI = (longitude of station) -117.00°.

SUMMARY AND CONCLUSIONS

Flood frequencies were determined from the annual peak-flow data for stations having 10 or more years of record on small ephemeral streams of eastern Washington. Logarithms of flood magnitudes at study stations determined for probabilities of exceedance of 50, 20, 10, 4, 2 and 1 percent in any year were related to logarithms of characteristics of study basins by multiple-linear-regression analyses. The characteristics used as independent variables were drainage areas and forest covers of the basins and the longitude indexes (station longitude -117.00°) of the stations. The regression analyses provided equations that are recommended for estimating magnitudes of floods for the six exceedance probabilities at any site on the small natural-flow ephemeral streams located in relatively undeveloped basins within the study area of eastern Washington. Use of the equations should be restricted to sites on ephemeral streams with upstream drainage areas less than about 40 mi^2 and basin forest covers less than about 30 percent. The standard errors of estimate of the equations range from 55 percent for the P4% flood to 100 percent for the P50% flood.

The regression equations using drainage area, forest cover and longitude index as independent variables more accurately estimate floods determined from frequency analyses of annual peak flows at 51 study stations than do regression equations using drainage area, forest cover and mean annual pecipitation as independent variables. Overall accuracy of the estimates of these floods by using either of the above set of equations is better than the accuracy of estimating the floods by using equations given by Cummans, Collings, and Nassar (1975).

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