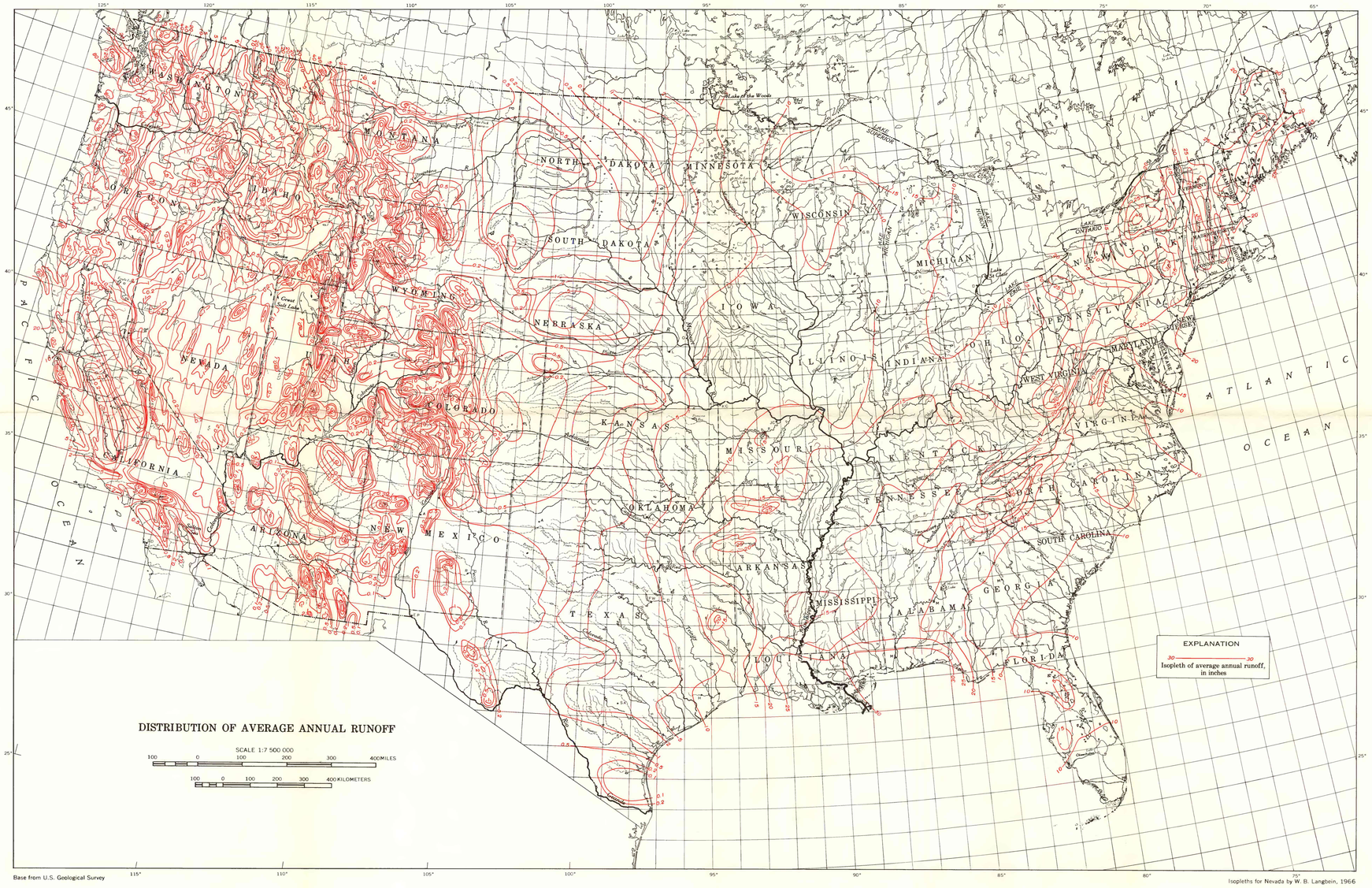

ANNUAL RUNOFF IN THE CONTERMINOUS UNITED STATES

By Mark W. Busby

INTRODUCTION

Runoff is that part of precipitation that appears as a flow of water in surface streams. As a source of water for modern society, it constitutes one of our basic renewable resources. The map of average annual runoff portrays the latest information on the geographic distribution of the average runoff in surface streams.

The collected flow from a watershed, as measured at gaging stations, is expressed on the map in terms of average inches depth per year. When expressed in inches, runoff represents an average depth over the basin. The map is drawn to show runoff at the place of origin--where runoff first collects into stream channels--rather than at point of measurement. In these terms the map is directly useful in hydrologic studies involving comparison of runoff with climatic or geologic characteristics of the terrain. The map is not intended to provide a means for estimating the flow of any specific stream. For that purpose, more information can be obtained from the wealth of streamflow data that has been collected by the U.S. Geological Survey.

The map displays the pattern of the distribution of runoff over the country. Runoff ranges from near zero in Great Salt Lake Desert to more than 160 inches in the Olympic Peninsula. Runoff is 10 inches or more in the third of the country that enjoys a humid climate; it ranges from 1 inch to 10 inches in the third that has a subarid or semiarid climate; it is less than 1 inch in the arid third of the country. This map updates the map by Langbein (1949) for the period 1921-45.

PREPARATION OF MAP

The map of annual runoff is based as far as possible on records of streamflow. About 16,000 gaging stations have been operated in the United States at one time or another, with about 8,000 stations being operated currently. However, relatively few of these stations can be used to define the map. A large number, particularly in the West, are not usable because of excessive diversions for irrigation; many are on streams that drain areas too large; and others are so close together on the stream as to represent essentially a single measuring point. Gaging stations were selected by the following criteria:

1. Drainage area between 1 and 1,500 sq mi.
2. Diversions to outside the basin less than 10 percent of the flow, or consumptive use by irrigation within the basin less than 10 percent of the annual runoff.
3. Drainage area of a downstream station more than twice that of an upstream station on the same stream.

After the elimination of stations that did not meet those criteria, about 2,000 stations remained, of which 882 had records that covered the 30-year base period 1931-60, 214 stations had records of 15 years or more for which mean flow could be readily adjusted to the selected 30-year base, and about 1,000 stations had records of at least 5 years, which were used without adjustment in regions where data were otherwise sparse and runoff highly irregular.

The mean runoff at each of the selected stations was entered in proper location within the contributing drainage basin on a base map of the United States. Where there was more than one qualified station on the same stream, the runoff figure was computed for the intervening area by subtracting the flow at the upstream station from that at the downstream station.

The runoff isopleths were drawn so they would give a figure for the average runoff in each basin that would agree with the runoff indicated by the gaging station. Isopleths in the mountainous regions where runoff and elevation are closely related and where there are few streamflow records, were based largely on the elevation, partly on the distribution of precipitation, and partly on the known characteristics of streams in the area. The isopleths in central and southern Nevada are based almost entirely upon such supplemental information.

The accuracy of definition of the map of runoff is highly variable. In general, the accuracy is proportional to the density of gaging stations and inversely proportional to the spatial variability of the runoff. Hence, the isopleths are less accurate in the mountain and intermontane regions of the west than in the eastern part of the country.

Table 1 shows density of gaging stations having at least 15 years of record used in preparing the map. The part numbers refer to the U.S. Geological Survey 1950 compilation series, Water-Supply Papers 1301 to 1318 (see fig. 1).

Table 1.—Distribution of station records by geographic areas

Part No.	No. of stations			Area (sq mi)	Gaged area used for map			Area per station (sq mi)
	Full term	Partial term	Total		Square miles	Percent	Average drainage area of stations (sq mi)	
1A	89	1	90	61,780	26,770	43	297	686
1B	111	3	114	90,120	31,190	35	274	791
2A	63	7	70	100,350	29,120	29	416	1,434
2B	10	41	51	179,050	28,760	16	553	3,511
3A	83	12	95	149,540	39,720	27	418	1,574
3B	41	5	46	60,210	16,130	27	351	1,309
4	50	11	61	123,960	21,270	17	349	2,032
5	38	18	56	240,050	40,720	17	727	4,286
6A	12	18	30	302,030	13,410	4	447	10,068
6B	27	4	31	210,530	17,260	8	557	6,791
7	32	19	51	345,900	36,360	10	713	6,782
8	33	17	50	319,540	26,210	8	524	6,391
9	28	17	45	249,690	18,030	7	401	5,549
10	33	15	48	215,260	11,830	6	246	4,485
11A	48	5	53	55,090	7,770	14	147	1,039
11B	49	4	53	61,000	12,570	21	237	1,151
12	50	7	57	85,000	19,200	23	337	1,490
13	36	3	39	109,200	15,310	14	393	2,800
14	49	7	56	63,750	13,560	21	242	1,138
Total	882	214	1,096	3,022,050	425,190			
Avg.						14	388	2,757

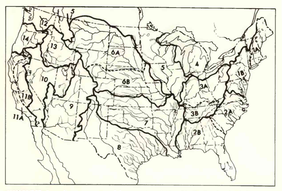

FIGURE 1.—Areas covered by parts of the U.S. Geological Survey 1950 compilation series, Water-Supply Papers 1301 to 1318.

In order to avoid inconsistencies that might result from using different periods of time and different lengths of record, a standard or base period was adopted. The 30-year period 1931 to 1960 was selected, not because of any particular hydrologic significance, but primarily to be in accord with the climatological standard period of the World Meteorological Organization. Table 2 shows a comparison of the 1931-60 period with the 1921-45 period used on the previous map, and with two longer periods.

Table 2.—Comparison of 1931-60 period with other periods

Name	Mean annual runoff, in inches			
	1931-60	1921-45	1911-60	1901-60
East Branch Penobscot River at Grindstone, Me.	23.73	22.51	23.79	- - -
Sudbury River at Framingham Center, Mass.	20.38	19.34	19.46	19.59
North Bald Eagle Creek at Beech Creek Station, Pa.	18.82	18.05	19.40	- - -
Yadkin River at Wilkesboro, N. C.	20.54	20.52	[1]20.58	- - -
Greenbrier River at Alderson, W. Va.	18.59	18.65	19.60	20.01
Hiawassee River above Murphy, N. C.	26.93	27.70	29.15	29.29
Fox River at Berlin, Wis.	9.62	10.48	10.41	10.44
Huron River at Ann Arbor, Mich.	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 R., Minn.	4.29	3.47	4.36	4.78
Apple River near Somerset, Wis.	7.03	6.85	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 Ana 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.	30.85	29.45	31.73	- - -
McKenzie River at McKenzie Bridge, Oreg.	65.07	59.98	64.78	- - -

[1] 40 years (1921-60).

Note: Mean annual runoff of Sudbury River at Framingham Center, Mass., for period 1876-1960 was 20.48 inches.

Mean annual runoff of Mississippi River at Winnibigoshish Dam, near Deer River, Minn., for period 1876-1960 was 4.85 inches.

MEAN RUNOFF IN THE UNITED STATES

Table 3 shows the areal distribution of runoff in the conterminous United States. This table was prepared by measuring the areas between isopleths on the map. The average runoff so determined is 9.4 inches.

Table 3.—Areal distribution of runoff

Runoff (inches)	Area	
	Square miles	Percent
0-.1	240,000	7.9
.1-.2	185,000	6.1
.2-.5	252,000	8.3
.5-1	295,000	9.8
1-2	210,000	6.9
2-5	292,000	9.7
5-10	412,000	13.6
10-20	737,000	24.5
20-40	344,000	11.4
40-80	41,000	1.3
80-120	12,000	.4
120-160	1,700	.1
over 160	700	--

Figure 2 shows the distribution of runoff by States. It should be recalled that the map displays runoff at point of origin, so that the total runoff for a State may exceed the total measured discharge in the major rivers of the State. This difference is caused by channel losses, the use of water for irrigation, and other factors explained by Langbein (1949). In the humid parts of the country, as in the East, where the losses as water travels downstream are small, the two should compare quite favorably, but in the arid regions of the West where channel losses may be great, the runoff as calculated for the map may exceed greatly the flows measured in the major streams of the State. In many places the excess may be a measure of the additional water supply available for capture.

VARIATION OF ANNUAL RUNOFF WITH TIME

In many parts of the country the variations in the annual runoff are almost as important as the mean annual runoff itself. This is particularly true in the more arid regions. Many streams in those regions have little or no flow for many years and then have one or two years of very high flow. This distribution causes the mean annual runoff to be much larger than would normally be expected, and indicates runoff in excess of the amount that could economically be developed most of the years. If sufficient storage is available, however, the few high years can provide water to last through many low years. The greater the variability of annual flow, the greater is the requirement for storage.

One way to describe this variability is to use the coefficient of variation, which is a measure of the variability expressed as a percentage of the mean. The coefficient of variation was computed for 200 gaging stations. Numerical values of the coefficient are not given herein, but areas of high and low variability are shown in figure 3, which shows that annual runoff in the Great Plains and the Southwest regions is more variable than in any other regions of similar extent. In contrast, the annual runoff in the Northeast and in the Pacific Northwest is relatively stable. In broad terms, the variation in annual runoff is less in the north than in the south; the variation is greatest in regions of continental climate, and least near both coasts where maritime climates prevail.

REFERENCE

Langbein, W. B., 1949, Annual runoff in the United States: U. S. Geological Survey Circ. 52, 14 p.

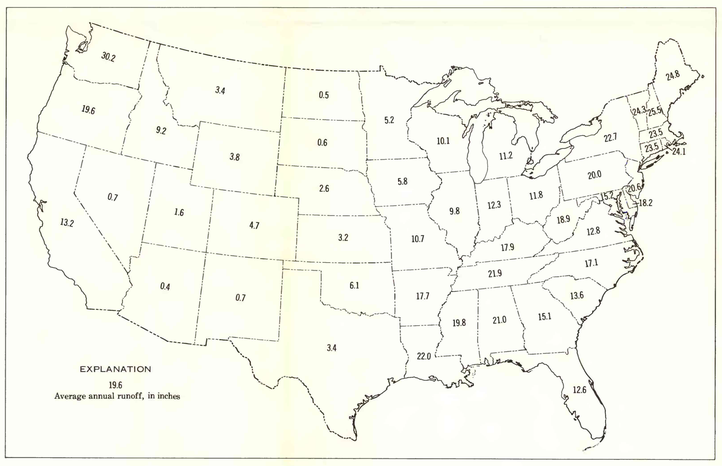

FIGURE 2.—DISTRIBUTION OF RUNOFF BY STATES

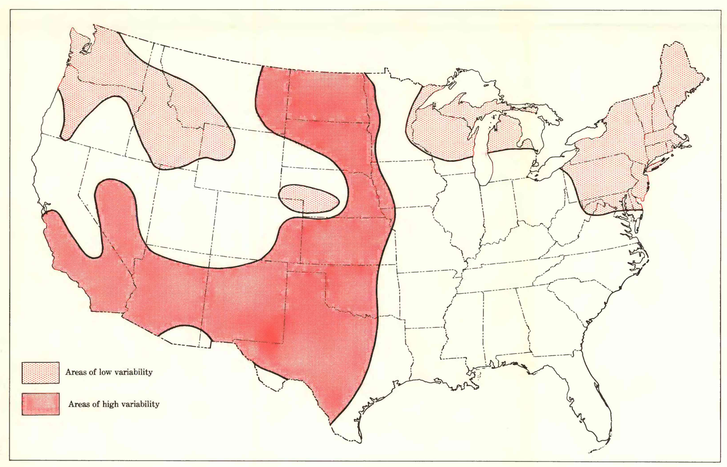

FIGURE 3.—COEFFICIENT OF VARIATION OF ANNUAL RUNOFF

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