Yearly Variations in Runoff for the Conterminous United States, 1931–60

By MARK W. BUSBY

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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A revision of a study by G. E. Harbeck, Jr., and W. B. Langbein covering the period 1921–45

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CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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ABSTRACT

In the late 1950's the World Meteorological Organization proposed that all countries adopt standard reference periods. The countries chose 30-year periods, starting with 1901, that do not overlap: for example as 1901–30, 1931–60, and 1961–90. The U.S. Geological Survey has adopted the period 1931–60 for use in its monthly Water Resources Review and has discontinued use of the period 1921–45 formerly used.

This report brings up to date and revises "Normals and variations in runoff, 1921–45," by G. E. Harbeck, Jr., and W. B. Langbein, issued in 1949 as supplement 2 of the Geological Survey's Water Resources Review.

A comparison of the mean annual runoff at 25 gaging stations selected at random throughout the conterminous United States showed no persistent difference between the periods 1921–45 and 1931–60.

INTRODUCTION

The accompanying maps and discussions show the year-to-year changes in runoff for the period 1931–60. This period was chosen, not because of any hydrologic significance, but primarily because it agrees with the climatological standard period of the World Meteorological Organization.

In the late 1950's the World Meteorological Organization (1956) proposed adoption by all countries of a standard reference period. They chose 30-year periods starting with 1901, that do not overlap: for example 1901–1930, 1931–1960, and 1961–90. The U.S. Geological Survey has adopted the climatological standard period, 1931–60 for use in its monthly Water Resources Review.

This period is probably most noted for two droughts during the 1930's and the middle 1950's. Although the wet years were not as noteworthy as the droughts, there were several—in the middle 1940's, 1951, 1952, and 1958. Many extremely high floods occurred during those years; and in almost every year, including the drought years, major floods took place somewhere in the conterminous United States. The runoff for the period 1931–60 is somewhat representative of the long-term runoff, although in some parts of the country the 1931–60 average was less than the long-term average.

The 30 maps of the conterminous United States supplemented by other discussions show the annual runoff in a way similar to the maps

and discussions published in the Water Resources Review. The section on "Regional variations in runoff" shows the year to year variations for the nine regions into which the country was divided. The section on "Monthly distribution of runoff" discusses the monthly variation for several stations. The section on "Excessive and deficient runoff" summarizes the map data in terms of percent of area of the country that was excessive or deficient each year. The last section discusses "Long-term trends in runoff."

This report brings up to date and revises the original study by Harbeck and Langbein (1949), which covered the period 1921–45. The findings are generally similar to those of the earlier report but with the benefit of 15 years of information added. Differences that may exist between the maps of the two reports for each year of the overlapping period 1931–45 are due to the use of different stations, to the use of arithmetic mean rather than the median for the normal, and to the use of different reference periods. Table 1 lists the gaging stations used in this report. For comparison, table 2 shows the mean annual runoff at selected gaging stations for the periods 1921–45 and 1931–60, as well as for longer periods where records are available.

TABLE 1.—*Gaging stations used in this report*

Name	Station	Map No. (fig. 31)	Drainage area (square miles)	30-year mean (inches)
Piscataquis River near Dover-Foxcroft, Maine	1A–0315	1	297	26. 71
Pemigewasset River at Plymouth, N.H.	1A–0765	2	622	29. 48
Quinebaug River at Jewett City, Conn.	1A–1270	3	711	24. 49
Sacandaga River near Hope, N.Y.	1B–3210	4	491	29. 89
South Branch Raritan River near High Bridge, N.J.	1B–3965	5	65. 3	24. 26
Swatara Creek at Harper Tavern, Pa.	1B–5730	6	333	23. 35
Seneca Creek at Dawsonville, Md.	1B–6450	7	101	12. 58
Slate River near Arvonia, Va.	2A–0305	8	235	12. 92
Neuse River near Clayton, N.C.	2A–0875	9	1, 140	14. 37
Yadkin River at Wilkesboro, N.C.	2A–1120	10	493	20. 54
Lynches River at Effingham, S.C.	2A–1320	11	1, 030	12. 32
St. Marys River near Macclenny, Fla.	2B–2310	12	720	11. 46
Fisheating Creek at Palmdale, Fla.	2B–2565	13	435	8. 76
Ochlockonee River near Havana, Fla.	2B–3290	14	1, 020	12. 35
Chattahoochee River near Roswell, Ga.	2B–3355	15	1, 230	24. 46
Conecuh River at Brantley, Ala.	2B–3715	16	492	18. 88
Mulberry Fork near Garden City, Ala.	2B–4500	17	368	22. 82
Strong River at Dlo, Miss.	2B–4875	18	429	17. 49
Little Beaver Creek near East Liverpool, Ohio	3A–1095	19	505	14. 00
Hocking River at Enterprise, Ohio	3A–1575	20	460	12. 83
Gauley River near Summersville, W. Va.	3A–1895	21	680	31. 14
Blue River near White Cloud, Ind.	3A–3030	22	461	18. 01
Eel River at North Manchester, Ind.	3A–3280	23	416	11. 47
Skillet Fork at Wayne City, Ill.	3A–3805	24	475	10. 74
Clear Fork near Robbins, Tenn.	3B–4095	25	278	22. 54
Harpeth River at Belleview, Tenn.	3B–4335	26	404	18. 33

TABLE 1.—*Gaging stations used in this report*—Continued

Name	Station	Map No. (fig. 31)	Drainage area (square miles)	30-year mean (inches)
Pigeon River at Middle Falls, below International Bridge, Minn	4–0105	27	600	11. 39
Oconto River near Gillett, Wis	4–0710	28	678	10. 31
Huron River at Ann Arbor, Mich	4–1745	29	711	8. 42
Genesee River at Scio, N.Y	4–2215	30	309	17. 24
Chateaugay River near Chateaugay, N.Y	4–2705	31	112	20. 87
Mustinka River above Wheaton, Minn	5–0490	32	834	. 71
Park River at Grafton, N. Dak	5–0900	33	742	. 88
Wintering River near Karlsruhe, N. Dak	5–1205	34	675	. 24
Big Fork River at Big Falls, Minn	5–1320	35	1, 460	5. 98
Namekagon River near Trego, Wis	5–3325	36	503	12. 64
Sugar River near Brodhead, Wis	5–4365	37	527	8. 10
Ralston Creek at Iowa City, Iowa	5–4550	38	3. 01	6. 22
Lime Creek at Mason City, Iowa	5–4595	39	526	5. 14
Money Creek at Lake Bloomington, Ill	5–5655	40	68. 6	7. 68
Big Muddy River at Plumfield, Ill	5–5970	41	753	12. 04
Red Rock River below Lima Reservoir, near Monida, Mont	6A–0125	42	570	2. 85
Tenmile Creek near Rimini, Mont	6A–0625	43	32. 7	6. 02
Judith River near Utica, Mont	6A–1100	44	331	1. 86
Milk River at Milk River, Alberta	6A–1345	45	1, 104	1. 59
Redwater Creek at Circle, Mont	6A–1775	46	534	. 41
Clarks Fork Yellowstone River at Chance, Mont	6A–2075	47	1, 340	9. 09
Wood River at Sunshine (near Meeteetse), Wyo	6A–2750	48	194	7. 53
Little Missouri River near Alzada, Mont	6A–3340	49	780	1. 04
Knife River near Golden Valley, N. Dak	6A–3395	50	1, 230	1. 04
Rapid Creek near Pactola (below Pactola Dam), S. Dak	6A–4115	51	315	1. 67
South Fork White River near Rosebud, S. Dak	6A–4495	52	1, 020	1. 39
Floyd River at James, Iowa	6B–6005	53	882	2. 56
Deer Creek at Glenrock, Wyo	6B–6465	54	216	3. 22
Blue Creek near Lewellen, Nebr	6B–6870	55	267	3. 58
Bear Creek at Morrison, Colo	6B–7105	56	165	4. 11
Tarkio River at Fairfax, Mo	6B–8130	57	508	4. 78
Frenchman Creek at Palisade (near Hamlet), Nebr	6B–8340	58	1, 500	. 89
Wakarusa River near Lawrence, Kans	6B–8915	59	458	5. 08
Locust Creek near Linneus, Mo	6B–9015	60	550	7. 57
Gasconade River near Hazelgreen, Mo	6B–9280	61	1, 250	11. 08
Bourbeuse River at Union, Mo	7–0165	62	808	10. 59
Wolf River at Rossville, Tenn	7–0305	63	503	18. 26
Little Red River near Heber Springs, Ark	7–0760	64	1, 141	22. 29
Lion Creek near Halfway, Colo	7–1010	65	2. 00	5. 66
Little Arkansas River at Valley Center, Kans	7–1442	66	1, 327	2. 61
Council Creek near Stillwater, Okla	7–1630	67	31	3. 61
Shoal Creek above Joplin, Mo	7–1870	68	410	11. 91
Rayado River at Sauble Ranch, near Cimarron, N. Mex	7–2085	69	65	2. 67
Petit Jean Creek at Danville, Ark	7–2605	70	741	16. 01
Little Wichita River near Archer City, Tex	7–3145	71	481	2. 35
Washita River near Cheyenne, Okla	7–3165	72	794	. 69
Mountain Fork River near Eagletown, Okla	7–3390	73	787	23. 64
Tensas River at Tendal, La	7–3695	74	309	14. 65

TABLE 1.—*Gaging stations used in this report*—Continued

Name	Station	Map No. (fig. 31)	Drainage area (square miles)	30-year mean (inches)
Tangipahoa River at Robert, La	7–3755	75	646	22. 67
Bayou des Cannes near Eunice, La	8–0100	76	131	25. 96
East Fork Trinity River near Lavon (near Rockwall), Tex	8–0610	77	779	7. 67
North Bosque River near Clifton, Tex	8–0950	78	971	3. 09
Yegua Creek near Somerville, Tex	8–1100	79	990	3. 88
Middle Concho River near Tankersly, Tex	8–1285	80	1, 280	. 50
Guadalupe River near Spring Branch, Tex	8–1675	81	1, 282	3. 02
Atascosa River at Whitsett, Tex	8–2080	82	1, 171	1. 70
Conejos River near Mogote, Colo	8–2465	83	282	15. 05
Bluewater Creek near Bluewater, N. Mex	8–3420	84	235	16. 92
Alamito Creek near Presidio, Tex	8–3740	85	1, 504	. 20
Rio Ruidoso at Hondo, N. Mex	8–3880	86	290	. 81
Pinto Creek near Del Rio, Tex	8–4550	87	236	1. 59
Roaring Fork at Glenwood Springs, Colo	9–0850	88	1, 460	11. 70
New Fork River near Boulder, Wyo	9–2010	89	552	9. 13
Yampa River at Steamboat Springs, Colo	9–2395	90	604	9. 67
Ashley Creek near Vernal, Utah	9–2665	91	101	12. 17
Animas River at Durango, Colo	9–3615	92	692	14. 85
Silver Creek near Snowflake (near Woodruff), Ariz	9–3935	93	886	. 35
Bright Angel Creek near Grand Canyon, Ariz	9–4030	94	98. 4	5. 01
San Carlos River near Peridot, Ariz	9–4685	95	1, 027	. 60
San Pedro River at Charleston, Ariz	9–4710	96	1, 219	. 64
Aqua Fria River at Lake Pleasant Dam, Ariz	9–5130	97	1, 459	. 51
Big Cottonwood Creek neat Salt Lake City, Utah	10–1685	98	48. 5	17. 86
Beaver River near Beaver, Utah	10–2345	99	82	8. 39
Palm Canyon Creek near Palm Springs, Calif	10–2585	100	94	. 70
Convict Creek near Mammoth Lakes, Calif	10–2652	101	18. 7	17. 54
Cottonwood Creek near Olancha, Calif	10–2860	102	39. 9	7. 29
Carson River near Fort Churchhill, Nev	10–3120	103	1, 450	3. 30
South Fork Humboldt River near Elko, Nev	10–3205	104	1, 150	1. 40
Martin Creek near Paradise Valley, Nev	10–3295	105	172	2. 52
Silvies River near Burnes, Oreg	10–3935	106	934	2. 42
Arroyo Seco near Pasadena, Calif	11A–0980	107	16. 4	7. 08
Miller Creek at Gerber Reservoir near Lorella, Oreg	11A–4835	108	220	4. 37
Los Gatos Creek above Nunez Canyon, near Coalinga, Calif	11B–2245	109	95. 5	. 76
Bear Creek near Lockeford, Calif	11B–3120	110	47. 6	3. 26
Big Chico Creek near Chico, Calif	11B–3840	111	67. 9	28. 77
Chehalis River near Grand Mound, Wash	12–0275	112	895	43. 27
Swan River near Bigfork, Mont	12–3700	113	671	21. 81
Coeur d'Alene River near Cataldo, Idaho	12–4135	114	1, 220	28. 74
Methow River at Twisp, Wash	12–4495	115	1, 330	14. 65
Snake River at Moran, Wyo	13–0110	116	824	22. 32
Trapper Creek near Oakley, Idaho	13–0830	117	53. 7	3. 44
Big Wood River at Hailey, Idaho	13–1395	118	640	9. 13
Grande Ronde River at La Grande, Oreg	13–3190	119	678	7. 40
Lochsa River near Lowell, Idaho	13–3370	120	1, 180	31. 77
Klickitat River near Glenwood, Wash	14–1100	121	360	30. 85
McKenzie River at McKenzie Bridge, Oreg	14–1590	122	345	65. 07
South Fork Coquille River at Powers, Oreg	14–3250	123	169	65. 13

TABLE 2.—*Comparison of 30-year normals of runoff with other long-term normals, in inches*

Name	Map No. (fig. 31)	Mean annual runoff					
		1931–60	1921–45	1911–60	1901–60	1886–60	1876–60
East Branch Penobscot River at Grindstone, Maine	------	23.73	22.51	23.79	------	------	------
Sudbury River at Framingham Center, Mass	------	20.38	19.34	19.46	19.59	20.50	20.48
North Bald Eagle Creek at Beech Creek Station, Pa	------	18.82	18.05	19.40	------	------	------
Yadkin River at Wilkesboro, N.C	10	20.54	20.52	[1] 20.58	------	------	------
Greenbrier River at Alderson, W. Va	------	18.59	18.65	19.60	20.01	------	------
Hiwassee River above Murphy, N.C	------	26.93	27.70	28.15	29.20	------	------
Fox River at Berlin, Wis	------	9.62	10.48	10.41	10.44	------	------
Huron River at Ann Arbor, Mich	29	8.42	6.98	8.51	------	------	------
St. Regis River at Brasher Center, N.Y	------	22.15	22.74	23.20	------	------	------
Mississippi River at Winnibigoshish Dam, near Deer River, Minn	------	4.29	3.47	4.36	4.78	4.85	------
Apple River near Somerset, Wis	------	7.03	6.35	6.92	7.46	------	------
Madison River below Hebgen Lake, near Grayling, Mont	------	13.42	12.69	14.26	------	------	------
Clear Creek near Golden, Colo	------	7.65	8.00	8.07	------	------	------
Arkansas River at Granite, Colo	------	9.35	10.37	10.69	------	------	------
Rio Grande near Del Norte, Colo	------	8.31	9.82	9.56	9.61	------	------
Virgin River at Virgin, Utah	------	2.57	3.10	2.98	------	------	------
Logan River above State Dam, near Logan, Utah	------	12.64	14.56	15.27	16.36	------	------
Santa Anna River near Mentone, Calif	------	4.62	5.87	5.66	5.82	------	------
Arroyo Seco near Soledad, Calif	------	8.56	9.28	8.81	------	------	------
North Fork Kaweah River at Kaweah, Calif	------	11.24	11.06	10.62	------	------	------
North Fork Feather River near Prattville, Calif	------	23.27	21.03	23.23	------	------	------
Chelan River at Chelan, Wash	------	29.58	25.93	28.07	------	------	------
Snake River at Morgan, Wyo	------	22.32	21.06	23.11	------	------	------
Klickitat River near Glenwood, Wash	121	30.85	29.45	31.73	------	------	------
McKenzie River at McKenzie Bridge, Oreg	122	65.07	59.98	64.78	------	------	------

[1] 40 years (1921–60).

MAPS OF ANNUAL RUNOFF

The maps of figures 1–30 show the annual runoff, in percent of the 1931–60 normal, in the conterminous United States for each year from 1931 to 1960.

Records at 123 stations (table 1) were used to define the areas of normal, excessive, and deficient runoff; the locations of these stations are shown in figure 31. The criteria used to select the 123 stations were as follows:

1. The drainage areas must range between 1 and 1,500 square miles.
2. Diversions are less than 10 percent of the flow or irrigation consumptive use is less than 10 percent of the annual runoff.
3. The downstream station must have a drainage area of more than twice that of an upstream station on the same stream.

In addition, records of two stations on the same stream were combined, if the drainage areas differ by less than 15 percent.

For this report, however, no two stations on the same stream and no station with regulated flow where the storage would affect the annual runoff by more than 10 percent were selected. Several station

(Text continues on p. S37.)

690-148 O - 63 - 2

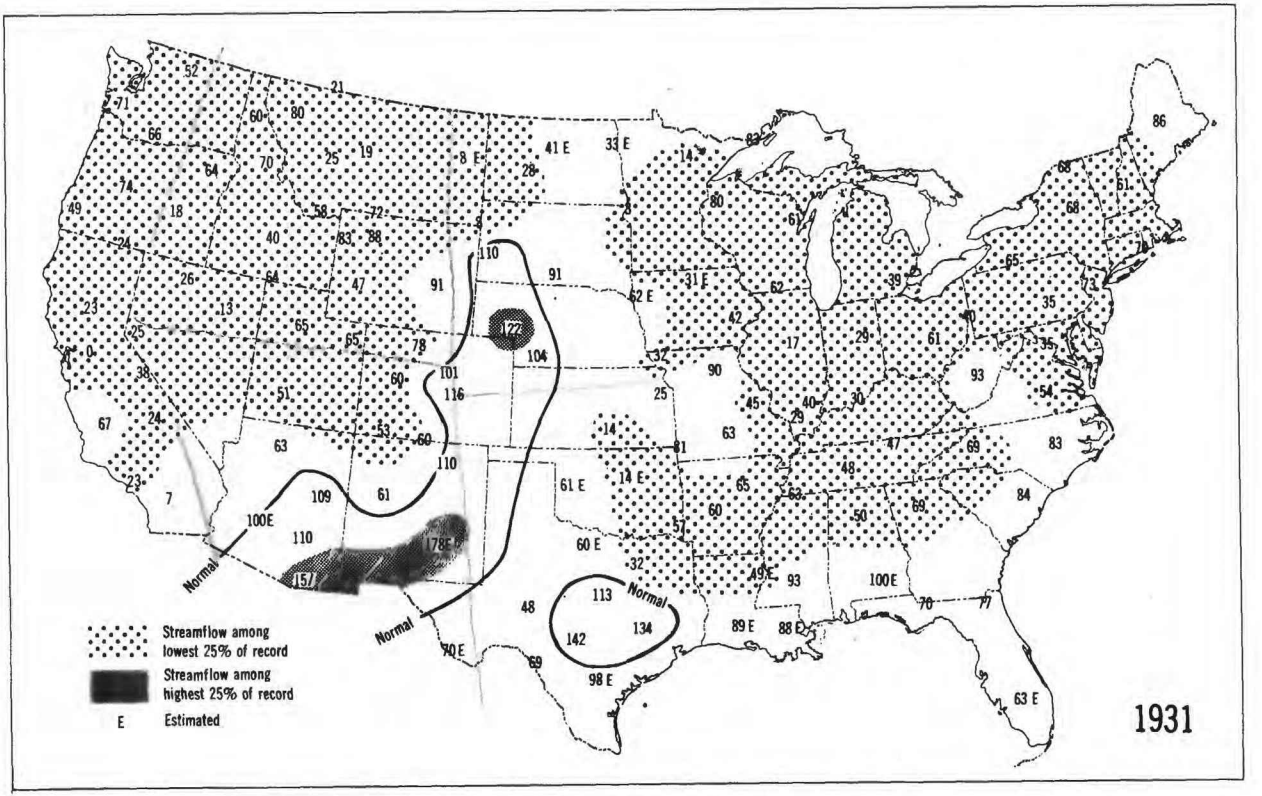

FIGURE 1.—Annual runoff, in percent of normal, for the water year 1931.

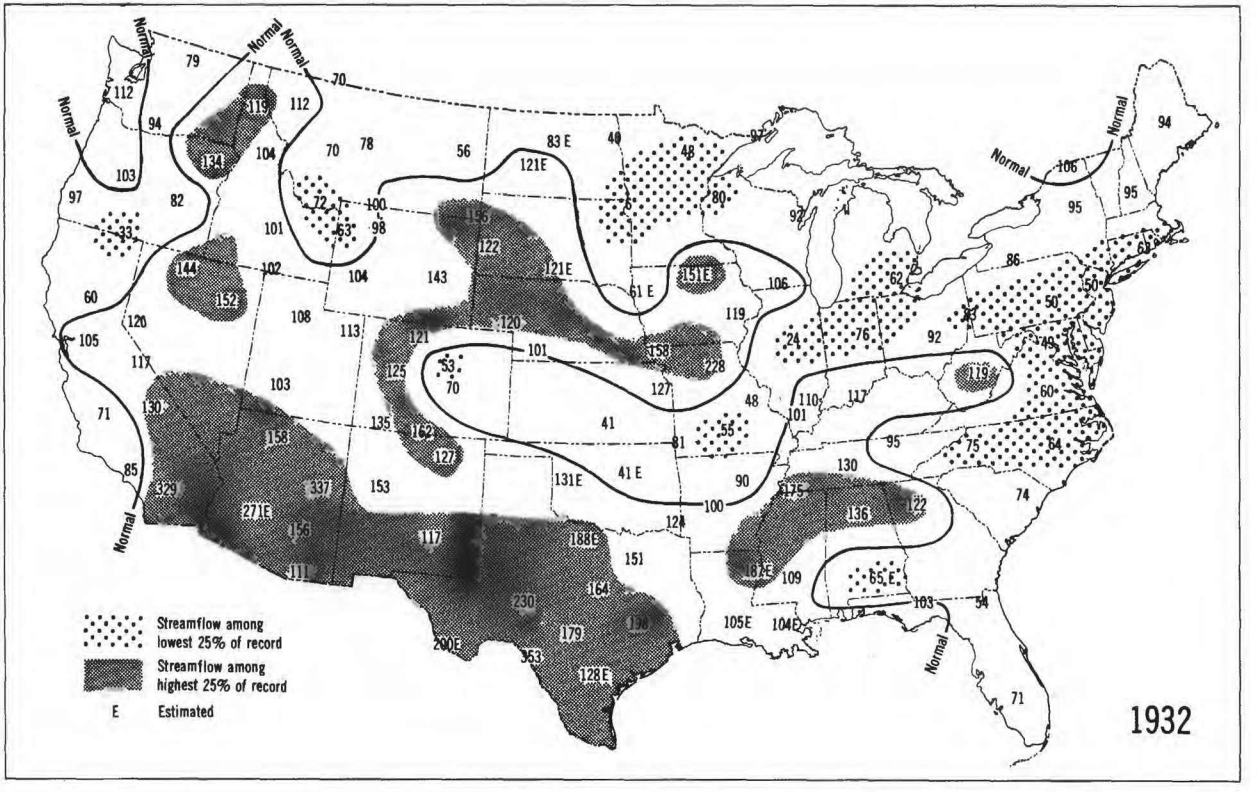

FIGURE 2.—Annual runoff, in percent of normal, for the water year 1932.

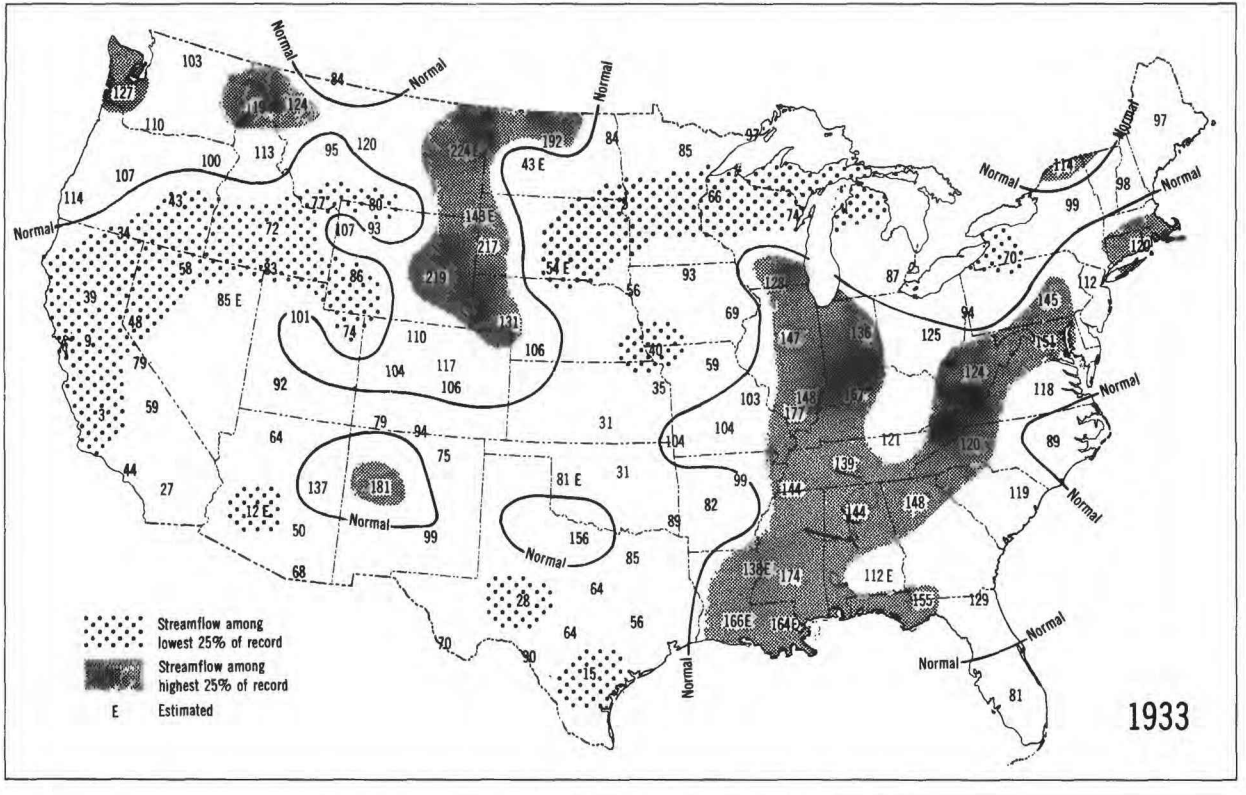

FIGURE 3.—Annual runoff, in percent of normal, for the water year 1933.

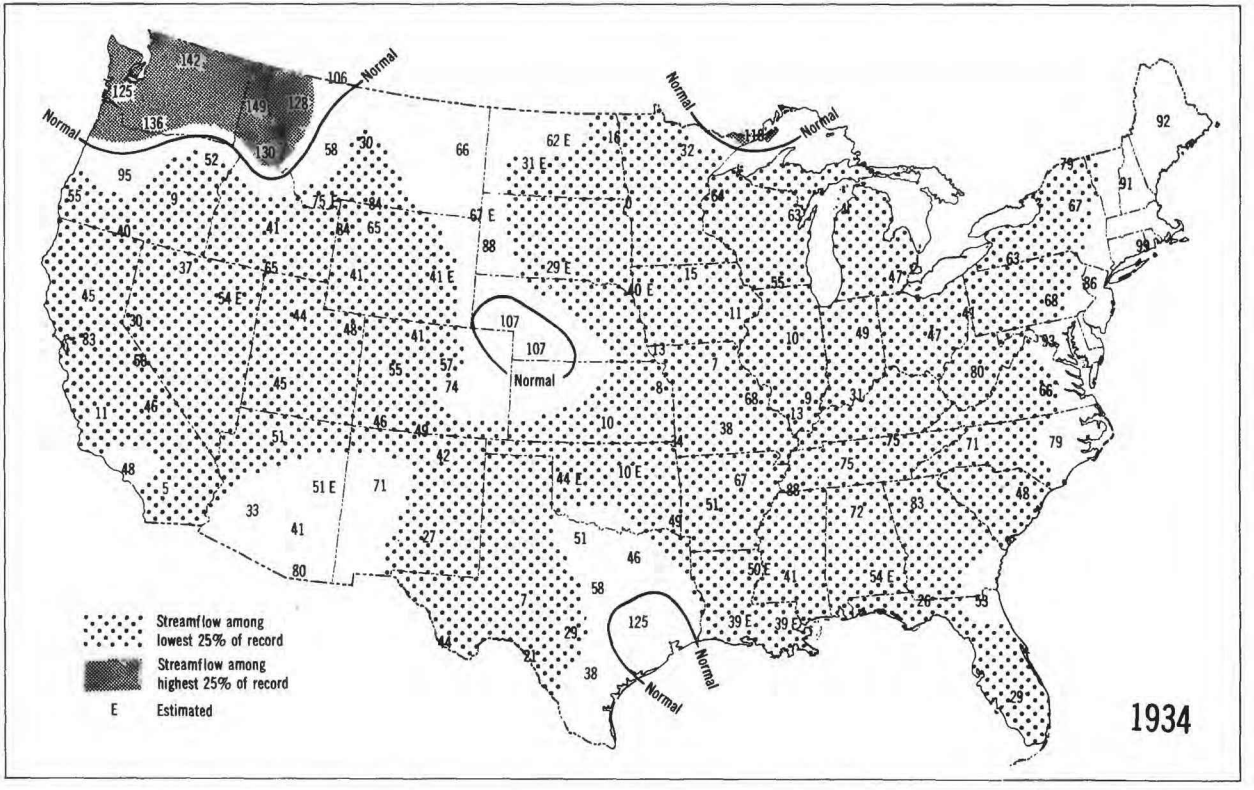

FIGURE 4.—Annual runoff, in percent of normal, for the water year 1934.

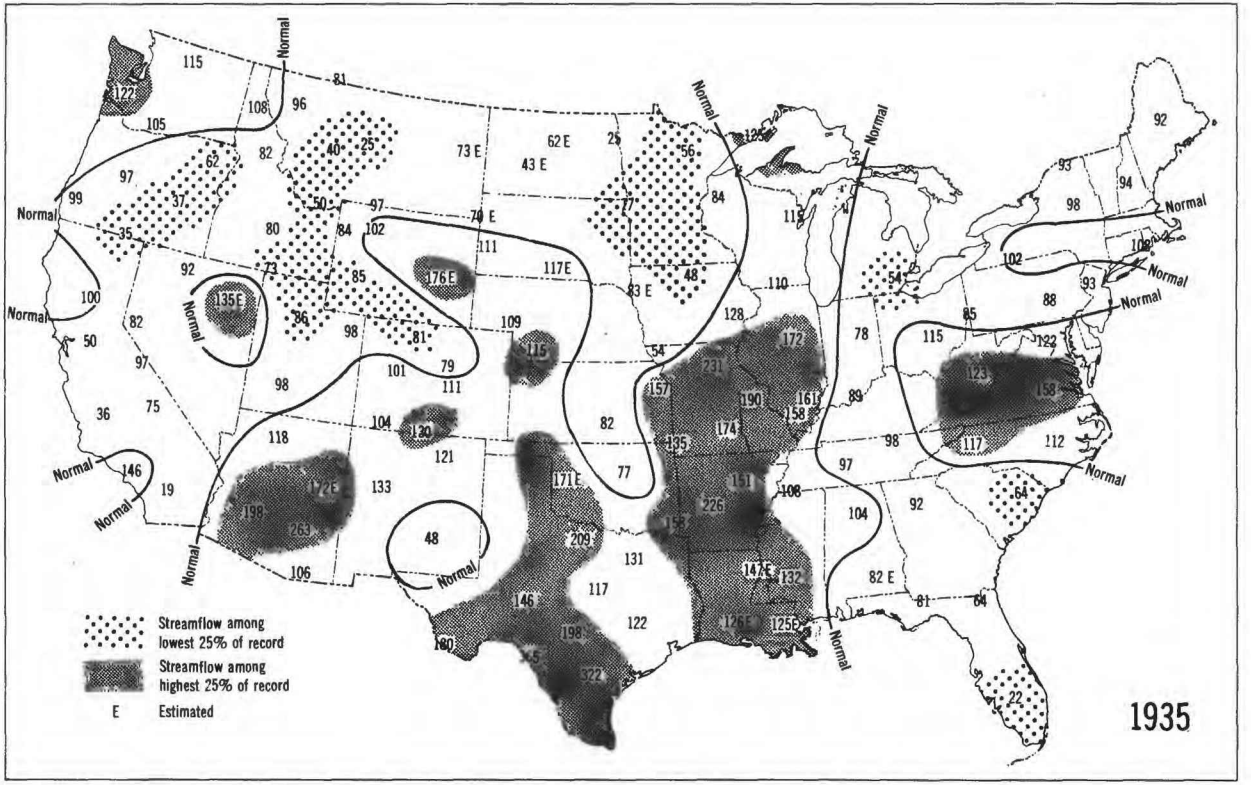

FIGURE 5.—Annual runoff, in percent of normal, for the water year 1935.

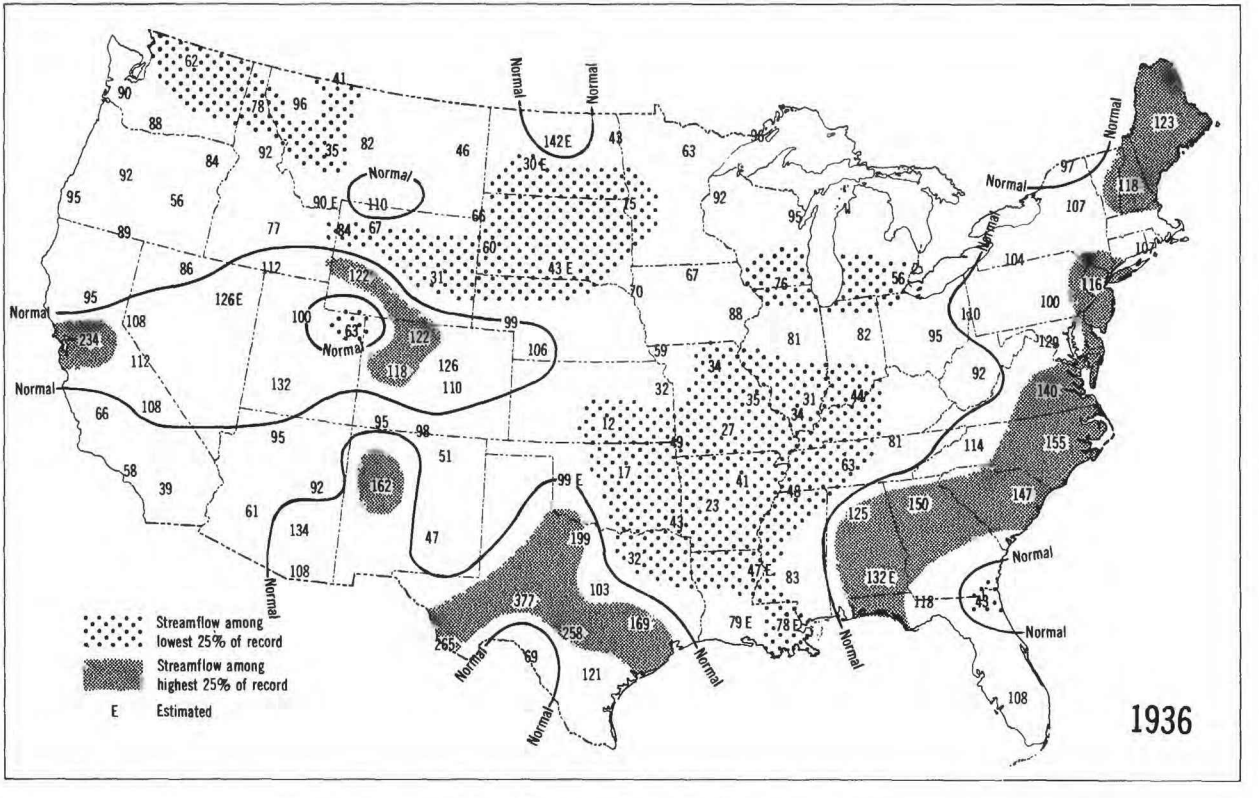

FIGURE 6.—Annual runoff, in percent of normal, for the water year 1936.

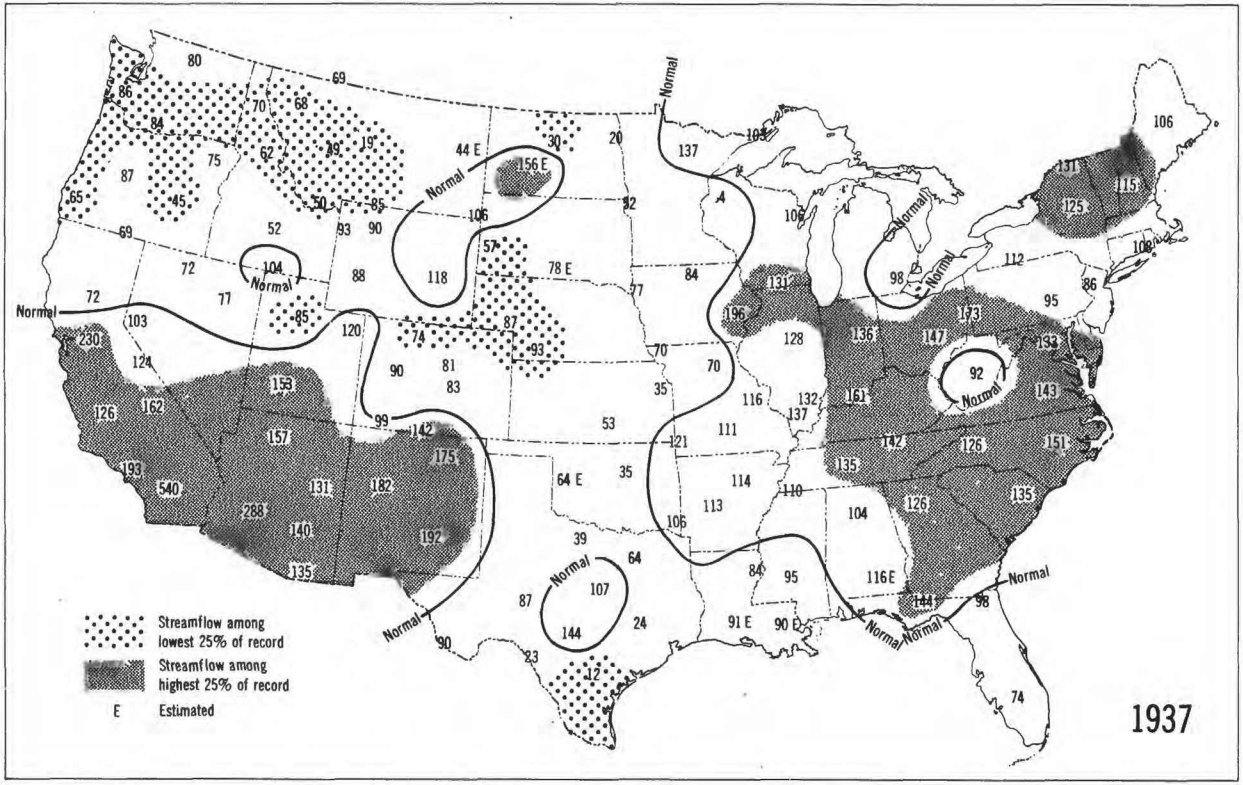

FIGURE 7.—Annual runoff, in percent of normal, for the water year 1937.

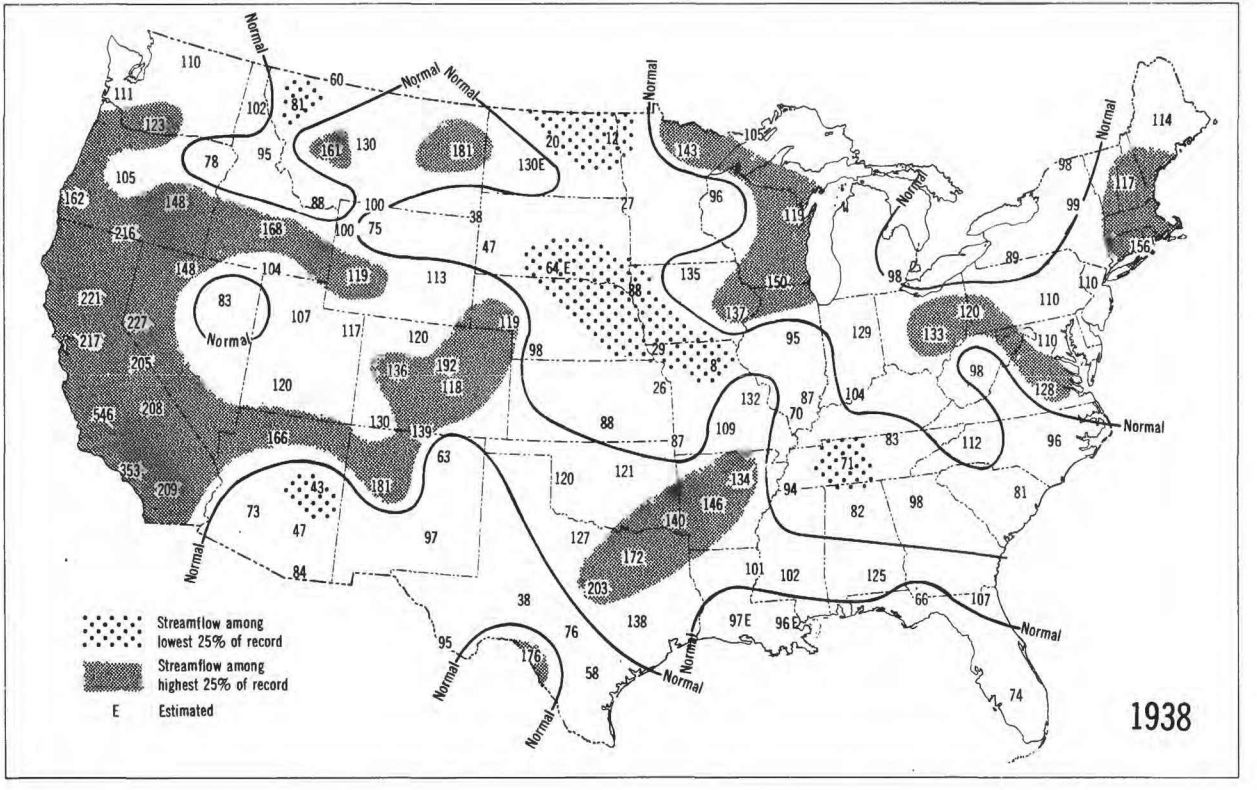

FIGURE 8.—Annual runoff, in percent of normal, for the water year 1938.

690-148 O - 63 - 3

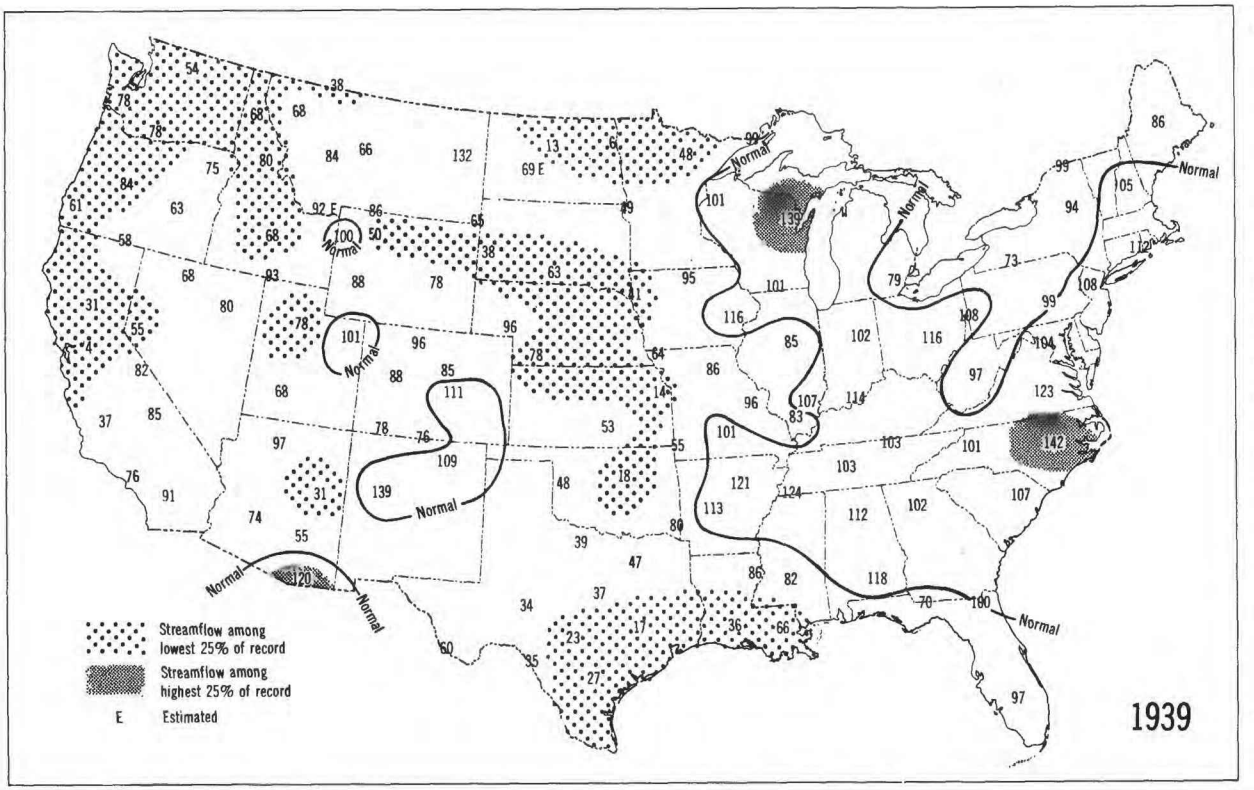

FIGURE 9.—Annual runoff, in percent of normal, for the water year 1939.

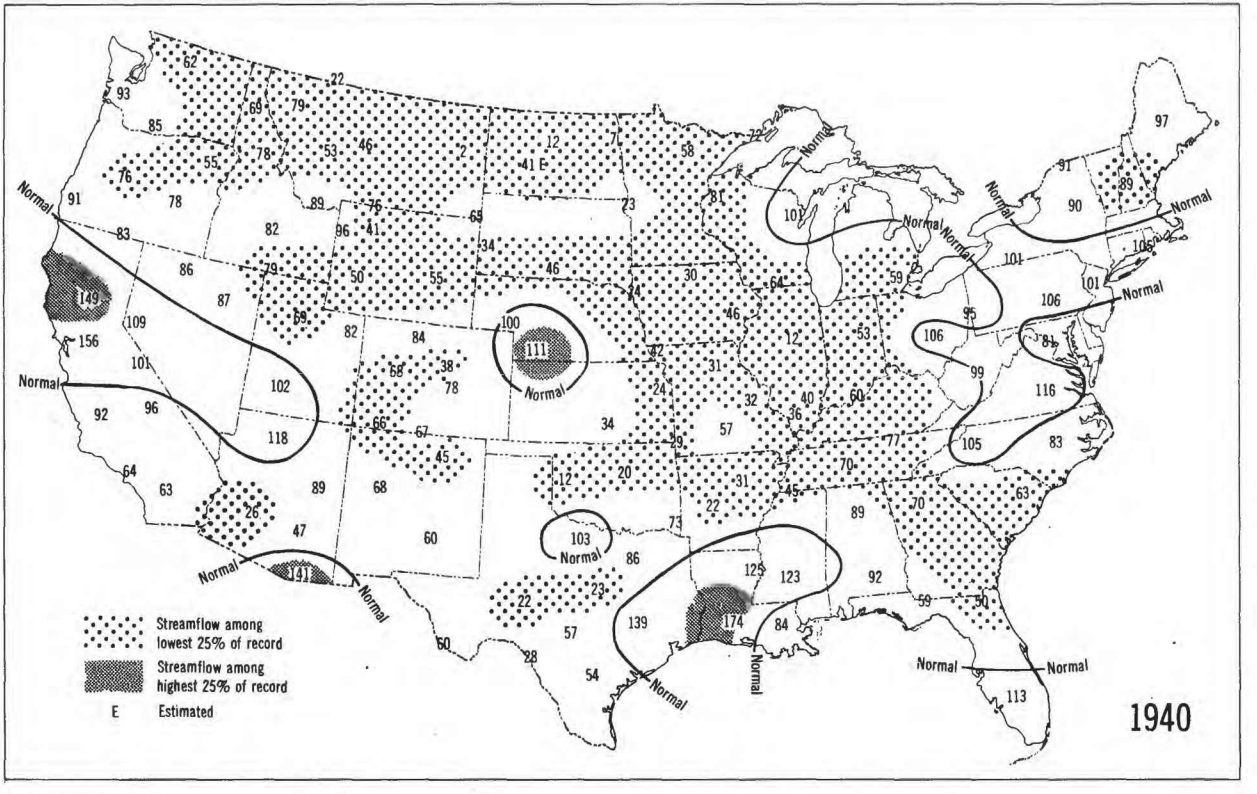

FIGURE 10.—Annual runoff, in percent of normal, for the water year 1940.

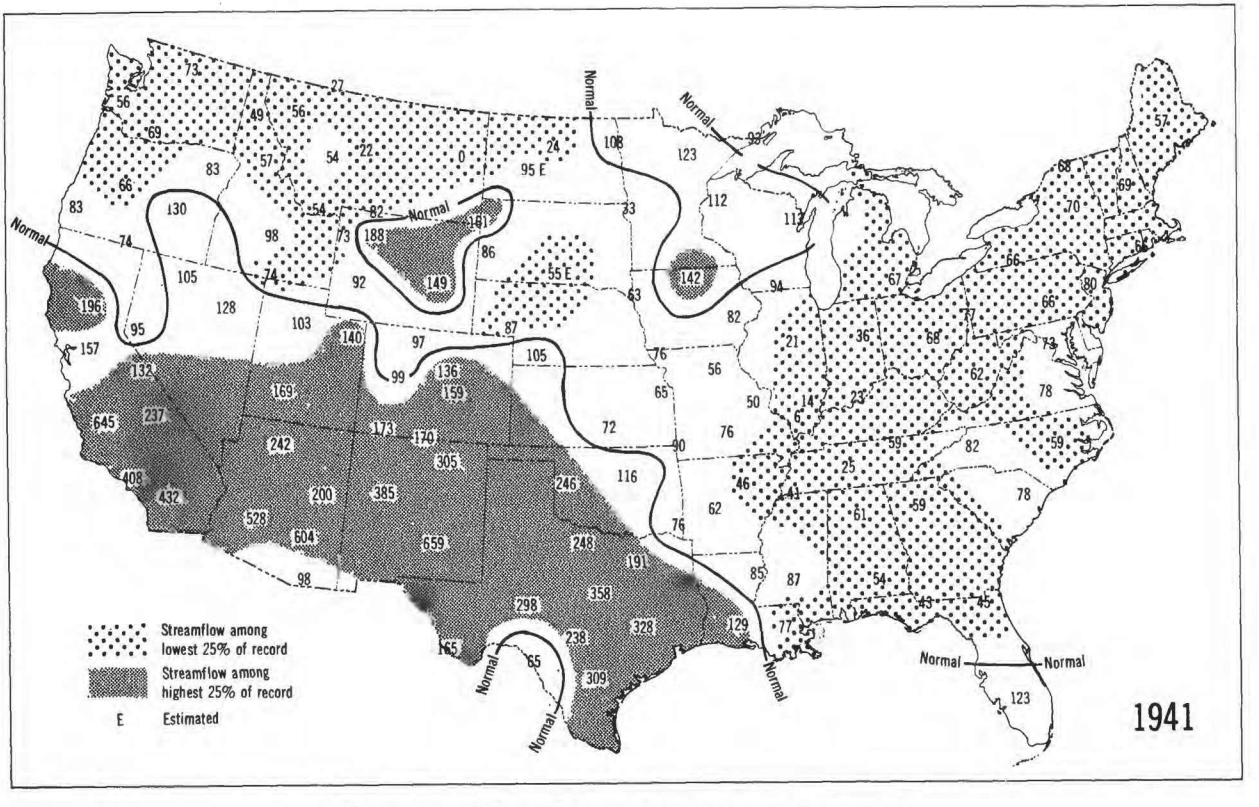

FIGURE 11.—Annual runoff, in percent of normal, for the water year 1941.

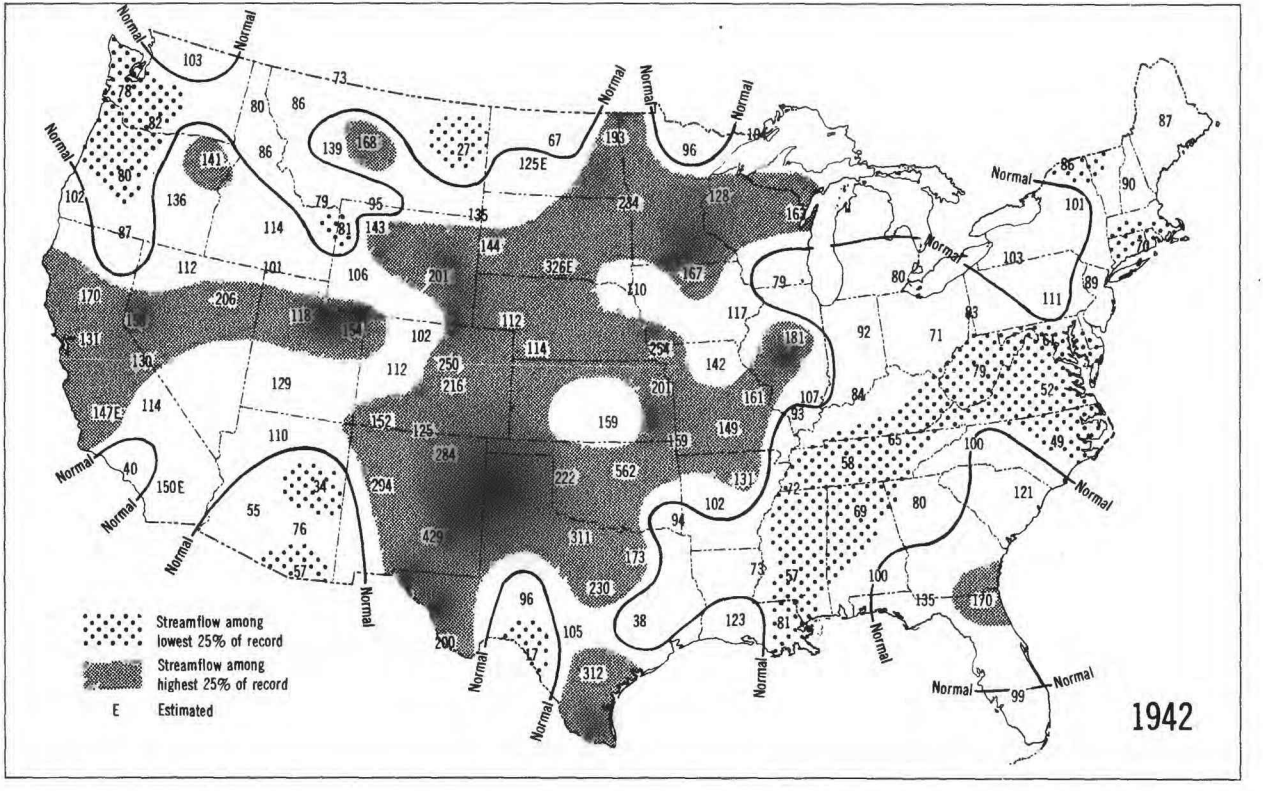

FIGURE 12.—Annual runoff, in percent of normal, for the water year 1942.

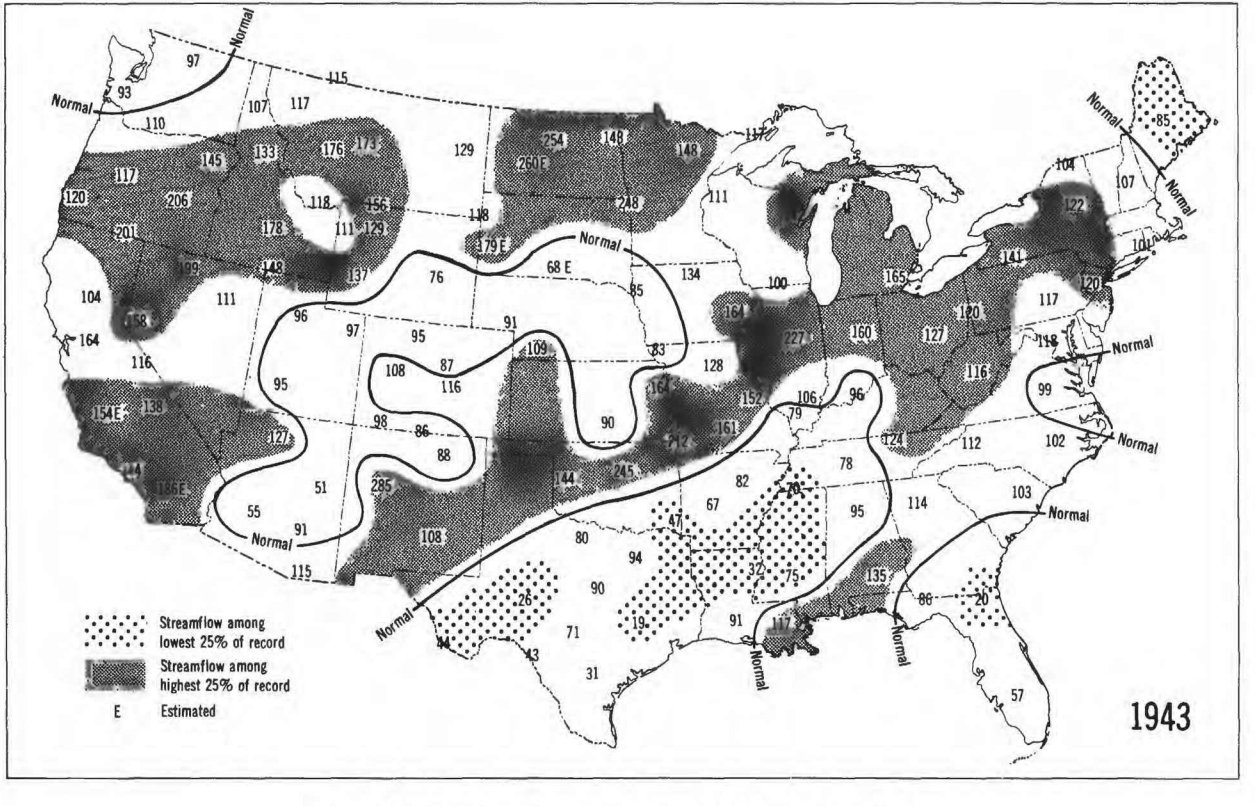

FIGURE 13.—Annual runoff, in percent of normal, for the water year 1943.

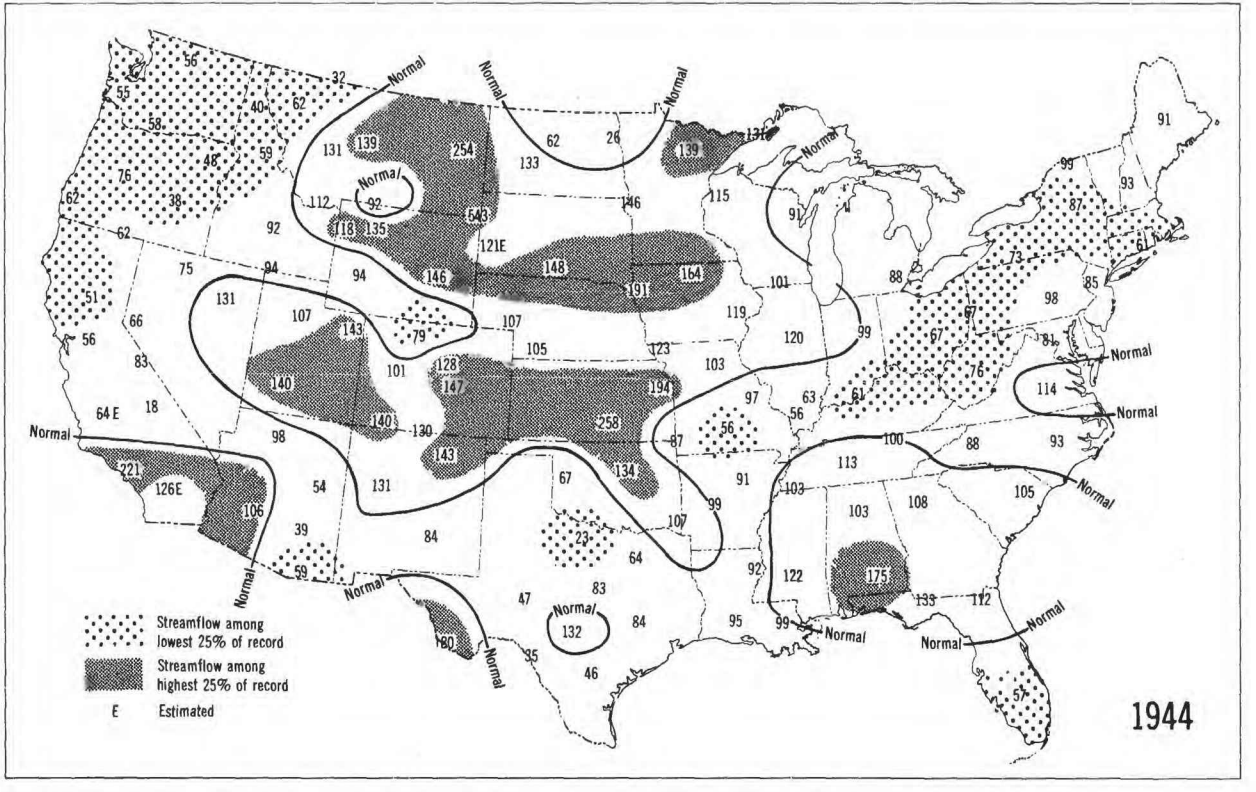

FIGURE 14.—Annual runoff, in percent of normal, for the water year 1944.

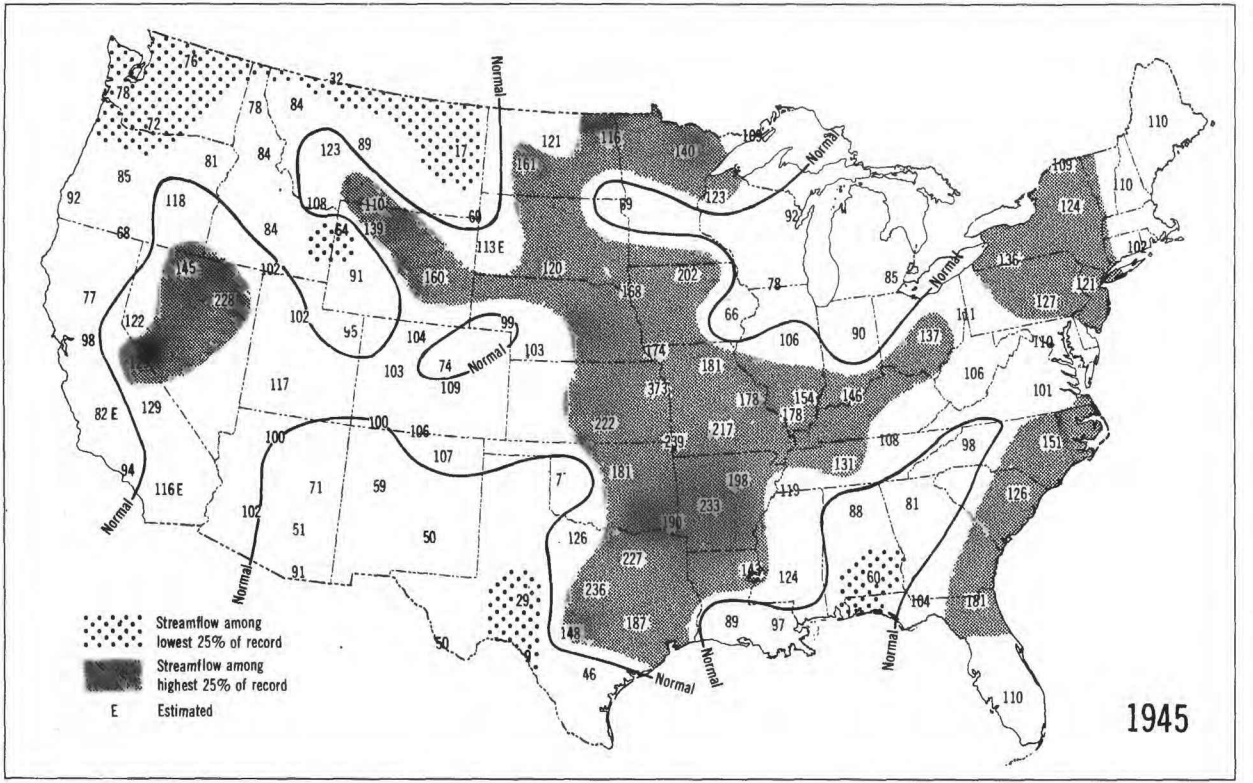

FIGURE 15.—Annual runoff, in percent of normal, for the water year 1945.

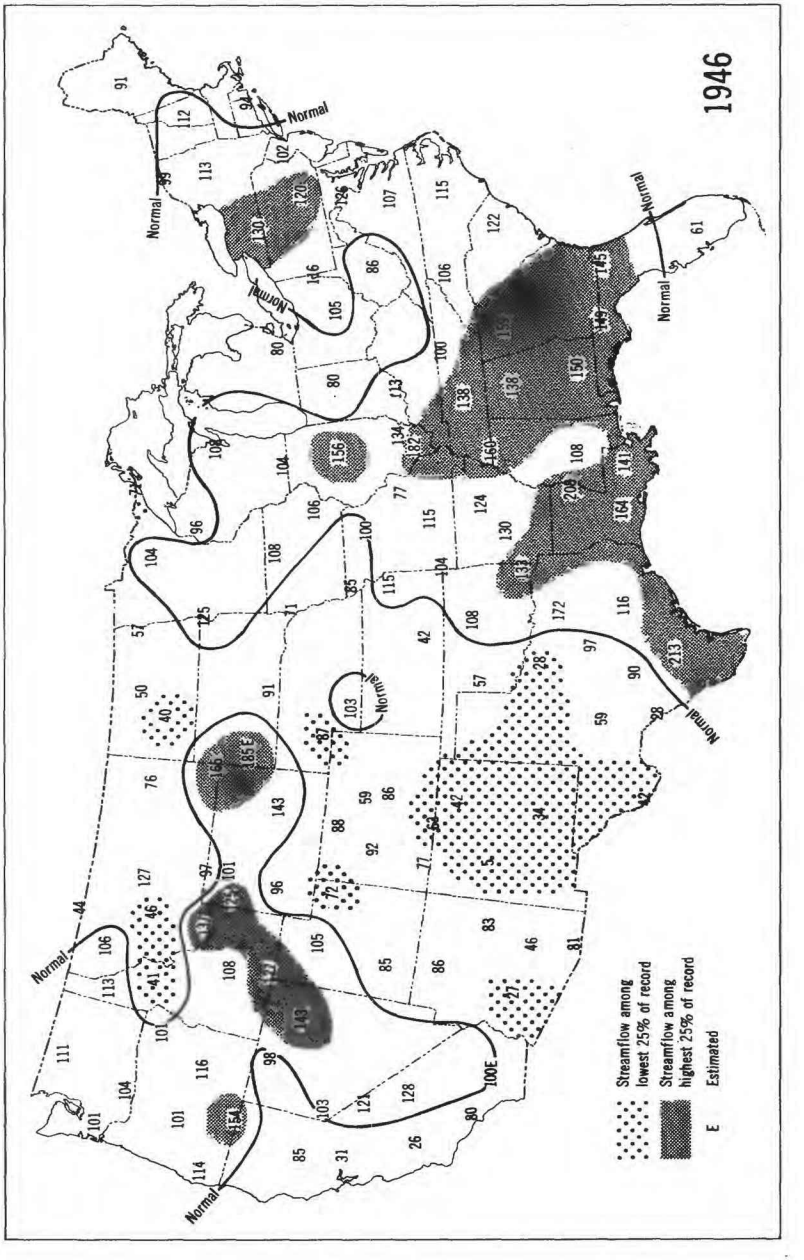

FIGURE 16.—Annual runoff, in percent of normal, for the water year 1946.

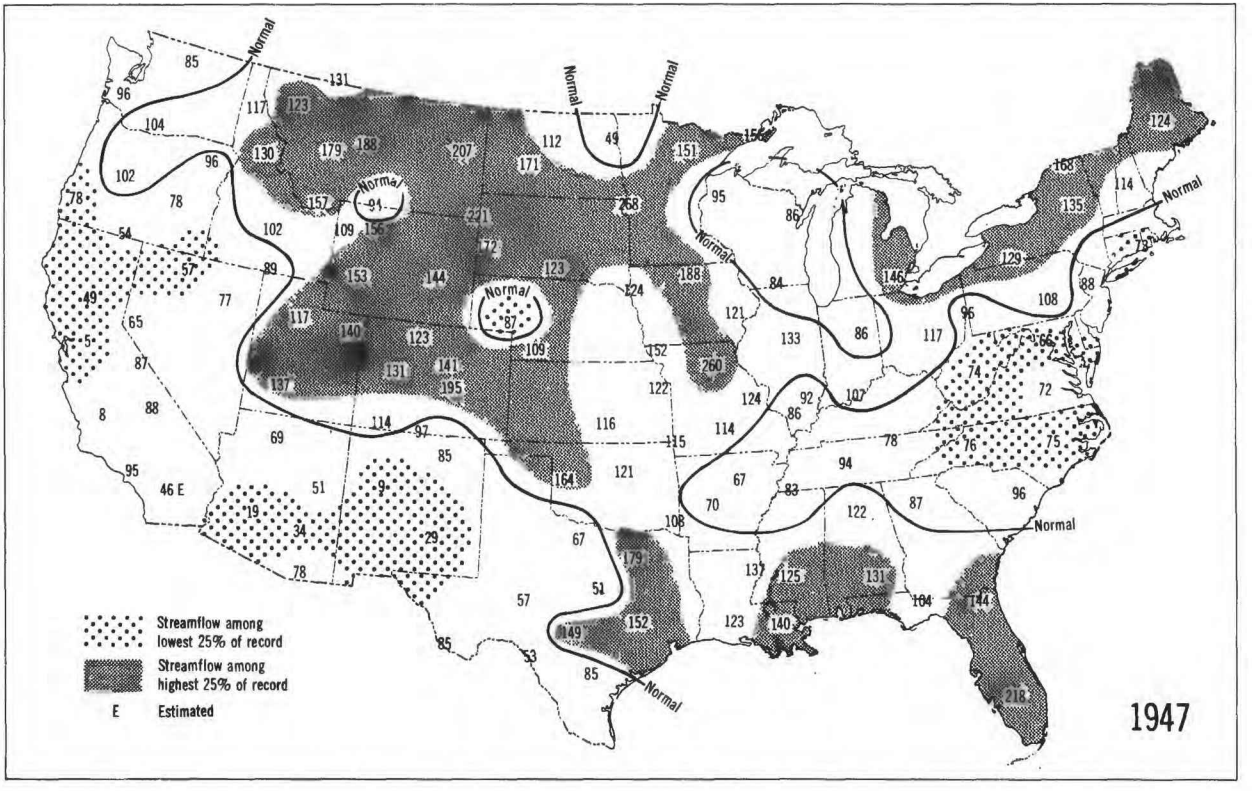

FIGURE 17.—Annual runoff, in percent of normal, for the water year 1947.

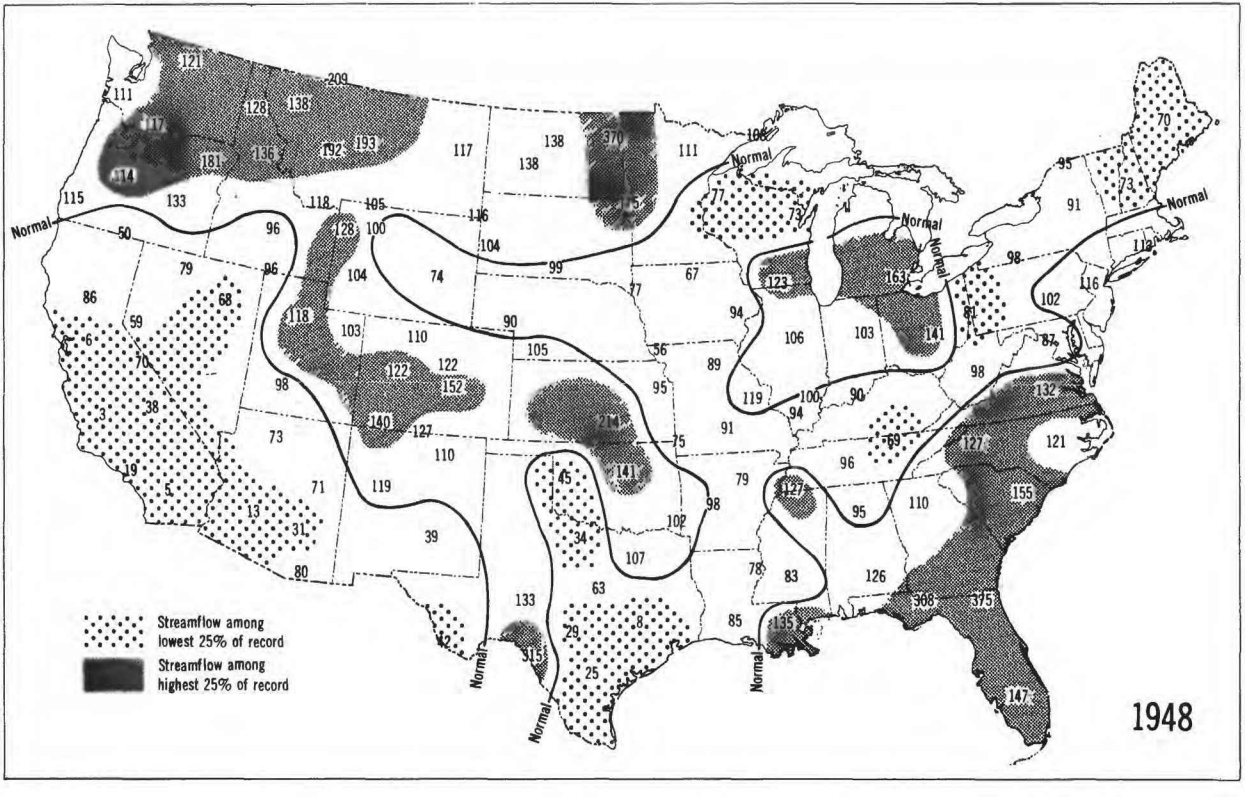

FIGURE 18.—Annual runoff, in percent of normal, for the water year 1948.

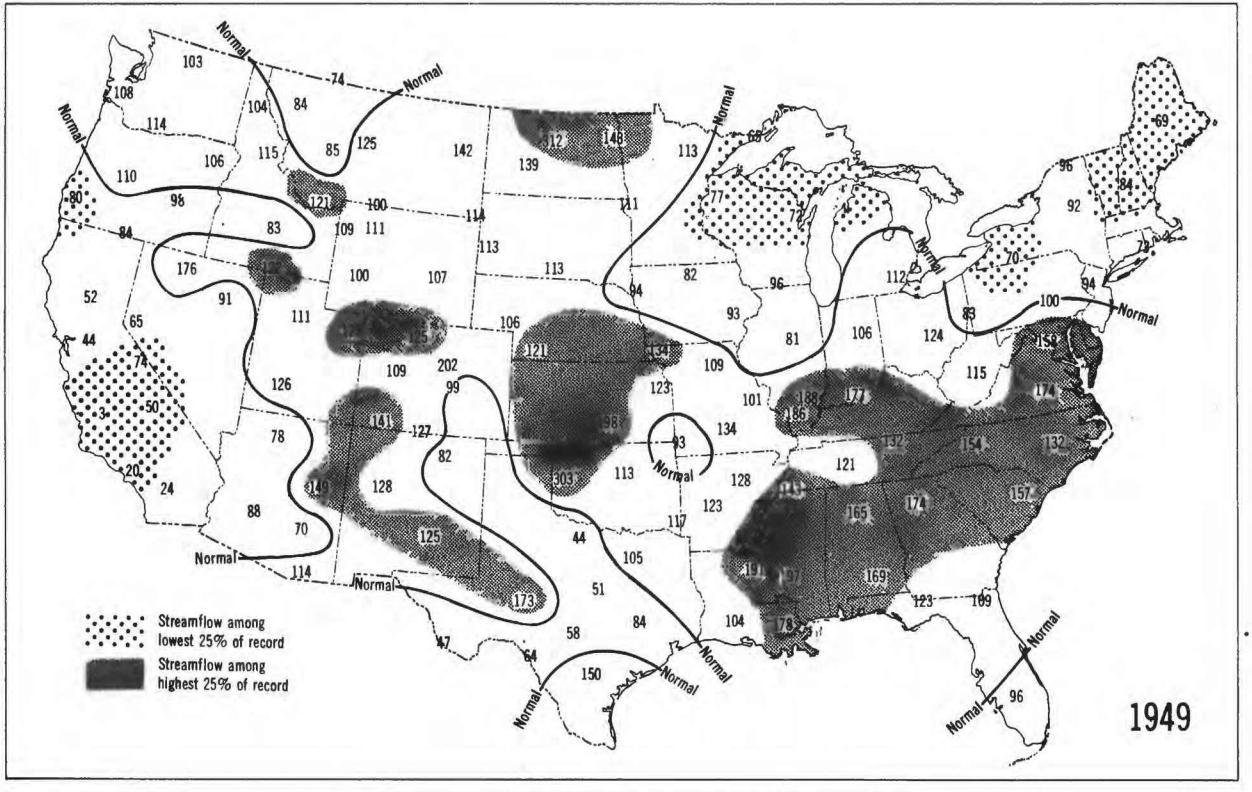

FIGURE 19.—Annual runoff, in percent of normal, for the water year 1949.

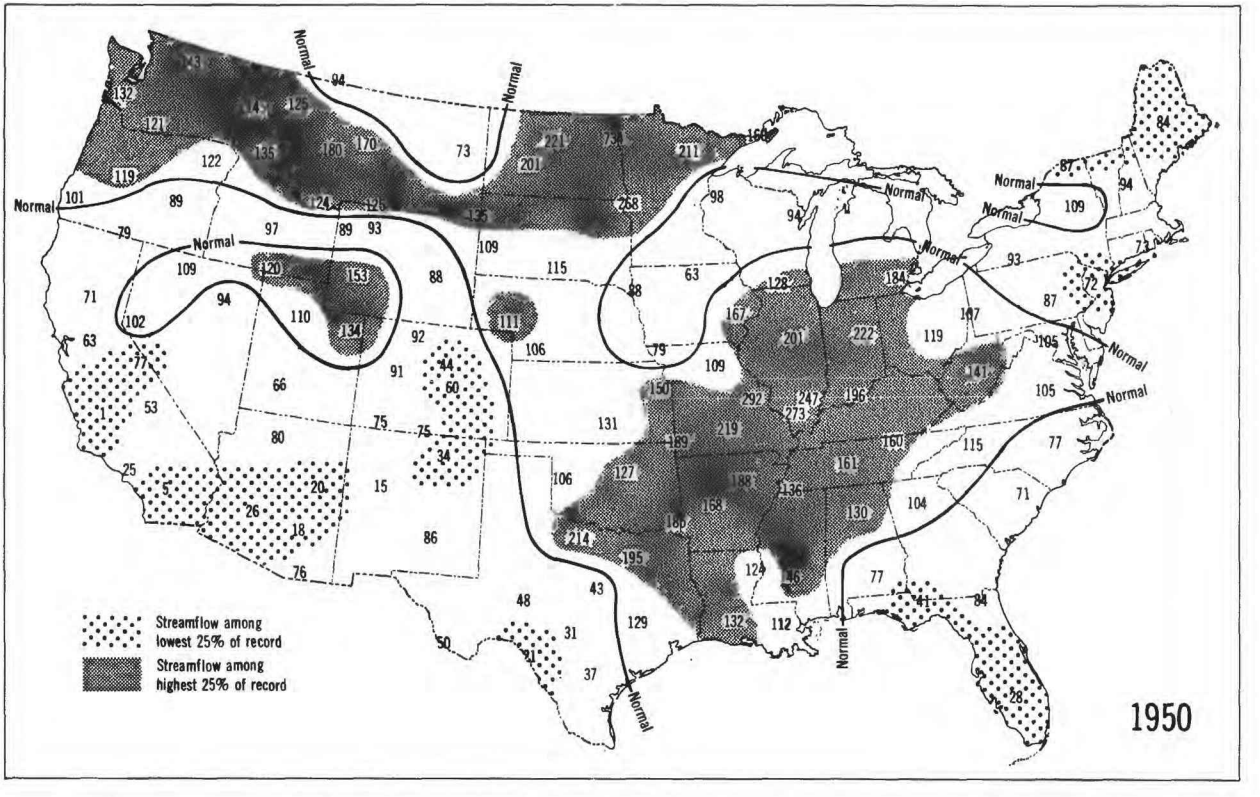

FIGURE 20.—Annual runoff, in percent of normal, for the water year 1950.

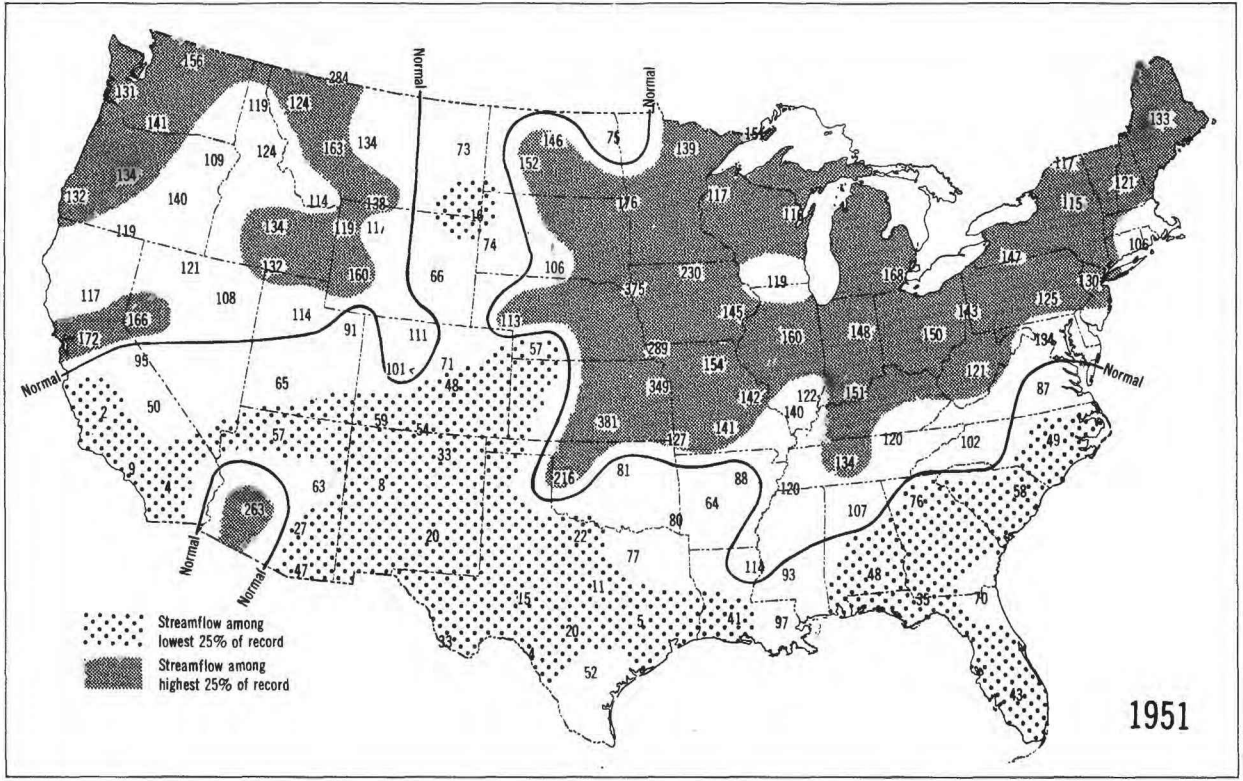

FIGURE 21.—Annual runoff, in percent of normal, for the water year 1951.

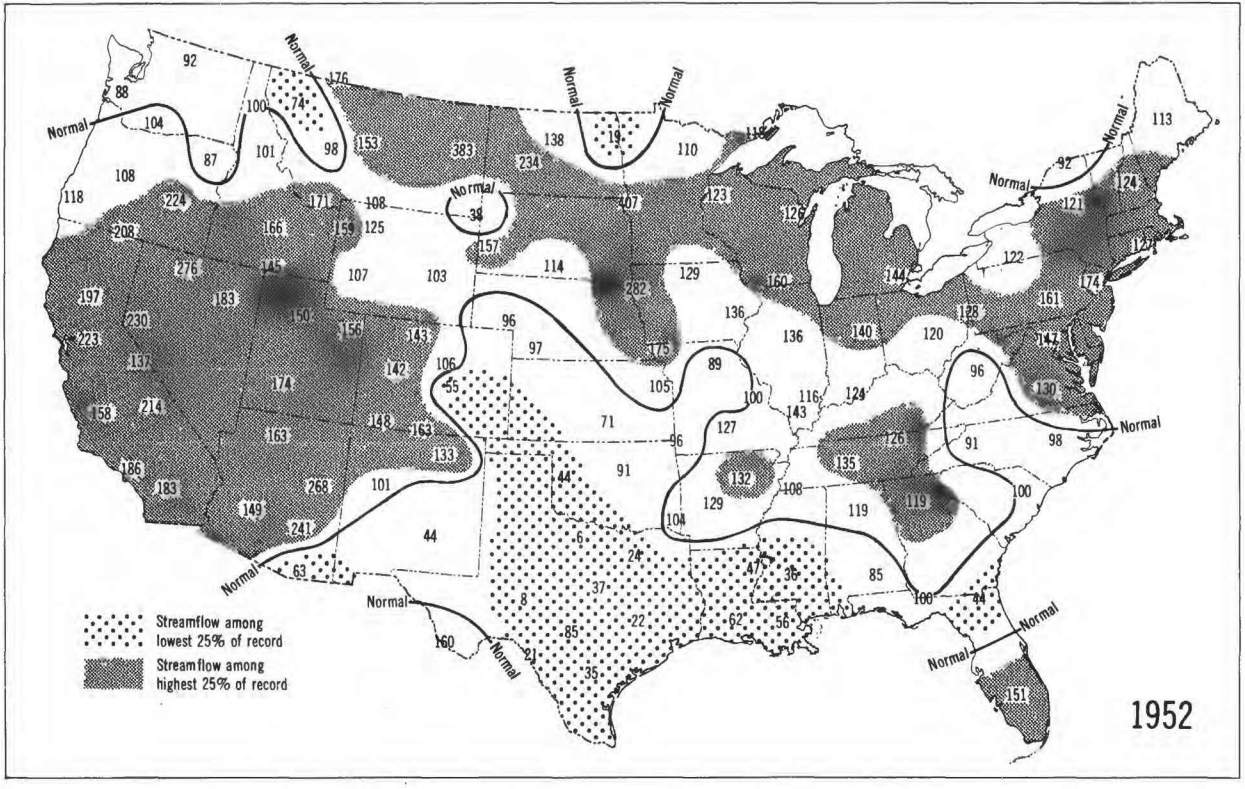

FIGURE 22.—Annual runoff, in percent of normal, for the water year 1952.

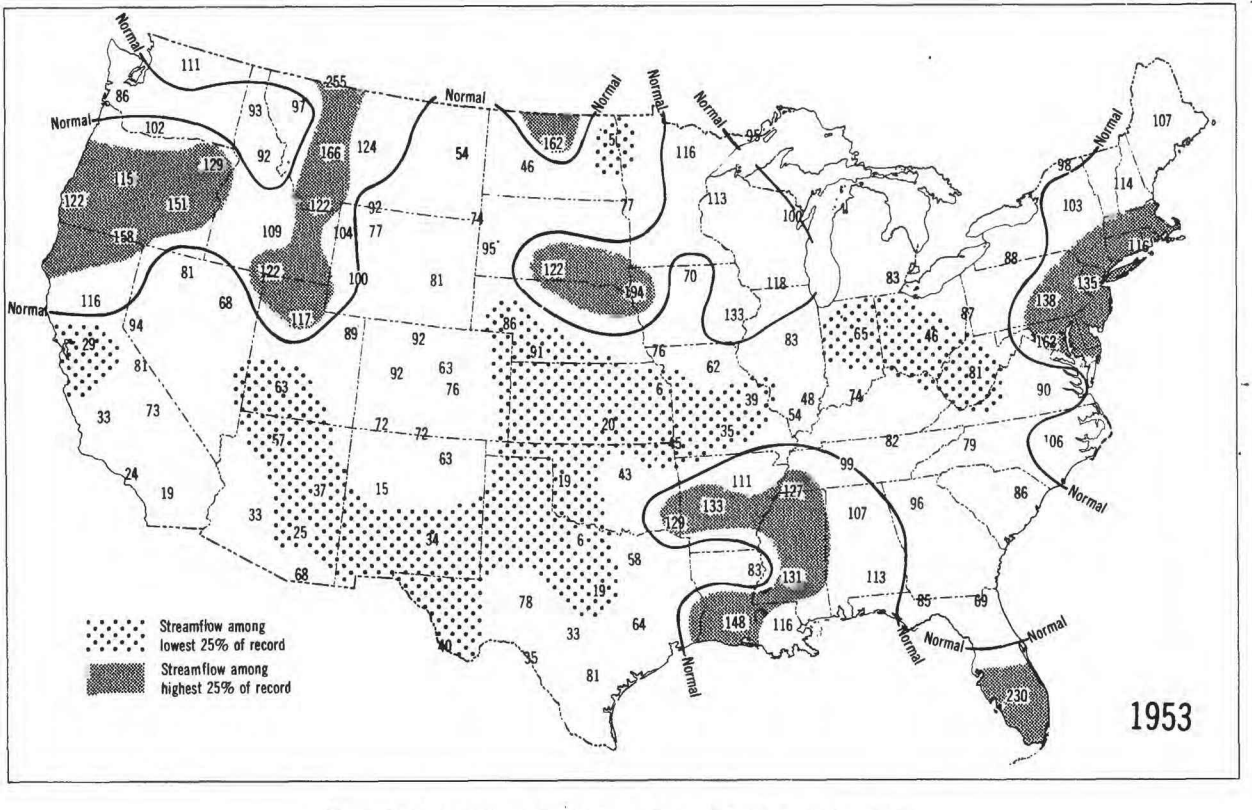

FIGURE 23.—Annual runoff, in percent of normal, for the water year 1953.

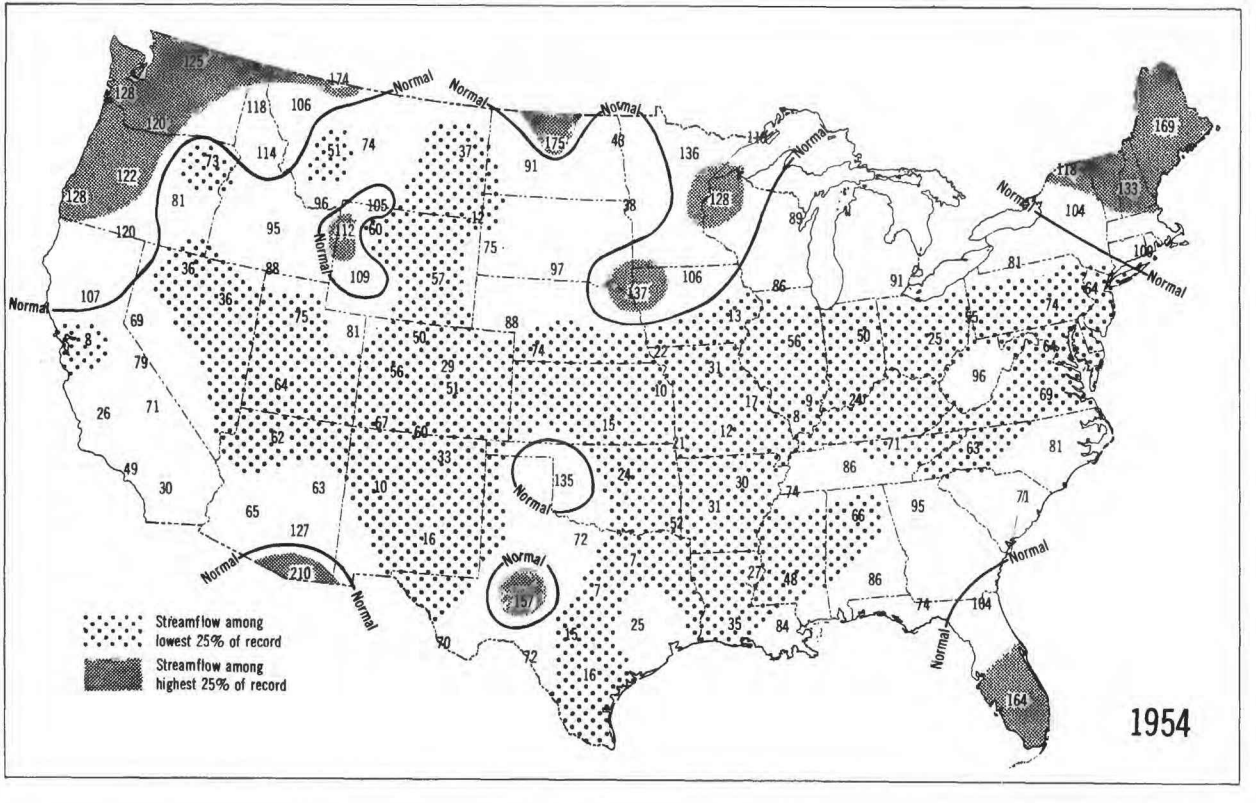

FIGURE 24.—Annual runoff, in percent of normal, for the water year 1954.

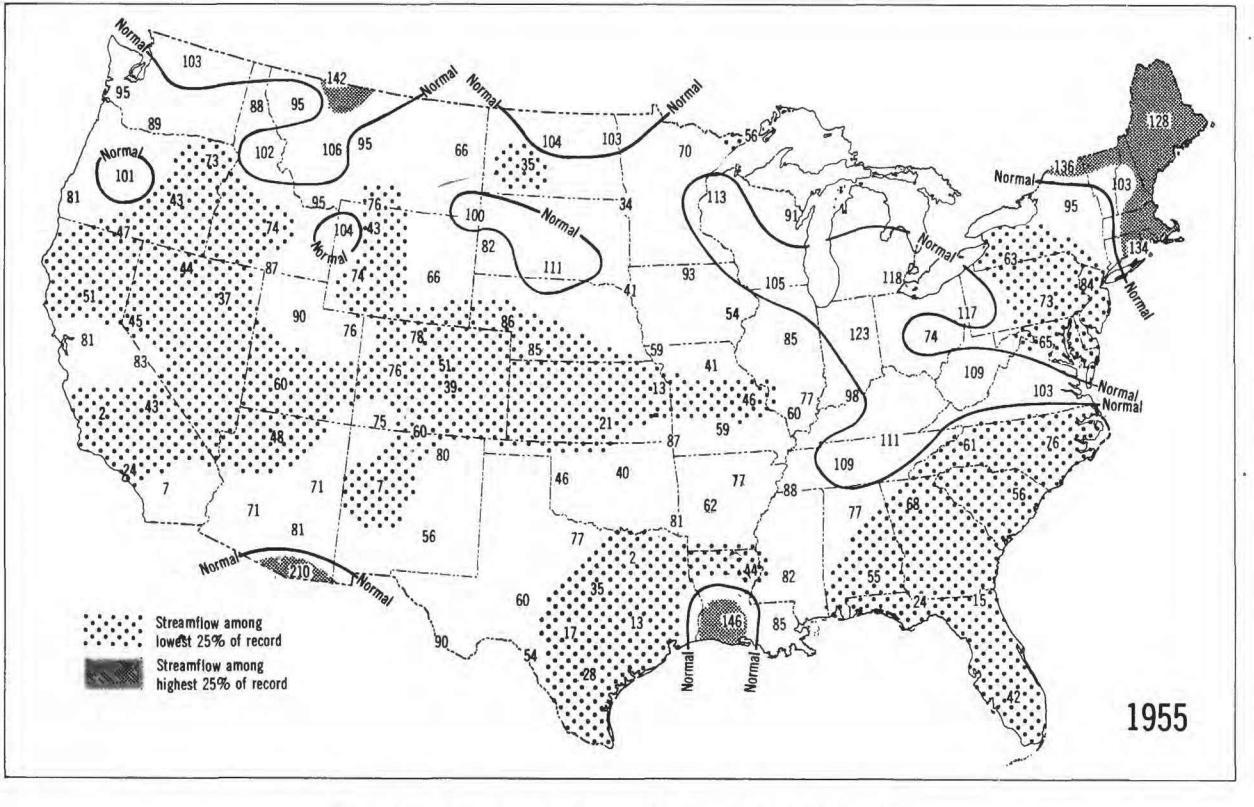

FIGURE 25.—Annual runoff, in percent of normal, for the water year 1955.

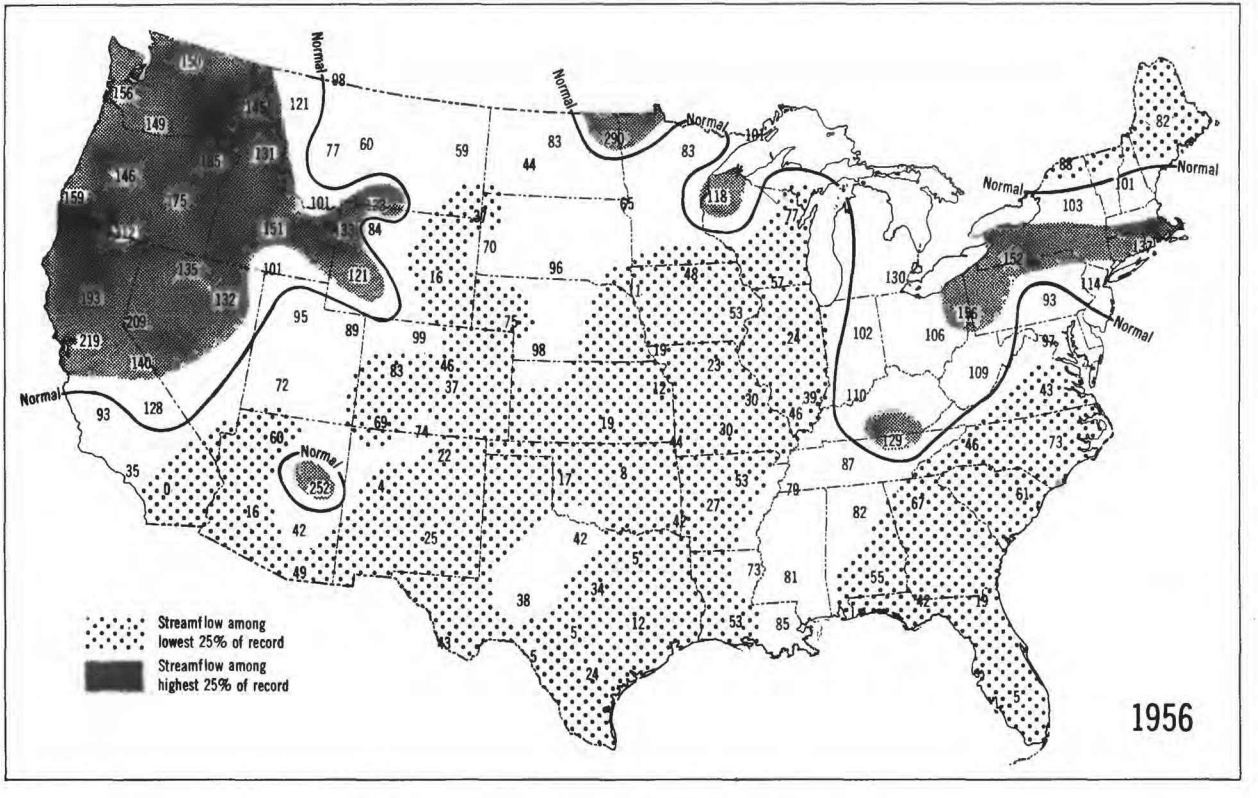

FIGURE 26.—Annual runoff, in percent of normal, for the water year 1956.

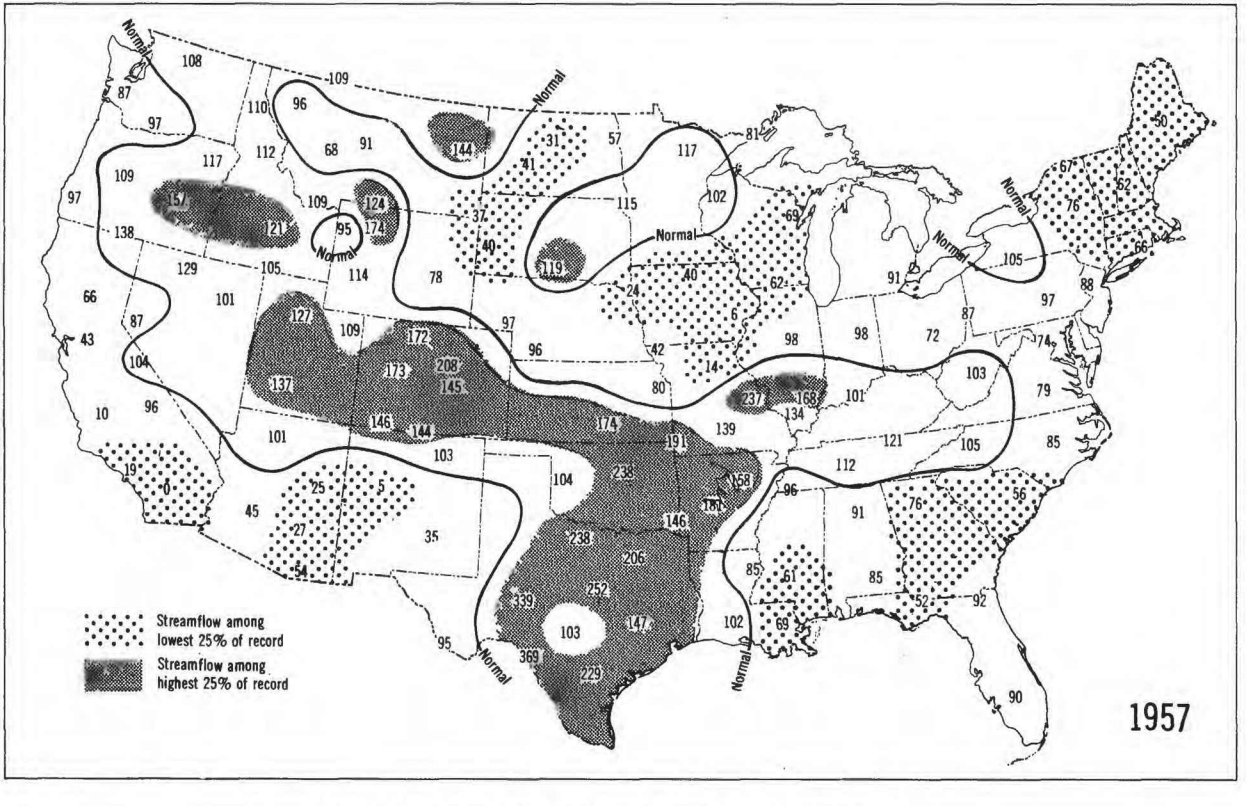

FIGURE 27.—Annual runoff, in percent of normal, for the water year 1957.

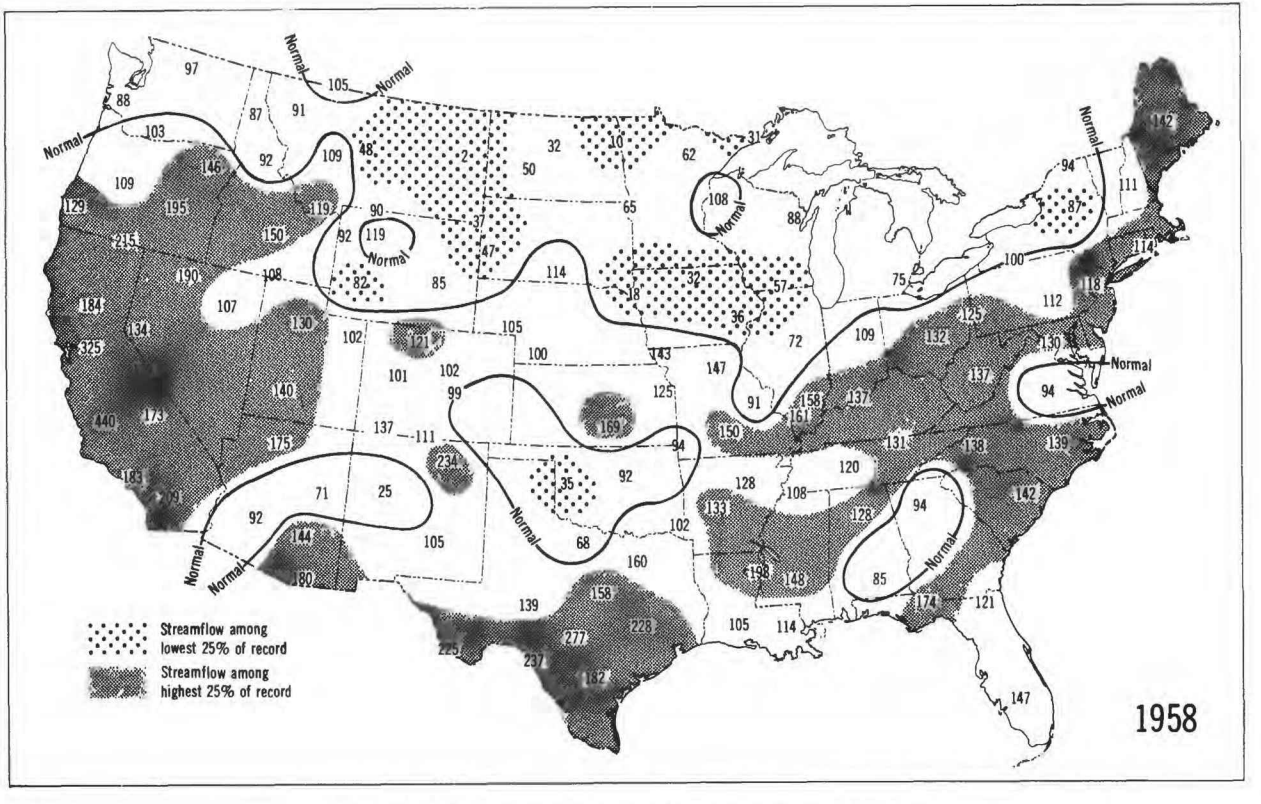

FIGURE 28.—Annual runoff, in percent of normal, for the water year 1958.

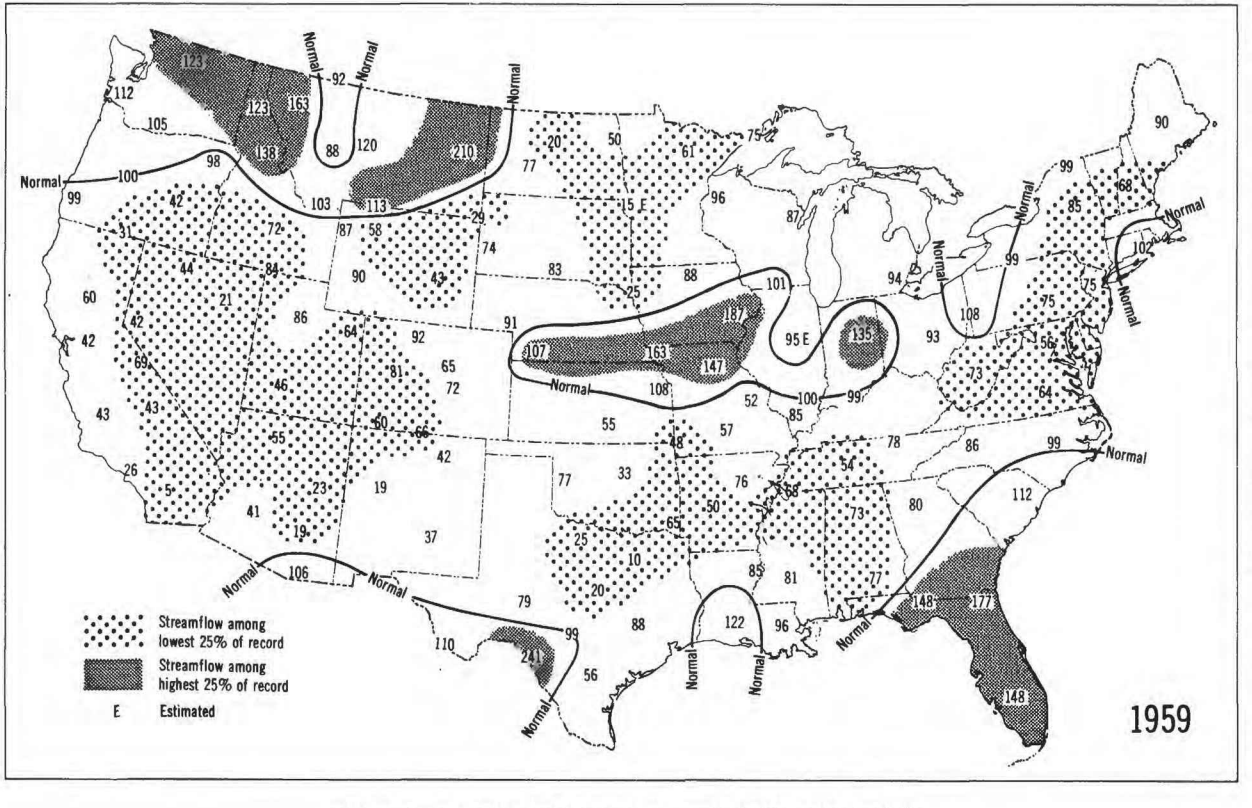

FIGURE 29.—Annual runoff, in percent of normal, for the water year 1959.

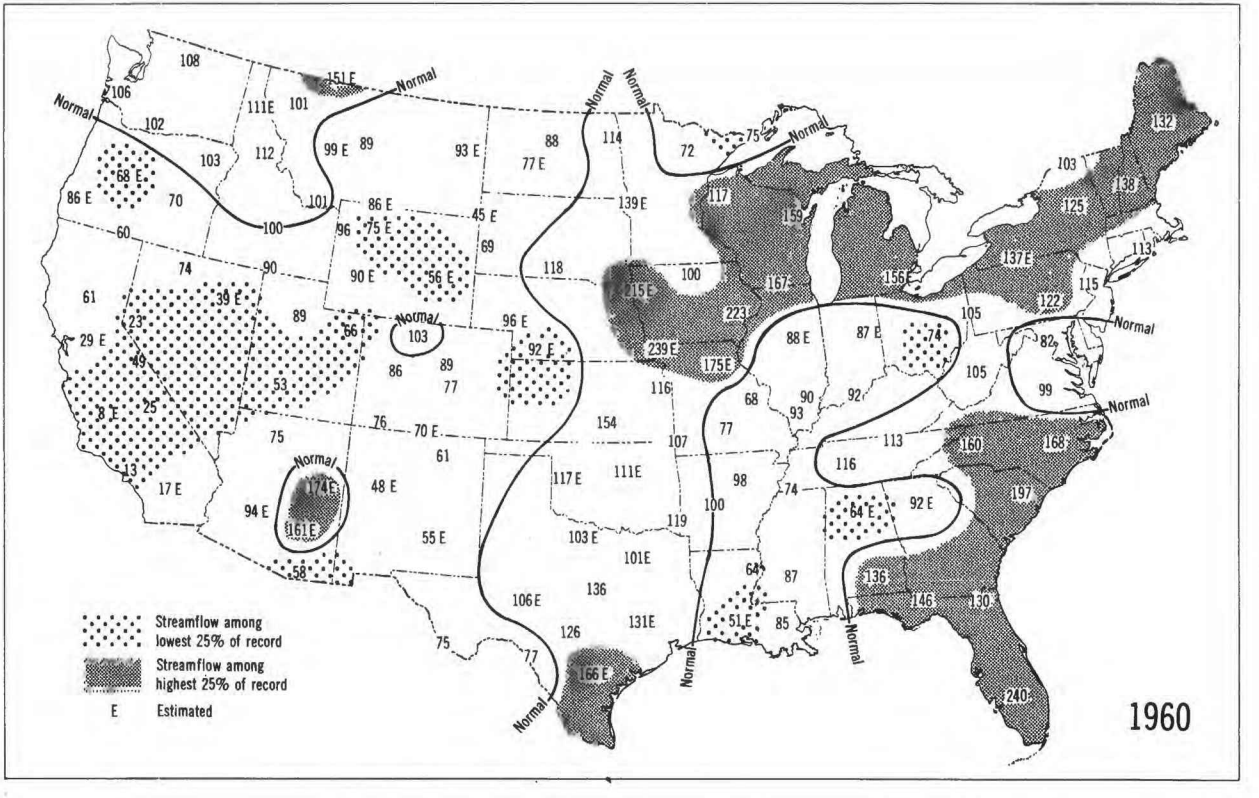

FIGURE 30.—Annual runoff, in percent of normal, for the water year 1960.

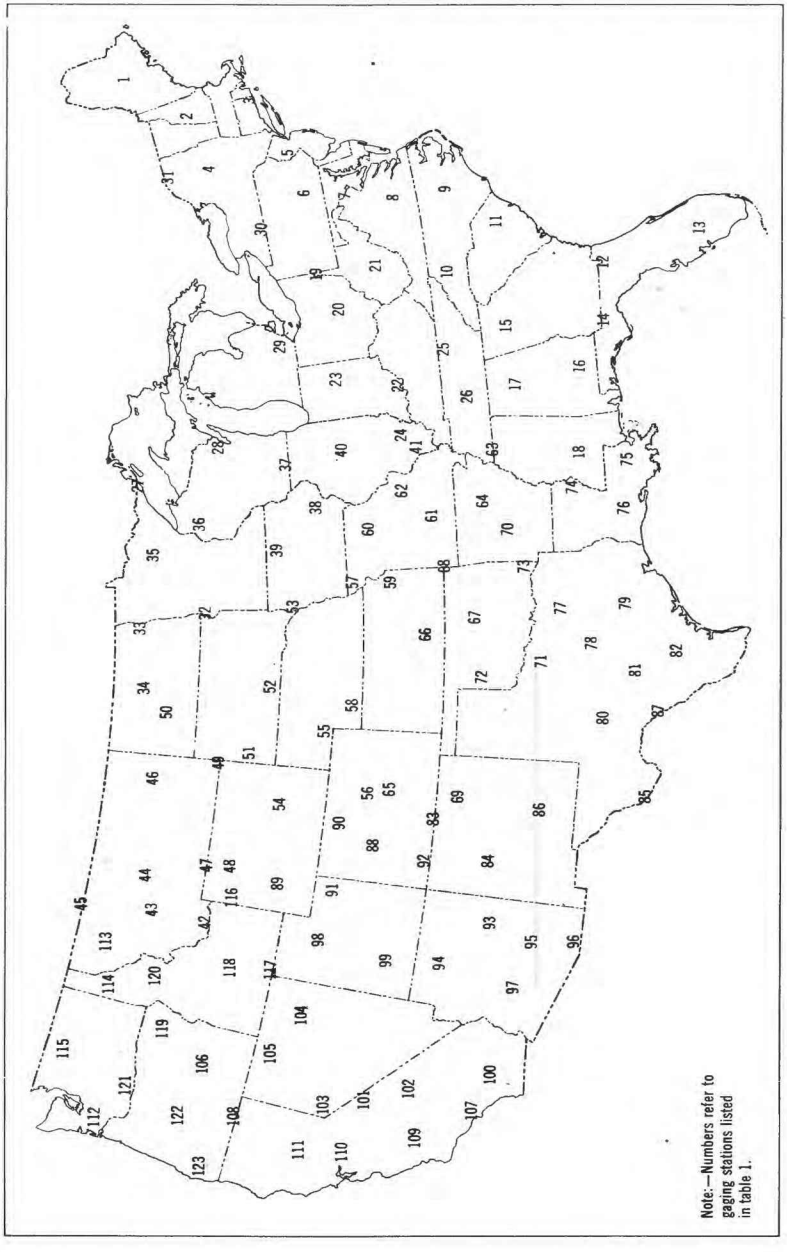

FIGURE 31.—Location of gaging stations used in this report.

records that did not span the entire 1931–60 period were extended by using the required record from a nearby station on the same stream if the drainage areas at the two sites differed by less than 15 percent. Records extended in that way were adjusted on the basis of the ratio of their drainage areas to make them comparable.

The normals used in this report are arithmetic means. The arithmetic mean allows the use of the map of mean annual runoff in conjunction with these maps. A study was made comparing the mean and median at the 123 stations. For almost two-thirds of the country the difference between the mean and median is small, and in only about one-sixth of the country is the difference greater than 25 percent. Either, therefore, could have been used with only little difference in the results, but the mean allows mathematical computations when compared with the map of annual runoff.

The lines of normal runoff separate the regions in which runoff was above normal from those in which runoff was below normal. In accordance with the procedures in the Water Resources Review, runoff for any given year was defined as excessive if among the highest 25 percent of record and deficient if among the lowest 25 percent of record. To determine the years excessive and deficient in runoff at any gaging station used for this report, the 30 annual events were ranked at follows: The highest 7 were called excessive and the lowest 7 were called deficient. The runoff at any gaging station, therefore, is called normal for 50 percent of the years, excessive for 25 percent, and deficient for 25 percent. The areas of excessive runoff are shown on the maps by dark shading and the areas of deficient runoff by light shading.

In order to have a full set of 30 values for each gaging station, it was necessary to estimate some annual runoff figures. At most stations, where estimates were needed, only 1 or 2 years were estimated. Seventy stations did not require estimates and 26 needed only one. Only 4 percent of the total 3,690 station years were estimated.

REGIONAL VARIATIONS IN RUNOFF

The country was divided into nine regions (fig. 32), which were delineated by gaging stations having similar patterns of annual runoff. The number of such stations within each region ranged from 9 to 20. The mean discharge for the period 1931–60 was computed for each station, and the yearly discharges, expressed in percent of the 30-year mean, were averaged within each region. These averages are plotted in figure 33 to depict the yearly variation in runoff within each region. An interesting fact shown by figure 33 is the variability of the runoff from year to year. For example, in the Lower Plains the percentages range from 18 percent to 211 percent.

Table 3 gives the average standard deviations of the percentage of annual runoff for each region. Because these percentages are approximately normally distributed, about two-thirds of the annual discharges will be within one standard deviation on each side of the mean. For example, the standard deviation for the Midwest region is 35 percent, or about two-thirds of the annual discharges within the region are within 35 percent of the mean. Figure 33 also shows how few prolonged periods of either above or below normal runoff there are for several of the regions. The Northeast, South, and Northwest regions alternate above and below the mean almost each year. The Upper Plains region, however, has basically only three different periods, 2 below and 1 above the mean. The Southwest has been below the mean almost continuously since 1945.

Several years are of special interest. Both 1931 and 1940 were below the mean for all regions; and 1934, 1939, 1954, 1955, and 1959 were below the mean for all but one region. There were no years when all regions were above normal; but in 1938, 1943, 1951, 1952, and 1958 all but two regions were above normal. For the country as a whole, 1934 had the lowest average percentage, only 56 percent, and 1942 had the highest, 129 percent; 1934 had the least variation and 1941 had the most variation. The whole period from 1941 through 1952 was above normal and the period from 1953 through 1956 was below, the wettest and dryest periods, respectively, between 1931 and 1960. Table 4 gives the average and the standard deviation for each year for the conterminous United States. These are the averages of the regional figures.

MONTHLY DISTRIBUTION OF RUNOFF

Figure 34 shows the normal distribution of runoff by months at selected gaging stations. The monthly percentages were computed by averaging the discharges for each month and then expressing them as a percentage of the mean annual flow for the period 1931–60. These

TABLE 3.—*Regional standard deviations of annual runoff for the conterminous United States, in percent*

Region	Number of stations in region	Standard deviation (percent)
Northeast	12	20
South	20	35
Midwest	17	35
Upper Plains	13	70
Lower Plains	12	75
Rocky Mountains	17	35
Southwest	12	75
Great Basin	11	35
Northwest	9	25
Average	123	50

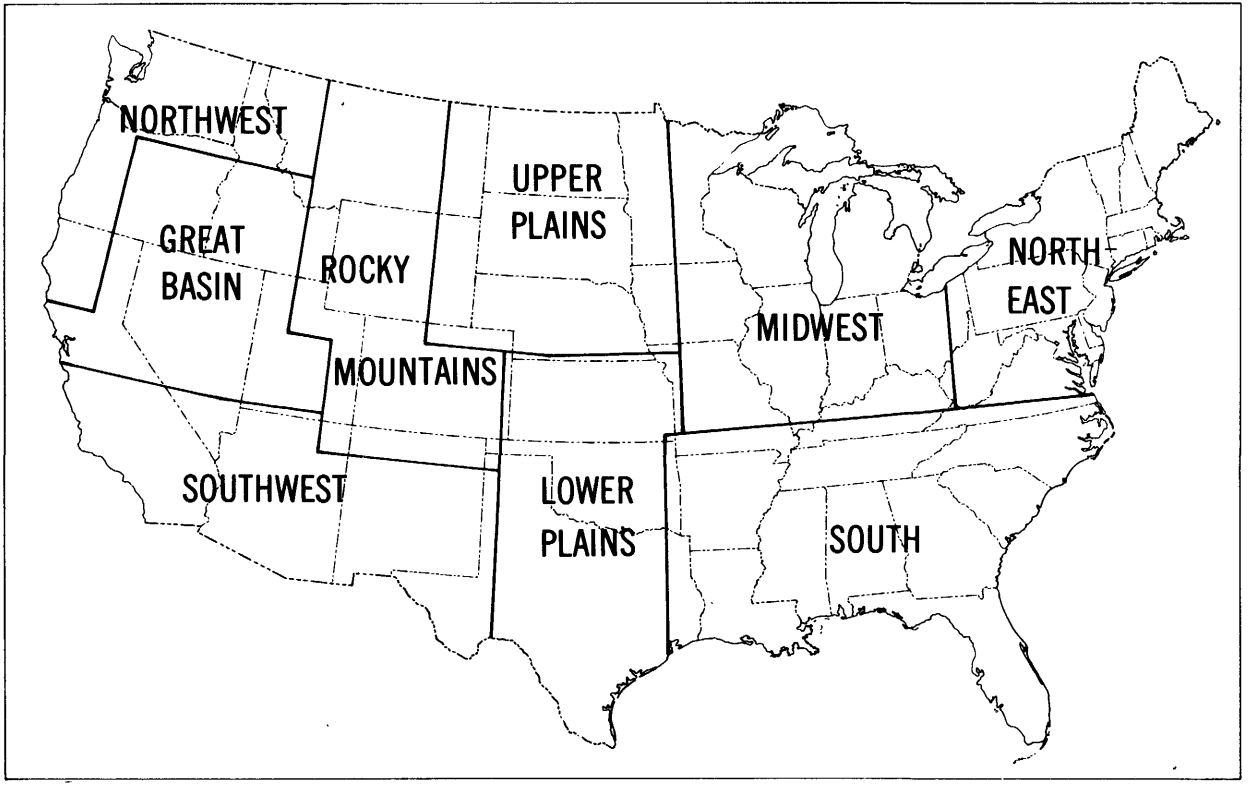

FIGURE 32.—Regional divisions of the conterminous United States.

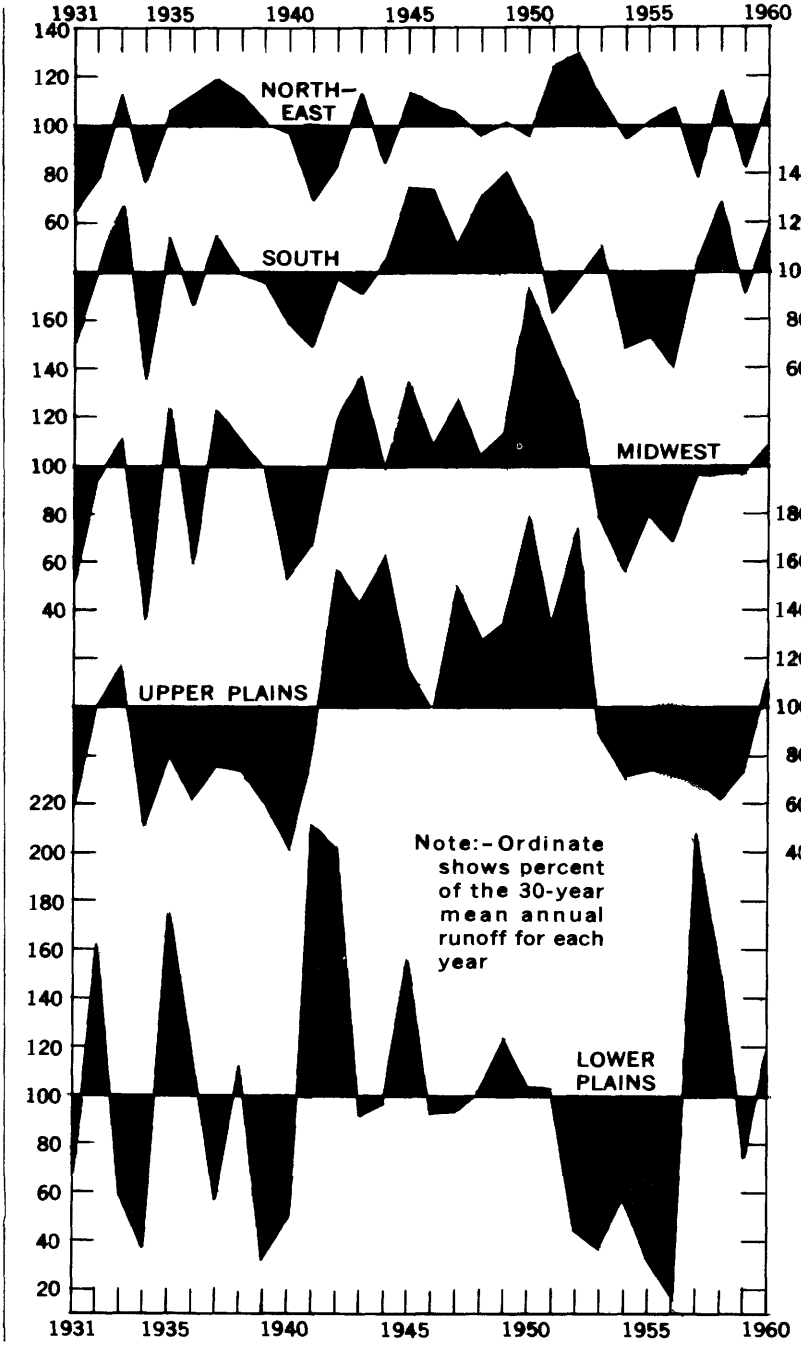

FIGURE 33.—Yearly regional variations in runoff.

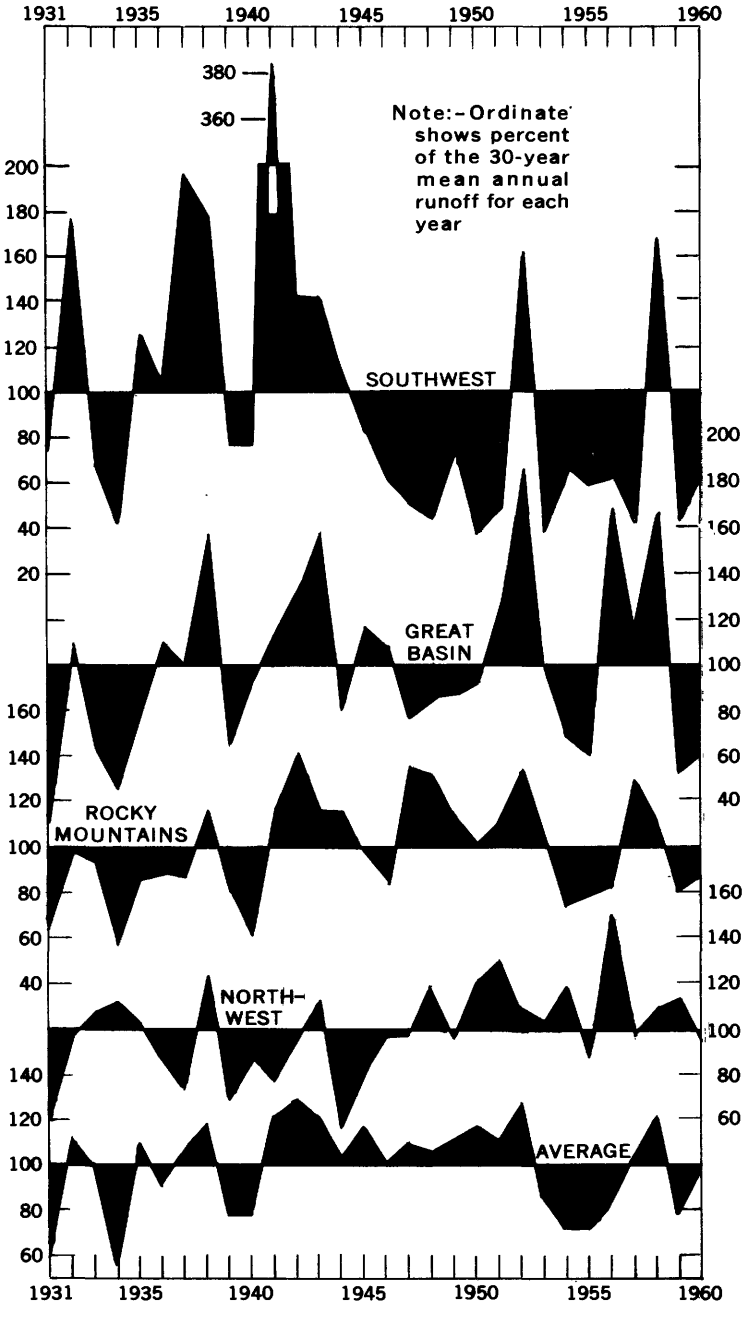

FIGURE 33.—Continued.

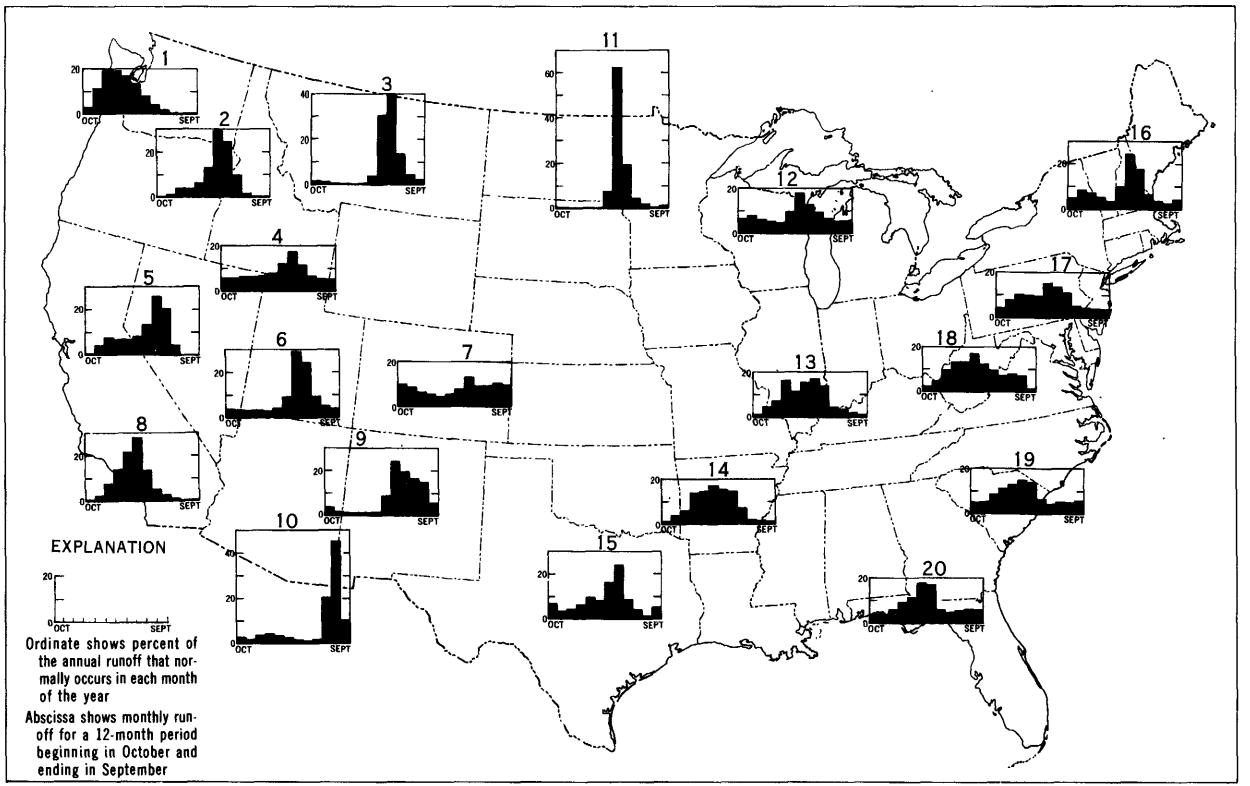

FIGURE 34.—Normal monthly distribution of runoff.

1. Chehalis River near Grand Mound, Wash.
2. Grande Ronde River at La Grande, Oreg.
3. Judith River near Utica, Mont.
4. Trapper Creek near Oakley, Idaho.
5. Carson River near Fort Churchill, Nev.
6. Beaver River near Beaver, Utah.
7. Lion Creek near Halfway, Colo.
8. Arroyo Seco near Pasadena, Calif.
9. Bluewater Creek near Bluewater, N. Mex.
10. San Pedro River at Charleston, Ariz.
11. Park River at Grafton, N. Dak.
12. Oconto River near Gillett, Wis.
13. Skillet Fork at Wayne City, Ill.
14. Petit Jean Creek at Danville, Ark.
15. North Bosque River near Clifton, Tex.
16. Pemigewasset River at Plymouth, N.H.
17. Swatara Creek at Harper Tavern, Pa.
18. Gauley River near Summersville, W. Va.
19. Lynches River at Effingham, S.C.
20. Ochlockonee River near Havana, Fla.

TABLE 4.—*Average and standard deviation of mean annual runoff, in percent*

Year	Average	Standard deviation	Year	Average	Standard deviation	Year	Average	Standard deviation
1931	61	31	1941	122	80	1951	111	65
1932	111	50	1942	129	72	1952	127	54
1933	98	39	1943	121	50	1953	87	35
1934	56	26	1944	103	54	1954	73	42
1935	110	49	1945	117	37	1955	73	30
1936	91	49	1946	101	33	1956	83	44
1937	106	49	1947	110	41	1957	105	46
1938	117	61	1948	106	55	1958	122	53
1939	79	23	1949	112	42	1959	80	26
1940	78	28	1950	117	71	1960	100	38

graphs show some patterns of runoff but may not represent what happens at any stream in the area. Many other patterns could be shown, such as the high flows in the fall and low flows in the spring in the Florida Peninsula or the extremely uniform flows in the Sand Hills of Nebraska.

It is interesting to note the seasons in which the maximum monthly discharge occurs. Starting in the Southeast where most of the high flows occur in February and March and progressing north and west to the Rocky Mountains where the high flows occur in May and June, there is a tendency for most of the flow to occur within progressively shorter periods. The shortest period of maximum flow occurs in the northern Great Plains. In the Park River in North Dakota more than 60 percent of the flow occurs in 1 month. Also worth noting are the high winter flows along the Pacific Coast, as shown by the Chehalis River in Washington, and the two high-water periods in the southern intermountain region as shown by the San Pedro River in Arizona.

EXCESSIVE AND DEFICIENT RUNOFF

Table 5 shows the percentage of area of the conterminous United States that was classified excessive or deficient in runoff each year. This table is another way of indicating the variation in runoff. There are no years when runoff was neither excessive nor deficient. The averages for the country as a whole for the period 1931–60 are: 18 percent deficient, 16 percent excessive, and 66 percent normal. These figures are exactly the same as for the period 1921–45 (Harbeck and Langbein, 1949), even though the individual years varied greatly.

Noteworthy deficiencies in runoff occurred in the years 1931 and 1934. More than two-thirds of the country was deficient in runoff in 1934, and more than one-half was deficient in 1931. There is no out-

standing wet year, although in 1952 more than one-third of the country had excessive runoff. Two years, 1939 and 1946, were notable because of the small amount of excessive and deficient runoff; the runoff was classified as normal over 80 percent of the country for both years.

Local variations from the nationwide pattern can be seen on almost every map. For example, in 1934 the Pacific Northwest had excessive runoff in contrast to most of the rest of the country, which had deficient runoff. The excessive and deficient runoff areas for 1932 and 1957 are intermixed and therefore are examples of no large regional pattern.

TABLE 5.—*Percent of area of the conterminous United States with deficient and excessive runoff*

Year	Deficient	Excessive	Year	Deficient	Excessive
1931	53	1	1948	12	16
1932	8	19	1949	6	18
1933	12	14	1950	7	25
1934	67	3	1951	18	27
1935	8	16	1952	11	35
1936	17	8	1953	16	9
1937	8	22	1954	39	5
1938	4	18	1955	31	1
1939	17	1	1956	38	15
1940	36	1	1957	13	15
1941	29	24	1958	8	27
1942	9	27	1959	30	6
1943	5	27	1960	10	13
1944	13	12			
1945	4	24	1931–60 average	18	16
1946	7	12			
1947	8	22			

Figures 35 and 36 show the maximum and minimum annual runoff, in percent of normal, for the 30-year period. The maximum annual runoff ranges from 115 percent of normal in Nebraska to more than 700 percent of normal in North Dakota and is more than 600 percent of normal in the Southwest. The minimum annual runoff ranges from 75 percent of normal in Nebraska to zero in Montana, Minnesota, and California.

The regions of greatest maximum percent of normal flow are the Upper Plains, the Southwest, and Southern California, whereas the regions of lowest minimum percent of normal flow include almost all the Plains States and Southern California. The maps are similar in pattern but opposite in values. The regions of highest maximum percent of normal runoff are generally the regions of lowest minimum percent of normal runoff and vice versa.

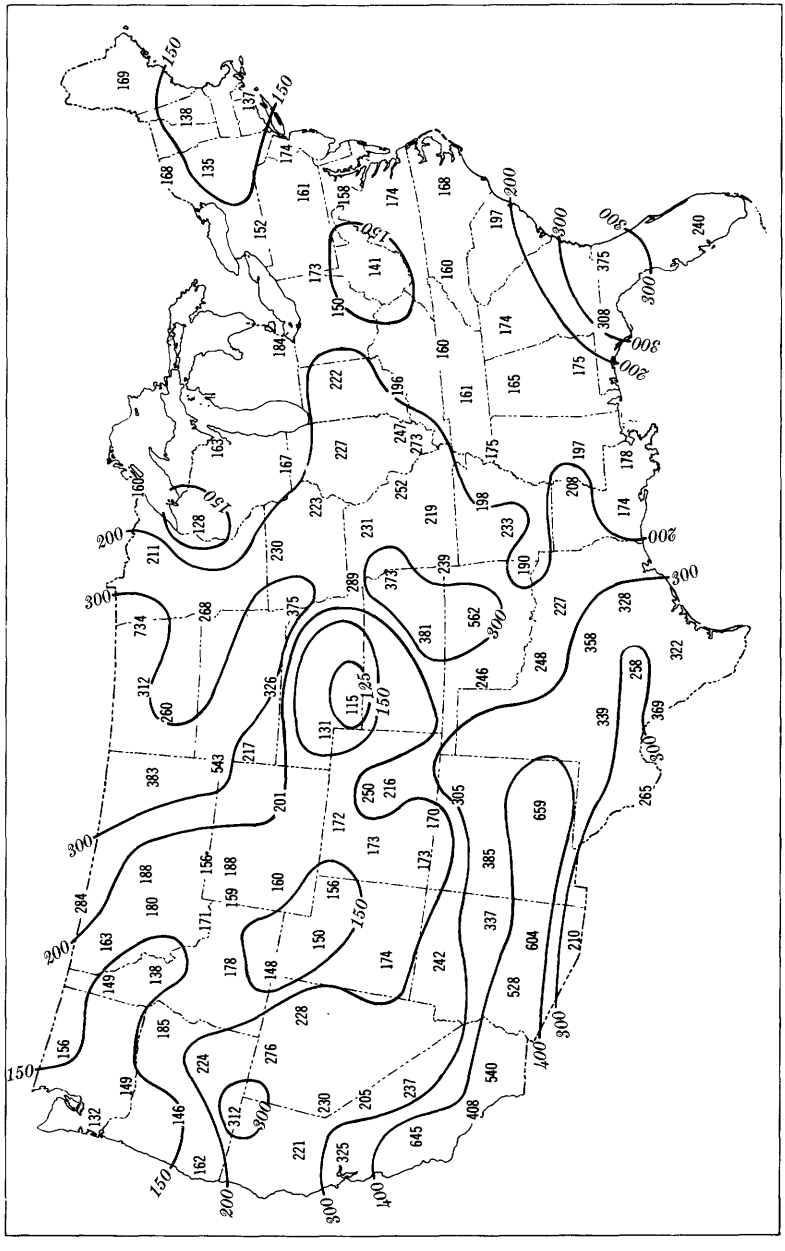

FIGURE 35.—Maximum annual runoff, in percent of normal, for the period 1931–60.

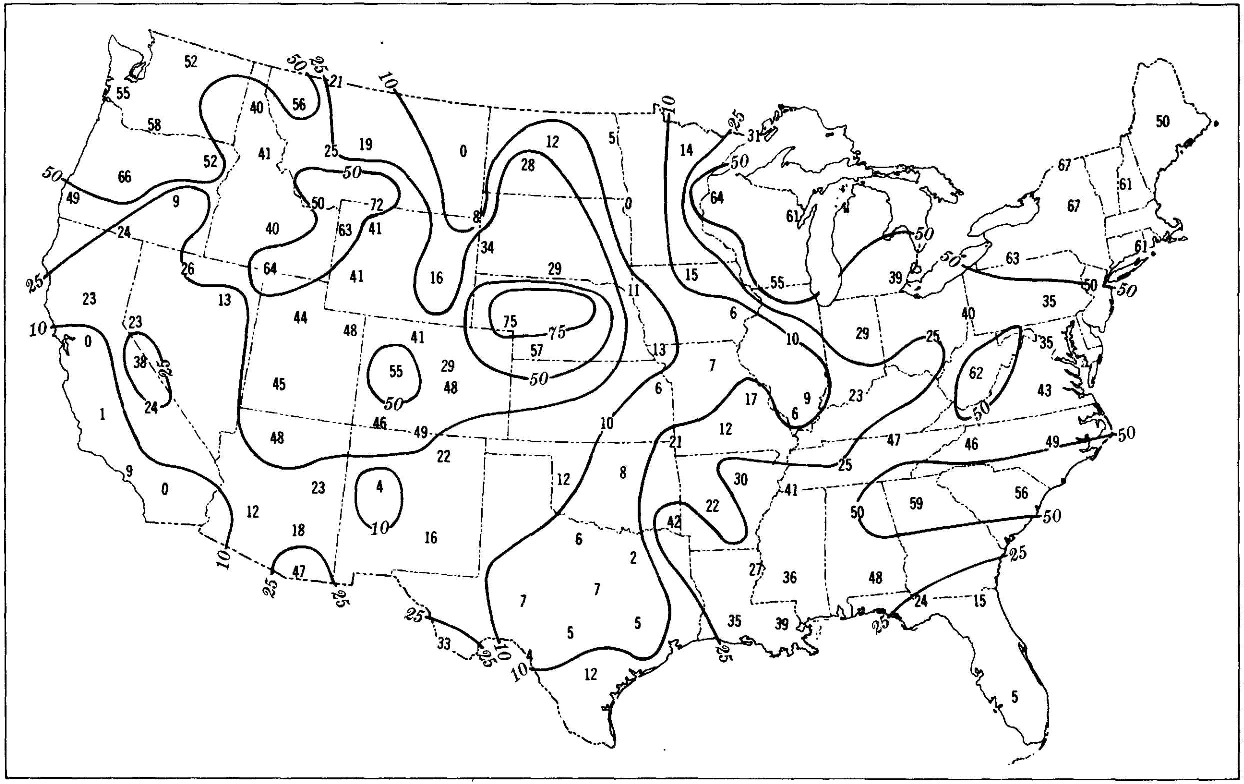

FIGURE 36.—Minimum annual runoff, in percent of normal, for the period 1931–60.

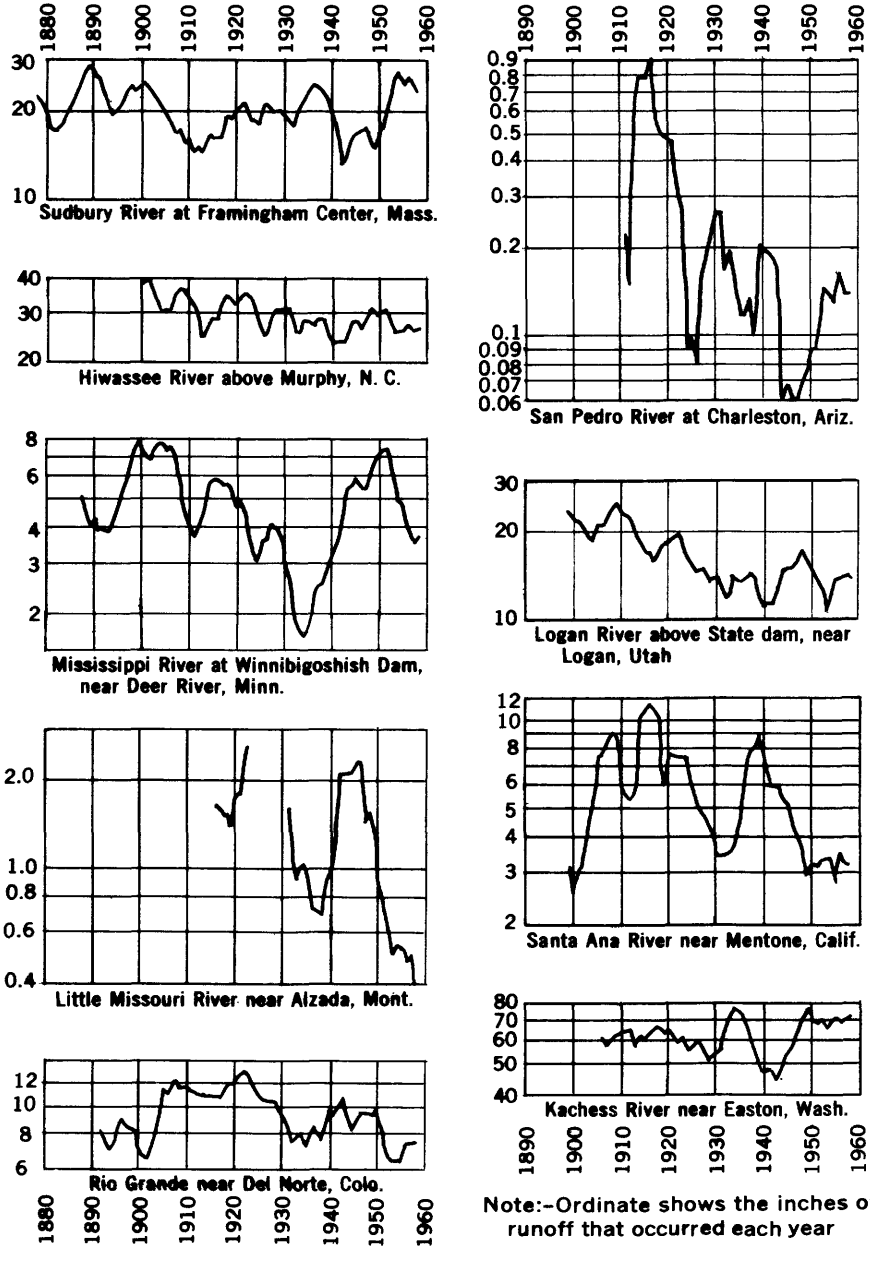

FIGURE 37.—Long-term trends in runoff.

The maximum annual discharge is less than twice the mean for most of the conterminous United States east of the Mississippi River and in a broad band from Colorado and Nebraska to the Pacific Northwest. The minimum annual discharge is at least one-half the mean for a much smaller area in the Northeast, Southeast, Upper Midwest, and scattered areas in Nebraska, Colorado, Idaho, and the Pacific Northwest.

LONG-TERM TRENDS IN RUNOFF

The runoff during the period 1931–60 agrees with that from the 50-year period 1911–60, except in the Central and Lower Plains and in the Southwest, where at places it has been considerably less (fig. 37). For most of the conterminous United States, except the Central and Lower Plains and the Southwest, the runoff during the 30-year period is slightly more than that during the previous base period, 1921–45. Table 5 shows the comparison of the 1931–60 period with the 1921–45 and the 1911–60 periods for 25 selected long-term stations and comparisons with the 60-year, 75-year and 85-year periods for a few stations. A comparison of the mean annual runoff for the base periods 1931–60 and 1921–45 shows no persistent difference between them. Furthermore, although the mean annual runoff during the two base periods was a little less than during the 50-year period 1911–60 at most of the 25 stations used in the comparison, neither base period seems to have a marked advantage over the other with respect to being more representative, nationwide, of the longer-term period.

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