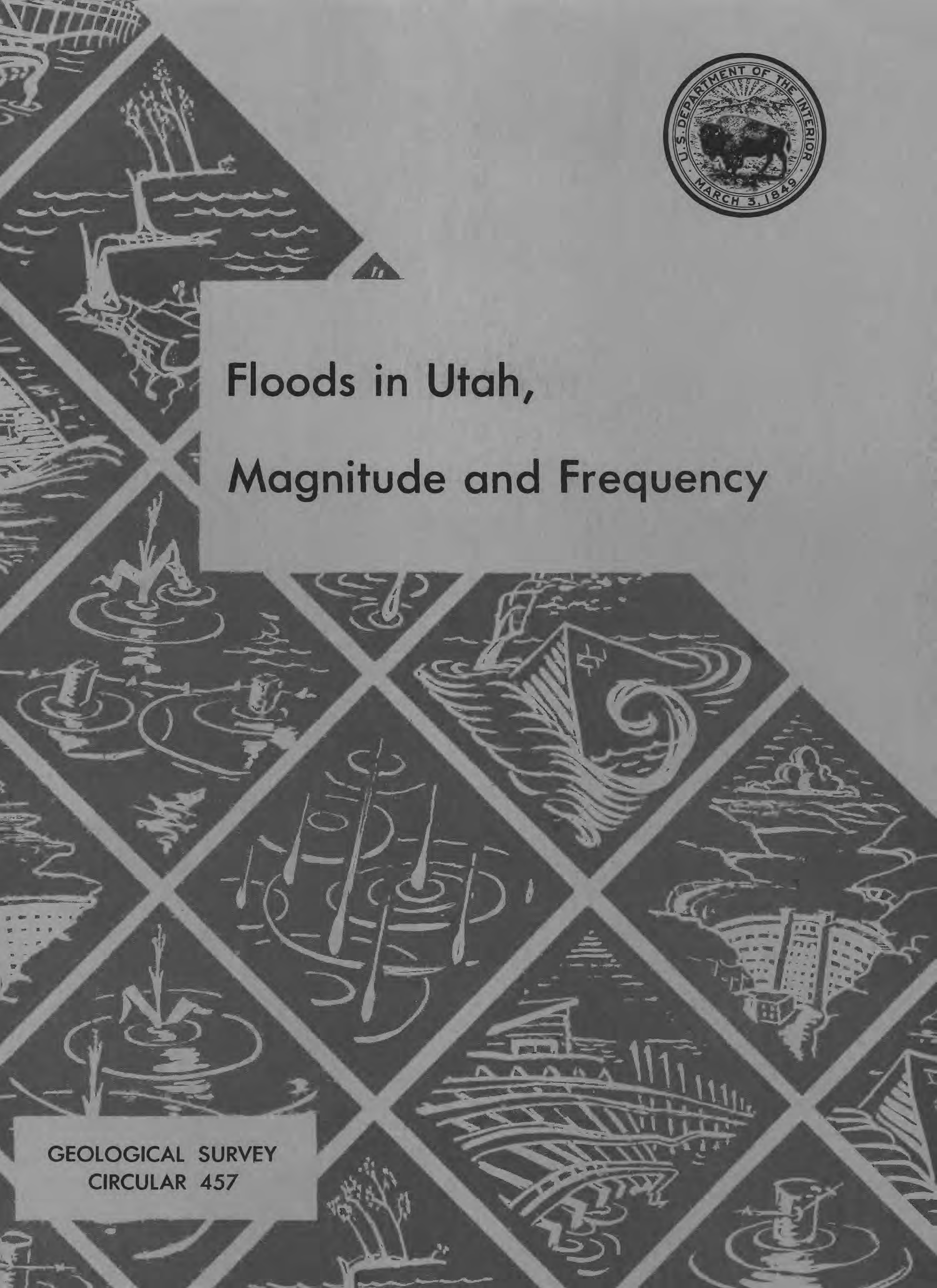

Floods in Utah, Magnitude and Frequency

GEOLOGICAL SURVEY CIRCULAR 457

Floods in Utah, Magnitude and Frequency

By V. K. Berwick

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ABSTRACT

This report presents a procedure for estimating the magnitude and frequency of floods, within the range of the base data, for any site, gaged or ungaged. From the relation of annual floods to the mean annual flood, a composite frequency curve was derived for recurrence intervals of 1.1 to 50 years. For regions of similar hydrologic characteristics, curves were developed by multiple correlation to express the relation of mean aunual flood to drainage area and mean altitude. The records of gaging stations having 5 or more years of record were used as base data when the natural conditions of streamflow are not affected by works of man. For major rivers where the flow is affected by diversion or regulation, separate analyses were made for each stream. The results may be applied to any area in Utah, except the Great Salt Lake Desert and a small area of the State in the Snake River basin.

INTRODUCTION

The proper design of structures in or near a stream should include the determination of the magnitude and frequency of floods. Where flooding may endanger human life, structures should be designed to withstand the greatest probable flood magnitude. In most instances, however, the risk to human life from flooding is small, and structures are designed to withstand a flood of some selected frequency of occurrence based on economics.

Floods result from the combined effects of climatic events and physiographic characteristics of a basin. Some of the principal physiographic factors affecting flood flows are: drainage area, altitude, geology, basin shape, slope, aspect, and vegetal cover.

Flood data for an individual site show what has occurred at that site during a definite period of time but could lead to erroneous results in the prediction of future events, even at that site, if the record is not representative of the long-term average. A composite flood-frequency curve based on many gaging-station records adjusted to a common time base is a logical means for predicting future flood expectancy anywhere within a homogeneous flood region. This report (a) outlines the homogeneous flood regions in Utah and presents a composite flood-frequency curve for each, and (b) outlines hydrologic areas and presents graphs showing the variation of mean annual flood with drainage area and altitude.

COOPERATION AND SUPERVISION

This report was prepared by the Geological Survey, in cooperation with the Utah Department of Highways and the U.S. Bureau of Public Roads. It was prepared in the office of the Geological Survey at Salt Lake City, Utah, under the direction of M. T. Wilson, district engineer. Technical guidance was furnished by the Floods Section, Water Resources Division, Geological Survey, Washington, D. C.

DESCRIPTION OF THE AREA

High, rugged mountain ranges are the most distinguishing features of the Utah landscape. Their presence influences the flow of air masses and therefore has a major affect upon precipitation and resulting streamflow. The State is divided by the Wasatch Mountains, a high range that runs in a north-south direction. On both sides of this divide are extensive deserts or arid regions with the exception of a humid section in the northern mountain ranges. The Uinta Mountains, one of the few mountain ranges in the Unites States with an east-west axis, extend eastward from the north-central part of the State almost to the Utah-Colorado State line.

The absence of a usable water supply in the arid regions of Utah has discouraged the collection of enough streamflow records to define flood-frequency relations; therefore, the Great Salt Lake Desert has not been included in this analysis.

PHYSICAL FEATURES

COLORADO RIVER BASIN

The Colorado River basin within Utah contains approximately 41,000 square miles, with plateaus and mountains ranging in altitude from 3,000 to 13,000 feet above sea level. The Uinta Mountains bisect the Green River basin near the Utah-Wyoming State line, forming the northern boundary of the Utah portion of the basin. The Wasatch Mountains and High Plateaus form the western boundary. Other mountain ranges and plateaus are interspersed throughout the area. Some of the more prominent ranges are the La Sal, Abajo, and Henry Mountains. Another orographic barrier in the Colorado River basin, known as the Book Cliffs, extends in a general east-west direction near the central part of the State. Drainage is predominately by streams with deep canyons and relatively steep slopes. Drainage areas of streams used in the study for the Colorado River basin range from 2 to 77,000 square miles.

The vegetal cover within the region varies considerably in kind and in growth depending largely upon the amount and seasonal distribution of precipitation. Parts of the Colorado River basin have an extremely shallow soil mantle with some large areas of exposed sandstone. Where these conditions exist the vegetal cover ranges from sparse to almost nonexistent.

THE GREAT BASIN

That part of the Great Basin considered in this study (approximately 18,000 square miles) includes the Wasatch Mountains and the western portions of the High Plateaus. The Wasatch Mountains extend southward from the Utah-Idaho State line and connect with the High Plateaus to form a north-south divide ending near the southwest corner of the State.

The geology of the Great Basin is complex and is not discussed here except in general terms. The Wasatch Mountains are characterized by rugged topography with high peaks and deep canyons. The mountains are long narrow ridges which rise abruptly from the valley floors with relatively small foothill areas. Several streams, including the Bear, Weber, and Provo Rivers, are classed as relatively old and have cut through the high mountain ranges in deep canyons. Many of the smaller streams in the area are younger in origin, and for the most part are responsible for much of the more recent erosion.

The High Plateaus consist of three parallel strips of tabletop formations that are common to both the Great Basin and the Colorado River basin. The altitudes range from 5,000 to 10,000 feet above sea level. The streams originating in the High Plateaus have steep slopes leading to gently sloping valley floors. When a stream reaches the mouth of a canyon, where the gradient is lower, the flow often spreads out on the valley floor. In some places, the surface flow disappears as the streams cross the alluvial fans at the entrance to mountain valleys. These conditions are more prevalent in the Great Basin, but apply to some degree in the Colorado River basin.

The vegetal cover in the Great Basin is similar to that in the Colorado River basin; however, in the northern part of both basins, the average annual precipitation is higher, and at some altitudes the forest is denser. Drainage areas of streams used in this study for the Great Basin range from 10 to 8,000 square miles.

The modifications of peak discharge by different geological formations are noticeable in both the Colorado River basin and the Great Basin hydrologic areas. One example of this modification is in the Logan River basin where extensive limestone deposits have a retarding effect on major floods by absorbing some of the surface flow. In other areas, the exposure of impervious formations hastens the rate of runoff. In general, the streams materially affected by geology are widely scattered, and because the flood data do not define these effects sufficiently, it is considered impractical to separate these drainage basins from the larger hydrologic areas.

SNAKE RIVER BASIN

Flood-frequency relations for the Snake River basin in Utah, a small area in the northwest corner of the State, are not included in this report. A flood-frequency report (Thomas, Broom, and Cummans, 1961) for the Snake River basin includes that area of Utah.

MAJOR RIVERS

The discharges of the main stems of the larger rivers are so modified by diversion and storage that only extreme floods would reflect the general characteristics of geology, topography, and other natural factors. Furthermore, the large rivers drain more than one flood region. Studies of frequency and magnitude for the larger rivers are, therefore, considered independently of the flood regions. The slopes of most streams, including the main stem of the larger streams, are relatively steep and for most channel reaches, floods of 50-year recurrence interval are confined within their natural banks.

CLIMATIC FEATURES

The climate of the State of Utah ranges widely from arid to humid over rather short distances. The average annual temperature is about 48°F. Extreme temperature observations recorded are a maximum of 116°F at St. George and a minimum of -50°F at Woodruff. These temperature variations have a considerable effect on the accumulation of snow. The annual snowfall ranges from less than 6 inches at St. George to 346 inches at Silver Lake in the Wasatch Mountains.

Utah is a region of relatively low rainfall with an average annual precipitation of about 12.6 inches. During an average year there are only 57 days on which 0.01 inch or more of precipitation falls anywhere in the State.

Variations in precipitation during two seasons of the year have a major effect on floods. During the winter months, when Pacific storms frequent the region, precipitation occurs in the form of snow. The precipitation during this season is the most consistent and becomes the major source of streamflow. In the northern part of the State, most streams are fed chiefly from perennial snowfields and the amount of runoff is a function of the snowfall. The southern part of the State is also subject to precipitation in the form of snow, and snowmelt floods may be significant at times. However, the annual maximum floods are usually caused by thunderstorms, and only on rare occasions is the annual maximum flood produced by a combination of rain and snowmelt. The second season is during the late summer and early fall when thunderstorms occur. These storms have a different source than the winter storms; the moisture, usually following a high-pressure system, is carried from the Gulf of Mexico by unstable air masses over the arid regions of southwestern United States. Occasionally, a storm from the Gulf of California extends into the State from the southwest, and some floods have been caused by this condition.

Some of the thunderstorm activity develops over the desert areas without regard to change in elevation and are triggered by convection currents. The amount of moisture available and the ambient temperatures play important roles in the summer storms. An important factor influencing the paths of thunderstorms is the proximity of the storm to mountains. Thunderstorms usually affect relatively small areas; therefore, a flood at a site will often be caused by a high-intensity storm covering only a part of the drainage basin above that site.

FLOOD-FREQUENCY RELATIONS

Methods developed by engineers of the Water Resources Division of the Geological Survey and others were used to compute magnitude and frequency relations for streams in Utah. Steps taken in the analysis were: (a) computation of a flood-frequency curve for each gaging station, (b) the combination of individual curves to define regions of homogeneous flood-frequency relations, and (c) computations of the mean annual flood from the related drainage basin characteristics.

FLOOD FREQUENCY AT A GAGING STATION

BASIC DATA

Streamflow records from 167 gaging stations (fig. 1) with 5 or more years of record were used in the analysis. Selection of records from 118 stations was based on the condition that the flood peaks resulted from natural flow. Records from the remaining 49 stations are for the major rivers and are affected by diversions or storage.

The effect of diversions or storage on flood flow may be inconsequential for extreme floods but may be significant for lesser floods. If peak flow was not affected by more than 10 percent, it was assumed that the streamflow record could be used without adjustment. Table 1 contains a list of the gaging stations for which records were used in the flood-frequency analysis. The table shows the maximum known flood and other pertinent data for each station.

To place all records on a comparable basis, it is desirable that they be adjusted to the same time period. The period 1938–57 was used for 71 stations in flood regions A and B (fig. 2). Except in flood regions C and D, the order of magnitude of the known peaks in shorter records was adjusted to this base by correlation with peaks at nearby stations.

FLOOD SERIES

Two methods for analyzing floods are by the annual flood series and by the partial-duration series. In an annual flood series, only the maximum instantaneous discharge for each water year is listed. In a partial-duration series, all floods equal to or greater than an arbitrarily selected base are listed. It should be noted that, in the annual flood series, no consideration is given to secondary floods, which in some years may be greater than the maximum for other years. On the other hand, in the partial-duration series, some water years may have no flood as great as the selected base discharge.

The recurrence interval in an annual flood series is defined as the average interval of time within which the given flood will be equaled or exceeded once as an annual maximum. The recurrence interval in a partial-duration series denotes elapsed time without regard to the water year or any other selected time unit. There is a statistical relation between recurrence intervals computed by the two methods, as shown in the following table by Langbein (1949):

Recurrence intervals, in years

Annual flood series	*Partial-duration series*
1.16	0.5
1.58	1.0
2.00	1.45
2.54	2.0
5.52	5.0
10.5	10
20.5	20
50.5	50
100.5	100

The annual flood series was used in this report. As will be noted from the table, recurrence intervals are essentially the same in both series for periods greater than 10 years. For those desiring information on the basis of the partial-duration series, it is suggested that results be computed by methods described in this report and conversion made by use of the table.

STATION FREQUENCY CURVE

The annual peak discharge for each station was listed in order of magnitude with no. 1 as the largest. The time scale, designated as the recurrence interval (T) and plotted as the abscissa on special probability paper (Gumbel, 1941; Powell, 1943), was fitted to the data by the formula

$$T = \frac{n + 1}{m}$$

where n is the number of years of record and m is the relative magnitude of the event with the largest as 1. Corresponding peak discharges were plotted as ordinates, and a smooth curve was then drawn on the basis of the plotted points. The use of extreme value probability paper tends to cause the plotted points for many stations to fall in a straight line.

REGIONAL FLOOD FREQUENCY

A composite frequency curve based on records for many gaging stations is a better tool for estimating the magnitude of future floods

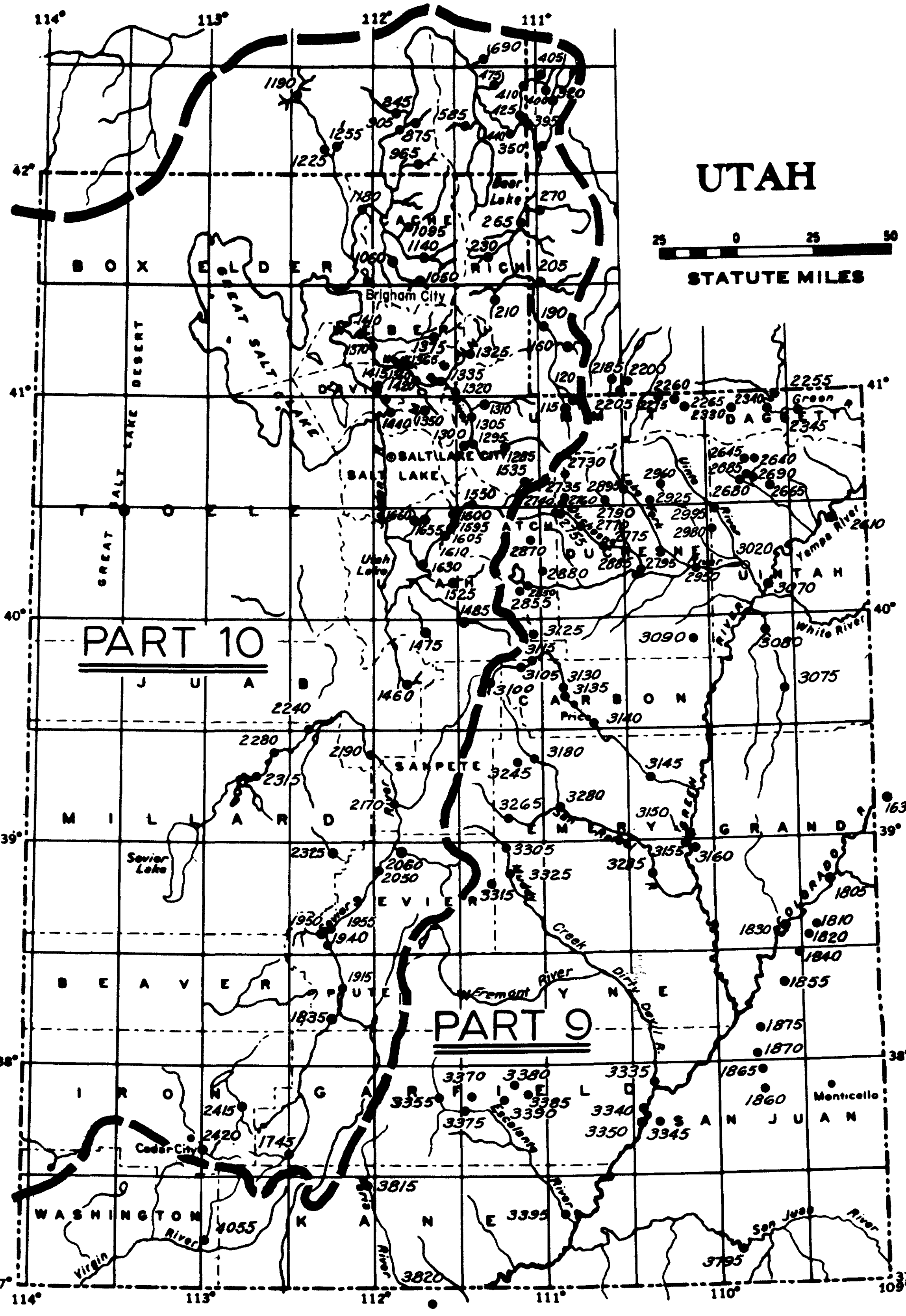

Figure 1.—Map of Utah showing location of gaging stations.

Table 1.—*Peak discharges at gaging stations used in frequency analysis*

Station No.	Gaging station	Drainage area (sq mi)	Period of record	Mean altitude (feet)	Areal $Q_{2.33}$ (cfs)	Maximum floods: Date	Maximum floods: Discharge (cfs)	Maximum floods: Ratio to areal $Q_{2.33}$ (cfs)	Flood region and hydrologic area
	COLORADO RIVER BASIN								
	Tributaries between Dolores River and Green River								
9-1810	Onion Creek near Moab, Utah	18.8	1950–55; 1959	5,810	677	Aug. 29, 1951	2,100	3.10	D9
1820	Castle Creek above diversions, near Moab, Utah	7.58	1950–55; 1957–59	9,480	34	June 7, 1952	23	.67	D8
1830	Courthouse Wash near Moab, Utah	150	1949–55	4,810	2,210	Aug. 5, 1957	12,300	5.57	D9
1840	Mill Creek near Moab, Utah	76	1914–19; 1949–59	7,170	1,070	Aug. 21, 1953	5,110	4.78	D9
1855	Hatch Wash near La Sal, Utah	370	1950–59	6,550	939	Aug. 4, 1959	3,210	3.42	D8
1860	Indian Creek near Monticello, Utah	4.5	1949–57	9,620	21	Aug. 6, 1955	122	5.84	D8
1865	Indian Creek above Cottonwood Creek near Monticello, Utah.	31.2	1949–59	7,130	93	July 20, 1955	582	6.26	D8
1870	Cottonwood Creek near Monticello, Utah	115	1949–57	7,210	340	July 10, 1953	2,140	6.29	D8
1875	Indian Creek above Harts Draw, near Monticello, Utah.	257	1949–57	6,580	2,100	Aug. 30, 1957	3,120	1.49	D9
	Green River basin								
2185	Blacks Fork near Millburne, Wyo	156	1939–59	10,270	1,140	June 7, 1957	2,530	2.22	A1
2200	East Fork of Smith Fork near Robertson, Wyo	53	1939–59	10,250	497	June 13, 1953	1,200	2.41	A1
2205	West Fork of Smith Fork near Robertson, Wyo	37.2	1939–59	9,790	325	May 30, 1950	920	2.83	A1
2260	Henry's Fork near Lonetree, Wyo	56	1942–59	10,270	522	June 13, 1953	1,860	3.56	A1
2265	Middle Fork Beaver Creek near Lonetree, Wyo	28	1948–59	10,480	329	June 12, 1953	663	2.02	A1
2275	West Fork Beaver Creek near Lonetree, Wyo	23	1948–59	10,680	302	June 13, 1953	417	1.38	A1
2330	Carter Creek near Manila, Utah	19	1948–54	10,280	229	June 3, 1952	153	.67	A1
2340	Carter Creek at mouth, near Manila, Utah	110	1946–55	9,010	565	June 4, 1952	928	1.64	A1
2640	Ashley Creek below Trout Creek near Vernal, Utah.	27	1943–54	9,930	343	May 19, 1948	630	1.84	B4

2645	South Fork Ashley Creek near Vernal, Utah	20	1943–55	10,480	316	June 18, 1949	460	1.46	B4
2665	Ashley Creek near Vernal, Utah	101	1911–59	9,440	800	May 29, 1921	2,050	2.56	B4
2680	Dry Fork above sinks, near Dry Fork, Utah	48	1939–59	10,240	570	June 8, 1957	926	1.62	B4
2685	North Fork of Dry Fork, near Dry Fork, Utah	12	1946–59	9,100	148	May 26, 1958	139	.94	B4
2690	East Fork of Dry Fork, near Dry Fork, Utah	12	1946–59	9,320	158	June 18, 1949	240	1.52	B4
2730	Duchesne River at Provo River Trail, near Hanna, Utah.	39	1929–33; 1935–43; 1944–54	10,200	483	June 13, 1953	1,180	2.44	B4
2735	Hades Creek near Hanna, Utah	7.5	1949–59	9,730	125	June 9, 1952	132	1.06	B4
2740	Duchesne River near Hanna, Utah	78	1921–23; 1929–30; 1946–59	9,810	731	June 13, 1953	1,500	2.05	B4
2755	West Fork Duchesne River near Hanna, Utah	61	1904; 1921–23; 1945–59	8,840	462	June 6, 1957	666	1.44	B4
2760	Wolf Creek above Rhodes Canyon near Hanna, Utah.	9	1945–59	9,040	118	June 8, 1952	82	.69	B4
2790	Rock Creek near Mountain Home, Utah	149	1937–57	10,100	1,280	June 14, 1953	2,390	1.87	B4
2855	Willow Creek near Soldier Springs, Utah	44	1943–47	8,760	353	July 30, 1943	192	.54	B4
2870	Currant Creek below Red Ledge Hollow, near Fruitland, Utah.	48	1904; 1945–59	8,880	391	May 2, 1952	688	1.76	B4
2880	Currant Creek near Fruitland, Utah	142	1934–59	8,360	747	May 4, 1952	1,260	1.69	B4
2895	Lake Fork above Moon Lake, near Mountain Home, Utah.	78	1933–34; 1942–55	10,800	943	June 26, 1944	2,700	2.86	B4
2925	Yellowstone Creek near Altonah, Utah	131	1944–59	10,440	1,270	June 19, 1949	1,880	1.48	B4
2960	Uinta River above Clover Creek, near Neola, Utah	132	1945–55	10,960	1,450	June 18, 1949	2,300	1.59	B4
2980	Farm Creek near Whiterocks, Utah	22	1949–59	9,720	278	May 25, 1951	204	.73	B4
2995	Whiterocks River near Whiterocks, Utah	115	1899–1904; 1907–10; 1913–59	10,370	1,130	June 20, 21, 1922	2,750	2.43	B4
3075	Willow Creek above diversions, near Ouray, Utah.	310	1950–55; 1957–59	7,650	411	July 31, 1953	399	.97	D5
3080	Willow Creek near Ouray, Utah	890	1947–55	7,080	600	Aug. 27, 1952	2,320	3.87	D5
3090	Minnie Maud Creek at Nutter Ranch, near Myton, Utah.	231	1947–55	7,880	377	Aug. 25, 1955	1,370	3.63	D5
3100	Gooseberry Creek near Scofield, Utah	16.4	1930–31; 1940–59	8,960	259	May 30, 1952	414	1.60	C7
3105	Price River above Scofield Reservoir, near Scofield, Utah.	62	1931–32; 1938–59	8,710	593	May 14, 1952	1,070	1.80	C7
3125	White River near Soldier Summit, Utah	53	1938–59	8,360	196	May 5, 1952	1,120	5.71	C5
3155	Saleratus Wash at Green River, Utah	200	1948–59	5,050	2,420	July 8, 1950	4,850	2.00	C9
3160	Browns Wash near Green River, Utah	75	1949–59	5,220	1,460	Aug. 19, 1959	5,620	3.85	C9

Table 1.—*Peak discharges at gaging stations used in frequency analysis*—**Continued**

Station No.	Gaging station	Drainage area (sq mi)	Period of record	Mean altitude (feet)	Areal $Q_{2.33}$ (cfs)	Maximum floods: Date	Maximum floods: Discharge (cfs)	Maximum floods: Ratio to areal $Q_{2.33}$ (cfs)	Flood region and hydrologic area
	COLORADO RIVER BASIN—Continued								
	Green River basin—**Continued**								
9-3180	Huntington Creek near Huntington, Utah	188	1909–59	9,000	1,400	Aug. 2 or 3, 1930	2,500	1.79	C7
3245	Cottonwood Creek near Orangeville, Utah	205	1909–27; 1932–59	8,860	1,410	Aug. 9, 1941	2,870	2.04	C7
3265	Ferron Creek (upper station) near Ferron, Utah.	157	1911–23; 1947–59	8,800	1,150	Aug. 27, 1952	4,180	3.63	C7
	Dirty Devil River basin								
3305	Muddy Creek near Emery, Utah	105	1909–14; 1949–59	8,850	891	May 10, 1952	3,340	3.75	C7
3315	Ivie Creek above diversions, near Emery, Utah	50	1950–59	8,870	199	Aug. 16, 1955	700	3.52	D8
3325	Muddy Creek below Ivie Creek, near Emery, Utah	440	1950–59	7,580	1,510	Aug. 3, 1951	2,890	1.91	C7
3335	Dirty Devil River near Hite, Utah	4,360	1948–59	6,600	10,700	Nov. 4, 1958	*25,000	------	C8
	North Wash basin								
3340	North Wash near Hite, Utah	140	1950–59	5,400	1,910	Aug. 7, 1952	8,900	4.66	D9
	White Canyon basin								
3345	White Canyon near Hite, Utah	276	1950–59	6,090	2,350	July 31, 1953	7,390	3.14	D9
	Escalante River basin								
3355	North Creek near Escalante, Utah	90	1950–55	8,240	331	Aug. 21, 1952	3,610	10.91	D6
3370	Pine Creek near Escalante, Utah	78	1950–55; 1957–59	8,890	310	Sept. 16, 1952	325	1.05	D8
3375	Escalante River near Escalante, Utah	310	1909–13; 1942–55	8,030	1,040	Aug. ?, 1953	3,450	3.32	D8
3380	East Fork Boulder Creek near Boulder, Utah	21.4	1950–55; 1957–59	10,500	109	May 27, 1951	264	2.42	D8

3385	East Fork Deer Creek near Boulder, Utah	1.9	1950–55	9,500	9	Aug. 6, 1955	56	6.34	D8
3390	Boulder Creek near Boulder, Utah	175	1950–55	8,320	625	July 25, 1955	4,650	7.44	D8
3395	Escalante River at mouth, near Escalante, Utah	2,010	1950–55	6,330	4,720	Aug. 4, 1951	14,600	3.09	D8
	Paria River basin								
3815	Paria River near Cannonville, Utah	220	1950–55	6,890	1,860	Aug. 16, 1955	5,160	2.77	C9
3820	Paria River at Lees Ferry, Ariz	1,570	1923–59	6,140	5,360	Sept. 12, 1958	19,000	3.54	C9
	Virgin River basin								
4055	North Fork Virgin River near Springdale, Utah	350	1913–14; 1923–59	7,560	2,120	Mar. 3, 1938	7,000	3.30	C9
	THE GREAT BASIN								
	Bear River basin								
10–115	Bear River near Utah-Wyoming State line	176	1942–59	9,770	1,060	June 6, 1957	2,800	2.64	A1
120	Mill Creek at Utah-Wyoming State line and Mill Creek near Evanston, Wyo.[1]	60	1942–48; 1949–59	9,320	398	June 7, 1957	690	1.73	A1
160	Sulphur Creek near Evanston, Wyo	80.5	1942–59	7,930	291	Apr. 23, 1952	1,220	4.19	A1
190	Bear River near Evanston, Wyo	715	1913–56	8,130	1,680	June 14, 1921	3,690	2.20	A1
205	Bear River near Woodruff, Utah	870	1942–59	7,930	1,790	Apr. 28, 1952	3,010	1.68	A1
210	Woodruff Creek near Woodruff, Utah	65	1937–43; 1949–59	7,900	244	May 25, 1950	528	2.16	A1
230	Big Creek near Randolph, Utah	52.2	1939–44; 1949–59	7,370	164	July 11, 1957	337	2.05	A1
265	Bear River near Randolph, Utah	1,640	1943–59	7,470	2,380	May 8, 1952	2,660	1.12	A1
270	Twin Creek at Sage, Wyo	246	1943–59	7,180	490	Mar. 18, 1947	649	1.32	A1
320	Smiths Fork near Border, Wyo	165	1942–59	8,270	579	June 7, 1957	1,500	2.59	A1
350	Smiths Fork at Cokeville, Wyo	275	1942–52	7,810	706	May 4, 1952	1,320	1.87	A1
395	Bear River at Border, Wyo	2,490	1937–59	7,390	3,160	May 11, 1952	3,680	1.16	A1
400	Thomas Fork near Geneva, Idaho	45.3	1939–51	7,170	134	May 18, 1950	418	3.12	A1
405	Salt Creek near Geneva, Idaho	37.6	1939–51	7,390	128	do	382	2.98	A1
410	Thomas Fork near Wyoming-Idaho State line	113	1949–59	7,290	284	do	869	3.06	A1
425	Thomas Fork near Raymond, Idaho	202	1942–52	7,090	404	May 19, 1950	1,070	2.65	A1
475	Montpelier Creek at irrigators weir, near Montpelier, Idaho.	50.9	1942–59	7,370	160	May 18, 1950	224	1.40	A1
585	Bloomington Creek near Bloomington, Idaho	22.1	1943–47	7,860	105	June 2, 1943	184	1.75	A1
690	Georgetown Creek near Georgetown, Idaho	22.2	1911; 1914; 1939–56	7,830	104	June 8, 1912	162	1.56	A1

*In excess of.

[1]Equivalent records combined.

Table 1.—*Peak discharges at gaging stations used in frequency analysis*—**Continued**

Station No.	Gaging station	Drainage area (sq mi)	Period of record	Mean altitude (feet)	Areal $Q_{2.33}$ (cfs)	Maximum floods: Date	Maximum floods: Discharge (cfs)	Maximum floods: Ratio to areal $Q_{2.33}$ (cfs)	Flood region and hydrologic area
	THE GREAT BASIN—Continued								
	Bear River basin—**Continued**								
10- 845	Cottonwood Creek near Cleveland, Idaho	61.7	1938–59	6,650	283	Apr. 21, 1948	680	2.40	A2
875	Mink Creek below Dry Fork, near Mink Creek, Idaho.	19.3	1947–52; 1955–59	7,070	286	May 29, 1948	600	2.10	A3
965	Maple Creek near Franklin, Idaho	21.2	1946–52	6,840	301	May 18, 1950	315	1.05	A3
1050	East Fork Little Bear River near Avon, Utah	50	1938–50	7,370	408	Apr. 18, 1946	960	2.35	A2
1060	Little Bear River near Paradise, Utah	203	1937–59	6,670	466	Dec. 23, 1955	1,830	3.93	A2
1095	Logan River near Logan, Utah	218	1896–1959	7,460	1,060	May 24, 1907	2,480	2.34	A3
1135	Blacksmith Fork above Utah Power & Light Co.'s dam, near Hyrum, Utah.	260	1913–59	7,150	701	May 15, 1917	1,620	2.31	A2
1190	Little Malad River above Elkhorn Reservoir, near Malad City, Idaho.	120	1911–13; 1931–32; 1940–59	6,080	250	Feb. 22, 1948	270	1.08	A2
1225	Devil Creek above Campbell Creek, near Malad City, Idaho.	13	1938–59	6,010	96	Apr. 2, 1943	160	1.67	A2
1255	Malad River at Woodruff, Idaho	485	1938–59	5,650	321	Jan. 22 or 23, 1943	650	2.02	A2
	Weber River basin								
1285	Weber River near Oakley, Utah	163	1904–59	9,090	1,030	June 13, 1921	4,170	4.05	B4
1300	Silver Creek near Wanship, Utah	28	1941–46	7,100	145	Apr. 4, 1942	430	2.97	B4
1310	Chalk Creek at Coalville, Utah	253	1904–05; 1927–59	7,540	874	Apr. 28, 1952	1,540	1.76	B4
1325	Lost Creek near Croydon, Utah	133	1921–23; 1941–59	7,320	501	May 10, 11, 18, 1923	770	1.54	B4
1350	Hardscrabble Creek near Porterville, Utah	28.1	1941–59	7,220	152	Aug. 20, 1945	464	3.05	B4
1375	South Fork Ogden River near Huntsville, Utah	148	1921–59	7,960	677	May 3, 1952	1,890	2.79	B4

	Tributaries between Weber and Jordan Rivers								
1415	Holmes Creek near Kaysville, Utah	2.49	1950–59	7,580	28	do	36	1.27	B4
1420	Farmington Creek above diversions, near Farmington, Utah.	10	1949–59	7,470	77	May 20, 1958	282	3.67	B4
1440	Stone Creek above diversions, near Bountiful, Utah.	4.48	1950–59	7,050	36	May 5, 1952	82	2.27	B4
	Jordan River basin								
1455	Salt Creek near Nephi, Utah	95	1925–38	7,330	255	July 17, 1932	800	3.14	D6
1475	Payson Creek above diversions, near Payson, Utah.	18.8	1947–59	7,610	141	May 4, 1952	465	3.30	C6
1485	Spanish Fork at Thistle, Utah	490	1908–25; 1933–59	7,130	441	do	1,800	4.08	C5
1525	Hobble Creek near Springville, Utah	105	1904–16; 1945–59	7,110	246	do	1,250	5.08	C6
1535	Provo River near Kamas, Utah	30	1949–59	9,710	349	June 6, 1957	825	2.36	B4
1550	Provo River near Hailstone, Utah	230	1949–59	8,600	1,150	June 4, 1957	3,880	3.37	B4
1600	Deer Creek near Wildwood, Utah	26	1938–50	7,450	155	May 3, 1945	99	.64	B4
1655	Dry Creek near Alpine, Utah	9.82	1947–55	8,770	116	June 13, 1953	304	2.62	B4
1660	Fort Creek at Alpine, Utah	6.55	1947–55	7,500	57	Aug. 4, 1951	246	4.34	B4
	Sevier Lake basin								
1745	Sevier River at Hatch, Utah	340	1911–28; 1939–59	8,480	621	May 26, 1922	1,490	2.40	D6
1835	Sevier River near Kingston, Utah	1,110	1914–59	7,790	830	Mar. 4, 1938	3,000	3.61	D6
1950	Clear Creek at Sevier, Utah	169	1912–19; 1934–58	7,690	365	Aug. 17, 1955	611	1.67	D6
2060	Salina Creek at Salina, Utah	298	1914–19; 1942–55	7,810	481	July 27, 1953	2,650	5.51	D6
	Pavant Valley								
2325	Chalk Creek near Fillmore, Utah	60	1914; 1943–59	8,020	261	May 4, 1952	509	1.95	D6
	Parowan Valley								
2415	Center Creek near Parowan, Utah	60	1942–50	8,680	317	Aug. 5, 1945	386	1.22	D6
	Cedar City Valley								
2420	Coal Creek near Cedar City, Utah	79	1915–20; 1935–59	8,640	352	July 9, 1936	2,910	8.27	C6

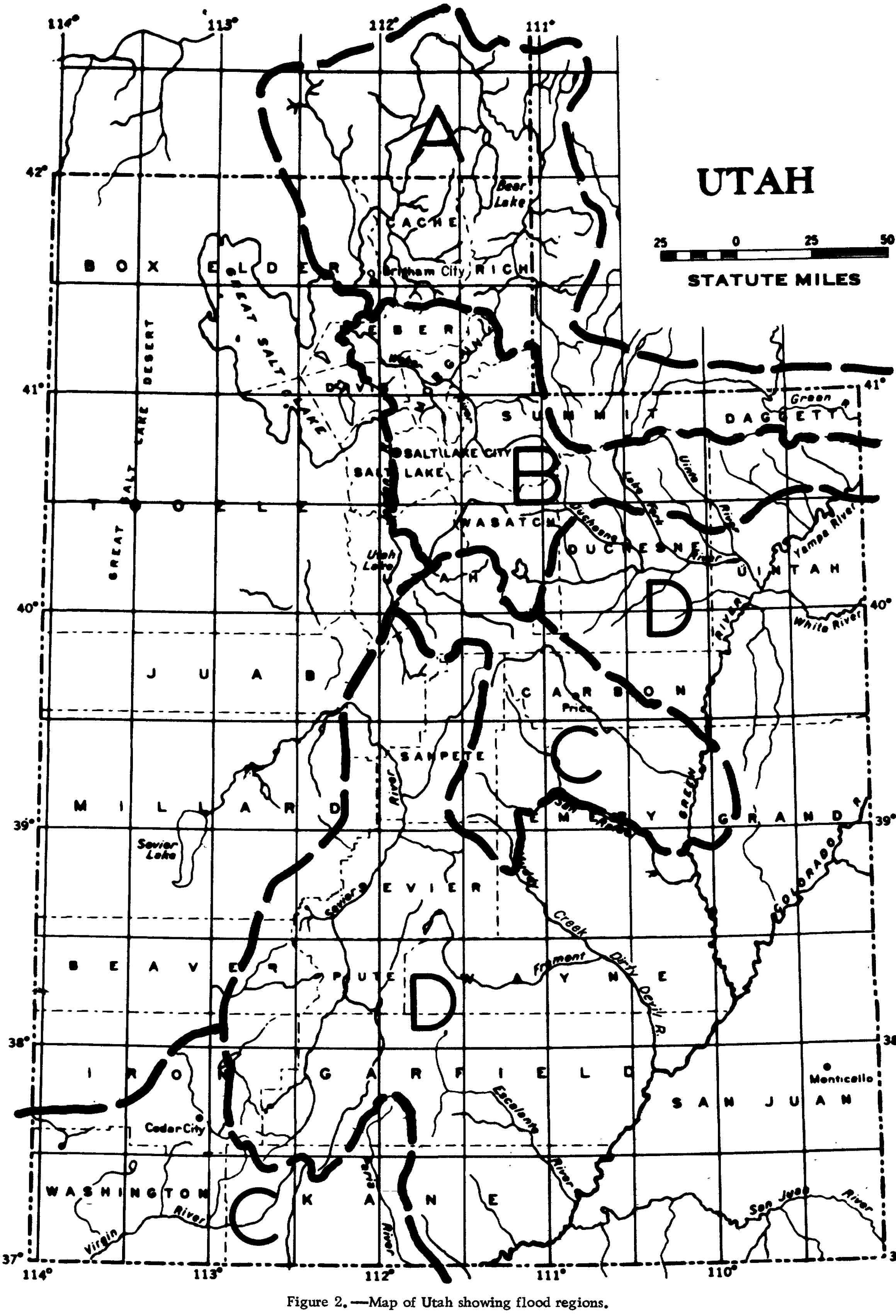

Figure 2.—Map of Utah showing flood regions.

than a curve based on records for any one site. To combine records, the relative magnitude of floods must be computed on a dimensionless basis. The ratio of each flood to the mean annual flood, or simply the flood ratio, is a means of satisfying this premise. Floods used in computing composite flood-frequency curves are expressed as the median flood ratio for each recurrence interval.

REGIONAL SAMPLING

Sampling for a flood-frequency study can be accomplished by two methods—time and areal sampling. Time sampling involves the collection of records at a few long-term stations, while areal sampling requires a large number of stations to evaluate the various characteristics of the region, without regard for the length of record. Streamflow records at the present time do not satisfy the requirements of either method, since the long-term records or the density of stations necessary to complete a statistical approach do not exist. An analysis of existing records will be helpful until such time as additional information can be obtained. To combine records from all the stations, it is advantageous to place the flood on a comparable basis as to time and physical characteristics of the drainage basin.

SELECTION OF COMPARABLE FLOODS

The peak flows of a stream at a given point integrate all of the flood characteristics of the drainage basin. A suitable index for the effect of physical features of a basin is the mean annual flood. Theoretically, a peak discharge with a recurrence interval of 2.33 years is the same as the arithmetical mean of an infinitely long series. An estimated value of the mean annual flood($Q_{2.33}$)may be obtained graphically from the flood-frequency curve for each individual station. All of the floods are placed on a dimensionless basis by dividing the recorded floods by the mean annual flood; thus, flood records for all gaging stations within the region are comparable irrespective of flood magnitude.

HOMOGENEITY

Before a group of stations can be combined on a regional basis, a test of homogeneity is necessary to show that all of the records are from a region of similar flood-frequency characteristics. A statistical test is applied to the slope of the individual frequency curves to determine whether or not the deviations from an average slope are due to chance alone. The selection of the flood regions shown in figure 2 was based on the results of the homogeneity test with consideration given to geographic differences.

COMPOSITE FREQUENCY CURVE

When the requirements of the homogeneity test were satisfied, the stations were grouped together and flood ratios for several recurrence intervals were computed. Ratios of floods from each record for the selected recurrence intervals were listed, and the median flood ratios were obtained from this tabulation. Each median flood ratio was plotted to its corresponding recurrence interval and a curve was fitted smoothly through these points (figs. 3 and 4). These curves, with the flood discharge expressed in terms of the ratio to the mean annual flood, were based on all of the significant discharge records and represent the most likely flood-frequency relation for each respective region. Ratios to the mean annual flood for any recurrence interval are obtained from the composite flood-frequency curve. At any desired recurrence interval, the magnitude of the discharge is estimated by multiplying this ratio by the mean annual flood.

REGIONAL ANALYSIS FOR SUMMER FLOODS

For flood regions C and D, the length of streamflow records range from 5 to 10 years with a few records of longer periods for large drainage basins. Floods in these regions are generally caused by summer thunderstorms. The extension of records and the determination of the order of magnitude of floods by correlation methods are unsatisfactory in these regions because each flood occurrence may be entirely independent of any other flood. A flood may occur on one stream while no flow would be experienced on a nearby stream.

If a station record of 1,000 years were available, it would be reasonable to assume that 20 floods having a recurrence interval of 50 years or more may be experienced.

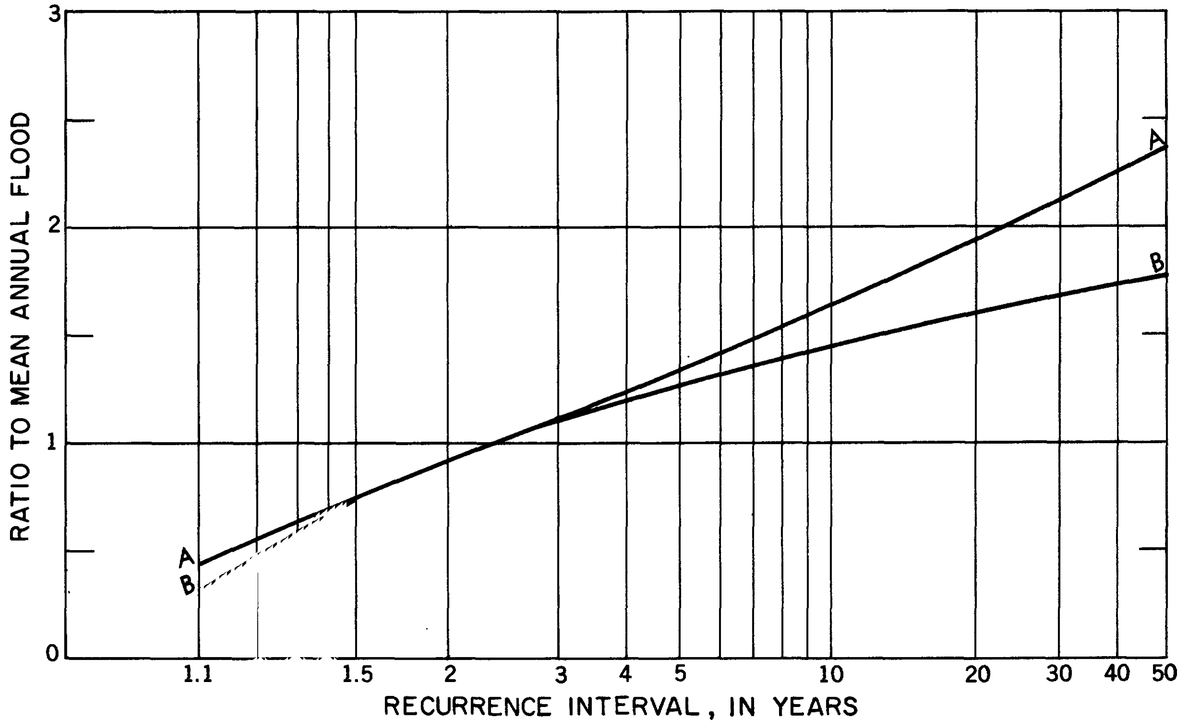

Figure 3.—Composite flood-frequency curves, regions A and B.

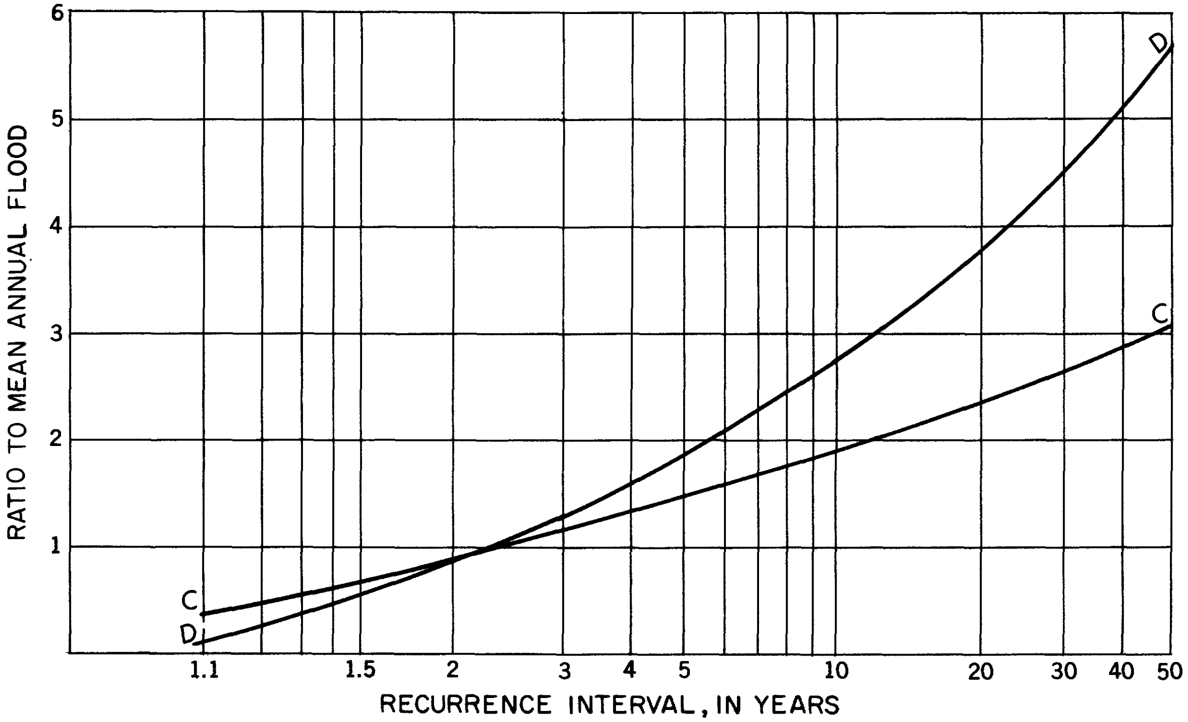

Figure 4.—Composite flood-frequency curves, regions C and D.

Within regions C and D, there are records of 690 annual peaks. If the same analogy is applied, then 2 percent of these annual peaks should be 50-year floods or greater. From an envelope curve drawn on a plot of annual floods versus drainage area to exclude 2 percent of the floods, it is possible to obtain an estimated 50-year flood for each of the 47 stations. The estimated flood selected from the envelope curve is used as a guide to extend the individual flood-frequency curves. Although it is difficult to meet all of the conditions set forth in an accepted regional analysis, the two composite frequency curves (fig. 4) should be a suitable substitute for predicting peak discharges until additional hydrologic information is available.

DERIVATION OF THE MEAN ANNUAL FLOOD

To use the regional flood-frequency curve, a means must be provided for the determination of the mean annual flood.

BASIN CHARACTERISTICS

Characteristics of the basin as they affect floods are numerous, and many are difficult to define or separate. The ones selected and investigated in this study are as follows:

1. Drainage area. Noncontributing area is normally deducted from the total.

2. Mean altitude. The mean altitude of a basin is the average altitude above a given point.

3. Slope. The slope of a stream is the total fall between any two points divided by the stream length between those points. The points selected were at 0.2 and 0.8 of the total stream length above the site.

4. Shape. The shape of a basin is approximated by the length-width ratio.

5. Aspect. The aspect of a basin is the compass direction of the main stream and is a measure of the usual storm pattern in the area as well as exposure to prevailing winds and sunshine. This characteristic is significant when considering the peak discharge that results from snowmelt.

The above five characteristics were tested for effect on the mean annual flood in order to determine which were significant. Curves were derived by a multiple correlation of the mean annual flood with the two most significant characteristics, drainage area and mean altitude of the basin. Use of the remaining three characteristics did not significantly improve the statistical correlation. Slope, shape, and aspect probably have some effect on the mean annual flood, but the effect, if any, cannot be adequately defined on the basis of available streamflow records.

MEAN ANNUAL FLOOD RELATIONS

The relationship of the mean annual flood to basin characteristics was correlated from the records of 188 gaging stations. Boundaries of the selected hydrologic areas (fig. 5) are somewhat arbitrary; however, the present program of data collection will aid in the verification of these boundaries. For each hydrologic area, a family of curves was drawn (fig. 6). The use of the curves is limited by the range of the basic data.

For all hydrologic areas except 3, and 9, the mean annual flood was found to be directly related to drainage area and mean altitude of the basin. In area 3 the effects of limestone deposits are known to change the characteristics of streamflow when compared with that from surrounding drainage basins where limestone deposits are not present or predominant. Also, in area 3, mean altitude was not used as a parameter because of relatively few gaging-station records. In hydrologic area 9, where the peak discharge generally results from summer storms, the mean annual flood is directly related to the drainage area; however, it is inversely related to the mean altitude of the basin. One condition which could contribute to this fact is the marked change in vegetal cover with respect to altitude. Vegetal cover is almost nonexistent at the lower altitudes, whereas at the higher altitudes the cover is sufficient to retard runoff. In area 9, winter precipitation in the form of snow at the higher altitudes aids the growth of a vegetal cover. Frequently, summer storms are triggered before reaching the higher altitudes, thus causing larger floods to occur at lower altitudes.

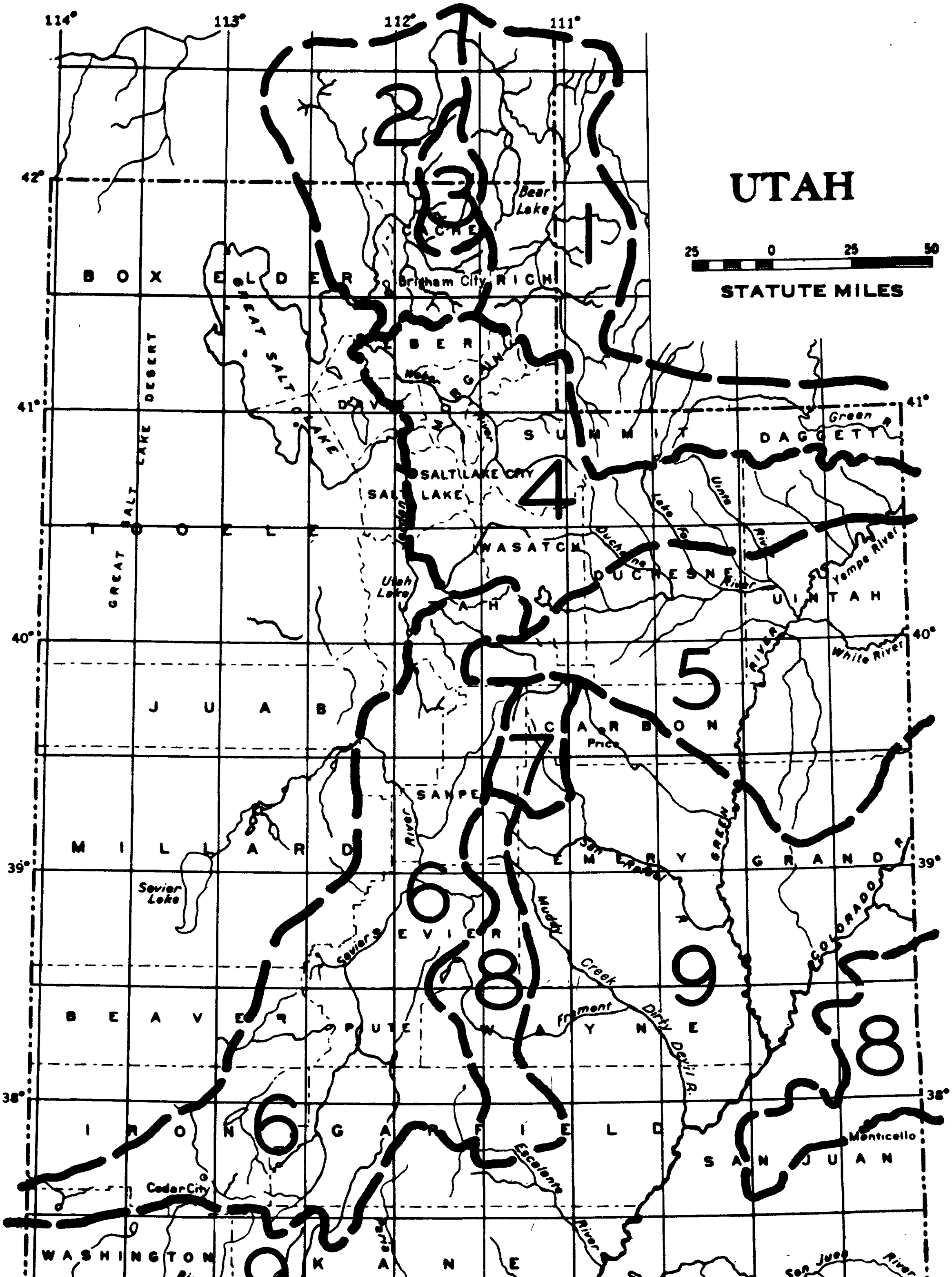

Figure 5.—Map of Utah showing hydrologic areas.

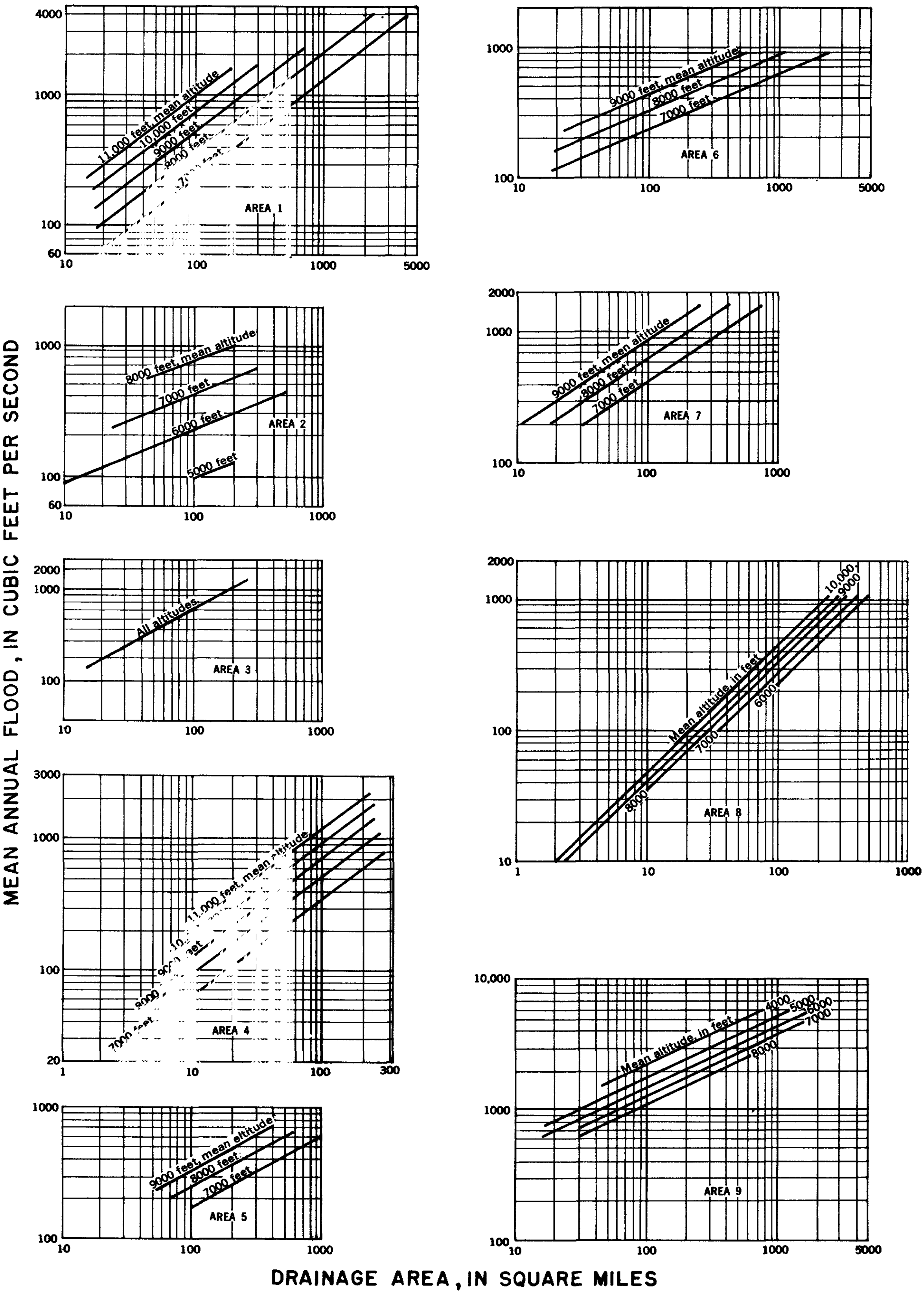

Figure 6.—Variation of mean annual flood with drainage area and mean altitude.

MAJOR RIVERS IN UTAH

In most reaches of the major rivers, nearly complete development of the water supply for irrigation and power is reflected by the absence of homogeneity with the tributary streams. The major rivers are not homogeneous among themselves; therefore, the use of a composite ratio curve for estimating flood frequencies similar to methods used for the smaller streams is unsatisfactory. Each major river was treated individually for estimating the magnitude and frequency of floods. Table 2 contains a list of gaging stations for which records were analyzed on the above basis. The data shown for each station are drainage area, length of annual peak record, and estimated discharge for the 50-year flood. The discharge for the 50-year flood at each gaging site was plotted against the corresponding river miles above the mouth (figs. 7–17). With the regimen of the rivers affected by regulation and diversion, it was impractical to compute the magnitude of the floods for recurrence intervals of less than 50 years.

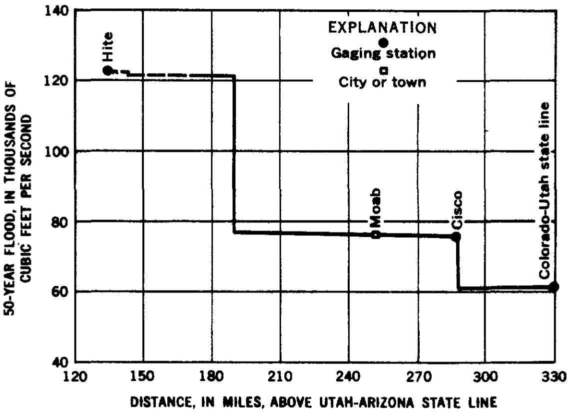

Figure 7.—Colorado River, discharge of 50-year flood within the State of Utah.

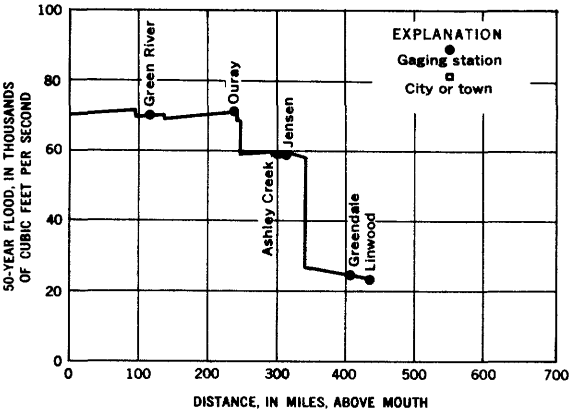

Figure 8.—Green River, discharge of 50-year flood below Wyoming-Utah State line.

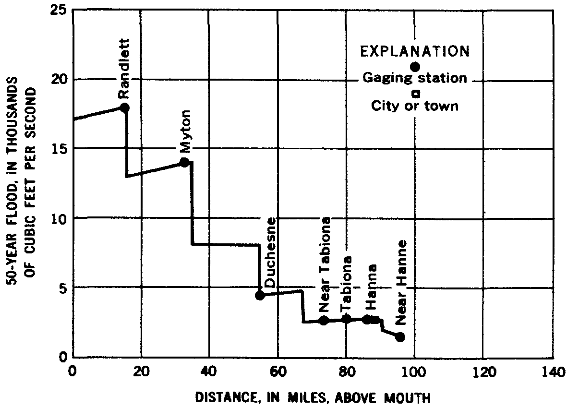

Figure 9.—Duchesne River, discharge of 50-year flood.

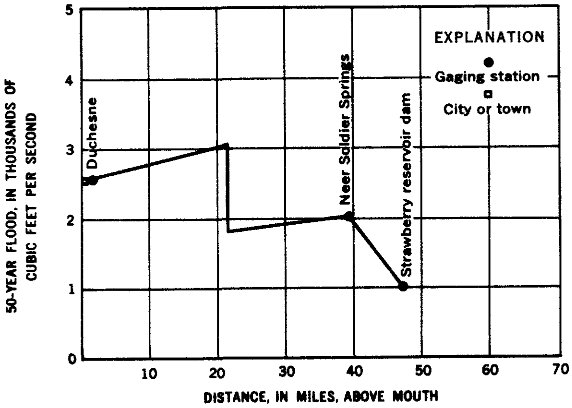

Figure 10.—Strawberry River, discharge of 50-year flood.

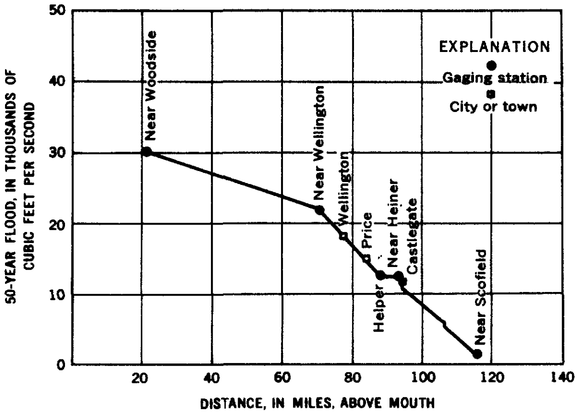

Figure 11.—Price River, discharge of 50-year flood.

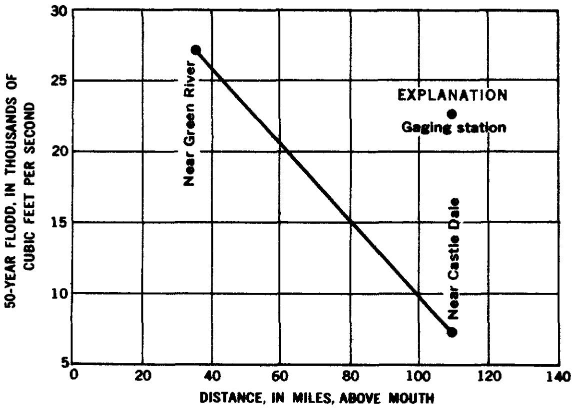

Figure 12.—San Rafael River, discharge of 50-year flood below Ferron Creek.

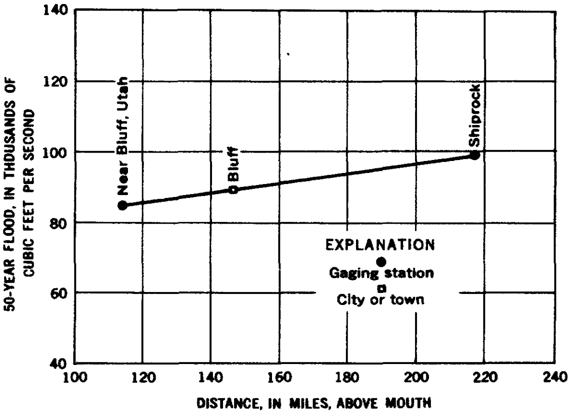

Figure 13.—San Juan River, discharge of 50-year flood below Shiprock, N. Mex.

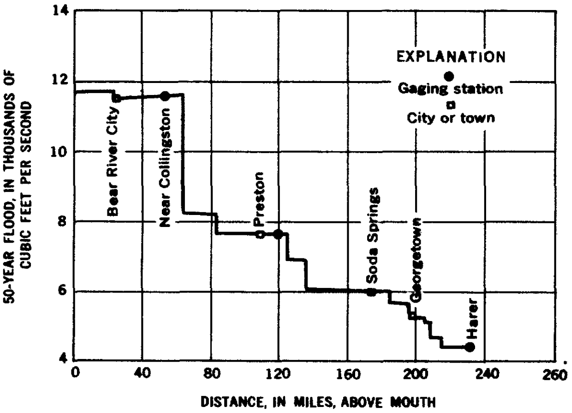

Figure 14.—Bear River, discharge of 50-year flood.

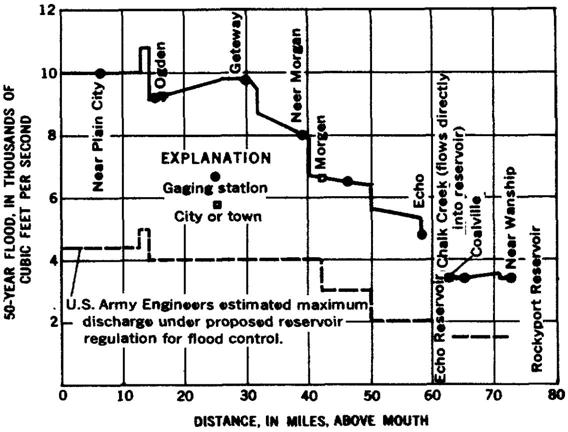

Figure 15.—Weber River, discharge of 50-year flood and U.S. Army Engineers' estimated maximum discharge under proposed flood-control project below Rockport Reservoir.

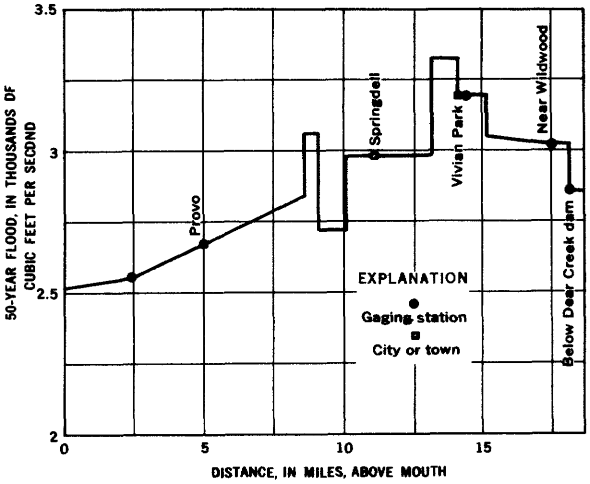

Figure 16.—Provo River, discharge of 50-year flood below Deer Creek Reservoir.

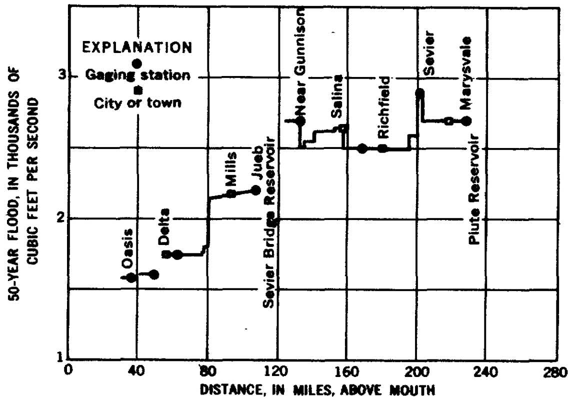

Figure 17.—Sevier River, discharge of 50-year flood below Piute Reservoir.

Table 2.—*Main stem gaging-station data*

Station No.	Gaging station	Drainage area (sq mi)	Period of record	50-year flood (cfs)
	COLORADO RIVER			
9-1635	Colorado River near Colorado-Utah State line	17,900	1951–59	61,000
1805	Colorado River near Cisco, Utah	24,100	1914–17, 1923–59	76,000
3350	Colorado River at Hite, Utah	76,600	1947–58	123,000
	GREEN RIVER			
2255	Green River near Linwood, Utah	14,300	1929–59	23,000
2345	Green River near Greendale, Utah	15,100	1951–59	24,000
2610	Green River near Jensen, Utah	25,400	1904, 1906, 1947–59	59,000
3070	Green River near Ouray, Utah	35,500	1948–55, 1957–59	71,000
3150	Green River at Green River, Utah	40,600	1895–1905, 1906–59	70,000
	DUCHESNE RIVER			
2740	Duchesne River near Hanna, Utah	78	1922–23, 1946–59	1,640
2770	Duchesne River at Hanna, Utah	230	1954–59	2,860
2775	Duchesne River near Tabiona, Utah	352	1919–59	2,550
2795	Duchesne River at Duchesne, Utah	660	1918–59	4,500
2950	Duchesne River at Myton, Utah	2,750	1900–59	14,000
3020	Duchesne River near Randlett, Utah	3,920	1943–59	18,000
	STRAWBERRY RIVER			
2850	Strawberry River near Soldier Springs, Utah	212	1943–56	3,050
2885	Strawberry River at Duchesne, Utah	1,040	1909–10, 1914–59	3,600
	PRICE RIVER			
3115	Price River near Scofield, Utah	163	1918–20, 1926–27, 1929–31, 1939–44, 1946–59	1,320
3130	Price River near Heiner, Utah	455	1935–59	12,500
3135	Price River near Helper, Utah	530	1905–06, 1908–11, 1913–34	12,500
3140	Price River near Wellington, Utah	850	1950–58	21,800
3145	Price River at Woodside, Utah	1,500	1909, 1946–59	30,000

Table 2.—*Main stem gaging-station data*—Continued

Station No.	Gaging station	Drainage area (sq mi)	Period of record	50-year flood (cfs)
	SAN RAFAEL RIVER			
9-3280	San Rafael River near Castle Dale, Utah	927	1948–59	7,100
3285	San Rafael River near Green River, Utah	1,690	1909–18, 1946–59	27,000
	SAN JUAN RIVER			
3680	San Juan River at Shiprock, N. Mex	12,900	1928–59	99,000
3795	San Juan River near Bluff, Utah	23,000	1915–17, 1927–59	85,000
	BEAR RIVER			
10- 440	Bear River at Harer, Idaho	2,780	1914–59	4,450
905	Bear River near Preston, Idaho	4,300	1890–98, 1900–02, 1904–16, 1944–59	7,650
1180	Bear River near Collinston, Utah	6,000	1890–1959	11,600
	WEBER RIVER			
1295	Weber River near Wanship, Utah	320	1951–55, 1958	----------
1305	Weber River near Coalville, Utah	438	1927–59	----------
1320	Weber River at Echo, Utah	732	1927–58	4,800
1335	Weber River at Devils Slide, Utah	1,100	1905–55	6,500
1360	Weber River near Morgan, Utah	----------	1951–55	8,000
1365	Weber River at Gateway, Utah	1,610	1890–93, 1895–99, 1901, 1921–59	9,800
1370	Weber River at Ogden, Utah	----------	1951–58	9,200
1410	Weber River near Plain City, Utah	2,060	1905–59	10,000
	PROVO RIVER			
1595	Provo River below Deer Creek Dam, Utah	560	1954–59	2,870
1605	Provo River near Wildwood, Utah	590	1939–49	3,030
1610	Provo River at Vivian Park, Utah	600	1912–59	3,200
1630	Provo River at Provo, Utah	680	1903–05, 1934, 1937–59	2,550
	SEVIER RIVER			
1915	Sevier River below Piute Dam, near Marysvale, Utah.	2,440	1912–59	2,700
1940	Sevier River above Clear Creek, near Sevier, Utah	2,700	1914–16, 1939–55	2,700

Table 2.—*Main stem gaging-station data*—Continued

Station No.	Gaging station	Drainage area (sq mi)	Period of record	50-year flood (cfs)
	SEVIER RIVER—Continued			
10-1955	Sevier River at Sevier, Utah	2,850	1917–29	2,900
2050	Sevier River near Sigurd, Utah	3,340	1915–59	2,500
2170	Sevier River below San Pitch River, near Gunnison, Utah.	4,880	1918–59	2,700
2190	Sevier River near Juab, Utah	5,120	1912–59	2,200
2240	Sevier River near Lynndyl, Utah	6,270	1914–19, 1943–59	1,740
2280	Sevier River near Delta, Utah	7,380	1913–19	1,600
2315	Sevier River at Oasis, Utah	8,080	1913–27	1,580

CLOUDBURST FLOODS AND MUD-ROCK FLOWS

Cloudburst floods and mud-rock flows are common to the southern parts of both the Colorado River basin and the Great Basin in Utah. These phenomena occur at less frequent intervals in other areas of the State. Most of the annual flood peaks in the southern regions occur during the summer storm period, as previously described, and are included in the flood-frequency relations for that region. In contrast to the annual floods observed in the snowmelt regions, occasional peak flows resulting from cloudburst storms in the central and northern parts of the State may have yields of 5,000 cfs (cubic feet per second) per square mile or more from small drainage basins. This is not to imply that these excessive flows occur more frequently in any one section of the State; instead, it is to acquaint the reader with the fact that these events have been observed. Although cloudburst storms may occur on many days in one season and may be distributed over a rather wide area, the high-intensity rainfall is limited to very small areas, often less than 1 square mile. Observations of rainfall intensities from unofficial observers have shown that as much as 7 inches fell in less than 1 hour during one of these storms. The probability of a cloudburst or high-intensity rainfall recurring in the same small drainage area during consecutive years is rather remote. Experience shows that in some drainage basins, the frequency of floods may vary from three in one year to one in each of three consecutive years to none in several years. Some drainage basins are subject to more cloudburst floods than others in the same general locality because of physical features such as topography, aspect, vegetal cover, and other contributing factors. One example is Pleasant Creek near Mount Pleasant where a large alluvial cone covering more than 12 square miles is evidence of frequent cloudburst flooding.

A cloudburst flood may occur without producing a mud-rock flow. Although mud-rock flows may be associated with cloudburst floods, the presence of certain soil conditions are required to produce them. Mud-rock flows are flows of mud, rock, debris, and water, mixed to a consistency similar to that of wet concrete. A wide variety of these flows has been observed—from those carrying a small load of sediment to others moving large amounts of mud, rock, and other debris. Some flows have just enough water to lubricate the mass of moving material and usually travel at a relatively slow velocity. Because of infrequent observation of these flows, it is difficult to estimate the probable recurrence interval at any given site. It has been noted by Wooley (1946) that the total discharge of debris and water can exceed 2,000 cfs per square mile.

The cost of replacing bridges, culverts, and sections of highway and other economic factors will determine whether design should be for rare floods of the above type which may have a recurrence interval in excess of 50 years.

APPLICATION OF FLOOD-FREQUENCY CURVES

The application of flood-frequency curves to any drainage basin within the scope of this report required analysis of the basin characteristics which effect peak discharge. The significant characteristics are those most readily available from topographic maps.

METHOD

To obtain the magnitude and frequency of floods for any basin within the study area, except on major rivers, the procedure is as follows:

1. Determine the drainage area above the site by planimeter or other acceptable procedure.

2. Locate site on figures 2 and 5 and determine the flood region and hydrologic area involved.

3. Determine the mean altitude for drainage basin above the selected site, unless basin is in hydrologic area 3. In this report the mean altitude was determined by using a grid system of rectangular coordinates as an overlay on topographic maps. From a list of the average altitudes of each square, an arithmetical mean was computed. The squares were of equal size and small enough to give a representative sampling, but not of a known scale. Contour maps of the Army Map Series, scale 1:250,000 were used.

4. Determine the mean annual flood for the site from hydrologic area curve selected in step 2 (fig. 6). One exception is that to determine the mean annual flood of the Dirty Devil River near Hite, Utah (9-3335), use hydrologic area 8 curve. This exception applies only to the main stem and should not be used for the tributary streams of the Dirty Devil River outside of area 8.

5. Determine the flood ratio to the mean annual flood for the selected recurrence interval from the appropriate flood-frequency curve obtained in step 2 (figs. 3 and 4). When the drainage area above the site is near another flood region or lies in two regions with widely different flood ratios, it is suggested that a weighted average of the two flood ratios be used.

6. Estimate the magnitude of the flood by multiplying the mean annual flood (step 4) by the flood ratio (step 5).

A complete frequency curve for a site may be derived by repeating steps 5 and 6 for various recurrence intervals.

USE OF FLOOD-FREQUENCY ANALYSIS ON MAJOR RIVERS

To determine the magnitude of the flood for a 50-year recurrence interval at a given location on a major river, scale the mileage of the main stem from a known reference point as indicated on each graph (figs. 7–17). Use of the main stem analysis will require some knowledge of local conditions and the operation of any reservoirs involved. The Weber River is the only major stream that has a specific flood-control plan. The proposed magnitude of the controlled flow is shown (fig. 15) with the flood experience prior to the initiation of this plan.

LIMITATIONS

The results of this study may be used to estimate the magnitude and frequency of floods, with recurrence intervals up to 50 years, for any drainage area in the State with the exception of the Great Salt Lake Desert and the Snake River basin.

The relationships of the hydrologic features of the drainage basins were defined from the records on streams with natural flows. To obtain the magnitude of any flood on any regulated stream, adjustments should be made for manmade development. Also, the varying effects of geology and vegetal cover were not given detailed consideration in this study. An investigation and evaluation of these factors may be justified in some specific areas.

The results obtained from the flood-frequency study are limited by the basic data available. The degree of confidence that can be placed in the results is closely related to the quantity of data used in defining the various curves. Extrapolation of curves beyond the limits shown is not recommended, and values obtained by such practice may be greatly in error.

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