Evaporation From The 17 Western States

By J. STUART MEYERS

With a section on

EVAPORATION RATES

By TOR J. NORDENSON, U.S. Weather Bureau

STUDIES OF EVAPORATION

GEOLOGICAL SURVEY PROFESSIONAL PAPER 272-D

An estimate of the amounts of water evaporated annually from the reservoirs, lakes, ponds, streams, and enclosed coastal bays in the 17 Western States

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EVAPORATION FROM THE 17 WESTERN STATES

By J. Stuart Meyers

ABSTRACT

The gross annual evaporation from exposed water surfaces was estimated for the 17 States lying wholly or partly west of the 100th meridian. The amount of evaporation in each subdivision of these States was computed as the product of the local evaporation rate multiplied by the water-surface area in the bays, lagoons, reservoirs, lakes, ponds, and streams within the subdivision.

Evaporation rates were taken from the map of Kohler, Nordenson, and Baker (1959); the western part of which is reproduced in this report at a larger scale. It shows isopleths of annual lake evaporation, derived from available evaporation-pan data and computed from meteorological records by the techniques developed during the comprehensive evaporation investigations at Lake Hefner and Lake Mead.

Water-surface areas for the larger reservoirs and regulated lakes were taken from Thomas and Harbeck (1956), who presented conditions as of January 1, 1954. Water-surface areas were individually measured on recent maps for coastal bays and lagoons; principal inland salt lakes; natural fresh-water lakes of 500 acres or more; and for the larger streams and canals. A sampling procedure was used for estimating the total areas of the many small stock ponds, reservoirs, lakes smaller than 500 acres; and minor streams and canals. All the identifiable bodies of water were measured on selected maps or aerial photographs within each 1° quadrangle; and from the sample data, the total water-surface area for each full quadrangle was derived. As the water-surface areas shown on maps and photographs and listed in available reports usually represent full-pool or bankfull conditions, most of the observed areas were reduced to arrive at the average effective area subject to evaporation.

Maps and tables present the estimated water-surface areas and the amounts of evaporation, subdivided by States and also by principal river basins. For the entire 17-State area, the average annual amount of evaporation is estimated as:

Fresh-water areas

	Acre-feet
Reservoirs and regulated lakes with capacities of 5,000 acre-feet or more	12,299,000
Other large lakes	1,987,000
Principal streams	4,421,000
Small stock ponds and lakes	3,369,000
Small streams and canals	1,565,000
Total evaporation	23,641,000

Salt-water areas

	Acre-feet
Large inland salt lakes	5,220,000
Enclosed coastal bays and lagoons	12,345,000
Total evaporation	17,565,000

INTRODUCTION

Evaporation from exposed water surfaces consumes a considerable part of the available supply of water in the United States. This may not be obvious because the continuous but invisible process of evaporation attracts much less public attention than the occasional but far more noticeable rain and snow storms, and the amount of water evaporated is much smaller than the total amount of precipitation. The evaporation estimated in this report is not taken directly from precipitation, however, but from the smaller quantities of water that find their way to the streams, lakes, and surface reservoirs which in many localities are the principal sources of water for man's needs. Evaporation losses attain special importance in the arid western regions where water is generally scarce and expensive.

Evaporation rates have long been studied as a part of the hydrologic cycle, and as an unavoidable loss in man's developments for water supply. Existing information is summarized on the map (pl. 3) prepared by Kohler, Nordenson, and Baker (1959), which is explained and discussed in the following section on "Evaporation rates." The figures shown on the map and used in this report represent the gross evaporation rate from a water surface. Net evaporation, which is a more useful term for some comparisons, may be obtained by subtracting average annual precipitation from these gross figures.

The isopleths on plate 3 are the annual evaporation rates for lakes and reservoirs. Different rates have sometimes been applied to shallow and to deep lakes, to flowing water in streams, and to salt water, based on limited experimental evidence. For this report the same evaporation rates were assumed to apply to all the classes of water surfaces.

In the material that follows, a distinction is made between two related terms: (a) Annual rate of evaporation, which is measured in inches or feet of depth from any water surface regardles of size and (b) annual amount of evaporation, which is measured in gallons or acre-feet from a body of water of definite size. Except for reservoir studies, the amount of evaporation has generally been a matter of academic interest only, because there has been no effective way of controlling or modifying the process. The developing possibilities of evaporation suppression by means of surface films, however, provide a new viewpoint for this old subject. An estimate of the amounts of water evaporated, as presented in this report, now promises to become a matter of practical importance.

This estimate of the amount of evaporation that occurs under present conditions should not be mistaken for an estimate of the amount of water that can be saved by the use of surface-film techniques for evaporation suppression. Because of the practical difficulty in maintaining surface films, particularly over large bodies of water, it appears to be impossible to prevent evaporation entirely, and often it would be undesirable even if it was possible.

In a different sense, these figures should not be interpreted as an estimate of the water losses that could be attributed to the construction of reservoirs or that could be prevented by the draining of lakes. The water stored in the reservoirs or lakes usually provides better controlled and more valuable flow for water users than could be obtained from unregulated streams. Increased water losses, if any, are partly or wholly offset by gains in the quantities of water made available at the desired times for beneficial use. A reservoir ordinarily submerges a reach of original stream channel, together with a fringe of relatively dense vegetation along the borders of the stream. Evaporation from the enlarged water surface of a new reservoir or lake, and from the new growth of fringing vegetation, is usually much greater than the evaporation under original conditions. The net increase in evaporation, however, is not the total under the new conditions, but is the difference between the new and the old evaporation. Similarly, the drainage of lakes and swamps ordinarily reduces evaporation losses, but the net saving is limited to the difference between the evaporation under the new and the old conditions. A general estimate of net water losses from reservoirs, lakes, and other water projects must therefore consider other factors in addition to this summary of the amounts of evaporatio from their exposed water surfaces.

SCOPE

This report presents an estimate of the gross an nual amount of evaporation from all identifiabl fresh-water surfaces in the 17 States lying wholly o partly west of the 100th meridian of longitude, a follows:

Arizona	Nebraska	South Dakota
California	Nevada	Texas
Colorado	New Mexico	Utah
Idaho	North Dakota	Washington
Kansas	Oklahoma	Wyoming
Montana	Oregon	

A less detailed estimate is also given for the amoun of evaporation from the salty or brackish water i the principal estuaries, bays, and lagoons along th coasts of the 17 States, and from 4 highly saline in terior lakes: Great Salt Lake, Salton Sea, Mono Lak and Devils Lake.

The water transpired by plants and evaporate from the soil surface is excluded from this estimat although those processes contribute a larger amoun of water vapor to the atmosphere than the dire evaporation from inland and coastal water surface Their estimate is a separate subject, however, requi ing a different approach and more elaborate compu tations than those undertaken here.

Water-surface areas, and consequently the amount of evaporation, vary to some extent with slow na ural changes and more rapidly with the constructio of new manmade developments. The average statu of natural features at any specific time cannot easil be determined, but the values used here are intende to represent conditions for the decade beginning wit 1950. The artificial features include those project completed or under construction at the beginning o 1954. Thomas and Harbeck (1956) used that limitin date in preparing "Reservoirs in the United States, which has been a principal source of reference mate rial for this report. Other projects started sinc 1954, together with those which will be undertake in the future, will further increase water-surface area and consequent evaporation.

ESTIMATION OF AMOUNT OF EVAPORATION

The amount of evaporation from a body of wate is computed as the product of its surface area multi plied by the evaporation rate. The surface areas var from season to season, and the evaporation rate range widely with time and geographic position.

Because of the great variations in these two basic factors, it was not practical to start with estimates for whole States or river basins. In order to obtain suitable small units, the territory within the 17 Western States was subdivided into 542 quadrangles, each covering 1° of latitude and 1° of longitude. Estimates were then made of the average water-surface area and of the average annual evaporation rate for each quadrangle. The amounts of evaporation were obtained by multiplying these factors individually, and then were summarized by States and by river basins.

ACKNOWLEDGMENTS

A large number of aerial photographs and topographic maps, some of which were not yet in finished form, were made available by the Army Map Service. Information from the files of the Bureau of Reclamation was used for estimating the average effective water-surface areas of reservoirs.

A principal contribution to this study is that of Tor J. Nordenson, U.S. Weather Bureau, who prepared the following section on "Evaporation rates."

EVAPORATION RATES

By Tor J. Nordenson, U.S. Weather Bureau

Evaporation is the process by which water in its liquid or solid state is transformed into the gaseous state of water vapor and released into the atmosphere. The sun provides the large amount of energy required for this transformation, but the amount of solar energy received at the earth's surface is not the only important element involved. It has been found that four principal meteorological factors—solar radiation, air temperature, dew point, and wind movement—must be determined for a satisfactory estimation of the rate of evaporation from a free water surface. The Interagency investigations of water losses at Lake Hefner (U.S. Geological Survey, 1954) and at Lake Mead (Harbeck and others, 1958) contain complete descriptions of the latest techniques for estimating evaporation.

There are four generally accepted methods for computing lake or reservoir evaporation: (a) Water budget, (b) energy budget, (c) mass transfer, and (d) coefficient applied to pan evaporation. For the purpose of preparing the annual lake evaporation map presented as plate 3, only the pan approach (method d) was practical, because no other data were generally available over the large areas to be represented. The water-budget method, which provided the basic control for the elaborate Lake Hefner studies, could be satisfactorily applied at only a few lakes and reservoirs where detailed data are available, and where the volumes of inflow, outflow, and changes in storage could be determined precisely. The energy-budget method, which has proved to be an accurate technique, requires such elaborate instrumentation that it is feasible only in special studies. The mass-transfer method requires observation of water-surface temperature, dew point, and wind movement, which are available at only a few places.

The evaporation map for the 17 Western States (pl. 3) was taken from the similar map for the 48 States prepared by Kohler, Nordenson, and Baker (1959). Earlier evaporation maps prepared by Horton (1943) and by Meyer (1942) show generally similar values, but the new map is based on more recent and complete pan data, supplemented by estimates of evaporation derived from meteorological factors. Kohler, Nordenson, and Fox (1955) described the procedures and presented the graphical relations used for estimating evaporation from solar radiation, air temperature, dew point, and wind movement. Another relation was presented for obtaining lake evaporation by correcting the measured pan evaporation for transfer of heat through the sides of the pan.

Preparation of the new lake evaporation map followed these steps:

1. The data used are averages for the 10-year period 1946–55.
2. Monthly average values of solar radiation, air temperature, dew point, and pan wind movement were computed for 255 Weather Bureau first-order meteorological stations, 114 of which were in the 17 Western States. For stations observing only percent sunshine, the solar radiation was estimated from the relation developed by Hamon, Weiss, and Wilson (1954).

Observed wind movement was adjusted to pan height by the power law

$$\frac{U_1}{U_2}=\left(\frac{Z_1}{Z_2}\right)^{0.3}$$

in which U_1 is wind movement at pan height,
U_2 is wind movement at first-order station anemometer,
Z_1 is height of pan anemometer (2 feet above ground),
Z_2 is height of first-order station anemometer.

Estimated pan winds were checked by comparisons with observed wind movement at nearby pan evaporation stations.

The dew point at a number of first-order stations was adjusted to the value for 6 feet above the ground by using the correction graph prepared by Meyer (1942, p. 28).

3. Monthly values of class A pan evaporation and of lake evaporation were computed for all Weather Bureau first-order stations, using the relations derived by Kohler, Nordenson, and Fox (1955, figs. 2, 6). Annual values for class A pan evaporation and for lake evaporation were obtained, and pan-to-lake coefficients were computed.
4. Average annual and seasonal (nonwinter) observed class A pan evaporation data were compiled for 146 stations with annual records and 151 stations with seasonal records, including 110 annual and 101 seasonal records in the 17 Western States. Some seasonal class A pan records were extrapolated to obtain annual values by using the ratio of annual to seasonal computed pan evaporation for nearby first-order stations.
5. Additional pan-to-lake coefficients were computed for class A pans with observed water temperatures, using the relations derived by Kohler, Nordenson, and Fox (1955, figs. 5, 7).
6. Observed and extrapolated annual class A evaporation (297 stations) and computed annual class A pan evaporation for Weather Bureau first-order stations (255 stations) were plotted on a map, and isopleths were drawn through the plotted points.
7. The pan-to-lake coefficients computed in 3 and 5 above were plotted on another map of the same scale, and isopleths of the coefficients were drawn.
8. The annual lake evaporation at any point could then be obtained by multiplying the annual class A pan evaporation (step 6) by the pan-to-lake coefficient (step 7) for the same point. Computed values for a great many points were plotted on a third map to get good coverage over the conterminous United States. Lake and reservoir evaporation estimates determined by special investigations such as those at Lake Hefner and Lake Mead were also plotted on the map, and all these data were considered in drawing the final isopleths that appear in plate 3 of this report.

The resulting map shows evaporation rates ranging from 20 inches annually in the extreme northwest to more than 80 inches along parts of the Rio Grande and the lower Colorado River and in Death Valley. The isopleth pattern is comparatively uniform and regular across the Great Plains in the eastern part of the 17-State area, but becomes quite irregular in the mountainous central and western parts.

The rates of lake evaporation are expressed in terms of the average number of inches for a full year, and they should be considered and used as annual values Rates of lake evaporation for individual months o for seasons might be approximated by prorating th annual total in proportion to the observed totals a nearby class A pans, but such monthly or seasona estimates would be applicable only to very shallow lakes or reservoirs. For deep lakes the factor o energy storage, which is negligible in an evaporatio pan, becomes important. At Lake Mead, for example, the maximum lake evaporation occurs in Augus although the maximum pan evaporation is in June Similarly, for Lake Ontario (Hunt, 1959) the maximum lake evaporation occurs in September, and th maximum pan evaporation in July. The amount o heat energy stored in a lake or reservoir varies considerably from month to month, but normally ther is little net change in energy from one year to th next. For the 10-year average annual values use in this report, differences in energy storage will b so small that they can safely be ignored in applyin estimated evaporation rates to deep lakes.

The positions of the isopleths on the evaporatio map are most dependable in those localities wher pan evaporation measurements were made or wher first-order weather data were observed. For the area between such control points the isopleths were draw with principal regard for topography, with som smoothing in the rougher mountains. The accurac of the map on an areal basis is considered to be generally good, particularly in the vicinities of the contro points where the error should be within about 1 percent, plus or minus. Somewhat less accuracy however, must be expected for point values in uncontrolled areas.

WATER-SURFACE AREAS

EXISTING DATA

Census reports list the land area and the inlan water area in square miles for each State and count in the conterminous United States. The figures hav been revised from time to time as better maps wer made, and as changes have occurred such as the creation of new reservoirs, shifts in river channels, an drainage of swamps. The U.S. Bureau of the Censu definition for inland water (Batschelet, 1940) is:

> Permanent inland water surfaces, such as lakes, reservoir and ponds having 40 acres or more of area; streams, slough estuaries, and canals one-eighth of a statute mile or more i width; deeply indented embayments and sounds and othe coastal waters behind or sheltered by headlands or island separated by less than 1 nautical mile of water; and island having less than 40 acres of area.

This definition excludes many small ponds and mos of the stream channels in which water is exposed fo evaporation, and it includes many areas of salt and brackish water along the seacoasts. The census data did not differentiate between areas of fresh water and salt water. Areas for the principal reservoirs in the conterminous United States were compiled by Thomas and Harbeck (1956), but they did not include information for many of the natural lakes, for small ponds, or for streams. As there were no satisfactory existing estimates for all water-surface areas, it was necessary to make a new determination.

The census areas for inland water in the 17 Western States, and also the water-surface areas estimated for this report are summarized in table 1. The census total is not greatly different from the new estimate, but the figures for some of the individual States show considerable variations. For Nevada and Oklahoma the census areas are much larger than the new areas, presumably because the available maps show expanded shorelines for some lakes that fluctuate in size, and show wide flood channels for some rivers that normally occupy only a small part of that width. On the other hand, the new areas are greater than the census areas for the Dakotas, where the very large Garrison and Oahe Reservoirs have begun storing water on the Missouri River, and for the State of Washington where all the area of the straits within United States boundaries has been included.

AREA DETERMINATIONS FOR THIS REPORT

The area of each principal reservoir, lake, bay, and lagoon, and of each major river and canal was measured individually on the latest available maps or aerial photographs, or taken from existing reports. The small reservoirs and ponds and the minor streams, however, are so numerous that measurement of each pond and stream channel was impractical, and a sampling procedure was employed for estimating their total water-surface areas.

Fresh-water and salt-water areas are separated in this report. For convenience in assembling data from different sources, the areas of bodies of fresh water were subdivided into these five classes:

1. Principal reservoirs and regulated lakes.
2. Other principal lakes, 500 acres and larger.
3. Principal streams and canals.
4. Small ponds and reservoirs.
5. Small streams.

TABLE 1.—*Water-surface areas in the 17 Western States*

[In thousand acres]

State and boundary river	"Inland water" areas from 1950 census [1]	Effective fresh-water areas, as estimated for this report						Principal salt-water areas	
		Principal reservoirs and regulated lakes	Other lakes exceeding 500 acres	Principal streams and canals	Small ponds and reservoirs	Small streams	Total	Interior lakes	Coastal waters
Washington	900	188	84	106	55	38	471	0	2, 144
Columbia River		66	0	95	0	0	161	0	92
Oregon	426	134	42	45	18	41	280	0	38
California	1, 250	325	17	75	77	70	564	242	339
Nevada	481	21	112	3	10	5	151	0	0
Idaho	504	394	12	53	16	25	500	0	0
Snake River		0	0	14	0	0	14	0	0
Utah	1, 645	124	4	29	54	11	222	1, 070	0
Arizona	214	18	2	16	9	7	52	0	0
Colorado River		171	3	11	0	0	185	0	0
Montana	806	478	58	103	91	45	775	0	0
Wyoming	261	84	117	23	31	19	274	0	0
Colorado	208	62	3	23	86	39	213	0	0
New Mexico	99	37	0	9	30	8	84	0	0
North Dakota	389	352	62	28	167	10	619	16	0
Red River of the North		18	0	3	0	0	21	0	0
South Dakota	327	391	41	35	79	16	562	0	0
Minnesota River		0	10	0	0	0	10	0	0
Big Sioux River		0	0	2	0	0	2	0	0
Missouri River		11	0	110	0	0	121	0	0
Nebraska	361	53	4	111	98	28	294	0	0
Kansas	108	46	0	63	20	31	160	0	0
Oklahoma	568	96	2	89	33	23	243	0	0
Red River		84	0	32	0	0	116	0	0
Sabine River		0	53	6	0	0	59	0	0
Rio Grande		57	0	25	0	0	82	0	0
Texas	2, 449	236	27	99	103	41	506	0	1, 580
Total	10, 996	3, 446	653	1, 208	977	457	6, 741	1, 328	4, 193

[1] These areas in acres were derived from published census data in square miles (U.S. Bur. Census, 1950).

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RELATION BETWEEN MEASURED AREA AND ACTUAL AREA OF RESERVOIRS AND LAKES

Topographic maps made by the Geological Survey show shorelines for reservoirs, lakes, and ponds that correspond to the normal water level, which is described as following the line of land-type vegetation. Where recent large-scale maps are available, the measured areas of perennial lakes and ponds can be accepted as the average water-surface areas exposed for evaporation.

Within the 17 Western States, however, many of the lakes and reservoirs are not perennial but intermittent, and the average actual water-surface areas may be much smaller than the outlines indicated by the maps. The shorelines drawn on older maps, even for perennial lakes, tend to represent the maximum rather than the average surface areas, at least for present conditions. A somewhat similar situation is found on aerial photographs, where the extent of the dark, vegetated area surrounding a lake or pond is often more sharply defined than the indefinite shoreline, so that the normal size of the lake is commonly smaller than the conspicuous dark spot. The available areas for the principal reservoirs are the surface areas for maximum controllable reservoir level, or full pool, so they also are larger than the average water-surface areas that are effective for evaporation.

Because the indicated water-surface areas obtaine from maps, aerial photographs, and reports generall exceed the actual average areas, an adjustment i needed. For this purpose the relation in figure 2 was developed, comparing the average observed water surface areas of reservoirs with their full-pool areas The 21 larger reservoirs selected for the compariso have a wide range in size and principal use and ar scattered through 14 of the 17 Western States. Perti nent data for these reservoirs are given in table 2 and their locations are shown in figure 26.

Monthly water levels and reservoir contents ar published in the series of Water-Supply Papers o "Surface-Water Supply of the United States." Dat for water-surface areas of reservoirs, however, ar not published and had to be computed. Curves an tables of area and capacity for the selected reservoir were obtained from Bureau of Reclamation and Geo logical Survey files, and water-surface areas were de termined for the end of each month. These end-of month areas for each of the reservoirs were average for a 10-year period, and the resulting figures ar shown in table 2 and plotted in figure 25.

This simple comparison does not show a very con sistent relation because of the diversity of hydrologi conditions and of the functions of the reservoirs. I does demonstrate, however, that the average area i considerably less than the full-pool area and that th

TABLE 2.—*Water-surface areas of 21 reservoirs*

Reservoir	River	State	Use of reservoir [1]	Symbol on figures 25 and 26	Usable storage at full pool (acre-ft)	Storage ratio [2] (years)	Surface areas: Full pool (acres)	Surface areas: 10-year average [3] (acres)	Effective area ratio
Fort Peck	Missouri	Mont	FNPR	FP	14, 900, 000	2. 0	244, 700	214, 400	0. 87
Lake Mead	Colorado	Nev.-Ariz	FIMPR	MD	27, 207, 000	2. 1	158, 100	124, 200	. 7[illegible]
Lake Texoma	Red	Okla.-Tex	FNPR	TX	4, 496, 000	1. 1	142, 700	83, 590	. 5[illegible]
Franklin D. Roosevelt Lake.	Columbia	Wash	IP	FDR	5, 071, 000	. 07	79, 400	77, 760	. 97
American Falls	Snake	Idaho	IP	AF	1, 700, 000	. 3	56, 055	47, 850	. 85
Elephant Butte	Rio Grande	N. Mex	FIPR	EB	2, 185, 400	2. 6	37, 848	13, 760	. 36
Shasta	Sacramento	Calif	FIP	SH	4, 377, 300	. 8	29, 600	23, 560	. 79
Lake Travis	Colorado	Tex	FIP	TV	1, 922, 000	1. 0	29, 044	13, 420	. 46
Pathfinder	North Platte	Wyo	IR	PA	1, 040, 500	1. 2	22, 011	11, 680	. 53
San Carlos	Gila	Ariz	IP	SC	1, 205, 000	4. 3	19, 580	2, 677	. 1[illegible]
Owyhee	Owyhee	Oreg	I	OY	715, 000	--------	12, 650	10, 590	. 8[illegible]
Rye Patch	Humboldt	Nev	I	RP	179, 100	1. 4	10, 780	8, 438	. 78
Strawberry	Strawberry	Utah	IPR	ST	270, 000	4. 5	8, 400	6, 380	. 76
Lake Altus	North Fork Red.	Okla	FIMR	ALT	140, 560	1. 1	6, 793	4, 061	. 59
Fresno	Milk	Mont	I	FO	127, 200	. 5	5, 730	3, 842	. 67
Millerton Lake	San Joaquin	Calif	FI	MT	503, 150	. 3	4, 920	3, 037	. 61
Alamogordo	Pecos	N. Mex	FIR	ALO	128, 400	. 7	4, 650	1, 588	. 3[illegible]
Vallecito	Los Pinos	Colo	I	VO	126, 280	. 5	2, 720	1, 809	. 66
Box Butte	Niobrara	Nebr	IR	BB	30, 460	1. 1	1, 600	1, 182	. 73
Unity	Burnt	Oreg	I	UN	25, 220	. 5	928	630	. 67
Hyrum	Little Bear	Utah	I	HY	15, 300	. 4	479	431	. 90

[1] Use of reservoir: F, flood control; I, irrigation; M, municipal; N, navigation; P, power; R, recreation.
[2] Storage ratio is the usable storage capacity divided by average annual inflow.
[3] Lake Texoma data are for 10-year period ending Sept. 30, 1955; Shasta, Altus and Box Butte data are for 10-year period ending Dec. 31, 1955; data for all othe reservoirs are for 10-year period ending Sept. 30, 1953.

relative difference tends to be less for the larger reservoirs. In order to extend the comparison down to farm ponds and stock tanks, similar data were taken from reports by Langbein, Haïnes, and Culler (1951) for stock-water reservoirs in Arizona and by Culler (1961) for small reservoirs in eastern Wyoming and southwestern South Dakota. Additional data would be desirable for areas between 50 and 500 acres, but none were readily available.

EFFECTIVE-AREA RATIO FOR RESERVOIRS AND PONDS

The line marked "assumed average effective-area ratio" on figure 25 is a general interpretation of the plotted data. For reservoirs or ponds whose full-pool area was given in a report, or indicated on a map or aerial photograph, the average effective water-surface area could be obtained by applying this ratio.

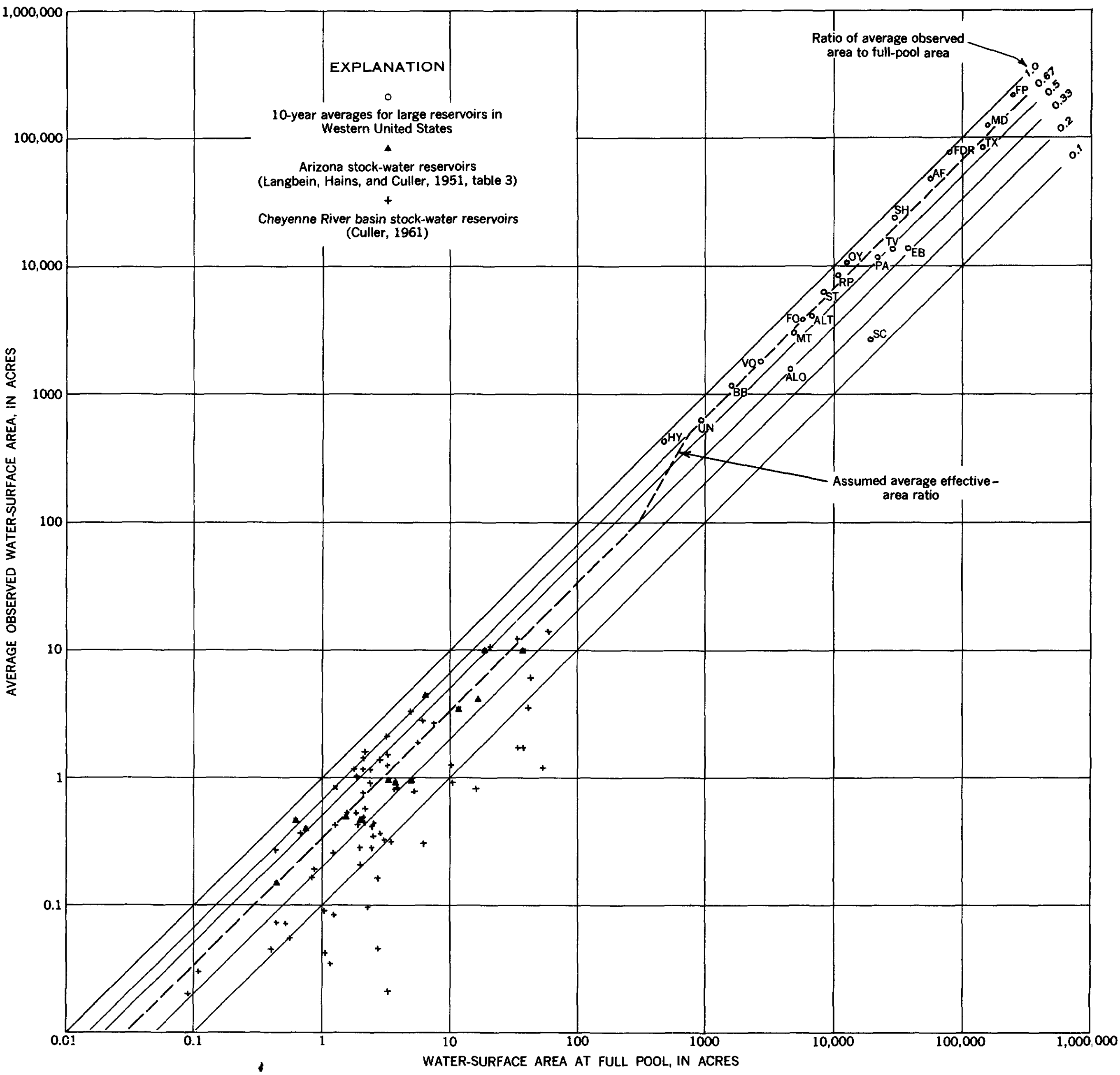

FIGURE 25.—Ratio of average to full-pool water-surface area for selected reservoirs. Symbols identify reservoirs listed in table 2.

In many cases the value of the ratio was modified because of special knowledge of local conditions, but when no special information was available the value was read directly from the line on the graph.

A ratio was selected for each reservoir, lake, and pond as a step in the procedure for estimating its effective area. The assumed ratios in most cases were in the range from unity to one-third, but in extreme cases such as dry lake beds and the areas behind water-spreading dams, ratios as small as one-twentieth were used.

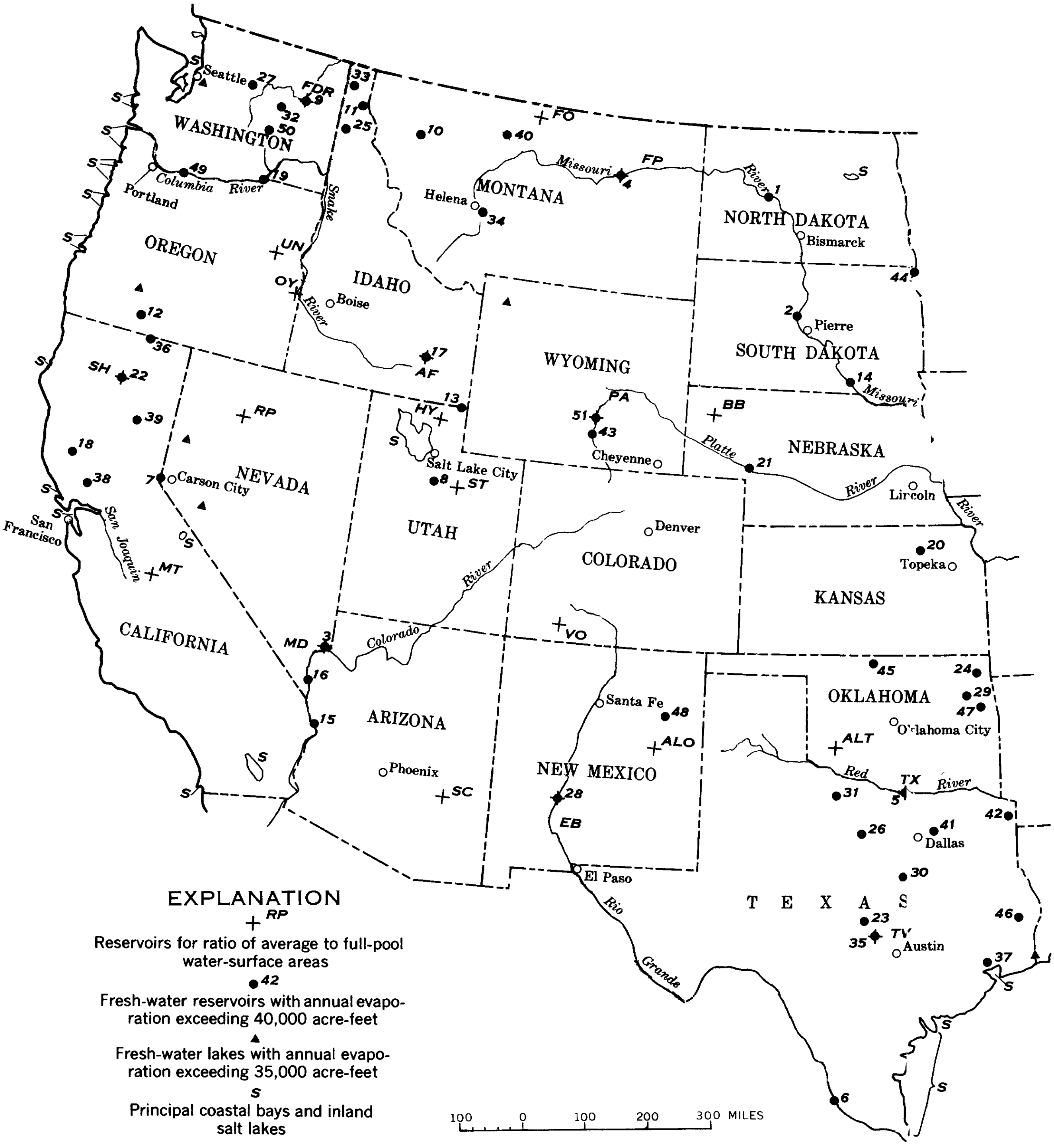

FIGURE 26.—Locations of principal reservoirs, lakes, and bays. Numbers and symbols refer to listings in tables 2 and 7.

WIDTH OF STREAMS

Insofar as possible, Geological Survey maps show the width of each stream at its normal stage, at which water fills the channel to the line of permanent vegetation along the banks. Widths can be accurately portrayed by double lines on maps of 1:24,000 scale only when channels are at least 40 feet wide, and on 1:62,500 maps only when channels are at least 80 feet wide. Narrower streams, which include most of those considered here, are represented by conventional solid or dashed lines whose widths are not drawn to scale. It was therefore necessary to estimate most of the channel widths rather than measure them on the maps.

Rivers in most of the 17-State area tend to develop the widely separated vertical banks that are typical of the Great Plains. The full width of such a channel may be occupied during floods, but the normal flow fills only a much narrower channel. In the many intermittent streams, water-surface widths diminish to zero for long periods of time. The width that can best be identified on the maps and aerial photographs, however, is commonly the full width between banks, so that figure was used as the initial step in the estimate.

Consideration of the local climate, the probable streambed materials, the slope of the river profile, and the regimen of streamflow as indicated by published discharge data then led to the selection of an effective-width factor. The assumed factors ranged from nearly unity for mountain streams in the wet northwest to as little as one five-hundredth (0.002) for some of the wide and dry sandy washes in the arid southwest. The measured or estimated full-channel width was reduced by multiplying it by the estimated factor to obtain the average effective width of water exposed to evaporation.

WATER-SURFACE AREAS ESTIMATED BY INDIVIDUAL MEASUREMENT

COASTAL WATERS AND SALT LAKES

As used in this report, coastal waters include each enclosed bay, lagoon, and estuary exceeding 1,000 acres in area. Shallow indentations of the coastlines, such as Monterey Bay and Santa Monica Bay in California, were not included. Areas were measured within the shorelines shown on the latest maps available at a scale of 1:250,000, with one exception. Recent maps of this scale were not yet available for the extreme northwestern corner of the United States; so the areas of these were measured on the 1:1,000,000 Aeronautical Charts prepared by the U.S. Coast and Geodetic Survey.

There are many lakes and sinks with no surface outlets in the arid parts of the 17 States. Under these conditions evaporation normally equals or exceeds inflow, and the dissolved mineral content of the remaining water gradually increases. Much the largest of these lakes is Great Salt Lake, which covers more than a million acres, and whose concentration of dissolved solids is about six times that of the ocean. Many saline lakes are not permanent, and the only areas measured and included here are those for Great Salt Lake, Salton Sea, Mono Lake, and Devils Lake.[1] Other saline lakes and sinks, such as Sevier Lake in Utah and Winnemucca Lake in Nevada, have been generally dry in recent years and their areas have not been estimated for this report.

Because the water in such saline inland lakes is as unsuitable as that of the ocean for man's ordinary use, the evaporation from their surfaces may not be regarded as a loss. In some places, however, the amount of evaporation may be an indication of the inflow to the lakes, and as such it may provide useful information. The areas of coastal waters and the four principal saline inland lakes were measured on available maps. Because of the relative permanence of these bodies of water, their areas were not reduced by effective-area factors.

PRINCIPAL RESERVOIRS AND REGULATED LAKES

Thomas and Harbeck (1956) list for the 17 Western States about 700 reservoirs and regulated lakes with usable storage capacities of 5,000 acre-feet or more. Each of these reservoirs and lakes was examined on topographic or State maps, and an effective-area ratio was chosen on the basis of topographic and climatic setting. Maximum water-surface areas were estimated from the same maps for the few reservoirs whose areas were not listed. Each tabulated or estimated maximum area was then multiplied by the selected ratio to obtain the average or effective water-surface area. The total effective area for these principal reservoirs and regulated lakes, as given in table 1, is 3,446,000 acres. This total is considerably larger than any of the other fresh-water area classifications and makes up almost exactly one-half of the overall total of 6,741,000 acres of all fresh-water classifications.

[1] The saline status of Devils Lake would be changed if a recent irrigation proposal is adopted. The plan contemplates diversion from Garrison Reservoir to dilute the water in Devils Lake, thus making it usable for irrigation and streamflow augmentation in the Sheyenne River basin.

OTHER PRINCIPAL LAKES, 500 ACRES AND LARGER

In addition to the regulated lakes that are included with the principal reservoirs, there are many other natural lakes whose outflow is not controlled to provide usable storage. Some of these are very large, notably Yellowstone Lake in Wyoming, Pyramid and Walker Lakes in Nevada, and Sabine Lake in Texas and Louisiana. Because of their number and size, a separate classification was made of all such natural lakes whose maximum water-surface area was 500 acres or more.

The arbitrarily chosen limit of 500 acres is comparable in size to the smaller reservoirs listed by Thomas and Harbeck (1956). Of the reservoirs and regulated lakes they list for the 17 States, 20 percent were smaller than 500 acres, and 80 percent were larger. The 500-acre size was also about as small as could be accurately delineated on the 1:500,000 State maps which are still the best map coverage for some areas.

The maximum area of each of the 350 lakes in this classification was measured on the best available map or aerial photograph, and multiplied by a ratio from figure 25 to obtain the estimated effective water-surface area. The sum of the areas of all such lakes (table 1) is 653,000 acres, which is about 9 percent of the fresh water-surface areas in all classifications.

PRINCIPAL STREAMS AND CANALS

Rivers, creeks, arroyos, washes, and minor drainage channels are found throughout the 17 Western States. Although perhaps not as impressive as the large lakes and reservoirs, their total water-surface area in some localities exceeds that of the more conspicuous reservoirs and lakes.

Estimates were made of the water-surface areas of each of about 450 principal streams and canals, which were subdivided for this purpose into nearly 700 segments or reaches. The distinction between principal streams and minor streams could not be satisfactorily expressed in terms of a minimum channel width in feet or a minimum yearly flow in acre-feet that would have the same significance throughout the 17 States. In the sense used here, a principal stream was one that was unusually large for its own locality.

The classification obviously included the longest rivers carrying the greatest flows, such as the Missouri, Columbia, Sacramento, and Colorado Rivers. It also included the Gila River whose small and varying flow usually diminishes to zero before it reaches the Colorado River near Yuma. The Gila River and its tributaries drain about half of Arizona, and directly support the principal irrigated area and population center of that State. The fact that the river is usually dried up by irrigation use is a measure of its importance rather than an indication of its insignificance. In contrast to the situation exemplified by the Gila River, there are many short streams in the Pacific Northwest with much greater and better sustained flows, but which are commonplace in their local settings and therefore they are not classified as principal streams.

Channel lengths for rivers and canals were measured on 1:1,000,000 State maps, and widths were estimated from the best available local maps, as described previously. The area for each stream was then computed as the product of its length, maximum width, and effective width factor, multiplied by the proper conversion factor to express the result in acres. The total estimated water-surface area for the principal streams and canals was about 1,208,000 acres or 18 percent of the 17-State total for all the fresh-water area classifications.

WATER-SURFACE AREAS ESTIMATED BY SAMPLING

In addition to the water-surface areas measured individually, there are smaller lakes, ponds, and streams so numerous that it would be a prodigious task to measure or estimate the areas of each of them separately. As detailed map and photographic coverage is not complete, a uniform system of measurement could not be devised. Because the territory in the 17 Western States lies generally in rather large provinces with similar geologic, topographic, and hydrologic features, sampling was considered appropriate and was adopted as a practical measure.

SAMPLING PROCEDURE

For good representation of the varying kinds of territory, samples were taken from each of the quadrangles defined by the 1° latitude and longitude lines. The 17 Western States cover 457 full 1° quadrangles, and the addition of the partly covered quadrangles along their boundaries brings the number to 542.

One or more detailed maps or aerial photographs from almost every one of these 542 quadrangles were examined, and the water-surface areas of all minor lakes, ponds, and streams were measured on each such sample. The average water-surface areas per square mile for the entire quadrangles were assumed to be the same as the corresponding measured values for the samples. The estimated water-surface areas for each quadrangle were then obtained by multiplying the sample measurements by the ratio of the size of the quadrangle to the size of the sample.

Aerial photographs usually provide better indications of the nature of the pond or stream, and also of the surrounding territory, than do the maps. The "high-altitude" photographs made for the Army Map Service, covering most of the Western States at a negative scale averaging about 1 inch per mile, were best suited for this purpose. As nearly all these photographs were made since 1952, they show most of the existing farm ponds and other recent changes. Each photograph ordinarily covers 70 to 80 square miles of territory, with satisfactory detail for estimating the water-surface areas for small ponds and small streams.

The photographic files conveniently accessible for this study were not complete, particularly for some of the most recent photographs which had not yet been checked and accepted from the contractors. Enough photographs were obtained, however, to serve as samples for 203 of the 542 1° quadrangles in the 17 States. It was decided to utilize map samples for the remaining 1° quadrangles, rather than to await the availability of more of the desired photographs.

Consideration was also given to the use of the many other available, but usually older, aerial photographs with negatives having scales of about 1,500 to 2,000 feet per inch. Individual photographs of this kind cover only about one-tenth as much territory as the high-altitude photographs, and their greater detail ordinarily would not be needed for the purpose of estimating water-surface areas. Also, because many of these photographs had been flown for mapping purposes, good recent maps were usually available for the same territory.

The topographic maps most satisfactory for samples are those made recently by photogrammetric methods rather than by the planetable methods formerly employed. Two series of such maps are published: the 15-minute maps at 1:62,500 scale and the 7½-minute maps at 1:24,000 scale. Many of the maps prepared by planetable at these same scales are still quite satisfactory, but some of the older maps show less detail, and of course do not indicate recent changes. Up-to-date features are shown on the new series of 1:250,000 maps now becoming available (these maps were prepared in part from the new high-altitude photographs previously mentioned), but their scale of approximately 4 miles to the inch is too small to show all the desired detail.

Good topographic maps were available for samples in 251 of the 1° quadrangles. The aerial photographs and the good recent maps together accounted for 454 of the total of 542 quadrangles, leaving 88 to depend on older or smaller scale maps. New maps at the 1:250,000 scale were on hand for all but 16 of these remaining 88 quadrangles. This coverage was accepted as satisfactory for the purpose of finishing the sampling job, and the water-surface areas for small lakes, ponds, and streams in the few remaining quadrangles were therefore estimated from other maps.

SELECTION OF SAMPLES

After considering the availability of maps and photographs, and the occurrence and size of the small ponds and streams, it was decided that a sample covering about one-sixteenth, or 6 percent, of each 1° quadrangle would be appropriate. When maps were used, the sample size usually was exactly one-sixteenth that of the full quadrangle. This would be obtained with four 7½-minute maps, or with a single 15-minute map. When aerial photographs were used, three of the photographs constituted a sample averaging approximately one-sixteenth of the full 1° quadrangle. The area in square miles covered by each photograph was determined from the scale and dimensions of the photograph. The ratio of the sum of the areas of the three photographs to the total area of the quadrangle was then used as the fractional coverage of the sample.

As the basis for selecting the samples within a 1° quadrangle, each of its sides was divided into 8 equal parts, and intersecting lines were drawn to produce 64 smaller quadrangles, Each of the 64 subdivisions then corresponded to the location of a 7½-minute topographic map, and a set of 4 adjacent subdivisions with a common corner corresponded to a 15-minute map.

A sequence of 64 numbers was obtained from a table of random numbers. In order to reduce the possible concentration of samples in any part of the 1° quadrangle, a "latin-square" criterion was applied so that the first 4 numbers would each fall in a separate 30-minute quadrangle and the first 16 numbers would each fall in a separate 15-minute quadrangle. The numbers for the remaining part of the sequence were then recorded as they were drawn. Figure 27 shows the pattern for the resulting sequence of 64 numbered locations.

When 15-minute topographic maps were the best available, the map including location 1 was normally used as the sample representing the 1° quadrangle. However, there might be no 15-minute map correspond-

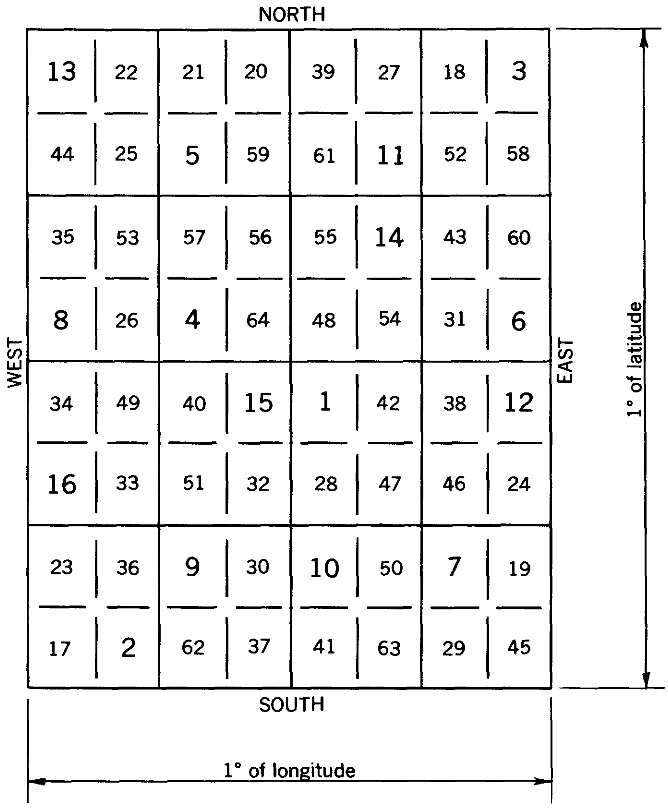

FIGURE 27.—Sequence of locations for samples in a 1° quadrangle.

ing to that location, or the map might contain part of one of the large reservoirs, lakes, or streams that had already been separately measured. Other maps were found to include salt water in a bay or estuary or to have some other abnormal feature. In such cases the selection would move on to locations 2, 3, 4, 5 or even farther until a satisfactory sample was found.

When 7½-minute topographic maps were used, the maps corresponding to locations 1, 2, 3, and 4 were normally taken as the sample. Usually, however, at least 1 of the first 4 maps was missing or was unsatisfactory for some reason, and the selection then moved on to succeeding numbers until 4 acceptable maps were found.

When aerial photographs were available for samples, they also were selected by the same sequence of 64 numbers. To accomplish this, temporary grid lines corresponding to the 64 subdivisions were placed on the 1° lines of the photographic index mosaic. The first photograph of the sample was then taken as the one whose center most nearly coincided with the center of location 1, the second photograph as the one coinciding with location 2, and so on until three acceptable photographs were selected.

SMALL PONDS AND RESERVOIRS

This area classification includes all the small bodies of water that could be definitely identified on the detailed topographic maps or aerial photographs used for samples. With few exceptions, there was no difficulty in identifying and measuring all ponds covering 1 acre or more when full. On good aerial photographs in open range country, it was sometimes possible to recognize features as small as metal stock-watering tanks, which were supplied with water by windmills. In most places, however, estimates were made for all full-pool areas down to about one-fourth acre in size, and it is believed that no ponds of any consequence were missed.

As shown by table 1, the estimated total effective area for the minor lakes, reservoirs, and ponds is 977,000 acres, which is about 14 percent of all the water-surface areas in all fresh-water classifications.

There is a wide range in the number of small lakes and ponds in different parts of the 17 States. The greatest concentration for a whole State is in North Dakota, with an average of 2.37 acres of effective water-surface area for each square mile of territory, and the least is in Arizona and Nevada, where the average is less than 0.1 acre per square mile. Another large concentration of small- to moderate-sized lakes is in the Sand Hills country in northwestern Nebraska, where the 15-minute Storm Lake map shows 747 lakes and swamps with a total effective water-surface area of 4,600 acres; an average of nearly 21 acres for each square mile.

Many small farm ponds have been constructed in some localities, principally in eastern Kansas, south-central Oklahoma, and central Texas. The greatest concentration was found on the Smoothingiron Mountain map, a 7½-minute quadrangle west of Llano, Tex. It shows 369 farm ponds with a total effective area of 30 acres, which averages about half an acre of water surface per square mile.

SMALL STREAMS

This classification includes all natural and artificial watercourses smaller than those estimated separately as principal streams and canals. When topographic maps were used for samples, water-surface areas were determined by measuring the lengths of all the perennial and ephemeral streams that were shown and multiplying these lengths by the estimated bankfull widths and by effective-width factors.

The map contours also show many other natural drainageways that have been eroded by the passage of water during occasional storms, but which have not formed distinct stream channels and are therefore not marked as streams. Similar minor drainageways are recognizable, in even larger numbers, on aerial photographs. Before measuring lengths on the photographs it was necessary to differentiate between the developed channels, which presumably would have been plotted on a map as streams, canals, or ditches, and the less distinct channels which would not have been so plotted. The vegetation and other details visible on the photographs were of great assistance in judging where each channel began.

The estimated effective area for small streams is shown in table 1 as 457,000 acres. This is about 7 percent of the total fresh-water areas in all classifications, and one-third the area of the principal streams. The greatest number of small streams was found in the Pacific Northwest, and their concentration is least in the arid Southwest.

AMOUNT OF EVAPORATION

COMPUTATION PROCEDURE

The amount of annual evaporation (in acre-feet per year) from a body of water is the product of the rate of evaporation (in feet per year) multiplied by the average effective area of the exposed water surface (in acres). For this estimate, evaporation rates were read from the map shown as plate 3, and water-surface areas were measured or derived as described in the preceding chapter.

A separate multiplication was made for each of the bodies of salt water, and for each of the major reservoirs, large fresh-water lakes, and principal streams whose areas had been measured individually. For the small lakes, ponds, and streams whose areas were obtained by sampling, an average evaporation rate was taken from plate 3 for each of the 542 1° quadrangles. Two multiplications were then made for each quadrangle—one for the total effective area of all the small lakes and ponds contained therein and another for the area of the small streams.

TABULATIONS AND MAPS OF ESTIMATED EVAPORATION

The annual evaporation from the principal bodies of salt water within and on the coasts of the 17 Western States is given in table 3. Most of the water evaporated from the bays and other coastal inlets is supplied by the ocean and is not a component part of the hydrologic cycle for the surrounding land area. The amount of such evaporation is impressively large, but it does not represent a depletion of available water that might be used for other purposes.

TABLE 3.—*Approximate annual evaporation from principal bodies of salt water, in the 17 Western States*

Body of water	Location	Approximate surface area (thousand acres)	Annual rate of evaporation (inches)	Quantity of annual evaporation (thousand acre-ft)
Great Salt Lake	Utah	1,070	[3] 42	3,750
Salton Sea	Calif	192	80	1,280
Mono Lake	do	50	36	150
Devils Lake	N. Dak	16	30	40
Total for 4 inland lakes		1,328		5,220
Puget Sound and adjacent coastal waters within U.S. boundaries.	Wash	2,000	21	3,500
Grays Harbor	do	60	20	100
Willapa Bay	do	84	20	140
Columbia River [1]	Wash. and Oreg.	92	21	160
Tillamook Bay	Oreg	8	21	14
Coos Bay	do	12	24	24
Six smaller bays [2]	do	18	21–23	33
Total for Washington-Oregon coast.		2,274		3,971
Humboldt-Arcata Bay	Calif	17	30	42
Tomales Bay	do	8	40	27
San Francisco Bay	do	300	42	1,050
San Diego-Mission Bay	do	14	47	55
Total for California coast		339		1,174
Galveston Bay	Tex	300	53	1,320
Matagorda Bay	do	280	55	1,280
Laguna Madre and smaller bays	do	1,000	55	4,600
Totals for Texas coast		1,580		7,200
Total		5,521		17,565

[1] Inland to long. 123°30′.
[2] Winchester, Alsea, Yaquina, Siletz, Netarts, and Nehalem Bays.
[3] Taken directly from pl. 3, with no adjustment for increased salinity.

The water evaporated from inland salt lakes, however, is supplied by surface streams, groundwater, and direct precipitation on the lake surfaces. The water from these sources might conceivably be utilized by man if it could be intercepted at the proper times and places. Such evaporation might therefore be considered as water loss, although attempts to salvage it would probably be uneconomical.

The water-surface areas and the amounts of gross evaporation from all the bodies of fresh water in each of the 17 Western States, and also in each major river basin, are given in table 4. To avoid confusion, separate listings are made for those parts of rivers that form State boundaries, instead of dividing the areas and evaporation between the adjacent States. The tabulation of water-surface areas previously introduced in table 1 is a summary of the more detailed figures in table 4.

For the computation of these figures, use was made of the river basin boundaries and the index subdivisions for their subbasins that were shown originally in Jones and Helland (1948) and reproduced as plate 1 of Thomas and Harbeck (1956). The figures of table 4 are assembled, however, in accordance with the somewhat different 14-part division of the United States that has been used in recent years for publication of annual streamflow reports. The 17-State territory with which this report is concerned includes all of parts 9, 10, 11, 12, 13, and 14; most of parts 6, 7, and 8; and only a small section of part 5.

The amounts of fresh-water evaporation given in table 4 are summarized by States and boundary rivers in table 5, and by principal river basins in table 6. For convenience, the figures in table 4 were tabulated as originally computed or as they were taken from different sources, and their totals are not consistently expressed to the same number of significant figures. The figures in tables 1, 5, and 6, however, have been rounded to the nearest 1,000 acres or acre-feet, to avoid the appearance of undue precision.

The amounts of evaporation from fresh-water surfaces that are summarized in tables 5 and 6 are also plotted on maps to show evaporation by States (fig. 28) and by principal river basins (fig. 29).

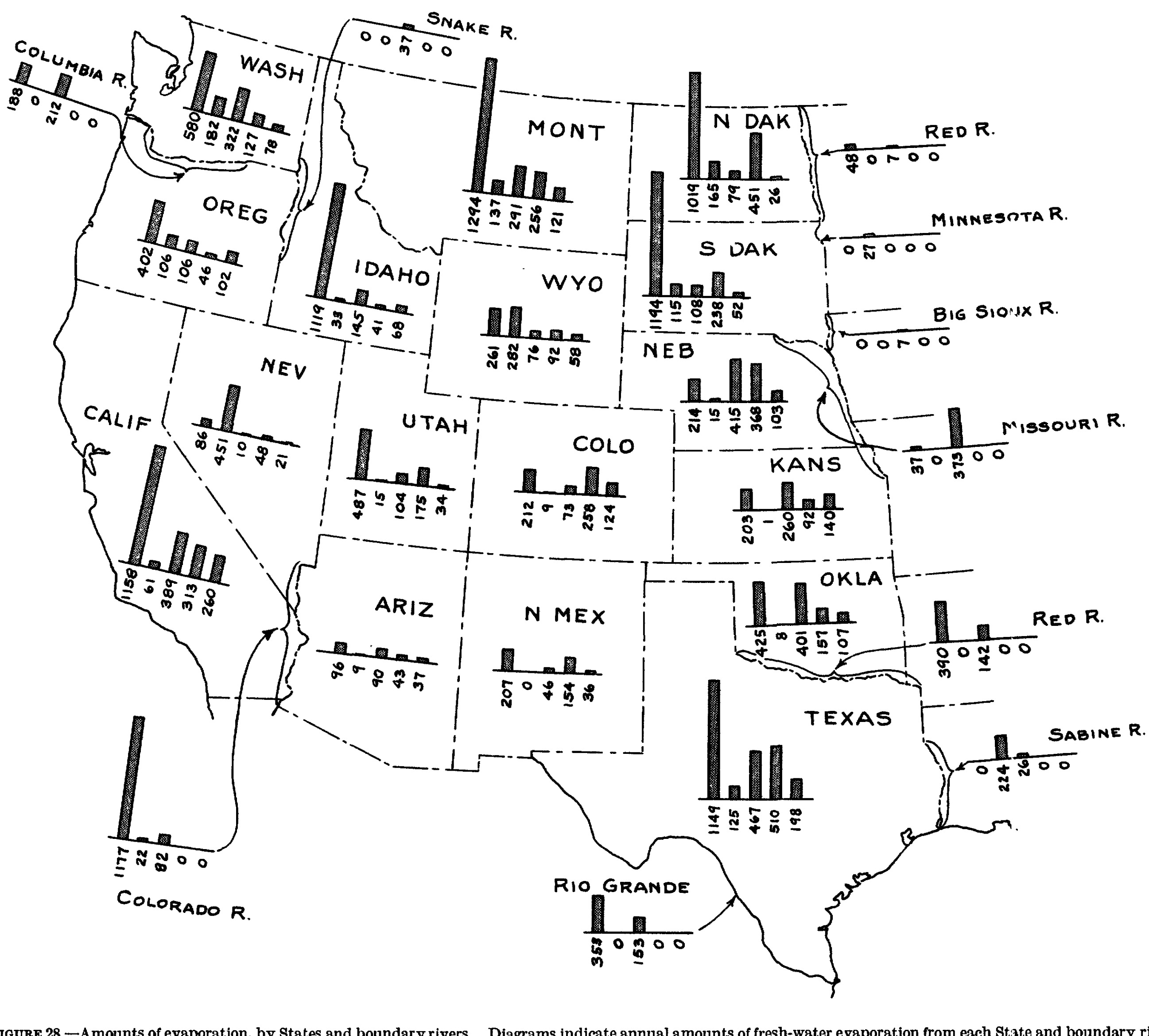

FIGURE 28.—Amounts of evaporation, by States and boundary rivers. Diagrams indicate annual amounts of fresh-water evaporation from each State and boundary river, from different kinds of water surfaces. First bar—principal reservoirs and regulated lakes. Second bar—other large lakes. Third bar—principal streams. Fourth bar—small lakes and ponds. Fifth bar—small streams. Figures are average annual evaporation in thousand acre-feet.

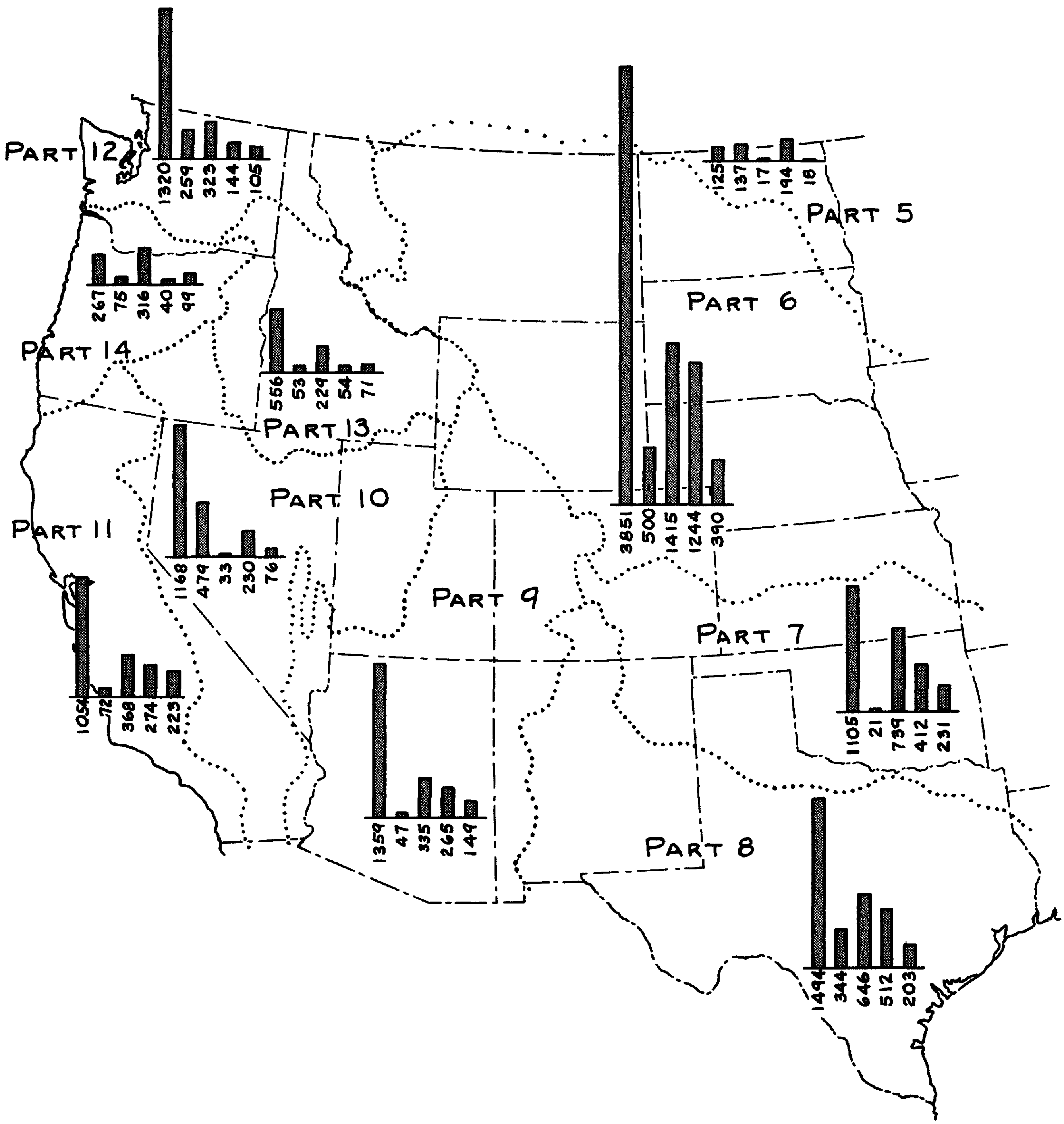

FIGURE 29.—Amounts of evaporation, by principal rivers basins. Diagrams indicate annual amounts of fresh-water evaporation from each principal river basin from different kinds of water surfaces. First bar—principal reservoirs and regulated lakes. Second bar—other large lakes. Third bar—principal streams. Fourth bar—small lakes and ponds. Fifth bar—small streams. Figures are average annual evaporation in thousand acre-feet.

TABLE 4.—*Fresh-water surface areas and evaporation in the 17 Western States*

Index designation for subbasin [1]	River subbasin	State and boundary river	Principal reservoirs and regulated lakes		Other lakes over 500 acres		Principal streams and canals		Small ponds and reservoirs		Small streams		Total for all classes	
			Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)
						Part 5.—Hudson Bay and upper Mississippi River basins								
5B	Minnesota River	South Dakota	0	0	0	0	0	0	5,461	14,615	196	527	5,657	15,142
		Minnesota River	0	0	10,400	27,300	0	0	0	0	0	0	10,400	27,300
		Total 5B	0	0	10,400	27,300	0	0	5,461	14,615	196	527	16,057	42,442
5O	Red River of the North above Red Lake River.	North Dakota	5. 540	14,362	7,530	19,550	1,454	3,640	11,717	30,119	2,309	5,577	28,550	73,248
		South Dakota	0	0	3,530	9,410	0	0	3,900	10,110	126	328	7,556	19,848
		Red River	18,400	47,500	0	0	2,330	5,630	0	0	0	0	20,730	53,130
		Total 5O	23,940	61,862	11,060	28,960	3,784	9,270	15,617	40,229	2,435	5,905	56,836	146,226
5P	Red River of the North below Red Lake River.	North Dakota	680	1,700	21,260	52,900	0	0	40,266	99,953	1,182	2,819	63,388	157,372
		Red River	0	0	0	0	700	1,575	0	0	0	0	700	1,575
		Total 5P	680	1,700	21,260	52,900	700	1,575	40,266	99,953	1,182	2,819	64,088	158,947
5R	Souris River	North Dakota	21,580	59,160	2,755	7,400	2,180	6,090	14. 684	38,854	2,987	7,969	44,186	119,473
5S	St. Marys River	Montana	1,153	2,690	8,385	20,120	0	0	240	560	180	420	9,958	23,790
	Subtotals by States and boundary rivers.	Montana	1,153	2,690	8,385	20,120	0	0	240	560	180	420	9,958	23,790
		North Dakota	27,800	75,222	31,545	79,850	3,634	9,730	66,667	168,926	6,478	16,365	136,124	350,093
		South Dakota	0	0	3,530	9,410	0	0	9,361	24,725	322	855	13,213	34,990
		Red River	18,400	47,500	0	0	3,030	7,205	0	0	0	0	21,430	54,705
		Minnesota River	0	0	10,400	27,300	0	0	0	0	0	0	10,400	27,300
	Grand total		47,353	125,412	53,860	136,680	6,664	16,935	76,268	194,211	6,980	17,640	191,125	490,878
						Part 6.—Missouri River basin								
6A	Missouri River above Three Forks.	Montana	20,062	46,395	6,000	14,500	5,911	13,046	8,309	18,116	3,060	6,772	43,342	98,829
		Wyoming	0	0	0	0	0	0	716	1,672	145	341	861	2,013
		Total 6A	20,062	46,395	6,000	14,500	5,911	13,046	9,025	19,788	3,205	7,113	44,203	100,842
6B	Missouri River, Three Forks to Fort Benton.	Montana	64,009	166,239	3,030	8,160	13,885	38,574	8,248	21,572	7,892	20,749	97,064	255,294
6C	Missouri River, Fort Benton to Milk River.	Montana	215,531	691,420	3,733	11,710	13,510	43,315	8,499	27,250	6,817	21,693	248,090	795,388
6D	Milk River	Montana	7,151	22,914	3,933	12,566	2,901	9,350	9,609	30,864	1,961	6,282	25,555	81,976
6E	Missouri River, Milk River to Yellowstone River.	Montana	7,540	22,900	0	0	15,415	48,155	17,141	52,620	1,851	5,723	41,947	129,398
		North Dakota	0	0	0	0	0	0	659	1,973	38	114	697	2,087
		Total 6E	7,540	22,900	0	0	15,415	48,155	17,800	54,593	1,889	5,837	42,644	131,485
6F	Yellowstone River above Bighorn River.	Montana	885	2,529	1,067	3,200	10,906	31,879	21,190	59,998	3,050	8,406	37,098	106,012
		Wyoming	0	0	82,700	186,000	1,794	4,095	2,303	5,182	725	1,663	87,522	196,940
		Total 6F	885	2,529	83,767	189,200	12,700	35,974	23,493	65,180	3,775	10,069	124,620	302,952
6G	Yellowstone River below Bighorn River.	Montana	1,866	6,060	0	0	15,910	50,510	3,892	13,565	6,649	21,826	28,317	91,961
		Wyoming	1,498	4,660	0	0	812	2,832	3,337	9,655	911	2,750	6,558	19,897
		North Dakota	0	0	0	0	0	0	163	503	66	203	229	706
		Total 6G	3,364	10,720	0	0	16,722	53,342	7,392	23,723	7,626	24,779	35,104	112,564
6H	Bighorn River	Montana	250	750	0	0	2,935	9,310	188	545	328	993	3,701	11,598
		Wyoming	19,120	59,470	7,250	23,160	6,934	24,210	3,262	9,566	2,126	6,234	38,692	122,640
		Total 6H	19,370	60,220	7,250	23,160	9,869	33,520	3,450	10,111	2,454	7,227	42,393	134,238
6J	Missouri River, Yellowstone River to Cheyenne River.	Montana	0	0	0	0	0	0	1,363	4,420	375	1,223	1,738	5,643
		Wyoming	0	0	0	0	0	0	533	1,821	204	697	737	2,518
		North Dakota	320,590	934,550	13,010	37,210	22,879	65,230	62,131	176,682	2,611	7,715	421,221	1,221,387
		South Dakota	4,800	14,800	1,330	3,880	1,648	4,940	17,603	52,427	2,091	6,441	27,472	82,488
		Total 6J	325,390	949,350	14,340	41,090	24,527	70,170	81,630	235,350	5,281	16,076	451,168	1,312,036
6K	Cheyenne River	Montana	0	0	0	0	0	0	41	133	11	37	52	170
		Wyoming	4,560	16,000	0	0	0	0	1,899	6,688	1,145	4,091	7,604	26,779
		South Dakota	11,190	38,454	0	0	5,100	16,590	9,087	30,412	4,117	13,829	29,494	99,285
		Nebraska	0	0	0	0	0	0	80	294	174	638	254	932
		Total 6K	15,750	54,454	0	0	5,100	16,590	11,107	37,527	5,447	18,595	37,404	127,166
6L	Missouri River, Cheyenne River to Platte River.	Wyoming	0	0	0	0	0	0	141	529	112	420	253	949
		North Dakota	3,630	9,460	17,245	47,365	1,697	4,520	38,160	103,215	429	1,134	61,161	165,694
		South Dakota	375,430	1,140,480	36,035	101,400	28,490	87,015	42,261	130,534	9,686	30,386	491,902	1,489,815
		Nebraska	1,182	4,440	4,490	15,590	16,593	35,500	26,846	93,389	5,125	18,180	48,236	167,099
		Big Sioux River	0	0	0	0	2,180	6,720	0	0	0	0	2,180	6,720
		Missouri River	11,300	36,800	0	0	53,970	173,700	0	0	0	0	65,270	210,500
		Total 6L	391,542	1,191,180	57,770	164,355	96,930	307,455	107,408	327,667	15,352	50,120	669,002	2,040,777

[1] Index designations for subbasins are the same as those used in Jones and Holland (1948) and Thomas and Harbeck (1956).

TABLE 4.—*Fresh-water surface areas and evaporation in the 17 Western States*—Continued

Index designation for subbasin [1]	River subbasin	State and boundary river	Principal reservoirs and regulated lakes		Other lakes over 500 acres		Principal streams and canals		Small ponds and reservoirs		Small streams		Total for all classes	
			Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)
Part 6.—Missouri River basin—Continued														
6M	Platte River below junction of North and South Platte Rivers.	Nebraska	4,585	18,325	0	0	61,327	221,628	22,065	80,417	14,381	52,089	102,358	372,459
6N	North Platte River	Wyoming	33,503	119,390	9,000	33,000	8,635	31,000	6,226	20,985	4,467	15,300	61,831	219,675
		Colorado	27	74	0	0	172	487	1,125	3,145	254	707	1,578	4,413
		Nebraska	34,560	135,390	0	0	22,315	87,270	30,561	119,388	1,549	5,936	88,985	347,984
		Total 6N	68,090	254,854	9,000	33,000	31,122	118,767	37,912	143,518	6,270	21,943	152,394	572,072
6O	South Platte River	Wyoming	63	194	0	0	0	0	637	2,086	759	2,564	1,459	4,844
		Colorado	29,649	97,524	227	720	4,302	15,588	13,664	44,365	4,396	15,106	52,238	173,303
		Nebraska	0	0	0	0	4,741	18,750	7,935	31,100	274	1,055	12,950	50,905
		Total 6O	29,712	97,718	227	720	9,043	34,338	22,236	77,551	5,429	18,725	66,647	229,052
6P	Missouri River, Platte River to Kansas River.	Nebraska	0	0	0	0	1,172	4,270	822	3,075	1,676	6,228	3,670	13,573
		Kansas	102	366	0	0	0	0	115	432	435	1,607	652	2,405
		Missouri River	0	0	0	0	55,700	199,300	0	0	0	0	55,700	199,300
		Total 6P	102	366	0	0	56,872	203,570	937	3,507	2,111	7,835	60,022	215,278
6R	Kansas River	Colorado	2,770	12,500	0	0	0	0	496	2,246	626	2,765	3,892	17,511
		Nebraska	12,650	56,300	0	0	11,170	47,289	9,547	40,473	4,550	18,501	37,917	162,563
		Kansas	43,837	192,536	300	1,300	32,710	116,574	7,142	32,884	15,938	72,776	99,927	416,070
		Total 6R	59,257	261,336	300	1,300	43,880	163,863	17,185	75,603	21,114	94,042	141,736	596,144
6S	Missouri River below Kansas River.	Kansas	0	0	0	0	889	3,560	2,564	9,911	1,682	6,590	5,135	20,061
	Subtotals by States and boundary rivers.	Montana	317,294	959,207	17,763	50,136	81,373	244,139	78,480	229,083	31,994	93,704	526,904	1,576,269
		Wyoming	58,744	199,714	98,950	242,160	18,175	62,137	19,054	58,184	10,594	34,060	205,517	596,255
		Colorado	32,446	110,098	227	720	4,474	16,075	15,285	49,756	5,276	18,578	57,708	195,227
		North Dakota	324,220	944,010	30,255	84,575	24,576	69,750	101,113	282,373	3,144	9,166	483,308	1,389,874
		South Dakota	391,420	1,193,734	37,365	105,280	35,238	108,545	68,951	213,373	15,894	50,656	548,868	1,671,588
		Nebraska	52,977	214,455	4,490	15,590	111,318	414,707	97,856	368,136	27,729	102,627	294,370	1,115,515
		Kansas	43,939	192,902	300	1,300	33,599	120,134	9,821	43,227	18,055	80,973	105,714	438,536
		Big Sioux River	0	0	0	0	2,180	6,720	0	0	0	0	2,180	6,720
		Missouri River	11,300	36,800	0	0	109,670	373,000	0	0	0	0	120,970	409,800
	Grand total		1,232,340	3,850,920	189,350	499,761	420,603	1,415,207	390,560	1,244,132	112,686	389,764	2,345,539	7,399,784
Part 7.—Lower Mississippi River basin														
7A	Arkansas River above Holly gage, near Colorado-Kansas line.	Colorado	12,848	52,228	1,793	6,308	3,708	14,655	11,537	42,413	7,641	28,142	37,527	143,746
		New Mexico	0	0	0	0	0	0	202	824	23	90	225	914
		Total 7A	12,848	52,228	1,793	6,308	3,708	14,655	11,739	43,237	7,664	28,232	37,752	144,660
7B	Cimarron River	Colorado	0	0	0	0	0	0	150	711	175	828	325	1,539
		New Mexico	0	0	0	0	0	0	262	1,165	58	260	320	1,425
		Kansas	0	0	0	0	557	2,885	163	854	392	2,056	1,112	5,795
		Oklahoma	3,270	16,310	0	0	8,686	42,053	2,922	14,794	1,357	6,887	16,235	80,044
		Total 7B	3,270	16,310	0	0	9,243	44,938	3,497	17,524	1,982	10,031	17,992	88,803
7C	Canadian River	New Mexico	8,433	44,043	0	0	1,086	5,601	5,646	27,002	1,018	4,600	16,183	81,246
		Oklahoma	9,086	46,877	0	0	25,512	122,320	5,129	25,958	3,842	18,731	43,569	213,886
		Texas	100	525	0	0	3,635	19,500	5,313	28,359	727	3,963	9,775	52,347
		Total 7C	17,619	91,445	0	0	30,233	147,421	16,088	81,319	5,587	27,294	69,527	347,479
7D	Arkansas River, Holly gage to Cimarron River.	Colorado	0	0	0	0	46	222	255	1,212	234	1,117	535	2,551
		Kansas	267	1,382	0	0	21,408	105,699	4,143	20,512	7,292	36,264	33,110	163,857
		Oklahoma	9,405	48,433	0	0	13,489	62,220	2,907	14,002	1,187	5,776	26,988	130,431
		Total 7D	9,672	49,815	0	0	34,943	168,141	7,305	35,726	8,713	43,157	60,633	296,839
7E	Arkansas River, Cimarron River to Canadian River.	Kansas	1,920	8,440	0	0	7,548	31,240	6,443	27,180	4,823	20,605	20,734	87,465
		Oklahoma	61,272	251,281	650	2,630	22,369	94,870	9,422	40,255	6,941	29,327	100,654	418,363
		Total 7E	63,192	259,721	650	2,630	29,917	126,110	15,865	67,435	11,764	49,932	121,388	505,828
7F	Arkansas River below Canadian River.	Oklahoma	5,000	20,000	0	0	8,304	33,100	1,151	4,640	2,580	10,446	17,035	68,186
7K	Red River above Washita River.	New Mexico	0	0	0	0	0	0	253	1,435	2	11	255	1,446
		Oklahoma	7,691	40,335	0	0	788	4,280	6,564	34,650	2,046	10,775	17,089	90,040
		Texas	22,480	122,370	0	0	1,049	5,755	12,853	70,835	2,272	12,464	38,654	211,424
		Red River	0	0	0	0	6,704	34,080	0	0	0	0	6,704	34,080
		Total 7K	30,171	162,705	0	0	8,541	44,115	19,670	106,920	4,320	23,250	62,702	336,990
7L	Red River, Washita River to Index gage near Texarkana.	Oklahoma	370	1,912	1,330	5,540	7,247	33,500	4,332	21,470	4,780	22,054	18,059	84,476
		Texas	1,290	5,700	0	0	0	0	1,522	6,845	633	2,820	3,445	15,365
		Red River	83,590	390,000	0	0	25,450	108,000	0	0	0	0	109,040	498,000
		Total 7L	85,250	397,612	1,330	5,540	32,697	141,500	5,854	28,315	5,413	24,874	130,544	597,841

[1] Index designations for subbasins are the same as those used in Jones and Holland (1948) and Thomas and Harbeck (1956).

TABLE 4.—*Fresh-water surface areas and evaporation in the 17 Western States*—Continued

Index designation for subbasin [1]	River subbasin	State and boundary river	Principal reservoirs and regulated lakes		Other lakes over 500 acres		Principal streams and canals		Small ponds and reservoirs		Small streams		Total for all classes	
			Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)
		Part 7.—Lower Mississippi River basin—Continued												
7M	Red River below Index gage.	Oklahoma	0	0	0	0	2,060	8,410	241	984	763	3,112	3,064	12,50
		Texas	13,500	55,370	1,670	6,990	2,645	11,030	6,110	25,895	2,414	10,211	26,339	109,49
		Total 7M	13,500	55,370	1,670	6,990	4,705	19,440	6,351	26,879	3,177	13,323	29,403	122,00
	Subtotals by States and boundary rivers.	Colorado	12,848	52,228	1,793	6,308	3,754	14,877	11,942	44,336	8,050	30,087	38,387	147,83
		New Mexico	8,433	44,043	0	0	1,086	5,601	6,363	30,426	1,101	4,961	16,983	85,03
		Kansas	2,187	9,822	0	0	29,513	139,824	10,749	48,546	12,507	58,925	54,956	257,11
		Oklahoma	96,094	425,148	1,980	8,170	88,455	400,753	32,668	156,753	23,496	107,108	242,693	1,097,93
		Texas	37,370	183,965	1,670	6,990	7,329	36,285	25,798	131,934	6,046	29,458	78,213	388,63
		Red River	83,590	390,000	0	0	32,154	142,080	0	0	0	0	115,744	532,08
	Grand total		240,522	1,105,206	5,443	21,468	162,291	739,420	87,520	411,995	51,200	230,539	546,976	2,508,62
		Part 8.—Western Gulf of Mexico basins												
8A	San Luis Valley closed basin.	Colorado	0	0	433	1,515	0	0	2,804	8,681	1,452	4,591	4,689	14,787
8B	Rio Grande above Rio Puerco.	Colorado	4,329	13,530	0	0	955	3,180	3,383	10,410	1,915	5,980	10,582	33,10
		New Mexico	4,188	16,999	0	0	2,366	10,105	3,075	11,941	1,947	8,129	11,576	47,174
		Total 8B	8,517	30,529	0	0	3,321	13,285	6,458	22,351	3,862	14,109	22,158	80,274
8C	Rio Grande, Rio Puerco to El Paso.	New Mexico	19,501	116,900	0	0	2,404	14,367	1,437	8,003	1,047	5,765	24,389	145,035
		Texas	0	0	0	0	0	0	2	12	1	6	3	18
		Total 8C	19,501	116,900	0	0	2,404	14,367	1,439	8,015	1,048	5,771	24,392	145,053
8D	Tularosa closed basin	New Mexico	0	0	0	0	0	0	648	3,577	346	1,885	994	5,462
		Texas	0	0	0	0	0	0	10	60	5	30	15	90
		Total 8D	0	0	0	0	0	0	658	3,637	351	1,915	1,009	5,552
8E	Rio Grande, El Paso to Pecos River.	Texas	0	0	0	0	192	1,168	632	3,768	397	2,405	1,221	7,341
		Rio Grande	0	0	0	0	9,090	56,000	0	0	0	0	9,090	56,00
		Total 8E	0	0	0	0	9,282	57,168	632	3,768	397	2,405	10,311	63,341
8F	Pecos River	New Mexico	4,854	28,146	0	0	1,473	8,513	11,029	61,868	1,495	7,875	18,851	106,402
		Texas	2,985	18,450	0	0	1,782	11,740	749	4,633	500	3,138	6,016	37,961
		Total 8F	7,839	46,596	0	0	3,255	20,253	11,778	66,501	1,995	11,013	24,867	144,363
8G	Closed basin east of El Paso.	New Mexico	0	0	0	0	0	0	180	988	78	428	258	1,416
		Texas	0	0	0	0	0	0	50	288	67	385	117	673
		Total 8G	0	0	0	0	0	0	230	1,276	145	813	375	2,089
8H	Closed basin west of Lubbock.	New Mexico	0	0	0	0	0	0	2,445	14,246	21	123	2,466	14,369
		Texas	0	0	850	5,030	0	0	1,039	6,067	41	241	1,930	11,339
		Total 8H	0	0	850	5,030	0	0	3,484	20,313	62	364	4,396	25,707
8J	Rio Grande below Pecos River.	Texas	620	4,080	310	1,500	939	5,958	2,869	15,986	2,571	13,441	7,309	40,965
		Rio Grande	56,500	353,000	0	0	16,370	97,200	0	0	0	0	72,870	450,20
		Total 8J	57,120	357,080	310	1,500	17,309	103,158	2,869	15,986	2,571	13,441	80,179	491,165
8K	Nueces, San Antonio, Guadalupe, Lavaca Rivers.	Texas	6,385	30,138	6,820	31,690	8,636	41,970	18,593	87,929	6,608	31,480	47,042	223,207
8L	Colorado River	New Mexico	0	0	0	0	0	0	412	2,496	27	163	439	2,659
		Texas	60,818	308,135	3,110	15,680	22,908	110,122	7,142	38,372	4,458	22,511	98,436	494,82
		Total 8L	60,818	308,135	3,110	15,680	22,908	110,122	7,554	40,868	4,485	22,674	98,875	497,479
8M	Brazos River	New Mexico	0	0	0	0	0	0	2,100	12,100	10	58	2,110	12,158
		Texas	52,605	261,307	2,370	11,395	27,897	132,330	21,421	112,613	6,672	32,912	110,965	550,557
		Total 8M	52,605	261,307	2,370	11,395	27,897	132,330	23,521	124,713	6,682	32,970	113,075	562,715
8N	Trinity River, San Jacinto River.	Texas	60,295	277,742	5,440	24,052	15,392	69,130	12,497	57,351	6,560	29,638	100,184	457,913
8O	Sabine River	Texas	15,320	65,300	6,770	29,160	13,590	58,330	11,675	50,783	7,458	32,035	54,813	235,60
		Sabine River	0	0	52,800	224,000	6,060	25,800	0	0	0	0	58,860	249,80
		Total 8O	15,320	65,300	59,570	253,160	19,650	84,130	11,675	50,783	7,458	32,035	113,673	485,40
	Subtotals by States and boundary rivers.	Colorado	4,329	13,530	433	1,515	955	3,180	6,187	19,091	3,367	10,571	15,271	47,88
		New Mexico	28,543	162,045	0	0	6,243	32,985	21,326	115,219	4,971	24,426	61,083	334,67
		Texas	199,028	965,152	25,670	118,507	91,336	430,748	76,679	377,862	35,338	168,222	428,051	2,060,49
		Rio Grande	56,500	353,000	0	0	25,460	153,200	0	0	0	0	81,960	506,20
		Sabine River	0	0	52,800	224,000	6,060	25,800	0	0	0	0	58,860	249,8
	Grand total		288,400	1,493,727	78,903	344,022	130,054	645,913	104,192	512,172	43,676	203,219	645,225	3,199,05

[1] Index designations for subbasins are the same as those used in Jones and Holland (1948) and Thomas and Harbeck (1956).

TABLE 4.—*Fresh-water surface areas and evaporation in the 17 Western States*—Continued

Index designation for subbasin [1]	River subbasin	State and boundary river	Principal reservoirs and regulated lakes		Other lakes over 500 acres		Principal streams and canals		Small ponds and reservoirs		Small streams		Total for all classes	
			Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)
		Part 9.—Colorado River basin												
9A	Green River above Yampa River.	Utah	0	0	0	0	1,340	3,800	2,773	7,403	521	1,396	4,634	12,599
		Wyoming	8,170	21,000	2,106	5,100	2,378	7,086	8,581	25,575	6,085	18,024	27,320	76,785
		Colorado	0	0	0	0	765	2,170	12	35	1,566	4,567	2,343	6,772
		Total 9A	8,170	21,000	2,106	5,100	4,483	13,056	11,366	33,013	8,172	23,987	34,297	96,156
9B	Green River, Yampa River to Colorado River.	Utah	8,445	23,546	0	0	8,022	25,281	11,374	31,710	2,344	6,666	30,185	87,203
		Colorado	0	0	0	0	668	1,912	4,489	12,023	2,574	7,403	7,731	21,338
		Total 9B	8,445	23,546	0	0	8,690	27,193	15,863	43,733	4,918	14,069	37,916	108,541
9C	Yampa River	Wyoming	0	0	0	0	201	603	21	63	378	1,135	600	1,801
		Colorado	0	0	0	0	2,466	7,053	1,028	2,874	5,743	16,427	9,237	26,354
		Total 9C	0	0	0	0	2,667	7,656	1,049	2,937	6,121	17,562	9,837	28,155
9D	Colorado River above Green River, excepting Gunnison River.	Utah	0	0	0	0	4,242	14,164	84	277	220	730	4,546	15,171
		Colorado	8,473	23,304	0	0	6,354	18,216	36,880	101,043	6,332	17,734	58,039	160,297
		Total 9D	8,473	23,304	0	0	10,596	32,380	36,964	101,320	6,552	18,464	62,585	175,468
9E	Gunnison River	Colorado	4,223	12,125	0	0	2,755	7,879	4,356	12,081	3,514	9,887	14,848	41,972
9F above compact point.	Colorado River, Green River to compact point, excepting San Juan River.	Utah	260	953	2,933	10,750	10,466	41,842	80	300	225	851	13,964	54,696
		Arizona	0	0	0	0	1,610	7,790	65	308	30	146	1,705	8,244
		Total 9F above compact point.	260	953	2,933	10,750	12,076	49,632	145	608	255	997	15,669	62,940
9G	San Juan River	Utah	0	0	0	0	2,300	9,580	45	172	169	651	2,514	10,403
		Arizona	442	1,880	0	0	0	0	294	1,268	1,085	4,524	1,821	7,672
		Colorado	100	334	0	0	627	1,996	5,531	17,007	2,823	8,811	9,081	28,148
		New Mexico	0	0	0	0	1,871	6,844	1,193	4,557	1,041	3,940	4,105	15,341
		Total 9G	542	2,214	0	0	4,798	18,420	7,063	23,004	5,118	17,926	17,521	61,564
	Subtotals by States for Colorado River basin above compact point near Lees Ferry.	Utah	8,705	24,499	2,933	10,750	26,370	94,667	14,356	39,862	3,479	10,294	55,843	180,072
		Arizona	442	1,880	0	0	1,610	7,790	359	1,576	1,115	4,670	3,526	15,916
		Wyoming	8,170	21,000	2,106	5,100	2,579	7,689	8,602	25,638	6,463	19,159	27,920	78,586
		Colorado	12,796	35,763	0	0	13,635	39,226	52,296	145,063	22,552	64,829	101,279	284,881
		New Mexico	0	0	0	0	1,871	6,844	1,193	4,557	1,041	3,940	4,105	15,341
	Grand totals for Colorado River above compact point.		30,113	83,142	5,039	15,850	46,065	156,216	76,806	216,696	34,650	102,892	192,673	574,796
9F below compact point.	Colorado River, compact point to Little Colorado River.	Arizona	0	0	0	0	3,960	20,100	30	149	37	184	4,027	20,433
9H	Colorado River, Little Colorado River to Virgin River.	Nevada	0	0	0	0	0	0	0	0	4	25	4	25
		Utah	0	0	0	0	0	0	11	50	20	90	31	140
		Arizona	0	0	0	0	7,610	44,400	1,380	7,124	501	2,676	9,491	54,200
		Colorado River	33,350	229,000	0	0	0	0	0	0	0	0	33,550	229,000
		Total 9H	33,550	229,000	0	0	7,610	44,400	1,391	7,174	525	2,791	43,076	283,365
9J	Little Colorado River	Arizona	1,160	5,462	1,240	5,790	306	1,409	3,921	17,926	706	3,203	7,333	33,790
		New Mexico	133	599	0	0	0	0	275	1,264	145	659	553	2,522
		Total 9J	1,293	6,061	1,240	5,790	306	1,409	4,196	19,190	851	3,862	7,886	36,312
9K	Virgin River and adjacent closed basins in Nevada.	Nevada	0	0	0	0	54	324	75	349	176	836	305	1,509
		Utah	0	0	0	0	57	266	74	338	156	712	287	1,316
		Arizona	0	0	0	0	54	261	224	1,063	22	105	300	1,429
		Colorado River	41,000	280,000	0	0	0	0	0	0	0	0	41,000	280,000
		Total 9K	41,000	280,000	0	0	165	851	373	1,750	354	1,653	41,892	284,254
9L	Colorado River below Virgin River, excepting Gila River.	California	489	31,500	0	0	2,152	14,313	381	2,163	1,380	8,954	4,402	28,930
		Nevada	0	0	0	0	0	0	24	155	30	193	54	348
		Arizona	0	0	0	0	513	3,420	319	1,971	161	1,008	993	6,399
		Colorado River	95,970	668,500	3,240	22,100	11,370	81,700	0	0	0	0	110,580	772,300
		Total 9L	96,459	672,000	3,240	22,100	14,035	99,433	724	4,289	1,571	10,155	116,029	807,977
9M	Gila River, excepting Salt, Verde, and Agua Fria Rivers.	Arizona	2,677	14,300	0	0	685	3,881	1,288	7,350	1,742	9,664	6,392	35,195
		New Mexico	0	0	0	0	127	656	442	2,260	336	1,734	905	4,650
		Total 9M	2,677	14,300	0	0	812	4,537	1,730	9,610	2,078	11,398	7,297	39,845
9N	Salt, Verde, Agua Fria Rivers.	Arizona	13,144	74,350	667	3,220	1,492	8,337	1,027	5,198	2,971	15,297	19,301	106,402

[1] Index designations for subbasins are the same as those used in Jones and Holland (1948) and Thomas and Harbeck (1956).

TABLE 4.—*Fresh-water surface areas and evaporation in the 17 Western States*—Continued

Index designation for subbasin[1]	River subbasin	State and boundary river	Principal reservoirs and regulated lakes		Other lakes over 500 acres		Principal streams and canals		Small ponds and reservoirs		Small streams		Total for all classes	
			Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)
Part 9.—Colorado River basin—Continued														
9P	Drainage to Mexico	Arizona	0	0	0	0	0	0	150	513	214	691	364	1,204
		New Mexico	0	0	0	0	0	0	70	371	113	600	183	971
		Total 9P	0	0	0	0	0	0	220	884	327	1,291	547	2,175
	Subtotals by states and boundary rivers for Colorado River basin below compact point near Lees Ferry.	California	489	3,500	0	0	2,152	14,313	381	2,163	1,380	8,954	4,402	28,930
		Nevada	0	0	0	0	54	324	99	504	210	1,054	363	1,882
		Utah	0	0	0	0	57	266	85	388	176	802	318	1,456
		Arizona	16,981	94,112	1,907	9,010	14,620	81,808	8,339	41,294	6,354	32,828	48,201	259,052
		New Mexico	133	599	0	0	127	656	787	3,895	594	2,993	1,641	8,143
		Colorado River	170,520	1,177,500	3,240	22,100	11,370	81,700	0	0	0	0	185,130	1,281,300
	Totals for Colorado River below compact point.		188,123	1,275,711	5,147	31,110	28,380	179,067	9,691	48,244	8,714	46,631	240,055	1,580,763
	Grand total		218,236	1,358,853	10,186	46,960	74,445	335,283	86,497	264,940	43,364	149,523	432,728	2,155,728
Part 10.—The Great Basin														
10A	Closed basins around Oregon-California-Nevada common corner.	Oregon	1,288	4,225	0	0	0	0	1,916	6,682	1,710	5,870	4,914	16,777
		California	2,083	7,171	5,867	21,000	0	0	1,849	6,881	837	2,995	10,636	38,047
		Nevada	0	0	0	0	0	0	438	1,664	243	941	681	2,605
		Total 10A	3,371	11,396	5,867	21,000	0	0	4,203	15,227	2,790	9,806	16,231	57,429
10B	Tahoe and Pyramid Lakes	California	116,898	331,520	150	450	143	429	409	1,219	674	2,013	118,274	335,631
		Nevada	0	0	82,130	327,450	343	1,318	1,208	4,721	275	1,071	83,956	334,560
		Total 10B	116,898	331,520	82,280	327,900	486	1,747	1,617	5,940	949	3,084	202,230	670,191
10C	Carson River	California	0	0	0	0	105	289	243	669	354	974	702	1,932
		Nevada	6,667	27,800	340	1,500	602	2,291	2,366	10,337	960	4,053	10,935	45,981
		Total 10C	6,667	27,800	340	1,500	707	2,580	2,609	11,006	1,314	5,027	11,637	47,913
10D	Humboldt River	Nevada	11,884	50,182	0	0	1,099	4,440	470	1,950	693	2,747	14,146	59,319
10E	Mono and Walker Lakes	California	3,076	9,230	563	1,595	23	77	1,769	5,316	1,462	4,412	6,893	20,630
		Nevada	1,470	5,070	29,300	122,000	298	1,190	802	3,020	874	3,188	32,744	134,468
		Total 10E	4,546	14,300	29,863	123,595	321	1,267	2,571	8,336	2,336	7,600	39,637	155,098
10F	Closed basins west of Tonopah.	California	0	0	200	667	0	0	79	264	173	576	452	1,507
		Nevada	0	0	0	0	0	0	595	2,573	633	2,637	1,228	5,210
		Total 10F	0	0	200	667	0	0	674	2,837	806	3,213	1,680	6,717
10G	Owens River	California	6,228	20,460	133	400	310	1,030	1,530	5,600	2,604	8,914	10,805	36,404
10H	Great Salt Lake basin	Nevada	0	0	0	0	0	0	11	42	136	483	147	525
		Idaho	84,019	245,767	0	0	1,042	3,109	168	527	983	2,977	86,212	252,380
		Utah	106,861	431,527	667	2,170	2,194	6,952	38,333	129,405	5,593	17,880	153,648	587,934
		Wyoming	0	0	0	0	282	798	201	562	446	1,272	929	2,632
		Total 10H	190,880	677,294	667	2,170	3,518	10,859	38,713	130,536	7,158	22,612	240,936	843,471
10J	Sevier River	Nevada	0	0	0	0	0	0	5	22	7	31	12	53
		Utah	8,459	31,360	450	1,910	557	2,058	1,361	5,023	1,367	5,170	12,194	45,521
		Total 10J	8,459	31,360	450	1,910	557	2,058	1,366	5,045	1,374	5,201	12,206	45,574
10K	Closed basins, eastern Nevada.	Nevada	0	0	0	0	0	0	276	1,134	453	1,822	729	2,956
10L	Closed basins, east-central Nevada.	Nevada	0	0	0	0	0	0	485	2,108	247	1,069	732	3,177
10M	Closed basins, south-central Nevada.	California	0	0	0	0	0	0	2,702	18,459	56	368	2,758	18,827
		Nevada	0	0	0	0	0	0	3,406	19,841	147	753	3,553	20,594
		Total 10M	0	0	0	0	0	0	6,108	38,300	203	1,121	6,311	39,421
10N	Mojave River, Salton Sea	California	729	3,650	50	238	1,247	8,549	336	2,050	532	3,406	2,894	17,893
		Nevada	0	0	0	0	0	0	5	32	6	38	11	70
		Total 10N	729	3,650	50	238	1,247	8,549	341	2,082	538	3,444	2,905	17,963
	Subtotals by States	Oregon	1,288	4,225	0	0	0	0	1,916	6,682	1,710	5,870	4,914	16,777
		California	129,014	372,031	6,963	24,350	1,828	10,374	8,917	40,458	6,692	23,658	153,414	470,871
		Nevada	20,021	83,052	111,770	450,950	2,342	9,239	10,067	47,444	4,674	18,833	148,874	609,518
		Idaho	84,019	245,767	0	0	1,042	3,109	168	527	983	2,977	86,212	252,380
		Utah	115,320	462,887	1,117	4,080	2,751	9,010	39,694	134,428	6,960	23,050	165,842	633,455
		Wyoming	0	0	0	0	282	798	201	562	446	1,272	929	2,632
	Grand total		349,662	1,167,962	119,850	479,380	8,245	32,530	60,963	230,101	21,465	75,660	560,185	1,985,633

[1] Index designations for subbasins are the same as those used in Jones and Holland (1948) and Thomas and Harbeck (1956).

TABLE 4.—*Fresh-water surface areas and evaporation in the 17 Western States*—Continued

Index designation for subbasin [1]	River subbasin	State and boundary river	Principal reservoirs and regulated lakes		Other lakes over 500 acres		Principal streams and canals		Small ponds and reservoirs		Small streams		Total for all classes	
			Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)
	Part 11.—Pacific slope basins in California													
11A	Klamath River	Oregon California	84,832 16,300	262,890 59,750	13,000 5,600	35,800 20,100	1,149 9,220	3,670 26,486	1,148 3,504	3,602 12,160	1,696 6,282	5,254 20,592	101,825 40,906	311,216 139,088
		Total 11A	101,132	322,640	18,600	55,900	10,369	30,156	4,652	15,762	7,978	25,846	142,731	450,304
11B	Sacramento River above Feather River.	Oregon California	2,466 30,782	9,250 130,490	0 178	0 660	0 13,339	0 56,972	71 7,410	268 28,628	95 8,008	356 32,564	2,632 59,717	9,874 249,314
		Total 11B	33,248	139,740	178	660	13,339	56,972	7,481	28,896	8,103	32,920	62,349	259,188
11C	Feather River	California	25,029	88,464	1,134	3,838	5,061	19,292	2,246	8,560	5,968	21,687	39,438	141,841
11D	Lower Sacramento River, American River, Putah Creek.	California	60,316	237,185	0	0	5,845	103,522	15,815	63,106	7,100	28,274	89,076	432,087
11E	Northern California coast below Klamath River.	California	2,609	9,980	0	0	3,071	9,780	1,522	5,113	6,686	21,260	13,888	46,133
11F	San Joaquin, Kings, and Kern Rivers.	California	39,207	168,063	1,735	4,912	34,252	147,223	31,010	129,582	18,420	74,225	124,624	524,005
11G	Southern California coast	California	21,437	88,397	1,688	6,697	172	627	6,121	22,890	4,943	19,015	34,361	137,626
	Subtotals by States	Oregon California	87,298 195,680	272,140 782,329	13,000 10,335	35,800 36,207	1,149 70,960	3,670 363,902	1,219 67,628	3,870 270,039	1,791 57,407	5,610 217,617	104,457 402,010	321,090 1,670,094
	Grand total		282,978	1,054,469	23,335	72,007	72,109	367,572	68,847	273,909	59,198	223,227	506,467	1,991,184
	Part 12.—Pacific slope basins in Washington and upper Columbia River basin													
12A	Kootenai River	Idaho Montana	0 0	0 0	800 2,632	2,070 5,840	2,300 3,440	5,950 7,460	150 1,198	362 2,571	241 2,057	622 4,438	3,491 9,327	9,004 20,309
		Total 12A	0	0	3,432	7,910	5,740	13,410	1,348	2,933	2,298	5,060	12,818	29,313
12B	Clark Fork above Bitterroot River.	Montana	4,553	9,507	1,800	3,750	2,899	6,040	3,875	8,149	2,622	5,511	15,749	32,957
12C	Flathead River	Montana	153,678	319,680	24,510	51,600	8,588	18,002	6,220	13,010	4,389	9,178	197,385	411,470
12D	Clark Fork (and Pend Oreille River) below Bitterroot River, excepting Flathead River.	Washington Idaho Montana	867 121,228 1,305	2,380 324,200 2,940	933 2,166 2,430	2,720 5,980 5,150	6,890 3,352 6,801	19,500 9,330 14,815	2,017 486 1,224	5,720 1,343 2,659	537 804 3,664	1,520 2,232 8,165	11,244 128,036 15,424	31,840 343,085 33,729
		Total 12D	123,400	329,520	5,529	13,850	17,043	43,645	3,727	9,722	5,005	11,917	154,704	408,654
12E	Columbia and Spokane Rivers above their junction, excepting Clark Fork.	Washington Idaho	3,451 32,000	11,600 93,400	3,373 4,534	10,320 13,340	2,391 2,584	7,540 6,910	4,583 406	14,128 1,103	1,465 2,979	4,476 7,737	15,263 42,503	48,064 122,490
		Total 12E	35,451	105,000	7,907	23,660	4,975	14,450	4,989	15,231	4,444	12,213	57,766	170,554
12F	Columbia River, Spokane River to Snake River.	Washington	157,603	516,278	21,494	62,114	60,209	200,050	10,416	29,279	5,094	12,992	254,816	820,713
12O	Washington coast	Washington	0	0	12,600	19,500	4,158	7,048	2,798	4,800	7,558	12,752	27,114	44,100
12P	Puget Sound	Washington	20,622	39,790	41,588	76,875	9,185	20,138	30,721	61,079	18,066	35,030	120,182	232,912
	Subtotals by States	Washington Idaho Montana	182,543 153,228 159,536	570,048 417,600 332,127	79,988 7,500 31,372	171,529 21,390 66,340	82,833 8,236 21,728	254,276 22,190 46,317	50,535 1,042 12,517	115,006 2,808 26,389	32,720 4,024 12,732	66,770 10,591 27,292	428,619 174,030 237,885	1,177,629 474,579 498,465
	Grand total		495,307	1,319,775	118,860	259,259	112,797	322,783	64,094	144,203	49,476	104,653	840,534	2,150,673
	Part 13.—Snake River basin													
12G	Snake River above Big Wood River.	Nevada Idaho Utah Wyoming	0 114,778 0 17,103	0 344,387 0 39,949	0 1,500 0 15,450	0 4,155 0 35,110	0 12,442 0 2,250	0 37,087 0 5,652	13 5,326 3 3,329	43 14,986 10 7,949	157 9,816 11 1,239	522 28,606 37 3,113	170 143,862 14 39,371	565 429,221 47 91,773
		Total 12G	131,881	384,336	16,950	39,265	14,692	42,739	8,671	22,988	11,223	32,278	183,417	521,606
12H	Snake River, Big Wood River to Clearwater River, excepting Salmon River.	Washington Oregon Nevada Idaho Snake River	0 18,437 915 41,735 0	0 56,700 3,050 111,615 0	0 267 0 500 0	0 868 0 1,405 0	408 3,902 0 14,221 14,300	1,125 11,572 0 42,535 37,000	28 1,184 24 4,350 0	79 3,603 81 11,796 0	72 3,919 199 2,327 0	204 11,428 682 6,220 0	508 27,709 1,138 63,133 14,300	1,408 84,171 3,813 173,571 37,000
		Total 12H	61,087	171,365	767	2,273	32,831	92,232	5,586	15,559	6,517	18,534	106,788	299,963
12J	Salmon River	Idaho	0	0	2,623	6,210	10,386	24,407	3,219	7,288	3,808	8,729	20,036	46,634

[1] Index designations for subbasins are the same as those used in Jones and Holland (1948) and Thomas and Harbeck (1956).

TABLE 4.—*Fresh-water surface areas and evaporation in the 17 Western States*—Continued

Index designation for subbasin[1]	River subbasin	State and boundary river	Principal reservoirs and regulated lakes		Other lakes over 500 acres		Principal streams and canals		Small ponds and reservoirs		Small streams		Total for all classes	
			Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evaporation (acre-ft)	Effective area (acres)	Annual evapo- ration (acre-ft
			Part 13.—Snake River basin—Continued											
12K	Clearwater River	Idaho	0	0	67	184	6,377	15,939	1,438	3,544	3,870	9,296	11,752	28,9
12L	Snake River below Clearwater River.	Washington	0	0	1,433	4,880	16,632	54,140	1,212	3,970	483	1,531	19,760	64,5
		Idaho	0	0	0	0	0	0	181	516	341	967	522	1,4
		Total 12L	0	0	1,433	4,880	16,632	54,140	1,393	4,486	824	2,498	20,282	66,0
	Subtotals by States and boundary rivers.	Washington	0	0	1,433	4,880	17,040	55,265	1,240	4,049	555	1,735	20,268	65,9
		Oregon	18,437	56,700	267	868	3,902	11,572	1,184	3,603	3,919	11,428	27,709	84,1
		Nevada	915	3,050	0	0	0	0	37	124	356	1,204	1,308	4,3
		Idaho	156,513	456,002	4,690	11,954	43,426	119,968	14,514	38,130	20,162	53,818	239,305	679,8
		Utah	0	0	0	0	0	0	3	10	11	37	14	4
		Wyoming	17,103	39,949	15,450	35,110	2,250	5,652	3,329	7,949	1,239	3,113	39,371	91,7
		Snake River	0	0	0	0	14,300	37,000	0	0	0	0	14,300	37,0
	Grand total		192,968	555,701	21,840	52,812	80,918	229,457	20,307	53,865	26,242	71,335	342,275	963,1
			Part 14.—Pacific slope basins in Oregon and Lower Columbia River basin											
12M	Columbia River between Snake River and Willamette River.	Washington	68	215	0	0	724	1,865	497	1,442	1,163	2,856	2,452	6,3
		Oregon	17,061	45,936	11,316	29,098	8,558	23,047	3,690	9,835	6,667	18,509	47,292	126,4
		Columbia River	65,655	188,000	0	0	41,300	108,800	0	0	0	0	106,955	296,8
		Total 12M	82,784	234,151	11,316	29,098	50,582	133,712	4,187	11,277	7,830	21,365	156,699	429,6
12N	Willamette River and Columbia River below Willamette River.	Washington	5,140	10,300	2,556	5,186	5,237	10,346	3,233	6,420	3,548	7,006	19,714	39,2
		Oregon	8,574	19,554	5,800	14,468	19,043	40,623	5,890	13,027	9,383	20,712	48,690	108,3
		Columbia River	0	0	0	0	53,600	103,000	0	0	0	0	53,600	103,0
		Total 12N	13,714	29,854	8,356	19,654	77,880	153,969	9,123	19,447	12,931	27,718	122,004	250,6
12R	Oregon coast north of Klamath River.	Oregon	1,223	3,171	11,970	25,580	12,077	27,172	4,358	8,733	17,934	40,487	47,562	105,1
		California	0	0	0	0	373	901	205	510	4,038	10,072	4,616	11,4
		Total 12R	1,223	3,171	11,970	25,580	12,450	28,073	4,563	9,243	21,972	50,559	52,178	116,6
	Subtotals by States and boundary rivers for part 14.	Washington	5,208	10,515	2,556	5,186	5,961	12,211	3,730	7,862	4,711	9,862	22,166	45,6
		Oregon	26,858	68,661	29,086	69,146	39,678	90,842	13,938	31,595	33,984	79,708	143,544	339,9
		California	0	0	0	0	373	901	205	510	4,038	10,072	4,616	11,4
		Columbia River	65,655	188,000	0	0	94,900	211,800	0	0	0	0	160,555	399,8
	Grand total		97,721	267,176	31,642	74,332	140,912	315,754	17,873	39,967	42,733	99,642	330,881	796,8
	Totals for the 17 Western States.		3,445,487	12,299,201	653,269	1,986,681	1,209,038	4,420,854	977,121	3,369,495	457,020	1,565,202	6,741,935	23,641,4

[1] Index designations for subbasins are the same as those used in Jones and Holland (1948) and Thomas and Harbeck (1956).

ACCURACY OF ESTIMATES

The accuracy of these estimates depends on the completeness of the available information for each body of water. The measurements at Lake Mead (Harbeck and others, 1958) determined the evaporation from that reservoir as 875,000 acre-feet for the 12-month period ending September 1953. In the 4 years since then for which evaporation from Lake Mead is published, the water-year totals ranged from 699,000 to 796,000 acre-feet. This range was mostly due to yearly variations in water-surface areas and only to a lesser extent in evaporation rates. The average annual evaporation for Lake Mead, as computed for this report for a 10-year period, is 849,000 acre-feet (table 7).

For the 5-year period of available evaporation record at Lake Mead, the maximum yearly amount was 25 percent greater than the minimum. Variations in the yearly evaporation from most of the other bodies of water in the 17 States are probably greate than for Lake Mead, where climatic factors and th pattern of storage regulation are relatively stabl and where there is good information on evaporatio rates and water-surface areas. Such variations, whicl are also found in other hydrologic factors, indicat how an average annual figure may differ considerabl from the actual amount in any given year.

In the section on "Evaporation rates," it was con cluded that the accuracy of the evaporation map (pl 3) was good and that the error should be within 1 percent, plus or minus, in the vicinity of the contro points. The map is less dependable in the intervenin areas between control points, particularly in moun tainous regions where evaporation rates change rapidl in short distances. The estimated amounts of evapora tion in the tables of this report are the products o several factors, including evaporation rate, each o which is subject to some uncertainty. The percentag of error of total evaporation may be considerably more than 10 percent, but the term loses meaning because it becomes an opinion rather than a determinable figure. As a general indication, these estimated amounts of evaporation should probably be regarded as good to no more than two significant figures.

TABLE 5.—*Summary of fresh-water evaporation, by States and boundary rivers*

State or boundary river	Average annual depth of evaporation from exposed water surfaces (feet)	Annual evaporation, in thousand acre-feet					
		Principal reservoirs and regulated lakes	Other lakes exceeding 500 acres	Principal streams and canals	Small ponds and reservoirs	Small streams	Total
Washington	2. 7	580	182	322	127	78	1, 289
Columbia River	2. 5	188	0	212	0	0	400
Oregon	2. 7	402	106	106	46	102	762
California	3. 9	1, 158	61	389	313	260	2, 181
Nevada	4. 1	86	451	10	48	21	616
Idaho	2. 8	1, 119	33	145	41	68	1, 406
Snake River	2. 6	0	0	37	0	0	37
Utah	3. 7	487	15	104	175	34	815
Arizona	5. 3	96	9	90	43	37	275
Colorado River	6. 9	1, 177	22	82	0	0	1, 281
Montana	2. 7	1, 294	137	291	256	121	2, 099
Wyoming	2. 8	261	282	76	92	58	769
Colorado	3. 2	212	9	73	258	124	676
New Mexico	5. 3	207	0	46	154	36	443
North Dakota	2. 8	1, 019	165	79	451	26	1, 740
Red River of the North	2. 6	48	0	7	0	0	55
South Dakota	3. 0	1, 194	115	108	238	52	1, 707
Minnesota River	2. 7	0	27	0	0	0	27
Big Sioux River	3. 5	0	0	7	0	0	7
Missouri River	3. 4	37	0	373	0	0	410
Nebraska	3. 8	214	15	415	368	103	1, 115
Kansas	4. 3	203	1	260	92	140	696
Oklahoma	4. 5	425	8	401	157	107	1, 098
Red River	4. 6	390	0	142	0	0	532
Sabine River	4. 2	0	224	26	0	0	250
Rio Grande	6. 2	353	0	153	0	0	506
Texas	4. 8	1, 149	125	467	510	198	2, 449
Total	3. 5	12, 299	1, 987	4, 421	3, 369	1, 565	23 641

TABLE 6.—*Summary of fresh-water evaporation, by principal river basins*

Principal river basin	Average annual depth of evaporation from exposed water surfaces (feet)	Annual evaporation in thousands of acre-feet					
		Principal reservoirs and regulated lakes	Other lakes exceeding 500 acres	Principal streams and canals	Small ponds and reservoirs	Small streams	Total
Part 5. Hudson Bay and upper Mississippi River basins	2. 6	125	137	17	194	18	491
Part 6. Missouri River basin	3. 2	3, 851	500	1, 415	1, 244	390	7, 400
Part 7. Lower Mississippi River basin	4. 6	1, 105	21	739	412	231	2, 508
Part 8. Western Gulf of Mexico basins	5. 0	1, 494	344	646	512	203	3, 199
Part 9. Colorado River basin	5. 0	1, 359	47	335	265	149	2, 155
Above compact point	3. 0	83	16	156	217	103	575
Below compact point	6. 6	1, 276	31	179	48	46	1, 580
Part 10. The Great Basin	3. 5	1, 168	479	33	230	76	1, 986
Part 11. Pacific slope basins in California	3. 9	1, 054	72	368	274	223	1, 991
Part 12. Pacific slope basins in Washington and upper Columbia River basin	2. 6	1, 320	259	323	144	105	2 151
Part 13. Snake River basin	2. 8	556	53	229	54	71	963
Part 14. Pacific slope basins in Oregon and lower Columbia River basin	2. 4	267	75	316	40	99	797
Total	3. 5	12, 299	1, 987	4, 421	3, 369	1, 565	23, 641

EVAPORATION FROM DIFFERENT CLASSES OF FRESH-WATER SURFACES

The estimated amount of gross evaporation from all the 17 Western States is 23,641,000 acre-feet annually, more than half of which, 12,299,000 acre-feet, is from the principal reservoirs. Most of this is in turn concentrated in a relatively small number of large units, as indicated by table 7 which shows all reservoirs with estimated annual evaporation exceeding 40,000 acre-feet. These 51 reservoirs and regulated lakes, whose locations are shown on figure 26, account for more than 9 million acre-feet, leaving about 3.2 million acre-feet as the total evaporation from the 600-odd other reservoirs in this class.

TABLE 7.—*Reservoirs and regulated lakes with largest amounts of evaporation*

Numbers shown on fig. 26	Reservoir	River	State	Average effective area (acres)	Average annual evaporation (acre-ft)
1	Garrison	Missouri	N. Dak	312, 000	910, 00
2	Oahe	Missouri	S. Dak	300, 000	900, 00
3	Lake Mead	Colorado	Ariz.–Nev	124, 200	849, 00
4	Fort Peck	Missouri	Mont	214, 400	688, 00
5	Lake Texoma	Red	Okla.–Tex	8[illegible], 600	390, 00
6	Falcon	Rio Grande	Tex	56, 500	353, 00
7	Lake Tahoe	Truckee	Calif.–Nev	114, 000	323, 00
8	Utah Lake	Jordan	Utah	95, 900	320, 00
9	Franklin D. Roosevelt Lake	Columbia	Wash	77, 800	272, 00
10	Flathead Lake	Flathead	Mont	12[illegible], 000	262, 00
11	Pend Oreille Lake	Clark Fork	Idaho	94, 600	252, 00
12	Upper Klamath Lake	Klamath	Oreg	81, 100	250, 00
13	Bear Lake	Bear	Idaho	82, 800	242, 00
14	Fort Randall	Missouri	S. Dak	71, 300	229, 00
15	Havasu Lake (Parker Dam)	Colorado	Ariz.–Calif	23, 800	171, 00
16	Lake Mohave (Davis Dam)	Colorado	Ariz.–Nev	22, 500	157, 50
17	American Falls	Snake	Idaho	47, 800	151, 50
18	Clear Lake	Cache Creek	Calif	36, 000	141, 00
19	McNary	Columbia	Oreg.–Wash	34, 100	111, 00
20	Tuttle Creek	Big Blue	Kans	26, 500	108, 00
21	McConaughy Lake	North Platte	Nebr	27, 000	106, 00
22	Shasta	Sacramento	Calif	23, 600	102, 00
23	Buchanan	Colorado	Tex	20, 500	101, 00
24	Pensacola	Neosho	Okla	25, 000	100, 00
25	Coeur d'Alene Lake	Spokane	Idaho	32, 000	93, 40
26	Possum Kingdom	Brazos	Tex	17, 000	89, 30
27	Lake Chelan	Chelan	Wash	32, 000	85, 30
28	Elephant Butte	Rio Grande	N. Mex	13, 800	82, 50
29	Fort Gibson	Neosho	Okla	17, 500	73, 00
30	Whitney	Brazos	Tex	14, 700	68, 60
31	Lake Kemp	Wichita	do	12, 000	66, 00
32	Grand Coulee Equalizing	Columbia [1]	Wash	18, 300	65, 60
33	Priest Lake	Priest	Idaho	23, 400	64, 40
34	Canyon Ferry	Missouri	Mont	26, 400	63, 80
35	Lake Travis	Colorado	Tex	13, 400	62, 60
36	Clear Lake	Lost	Calif	14, 400	53, 40
37	Lake Houston	San Jacinto	Tex	12, 000	53, 00
38	Monticello	Putah Creek	Calif	12, 800	52, 50
39	Lake Almanor	North Fork Feather	do	14, 600	52, 40
40	Tiber	Marias	Mont	16, 600	50, 60
41	Lavon	East Fork Trinity	Tex	10, 700	49, 00
42	Texarkana	Sulphur	do	12, 000	49, 00
43	Seminoe	North Platte	Wyo	13, 400	48, 00
44	Lake Traverse	Red	Minn.–S. Dak	18, 400	47, 50
45	Great Salt Plains	Salt Fork Arkansas	Okla	9, 000	46, 50
46	Town Bluff (dam B)	Neches	Tex	10, 800	45, 90
47	Tenkiller Ferry	Illinois	Okla	10, 700	43, 70
48	Conchas	Canadian	N. Mex	8, 300	43, 60
49	Bonneville	Columbia	Oreg.–Wash	19, 400	43, 50
50	Potholes	Crab Creek	Wash	10, 800	42, 30
51	Pathfinder	North Platte	Wyo	11, 700	41, 90
	Total			2, 547, 100	9, 066, 30

[1] Off stream.

The evaporation from "other principal lakes" totals 1,987,000 acre-feet annually, nearly half of which is lost from six large lakes:

		Acre-feet
Pyramid Lake, Nev	(part 10)	320,000
Sabine Lake, La	(part 8)	224,000
Yellowstone Lake, Wyo	(part 6)	186,000
Walker Lake, Nev	(part 10)	122,000
Lake Washington, Wash	(part 12)	46,000
Crater Lake, Oreg	(part 11)	35,800
Total		933,800

The principal rivers evaporate nearly 4½ million acre-feet of water annually. This is about 19 percent—nearly one-fifth—of the total evaporation in the 17 States, more than from any other class of water surfaces except the principal reservoirs.

Annual evaporation from the small ponds and from the small streams is about 3½ and 1½ million acre-feet, respectively. These 2 classes of water surfaces together account for 21 percent of all the fresh-water evaporation in the 17 States.

EVAPORATION COMPARED WITH OTHER HYDROLOGIC FACTORS

A general concept used by many hydrologists has been expressed by Williams and others (1940) as follows: "The water loss of a drainage basin is the difference between the average rainfall over the basin and the runoff from the basin for a given period." Evaporation from fresh-water surfaces, according to this concept, is only one of several items grouped under the heading of water loss, others being deep ground-water flow, the interception by plants and the subsequent evaporation of a part of the precipitation that never reaches the ground, the water withdrawn from the soil by the roots of plants and transpired into the air through the leaves, and direct evaporation from exposed soil surfaces and from snowfields. The amounts of evaporation determined in this report are usually rather small in relation to the other hydrologic factors, as indicated by the comparisons in the following paragraphs.

Precipitation and evaporation for each of the principal river basins are compared in table 8. Approximate annual depth of precipitation, computed from Weather Bureau normals for the 30-year period 1921–50, ranges from a minimum of 10 inches in the Colorado River basin below the compact point and in the Great Basin to a maximum of 35 inches in part 14. Evaporation, when expressed in the same units, ranges from 0.10 inch in the Colorado River basin above the compact point to 0.46 inch in part 12. For the entire 17-State area, the amount of evaporation is only 1.3 percent of the amount of precipitation, with a range from 0.7 to 1.9 percent in principal basins.

Runoff and evaporation are less easily compared for the same principal river basins, because runoff usually would have to be computed from the records of a number of stream-gaging stations. For smaller subdivisions of the principal basins, however, comparisons are simpler where gaging stations are located at or near the outlet points. At such points the evapora-

TABLE 8.—*Evaporation and precipitation, by principal river basins*

Principal river basin	Approximate land area (thousand square miles)	Average annual evaporation from fresh-water surfaces		Average annual precipitation		Evaporation (percent of precipitation)
		Amount (thousand acre-feet)	Average depth over entire basin (inches)	Approximate amount (million acre-feet)	Average depth over entire basin (inches)	
Part 5. Hudson Bay and upper Mississippi River basins	33	491	0. 28	30	18	1. 6
Part 6. Missouri River basin	447	7, 400	. 31	410	17	1. 8
Part 7. Lower Mississippi River basin	198	2, 508	. 24	270	26	. 9
Part 8. Western Gulf of Mexico basins	305	3, 199	. 20	370	23	. 9
Part 9. Colorado River basin	253	2, 155	. 16	150	11	1. 4
above compact point	104	575	. 10	67	12	. 9
below compact point	149	1, 580	. 20	83	10	1. 9
Part 10. The Great Basin	205	1, 986	. 18	110	10	1. 8
Part 11. Pacific slope basins in California	114	1, 991	. 33	150	25	1. 3
Part 12. Pacific slope basins in Washington and upper Columbia River basin	88	2, 151	. 46	140	30	1. 5
Part 13. Snake River basin	109	963	. 17	80	14	1. 2
Part 14. Pacific slope basins in Oregon and lower Columbia River basin	63	797	. 24	120	35	. 7
Total	1, 815	23, 641	. 24	1, 830	19	1. 3

tion amounts given by subbasins in table 4 were compared directly with published runoff data, but no consistent relation between the two factors was observed. In headwater areas where there are few lakes and reservoirs and little population or agricultural development, such as the Salmon and Clearwater Rivers in north-central Idaho and the upper reaches of Clark Fork in western Montana, evaporation is less than 1 percent of runoff. In other headwater areas with lakes and reservoirs of significant size, such as the Flathead River in northwestern Montana and the Klamath River in Oregon and California, evaporation is about 5 percent of runoff.

The percentage tends to increase along the lower reaches of many rivers, particularly for those with large reservoirs. For the Missouri River on its long course across the Great Plains and through Fort Peck, Garrison, Oahe, Fort Randall, and Gavins Point Reservoirs, evaporation amounts to about 20 percent of the streamflow. For other rivers whose flows are much depleted by irrigation use, the percentage of evaporation is still larger. It reaches 40 percent for the Humboldt River in Nevada and for the Pecos River in New Mexico and Texas, and 70 percent for the South Platte River at Julesburg in the northeast corner of Colorado. For the Gila River in southern Arizona, which has previously been mentioned as an example of a stream which is completely dried up for most of the time, the percentage would be almost infinitely large because the runoff is practically zero.

Water loss and evaporation, when compared in the same way that precipitation and runoff were compared with evaporation, do not show any more consistent relation. Where lakes or reservoirs cover a large part of a river basin, as in the upper reaches of the Klamath, Flathead, and Yellowstone Rivers, evaporation can account for as much as half of the water loss. For the Misouri River above Kansas City, which includes a wide expanse of relatively dry territory in addition to the series of large reservoirs mentioned above, evaporation from exposed water surfaces amounts to about 1.8 percent of the total water loss. For the Snake River above its junction with the Columbia River the corresponding figure is about 2 percent, for the upper Colorado River above the compact point it is about 1 percent, and for some of the drier basins it is less than 1 percent. In every case, except for local situations where lakes or reservoirs cover a large part of a watershed, the amount of evaporation from exposed water surfaces is but a minor part of the total water loss.

A further comparison of evaporation with othe hydrologic data is given in table 9, which gives th annual amounts of evaporation from reservoirs as per centages of usable reservoir capacities. Evaporatio from a reservoir is of course proportional to its sur face area, but for many reservoirs surface-area dat are not easily obtainable. Storage capacity is a mor significant term for describing and classifying reser voirs and is the item of information most likely to b available. A direct relation between storage capacit and evaporation would therefore be helpful, but th widely different percentages in table 9 do not defin such a relation.

From the comparisons of the preceding paragraphs it appears that evaporation is more closely related t the status of development in a river basin than to any thing else. For dependable estimates of evaporation, i will probably be necessary to continue using the basi concept that amount of evaporation equals the prod uct of evaporation rate multiplied by water-surfac area.

TABLE 9.—*Reservoir evaporation and reservoir storage capacity*

State	Evaporation from principal reservoirs [1] (thousand acre-feet per year)	Total usable reservoir storage [2] (thousand acre-feet)	Annual evaporatio (percentag of storage)
Washington	580	11,365	5.
Oregon	590	3,747	15.
California	1,158	17,701	6.
Nevada	86	673	12.
Idaho	1,119	9,530	11.
Utah	4[illegible]7	2,053	23.
Arizona	1,273	33,247	3.
Montana	1,294	23,888	5.
Wyoming	261	4,856	5.
Colorado	2[illegible]2	3,827	5.
New Mexico	207	3,531	5.
North Dakota	1,0[illegible]9	18,786	5.
South Dakota	1,2[illegible]	[3] 22,614	5.
Nebraska	2[illegible]	3,842	6.
Kansas	203	4,009	5.
Oklahoma	8[illegible]5	10,248	8.
Texas	1,502	18,853	8.
Total	12,2[illegible]9	192,770	6.

[1] State totals from table 5 have been adjusted to include evaporation from adjacen boundary rivers.
[2] From Thomas and Harbeck (1956, table 2).
[3] Includes 137,000 acre-feet for Lake Traverse, at head of Red River of the North

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