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ESTIMATED USE OF WATER IN THE UNITED STATES, 1955

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By Kenneth A. MacKichan

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By Kenneth A. MacKichan

ABSTRACT

The estimated withdrawal use of water in the United States during 1955 was about 1,740,000 mgd (million gallons per day). Withdrawal use of water requires that it be removed from the ground or diverted from a stream or lake. In this report it is divided into five types: public supplies, rural, irrigation, self-supplied industrial, and waterpower. Consumptive use of water is the quantity discharged to the atmosphere or incorporated in the products of the process in which it was used. Only a small part of the water withdrawn for industry was consumed, but as much as 60 percent of the water withdrawn for irrigation may have been consumed.

Of the water withdrawn in 1955 about 1,500,000 mgd was for generation of waterpower, and all other withdrawal uses amounted to only about 240,000 mgd. Surface-water sources supplied 194,000 mgd and ground-water sources supplied 46,000 mgd. The amount of water withdrawn in each State and in each of 19 geographic regions is given.

The quantity of water used without being withdrawn for such purposes as navigation, recreation, and conservation of fish and wildlife was not determined. The water surface area of the reservoirs and lakes used to store water for these purposes is sufficiently large that the evaporation from this source is greater than the quantity of water withdrawn for rural and public supplies.

The amount of water used for generation of waterpower has increased 36 percent since 1950. The largest increase, 43 percent, was in self-supplied industrial water. Rural use, excluding irrigation, decreased 31 percent.

The upper limit of our water supply is the average annual runoff, nearly 1,200,000 mgd. The supply is depleted by the quantity of water consumed rather than by the quantity withdrawn. In 1955 about one-fourth of the water withdrawn was consumed. The amount thus consumed is about one-twentieth of the supply.

INTRODUCTION

Water supply is affected by many of man's activities. This report evaluates the effects of only those activities that require the withdrawal of water from surface or underground sources. Nonwithdrawal uses also have appreciable effects, but these are difficult to evaluate in terms of quantity used.

The use of water generally reduces the supply and frequently deteriorates the quality whether the use is withdrawal or nonwithdrawal, consumptive or nonconsumptive. The quality may be adversely affected by addition or concentration of mineral constituents, addition of bacteria or organic matter, or the addition of heat. Because the use of water affects the supply, an adequate evaluation of the Nation's water resources requires a knowledge of the quantity of water used, where it is used, and the type of use.

The purpose of this report is to evaluate the use of water in large geographical areas and in broad categories. The data presented are in sufficient detail for broad planning but not for the evaluation of the water resources of small areas. The magnitude of the quantity of water used for different purposes is shown by States and regions. It also shows the trend in water withdrawals between 1950 and 1955.

Previous Investigations

Until recently few attempts were made to estimate the total quantity of water withdrawn for use in the United States. Some investigators made inventories or estimates of water used by a single industry. The U. S. Public Health Service (1948 and 1955), in cooperation with the sanitary-engineering divisions of the State health departments, made inventories of public water-supply facilities in 1945 and 1954 which included data on the quantity of water used. The U. S. Bureau of the Census (1955) made a survey of water used by the manufacturing industries in 1953, as part of their annual survey of manufactures. Picton (1952 and 1956) made estimates of water used in the United States from 1900 to 1950 and 1955 and forecast estimates of future use. Guyton (1950) made an estimate of ground water used in the United States during 1945, and Langbein (1950) made an estimate of the quantity of water used in the United States in 1946 for the generation of hydroelectric power. An inventory made by Mangan and Graham (1953) showed the quantity of water used in Pennsylvania in 1951. MacKichan (1951) also made an estimate of the quantity of water used in each of the 48 States during 1950 for five major uses, rural, public supplies, industry, irrigation, and waterpower, to which the present inventory is similar in objective and scope.

Present Investigation

This report presents an estimate of the quantity of water withdrawn in 1955 from ground and surface sources. Some water was withdrawn from a source, used, and discharged into a stream or the ground, only to be withdrawn again. Sometimes a subsequent withdrawal was not made directly from a stream or the ground but was made from the returning flow of a previous withdrawal—such as sewage withdrawn for

irrigation. Each time the water was withdrawn it was added to the accumulated total; therefore, the same water was withdrawn several times and was counted each time that it was withdrawn. However, if the water was withdrawn and recirculated, so that it was used several times in the same plant before it was discharged into a stream or the ground, it was counted only once. Although the best information available was used, the estimates in this report are, in general, only approximations of the quantity of water used. The estimate for municipal use is probably the most accurate and that for industrial use the least accurate. Some quantities are given to three or more significant figures because they are the sum of two or more quantities that are given to two significant figures. The quantities presented in this report are not applicable to more than two significant figures.

Estimates of water used are given for the District of Columbia and each State in the continental United States and for the major drainage regions in the United States. The drainage regions are shown in figure 6 and are described as follows:

North Atlantic. North Atlantic slope drainage, Maine to Connecticut.

Upper Hudson. Hudson River basin above and including Orange and Putnam Counties, N. Y.

Lower Hudson and coastal area. Hudson River below and including Westchester and Rockland Counties and Long Island; and North Atlantic slope drainage, Hudson River to Delaware River.

Delaware. Delaware River basin.

Chesapeake. North Atlantic slope drainage, Chesapeake Bay to York River.

Southeast. Atlantic slope and Gulf of Mexico drainage, James River to Pearl River.

Tennessee-Cumberland. Tennessee and Cumberland River basins.

Ohio. Ohio River basin exclusive of Tennessee and Cumberland River basins.

Eastern Great Lakes-St. Lawrence. St. Lawrence River basin below the mouth of St. Clair River.

Western Great Lakes. St. Lawrence River basin above the mouth of St. Clair River.

Missouri-Hudson Bay. Missouri River basin and Hudson Bay basin.

Upper Mississippi. Mississippi River basin above the Ohio River and exclusive of the Missouri River basin.

Lower Mississippi. Mississippi River basin below the Ohio River and exclusive of the Arkansas-White-Red River basins.

Arkansas-White-Red. Arkansas, White, and Red River basins.

Western Gulf. Gulf of Mexico drainage, west of the Mississippi Delta.

Colorado. Colorado River basin.

Great Basin. The Great Basin.

Pacific Northwest. Pacific slope drainage north of California.

South Pacific. Pacific slope drainage in California.

Areas of drainage regions are given in table 11.

District offices of the Water Resources Division of the Geological Survey supplied estimates of water used for public supplies and for manufacturing and nonmanufacturing industries. The estimates were based on data in the Geological Survey files and those furnished by State officials. The quantities of water used for electric utilities, rural domestic and stock use, and irrigation were computed using statistics of the U. S. Bureau of the Census (1952, 1953, 1955, and 1956), the U. S. Federal Power Commission (1953 and 1955), and the U. S. Department of Agriculture (1955). Information on the sources of water (ground water, surface water, or sewage) was furnished by the district offices of the Water Resources Division of the Geological Survey.

Definition of Terms

Uses of water may be classified in several different ways. Among them are withdrawal and nonwithdrawal uses and consumptive and nonconsumptive uses. Withdrawal uses require that the water be removed from the ground or diverted from a stream or lake. Irrigation, domestic, stock, public, and industrial uses are of this type. Generation of waterpower is also considered a withdrawal use; even in run-of-river plants the water is diverted through the turbines and frequently the generation of waterpower has a very definite effect on the streamflow. The quantity withdrawn is the entire quantity of water taken for use. This quantity is sometimes labeled "pumpage," "water intake," "duty of water," or "water requirement" (Am. Water Works Assoc. Task Group, 1953). Nonwithdrawal uses do not require diversion. Navigation, recreation, waste disposal, and conservation of fish and wildlife are examples of nonwithdrawal uses.

Consumptive use is the quantity of water discharged to the atmosphere or incorporated in the products of the process in connection with vegetative growth, food processing, or incidental to an industrial process (Am. Water Works Assoc. Task Group, 1953).

Saline water has been defined as water containing more than 1,000 ppm (parts per million) of dissolved solids (Krieger, R. A., Hatchett, J. L., and Poole, J. L., 1956) regardless of the composition of the solids and is not necessarily a salty (NaCl) water.

Quantities of water given in this report are generally in million gallons per day (mgd); however, some quantities are also given in acre-feet per year. An acre-foot of water will cover an acre to a depth of 1 foot; 1,000 acre-feet per year equals 0.89 mgd.

WITHDRAWAL USE

Withdrawal uses can be evaluated quantitatively because they require removal of the water from the ground, stream, lake, or reservoir. An evaluation of the total quantity of water withdrawn can be made by adding together the known amounts of withdrawals. The primary withdrawal uses are public supplies, rural domestic and stock, irrigation, self-supplied industrial, and waterpower. Although generation of waterpower may be considered a self-supplied industrial use of water, it is treated as a primary withdrawal use in this report because it neither degrades nor consumes the water withdrawn. The primary withdrawal uses may be subdivided. Fuel-electric utilities and air conditioning are important secondary withdrawal uses and, therefore, have been evaluated in this report.

Public Supplies

Public water-supply systems served almost 115 million people an average of 148 gallons per person per day or about 17,000 mgd (fig. 1). Water used for public supplies includes all water pumped into the system. This water may be used for fire protection, street flushing, irrigation of lawns and gardens, and by industrial and commercial establishments as well as for domestic supply. Because the water is measured at the source, leakage is also included. Public water-supply systems may be either publicly or privately owned.

Of the 17,000 mgd withdrawn for public supplies, almost three-fourths was obtained from surface sources and slightly more than one-fourth was obtained from wells and springs (tables 1 and 9). About one-third of the water withdrawn was used by industrial and commercial establishments.

Rural

About 2,500 mgd was used in rural homes and for stock watering during 1955 (fig. 2). Nearly three-fourths of the water was taken from wells or springs, and slightly more than one-fourth was taken from streams, ponds, and lakes, (tables 2 and 9). Rural homes are defined as those not served by public water-supply systems.

Table 1.—Water withdrawn for public supplies, by regions

Region	Ground water (mgd)	Surface water (mgd)	Total (mgd)	Population served	Use per capita (gpd)	Used by industry (mgd) 1/
North Atlantic	120	830	950	8,560,787	111	240
Upper Hudson	26	170	196	1,147,080	171	40
Lower Hudson and coastal area	280	2/ 1,440	2/ 1,720	13,386,500	128	478
Delaware	130	3/ 590	3/ 720	5,104,600	141	254
Chesapeake	73	790	863	5,826,972	148	360
Eastern Great Lakes and St. Lawrence	120	1,400	1,520	8,060,751	189	940
Western Great Lakes	270	1,500	1,770	8,404,200	211	1,000
Upper Mississippi	310	270	580	6,068,674	96	92
Southeast	500	840	1,340	11,230,127	119	320
Tennessee-Cumberland	51	190	241	1,629,032	148	50
Ohio	420	1,200	1,620	11,361,610	143	480
Missouri-Hudson Bay	330	470	800	4,952,283	162	240
Lower Mississippi	170	330	500	3,516,600	142	89
Arkansas-White-Red	260	350	610	4,499,050	136	110
Western Gulf	590	460	1,050	5,560,630	189	380
Colorado	140	4/ 50	4/ 190	1,082,960	175	24
Great Basin	120	5/ 100	5/ 220	744,900	295	22
Pacific Northwest	240	580	820	3,237,700	253	320
South Pacific	530	6/ 740	6/ 1,270	10,621,400	120	300
United States	4,700	12,000	17,000	115,000,000	148	5,700

1/The amount used by industry is included in the total and includes water used for air conditioning. (See table 7.)

2/Includes about 350 mgd diverted from Delaware River (New York City Board of Water Supply, 1956).

3/Does not include 350 mgd diverted into the lower Hudson and coastal area (New York City Board of Water Supply, 1956).

4/Does not include about 230 mgd diverted into south Pacific region (California Water Resources Board, 1955).

5/Does not include about 280 mgd diverted into south Pacific region (California Water Resources Board, 1955).

6/Includes about 510 mgd diverted from the Colorado and Great Basin regions (California Water Resources Board, 1955).

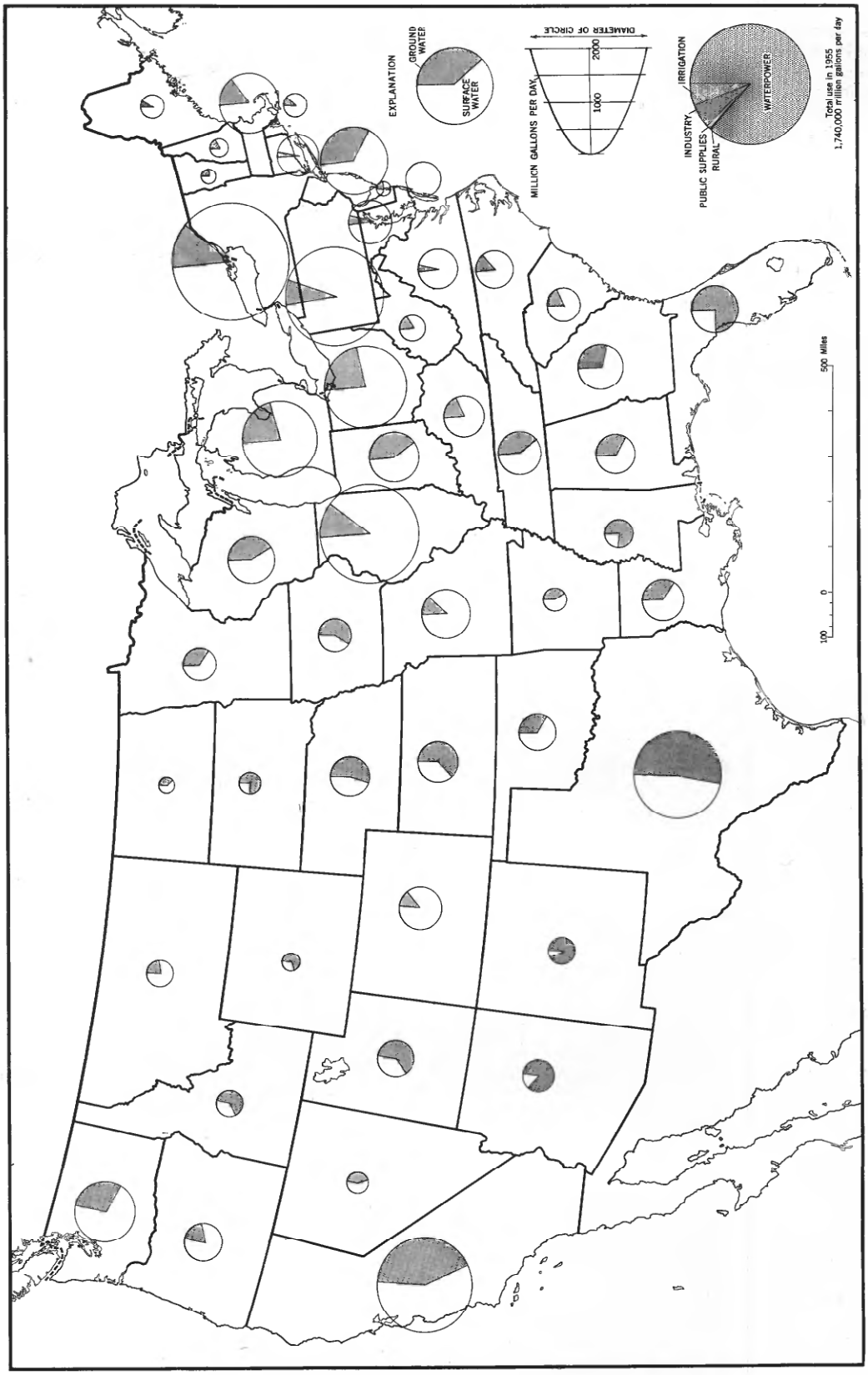

Figure 1.—Water withdrawn for public supplies.

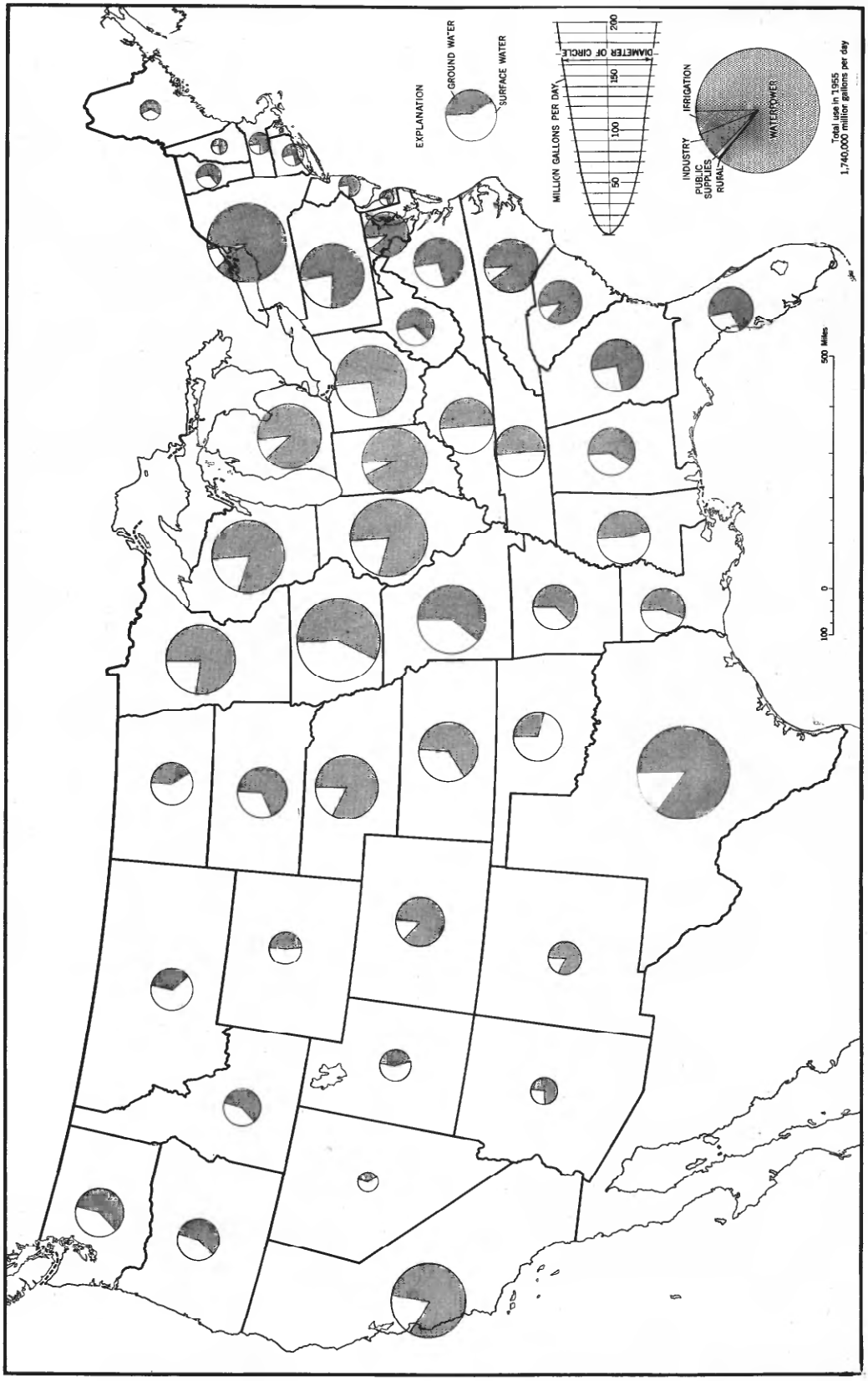

Figure 2.—Water withdrawn for rural use.

Table 2.—Water withdrawn for rural use, in million gallons per day, by region

Region	Ground water	Surface water	Total
North Atlantic	27	11	38
Upper Hudson	25	2	27
Lower Hudson and coastal area.	36	1	37
Delaware	24	6	30
Chesapeake	80	20	100
Eastern Great Lakes and St. Lawrence.	94	20	114
Western Great Lakes	140	24	164
Upper Mississippi	210	80	290
Southeast	175	65	240
Tennessee-Cumberland	41	29	70
Ohio	190	64	254
Missouri-Hudson Bay	240	140	380
Lower Mississippi	38	32	70
Arkansas-White-Red	120	79	199
Western Gulf	130	28	158
Colorado	22	10	32
Great Basin	21	18	39
Pacific Northwest	61	42	103
South Pacific	80	20	100
United States	1,800	690	2,500

The rural population of the United States in 1955 was about 47 million. About 20 percent of these people live in homes having running water. Frank (1955) states that people living in the average electrified farm or urban home in the United States use an average of 60 gallons or more each day for household and lawn watering. The corresponding average for homes without running water is only 10 gpd per person. Other investigators report that only 50 gpd per person is used in homes having running water. Assuming these averages, about 970 mgd was used for rural domestic purposes, most of which was from wells.

About 1,500 of the 2,500 mgd was used for stock watering and about 60 percent of the stock water was from wells and springs. The quantity of water used by livestock ranges widely, depending on kind and age of the animal and the air temperature (Sykes, 1955). Several authorities (Sykes, 1955; Marion, 1952; Arkansas-White-Red Basins Inter-Agency Committee, 1957) have given the water requirements of livestock. The per capita rates used in this report were taken from several sources and are given in the following tabulation:

Livestock	Per capita use (gallons per day)
Horses and mules	10
Beef cattle	10
Milk cows	20
Hogs	3
Sheep	2
Goats	2
Chickens	.04
Turkeys	.06

Irrigation

Water used for irrigation might be defined in at least four ways: that which is transpired or evaporated from a cropped area, that which is delivered to the farms, that which is withdrawn from the source, or the gross over-all supply required. Water delivered to the farms includes evaporation and seepage from the distribution ditches as well as that transpired and evaporated from the cropped areas. Water withdrawn from the source is the water delivered plus conveyance losses. The gross over-all supply is the water withdrawn plus evaporation and seepage from storage reservoirs when such are part of the system.

Most of the water lost in conveyance seeps into the ground and, therefore, is not lost as a resource as it can be recovered through wells. Some water lost in conveyance may be transpired by phreatophytes and cannot be recovered. If the farm irrigation efficiency is high, most of the water delivered to the farm is consumed in growing crops. Therefore, the quantity of water delivered to the farm is an indication of the depletion of the resource, and the quantity of water withdrawn from the streams or wells (water delivered to farms plus conveyance losses) is an indication of the depletion of the stream or aquifer in the vicinity. In this report water withdrawn for irrigation is the amount taken from the source and has been divided into the amount delivered to the farms and the amount lost in conveyance.

About 123 million acre-feet of water was used in 1955 to irrigate 34 million acres. Of this amount 91 million acre-feet was delivered to farms and 32 million acre-feet was lost in conveyance. About 27 percent of the water used came from wells and springs, 73 percent came from surface sources, and less than 0.1 percent was sewage (tables 3, 4, and 9). Most of the irrigation was in the Western States (fig. 3).

Irrigation water is usually measured in acre-feet per year. However, in this report it is given also in average million gallons per day so that the quantities can be compared with and added to quantities of water used for other purposes. Irrigation water is applied during only a part of each year, and at variable rates; therefore, the actual rate of application is much greater than the average daily rate given in tables 3 and 9.

Self-Supplied Industrial

Water has many industrial uses, including processing, cooling, conveyance of material, boiler feed, and sanitation. Some industries require water of very high quality whereas to other industries water quality is relatively unimportant. Most industrial water is self-supplied although a small amount is purchased from public supplies (table 1). Industry used an average of 110,000 mgd during 1955. Most self-supplied industrial water, 91 percent, was from surface sources. Underground sources supplied 9 percent, and less than 0.1 percent was reclaimed sewage (tables 5 and 9). Most industrial water is used in the States east of the Mississippi River (fig. 4).

A large part of the industrial water is used for cooling and is returned to a stream or an aquifer

Table 3.—Water withdrawn for irrigation, by regions

Region	Delivered to farms						Conveyance losses					
	Ground water		Surface water		Reclaimed sewage		Ground water		Surface water		Reclaimed sewage	
	1,000 acre-ft per year	Average (mgd)	1,000 acre-ft per year	Average (mgd)	1,000 acre-ft per year	Average (mgd)	1,000 acre-ft per year	Average (mgd)	1,000 acre-ft per year	Average (mgd)	1,000 acre-ft per year	Average (mgd)
North Atlantic	2.0	1.8	20	18	0	0	0	0	0	0	0	0
Upper Hudson	2.5	2.2	2.9	2.6	0	0	0	0	0	0	0	0
Lower Hudson and coastal area	25	22	24	21	0	0	0	0	0	0	0	0
Delaware	17	16	18	16	0	0	0	0	0	0	0	0
Chesapeake	2.5	2.2	28	25	0	0	0	0	0	0	0	0
Eastern Great Lakes and St. Lawrence	7.2	6.5	19	17	0	0	0	0	0	0	0	0
Western Great Lakes	8.1	7.3	49	43	0	0	0	0	0	0	0	0
Upper Mississippi	15	12	19	17	0	0	0	0	.1	.08	0	0
Southeast	310	280	340	300	.05	.04	4.7	4.2	15	12	0	0
Tennessee-Cumberland	2.4	2.2	28	25	0	0	0	0	0	0	0	0
Ohio	7.7	7.0	18	16	0	0	0	0	0	0	0	0
Missouri-Hudson Bay	1,800	1,600	11,000	10,000	7.4	6.6	200	190	7,100	6,200	1.9	1.7
Lower Mississippi	650	580	400	350	0	0	74	65	130	120	0	0
Arkansas-White-Red	3,300	3,000	1,300	1,200	4.2	3.8	360	330	290	260	1.0	.91
Western Gulf	6,100	5,500	5,000	4,600	35	31	1,200	1,100	1,400	1,200	8.0	7.1
Colorado	4,500	4,000	11,000	9,500	17	16	900	800	2,500	2,100	2.4	2.1
Great Basin	1,200	1,000	8,300	7,500	0	0	280	250	2,900	2,500	0	0
Pacific Northwest	1,500	1,300	17,000	15,000	7.1	6.4	200	180	10,000	9,300	3.1	2.8
South Pacific	8,300	7,400	8,400	7,500	22	19	2,300	2,000	2,700	2,400	5.8	5.2
United States	28,000	25,000	63,000	56,000	93	83	5,500	4,900	27,000	24,000	22	20

unchanged except for an increase in temperature. Cooling water does not need to be of high quality; some cooling equipment is designed for use of sea water or other saline water.

Fuel-Electric Power (Public Utility)

The amount of water used by public utilities for fuel-electric power was almost twice the amount of self-supplied industrial water used by other industries (table 5). About 94 percent of the water used by public utilities for generation of fuel-electric power was for condenser cooling (table 6), and the remaining 6 percent was for other uses, such as boiler feed, sanitary services, cooling of machinery within the plant, and irrigation of lawns. Two percent of the condenser cooling water was obtained from wells or springs and 98 percent from surface sources. Almost all of the ground water was fresh, but about 17 percent of the surface water was saline. The only use made of saline water was in condensers.

The quantity of water used per kilowatt hour of electric power generated by steam plants varies widely. According to the Arkansas-White-Red Basins Inter-Agency Committee (1957), in those basins plants that do not recirculate water used from 40 to 280 gallons per kilowatt hour and averaged 91 gallons per kilowatt hour. The Committee also reported that the plants that recirculate water used from 0.5 to 9.2 gallons per kilowatt hour and averaged 0.9 gallon per kilowatt hour. Most of the water used in plants that recirculate water was evaporated, whereas most of the water used without recirculation was discharged to a stream. Most plants in areas of abundant water supply do not recirculate water. In the Arkansas-White-Red River basins about two-thirds of the fuel-electric power is generated in plants that recirculate the water(Arkansas-White-Red Basins Inter-Agency Committee, 1957).

Air Conditioning

Almost half (490 mgd) of the water used for air conditioning is taken from public supplies and most of the remainder is from privately owned wells (table 7). The 490 mgd is part of the 5,700 mgd taken from public supplies and used by industry (table 1). The remaining 590 mgd is part of the 110,000 mgd of self-supplied industrial water reported in table 5. The quantities of water used for air conditioning are annual rates. Air conditioning is highly seasonal, with most of the water used in a 4 to 6 month period each year. Therefore, during the air-conditioning season water is used at a much higher rate than that shown in table 7, and during the remainder of the year little or no water is used. The increased draft on public supplies for water for air conditioning during hot weather is a serious problem in some places. During a 10-day hot period in September 1955 the draft on the public-supply system of Pasadena, Calif., reached a maximum daily rate of 430 gallons per capita (Blackburn, 1956). The average daily use in Pasadena during the year 1954-55 was only 178 gallons per capita.

Waterpower

About 1,600 million acre-feet of water was used during 1955 to generate waterpower (tables 8 and 9). The rate of use is variable and depends on the water available and the demand for power. The quantities of water were computed with the aid of two publications of the U. S. Federal Power Commission (1953 and 1955). The average plant efficiency and other factors were estimated. Much of the water was used more than once.

Summary of Withdrawals

The estimated withdrawal of water in the United States amounted to about 1,740,000 mgd during 1955.

Table 4.—Water withdrawn for irrigation, in thousand acre-feet per year, by States

State	Delivered to farms			Conveyance losses		
	Ground water	Surface water	Sewage	Ground water	Surface water	Sewage
Alabama	2.7	15	0	0	0	0
Arizona	4,400	2,000	10	880	480	1.5
Arkansas	880	98	0	2.6	.39	0
California	8,800	12,000	22	2,400	3,200	5.9
Colorado	980	5,000	3.0	200	1,000	.60
Connecticut	1.5	13	0	0	0	0
Delaware	.43	1.4	0	0	0	0
District of Columbia	0	0	0	0	0	0
Florida	280	270	0	2.6	11	0
Georgia	14	20	.05	0	0	0
Idaho	1,100	10,000	0	110	5,100	0
Illinois	3.6	5.4	0	0	0	0
Indiana	5.7	3.7	0	0	0	0
Iowa	3.8	1.3	0	0	0	0
Kansas	680	150	0	0	0	0
Kentucky	4.4	5.0	0	0	0	0
Louisiana	430	540	0	0	390	0
Maine	.21	.75	0	0	0	0
Maryland	.75	15	0	0	0	0
Massachusetts	.20	4.6	0	0	0	0
Michigan	6.0	47	0	0	0	0
Minnesota	2.5	7.5	0	0	0	0
Mississippi	440	300	0	74	48	0
Missouri	22	27	0	0	0	0
Montana	110	5,500	3.6	54	5,300	3.6
Nebraska	910	790	0	37	1,200	0
Nevada	200	1,500	7.0	33	410	.70
New Hampshire	.02	1.0	0	0	0	0
New Jersey	25	17	0	0	0	0
New Mexico	1,200	950	12	300	320	3.7
New York	25	28	0	0	0	0
North Carolina	1.6	8.6	0	0	0	0
North Dakota	1.6	80	0	0	58	0
Ohio	1.2	11	0	0	0	0
Oklahoma	170	61	0	0	22	0
Oregon	360	4,100	4.0	190	3,000	0
Pennsylvania	1.8	16	0	0	0	0
Rhode Island	.05	.50	0	0	0	0
South Carolina	13	20	0	0	0	0
South Dakota	7.0	18	0	.70	6.3	0
Tennessee	4.1	27	0	0	0	0
Texas	6,100	3,400	27	1,200	690	5.3
Utah	280	3,300	.20	28	1,100	.10
Vermont	0	1.2	0	0	0	0
Virginia	.48	7.6	0	0	0	0
Washington	250	2,700	0	1.5	2,700	0
West Virginia	0	.92	0	0	0	0
Wisconsin	2.9	7.2	0	0	0	0
Wyoming	26	9,900	3.9	5.3	2,000	.80
United States	28,000	63,000	93	5,500	27,000	22

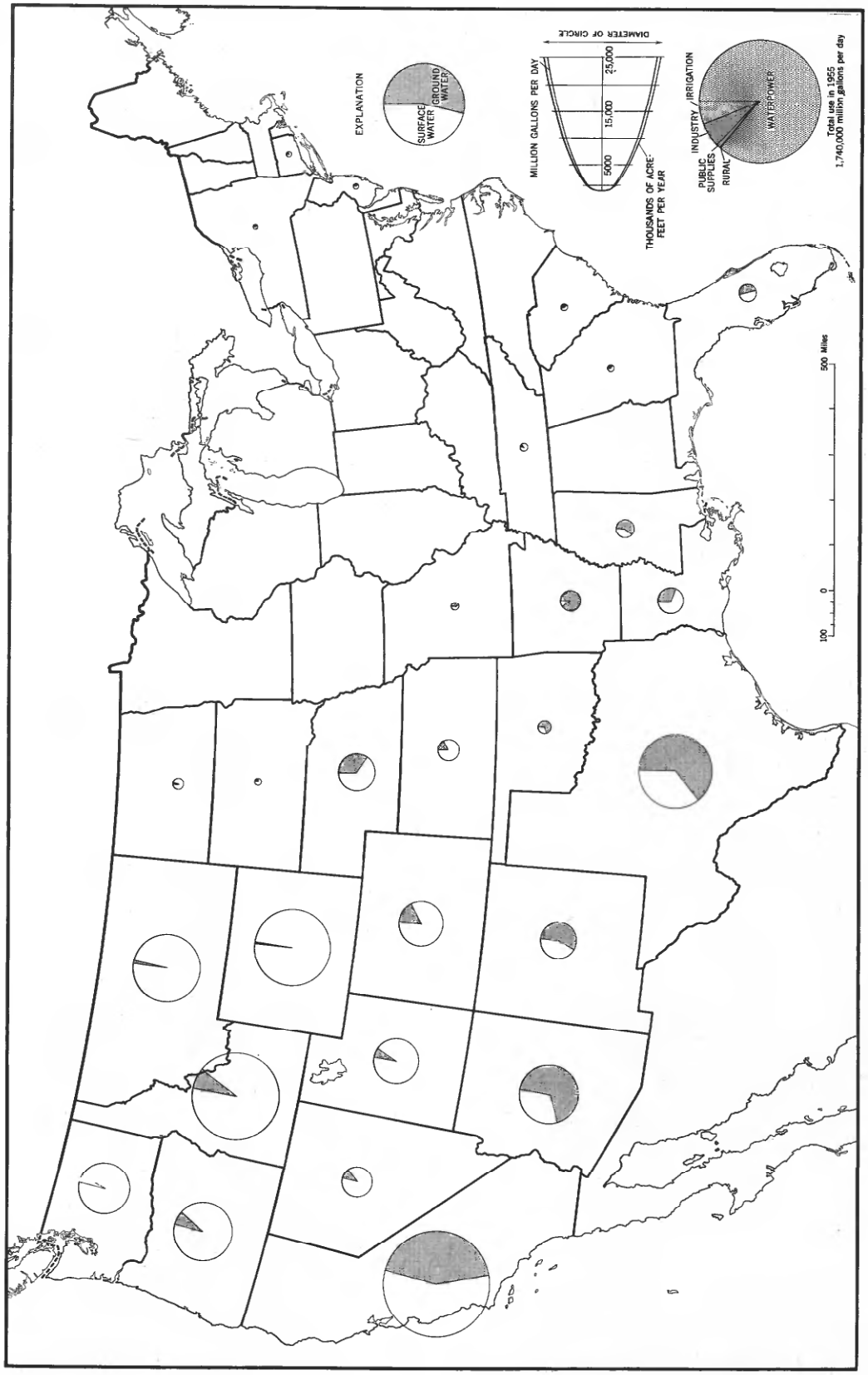

Figure 3.—Water withdrawn for irrigation including conveyance losses.

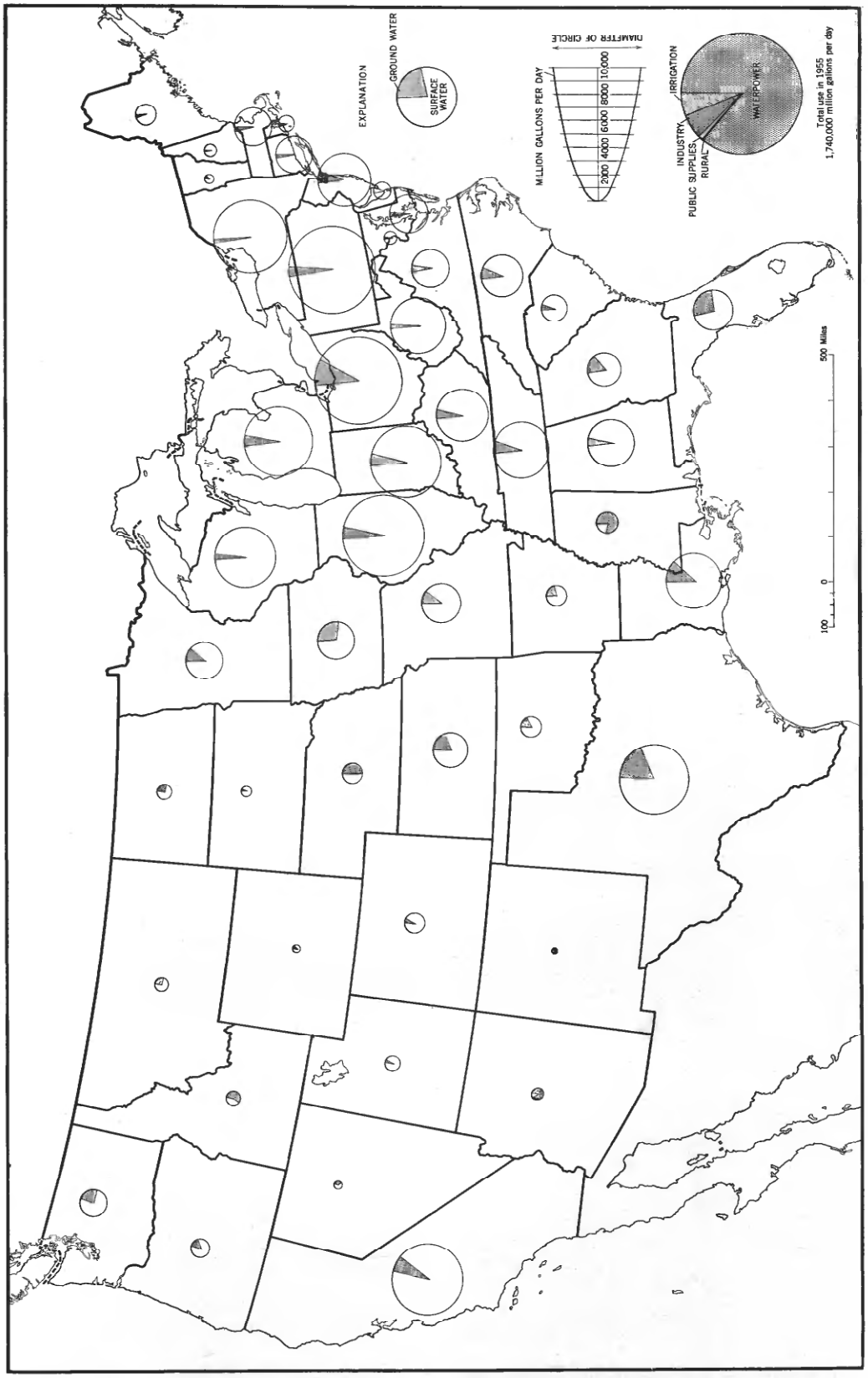

Figure 4.—Self-supplied industrial water.

Table 5.—Self-supplied industrial water, in million gallons per day, by regions

Region	Fuel-electric power (public utility)						Other							Total		
	Ground water			Surface water			Ground water			Surface water			Re-claimed sewage	Ground water	Surface water	Total
	Fresh	Saline	Total	Fresh	Saline	Total	Fresh	Saline	Total	Fresh	Saline	Total				
North Atlantic	1	0	1	870	1,900	2,770	140	7	147	1,500	450	1,950	0	148	4,720	4,868
Upper Hudson	2	0	2	410	0	410	12	0	12	580	0	580	0	14	990	1,004
Lower Hudson and Coastal area	150	1	151	900	2,500	3,400	240	7	247	830	1,600	2,430	0	398	5,830	6,228
Delaware	16	0	16	2,140	480	2,620	250	4	254	1,100	850	1,950	0	270	4,570	4,840
Chesapeake	41	0	41	1,074	760	1,834	200	3	203	870	740	1,610	68	244	3,444	3,756
Eastern Great Lakes and St. Lawrence	250	0	250	6,110	0	6,110	140	5	145	2,500	0	2,500	0	395	8,610	9,005
Western Great Lakes	249	0	249	9,390	0	9,390	210	21	231	2,900	0	2,900	0	480	12,290	12,770
Upper Mississippi	440	0	440	5,960	0	5,960	460	15	475	1,400	0	1,400	.7	915	7,360	8,276
Southeast	174	0	174	6,160	1,040	7,200	1,000	18	1,018	1,300	130	1,430	0	1,192	8,630	9,822
Tennessee-Cumberland	44	0	44	2,730	0	2,730	120	0	120	1,800	0	1,800	0	164	4,530	4,694
Ohio	580	0	580	14,470	0	14,470	820	15	835	6,000	6	6,006	0	1,415	20,476	21,891
Missouri-Hudson Bay	360	0	360	2,422	0	2,422	390	6	396	1,000	3	1,003	0	756	3,425	4,181
Lower Mississippi	314	0	314	1,319	58	1,377	470	0	470	1,300	0	1,300	0	784	2,677	3,461
Arkansas-White-Red	146	0	146	1,003	52	1,055	330	45	375	400	2	402	0	521	1,457	1,978
Western Gulf	159	0	159	1,444	510	1,954	460	500	960	1,200	1,900	3,100	.5	1,119	5,054	6,173
Colorado	25	0	25	18	0	18	140	0	140	96	0	96	0	165	114	279
Great Basin	40	0	40	51	0	51	100	0	100	60	0	60	0	140	111	251
Pacific Northwest	15	0	15	304	66	370	370	0	370	760	33	793	0	385	1,163	1,548
South Pacific	210	0	210	530	4,700	5,230	230	0	230	76	550	626	.3	440	5,856	6,296
United States	3,200	1	3,200	57,000	12,000	69,000	6,100	650	6,700	26,000	6,200	32,000	70	9,900	100,000	110,000

Table 6.—Water withdrawn by public utilities in generation of fuel-electric power, in million gallons per day, by regions.

Region	Condenser cooling						Other uses		All uses	
	Ground water			Surface water			Fresh ground water	Fresh surface water	Ground water	Surface water
	Fresh	Saline	Total	Fresh	Saline	Total				
North Atlantic	0	0	0	710	1,900	2,610	1	160	1	2,770
Upper Hudson	0	0	0	390	0	390	2	21	2	411
Lower Hudson and coastal area	0	1	1	850	2,500	3,350	150	50	151	3,400
Delaware	0	0	0	2,000	480	2,480	16	140	16	2,620
Chesapeake	3	0	3	1,000	760	1,760	38	74	41	1,834
Eastern Great Lakes and St. Lawrence	110	0	110	5,900	0	5,900	140	210	250	6,110
Western Great Lakes	39	0	39	9,100	0	9,100	210	290	249	9,390
Upper Mississippi	230	0	230	5,800	0	5,800	210	160	440	5,960
Southeast	14	0	14	5,900	1,040	6,940	160	260	174	7,200
Tennessee-Cumberland	0	0	0	2,600	0	2,600	44	130	44	2,730
Ohio	220	0	220	14,000	0	14,000	360	470	580	14,470
Missouri-Hudson Bay	220	0	220	2,400	0	2,400	140	22	360	2,422
Lower Mississippi	240	0	240	1,300	58	1,358	74	19	314	1,377
Arkansas-White-Red	66	0	66	990	52	1,042	80	13	146	1,055
Western Gulf	19	0	19	1,400	510	1,910	140	44	159	1,954
Colorado	10	0	10	18	0	18	15	0	25	18
Great Basin	27	0	27	50	0	50	13	1	40	51
Pacific Northwest	0	0	0	290	66	356	15	14	15	370
South Pacific	100	0	100	420	4,700	5,120	110	110	210	5,230
United States	1,300	1	1,300	55,000	12,000	67,000	1,900	2,200	3,200	69,000

Of this amount, about 1,500,000 mgd was withdrawn for production of waterpower (table 9). The 240,000 mgd remaining was withdrawn for public supplies, rural use, self-supplied industrial and irrigation, including conveyance losses (fig. 5) which amounted to 1,500 gallons per capita per day. Surface-water sources supplied 194,000 of the 240,000 mgd, and ground-water sources supplied 46,000 mgd.

About equal quantities of water, 110,000 mgd, were withdrawn for self-supplied industry and irrigation. About 17,000 mgd was withdrawn for public supplies and the smallest quantity, 2,400 mgd, was withdrawn for rural domestic and stock use. The withdrawal of water was greatest in the eastern industrial areas and in western areas where irrigation is practiced extensively (fig. 6). Withdrawals in the midcontinent region were the smallest.

Table 7.—Water withdrawn for air conditioning, in million gallons per day, by regions

Region	Self-supplied industrial water[1]		Public supplies[2]	Total
	Ground water	Surface water		
North Atlantic	0	0	0	0
Upper Hudson	2	4	3	9
Lower Hudson and Coastal area.	55	37	53	145
Delaware	21	13	20	54
Chesapeake	7	4	28	39
Eastern Great Lakes and St. Lawrence.	18	2	7	27
Western Great Lakes.	14	45	21	80
Upper Mississippi	8	0	43	51
Southeast	110	14	42	166
Tennessee-Cumberland.	10	9	11	30
Ohio	22	7	32	61
Missouri-Hudson Bay.	11	6	22	39
Lower Mississippi	44	15	27	86
Arkansas-White-Red.	20	8	51	79
Western Gulf	20	1	45	66
Colorado	12	2	6	20
Great Basin	4	0	4	8
Pacific Northwest	4	0	3	7
South Pacific	36	0	70	106
United States	420	170	490	1,100

1/ See table 5.
2/ Water from public supplies used for air conditioning is part of the 5,700 mgd used by industry. (See table 1.)

NONWITHDRAWAL USES

Nonwithdrawal uses do not lend themselves to evaluation in terms of the quantity of water used. These uses, however, do have a very large economic value and may have an appreciable effect on the quantity and quality of water available for other uses. The most important nonwithdrawal uses are navigation, waste disposal, recreation, and conservation of fish and wildlife.

CONSUMPTIVE USE

Only about a fourth of all withdrawn water is consumed. Consumption, expressed as a percentage of withdrawals, depends on many factors, including climate, season, and the use of the water. Most of the water consumed is used for irrigation; a fact of added importance when we consider that irrigation is practiced at times and places where the water supply is likely to be inadequate. Generally a higher percentage of the water withdrawn is consumed in areas having a dry climate than in humid areas, and a higher percentage is consumed in the hot dry part of the year.

Public Supplies

Not much of the water withdrawn by public supplies is consumed; Jordan (1955) estimated that not more than 10 percent of it fails to reach watercourses below the cities. A larger percentage of the water is probably consumed during the summer when lawns are watered.

Rural

The principal rural uses are stock watering and domestic. Water withdrawn for domestic use probably is consumed at about the same rate as water from public supplies; that is, about 10 percent of the withdrawals. Nearly all the water withdrawn for stock watering is consumed.

Irrigation

Irrigation is considered a consumptive use, although a large part of the water may reach a stream or the water table as return flow. Generally not more than 60 percent of the water delivered at the farm head gate is consumed by the crops (Blaney, 1955). If a sprinkler irrigation system is used, a much greater percentage of the water applied is transpired or evaporated.

Self-Supplied Industrial

The amount of self-supplied industrial water consumed is small, although the percentage of the amount withdrawn varies widely among industrial plants. For example, Mussey (1955) reported that in the manufacture of paper about 690 gallons of water per ton of paper was evaporated, which amounts to less than 2 percent of the plant intake. On the other hand, Conklin (1956) reported that almost all process water used in the production of carbon black was consumed, although the amount used was small. Only about 2 percent of all self-supplied industrial water is consumed.

Table 8.—Water withdrawn for production of water-power, by regions

Region	Million gallons per day	1,000 acre-feet per year
North Atlantic	180,000	200,000
Upper Hudson	35,000	39,000
Lower Hudson and coastal area.	1,200	1,400
Delaware	1,700	1,900
Chesapeake	73,000	82,000
Southeast	110,000	120,000
Tennessee-Cumberland	210,000	230,000
Ohio	48,000	54,000
Eastern Great Lakes and St. Lawrence.	100,000	110,000
Western Great Lakes	89,000	99,000
Upper Mississippi	130,000	140,000
Missouri-Hudson Bay	46,000	51,000
Lower Mississippi	0	0
Arkansas-White-Red	11,000	13,000
Western Gulf	9,300	10,000
Colorado	26,000	29,000
Great Basin	8,100	9,000
Pacific Northwest	360,000	410,000
South Pacific	32,000	36,000
United States	1,500,000	1,600,000

Table 9.—Withdrawal of water, in million gallons per day, by States

State	Public supplies			Rural			Irrigation				Self-supplied industrial						Total excluding water-power	Water power
	Ground water	Surface water	Total	Ground water	Surface water	Total	Ground water	Surface water	Sewage	Total	Ground water		Surface water		Sewage	Total		
											Fresh	Saline	Fresh	Saline				
Alabama	67	130	197	28	18	46	2.4	14	0	16.4	140	2	2,600	10	0	2,752	3,011	95,000
Arizona	110	21	131	10	4	14	4,700	2,200	10	6,910	140	0	17	0	0	157	7,212	11,000
Arkansas	28	39	67	24	14	38	790	88	0	878	110	11	410	0	0	531	1,514	4,100
California	540	750	1,290	89	22	111	10,000	13,000	25	23,025	460	0	620	5,200	.3	6,280.3	30,706	45,000
Colorado	28	200	228	39	7	46	1,000	5,300	3.2	6,303.2	35	0	470	0	0	505	7,082	3,800
Connecticut	10	240	250	8	3	11	1.3	12	0	13.3	51	6	1,000	680	0	1,737	2,011	11,000
Delaware	11	33	44	3	1	4	.36	1.2	0	1.56	25	0	46	250	0	321	371	0
District of Columbia	0	160	160	0	0	0	0	0	0	0	11	0	6	200	0	217	377	31
Florida	240	79	319	27	11	38	250	260	0	510	500	15	800	630	0	1,945	2,812	510
Georgia	85	200	285	23	13	36	12	18	.04	30	210	0	1,400	240	0	1,850	2,201	20,000
Idaho	56	30	86	15	10	25	1,100	14,000	0	15,100	120	0	94	0	0	214	15,425	61,000
Illinois	160	1,200	1,360	95	22	117	3.2	4.8	0	8.0	380	13	8,000	0	.7	8,393.7	9,879	27,000
Indiana	140	200	340	79	5	84	5.1	3.3	0	8.4	380	10	6,200	0	0	6,590	7,022	5,300
Iowa	100	41	141	79	57	136	3.4	1.2	0	4.6	410	9	1,100	0	0	1,519	1,801	16,000
Kansas	130	75	205	46	24	70	610	130	0	740	220	0	1,000	0	0	1,220	2,235	1,100
Knetucky	45	180	225	29	28	57	3.9	4.5	0	8.4	160	0	3,000	0	0	3,160	3,450	43,000
Louisiana	83	160	243	22	17	39	380	830	0	1,210	480	0	3,200	0	0	3,680	5,172	0
Maine	6	66	72	5	3	8	.19	.67	0	.86	10	1	340	120	0	471	552	100,000
Maryland	17	260	277	36	3	39	.68	13	0	13.68	76	3	360	1,100	68	1,607	1,937	17,000
Massachusetts	82	420	502	7	2	9	.18	4.1	0	4.28	65	0	680	1,200	0	1,945	2,460	25,000
Michigan	180	640	820	73	8	81	5.3	43	0	48.3	290	25	5,700	0	0	6,015	6,964	60,000
Minnesota	50	94	144	72	21	93	2.2	6.7	0	8.9	190	0	1,400	0	0	1,590	1,836	32,000
Mississippi	95	27	122	24	28	52	460	310	0	770	430	0	52	58	0	540	1,484	0
Missouri	41	300	341	56	36	92	20	24	0	44	190	0	1,600	0	0	1,790	2,267	6,200
Montana	21	73	94	13	23	36	150	9,600	6.4	9,756.4	60	2	150	3	0	215	10,101	37,000
Nebraska	120	100	220	60	13	73	850	1,700	0	2,550	250	0	240	0	0	490	3,333	5,300
Nevada	29	36	65	3	5	8	210	1,700	6.8	1,916.8	22	0	31	0	0	53	2,043	3,300
New Hampshire	9	36	45	3	1	4	.02	.92	0	.94	4	0	110	92	0	206	256	31,000
New Jersey	160	420	580	8	2	10	22	15	0	37	290	6	2,200	1,200	0	3,696	4,323	1,500
New Mexico	85	8	93	16	4	20	1,400	1,100	14	2,514	42	4	4	4	.5	54.5	2,681	81
New York	260	1,700	1,960	110	10	120	22	25	0	47	250	7	3,000	3,500	0	6,757	8,884	130,000
North Carolina	28	150	178	52	5	57	1.4	7.6	0	9.0	170	0	1,800	0	0	1,970	2,214	41,000
North Dakota	10	16	26	14	21	35	1.4	120	0	121.4	66	0	160	0	0	226	408	0
Ohio	250	850	1,100	77	28	105	1.1	10	0	11.1	940	0	8,600	0	0	9,540	10,756	1,600
Oklahoma	45	140	185	15	35	50	150	75	0	225	70	32	360	54	0	516	976	3,300
Oregon	36	160	196	18	13	31	490	6,300	3.6	6,793.6	65	0	370	0	0	435	7,456	180,000
Pennsylvania	120	1,300	1,420	60	17	77	1.6	14	0	15.6	340	0	8,700	461	0	9,501	11,014	41,000
Rhode Island	10	66	76	1	0	1	.04	.44	0	.48	11	0	70	240	0	321	398	960
South Carolina	27	120	147	30	4	34	12	18	0	30	50	0	690	0	0	740	951	29,000
South Dakota	46	16	62	34	16	50	6.8	21	0	27.8	96	2	7	0	0	105	245	6,400
Tennessee	100	150	250	26	25	51	3.6	24	0	27.6	250	0	3,700	0	0	3,950	4,279	100,000
Texas	550	500	1,050	140	27	167	6,500	3,700	29	10,229	530	500	2,300	2,400	0	5,730	17,176	11,000
Utah	110	64	174	8	10	18	270	3,900	.27	4,170.27	130	0	110	0	0	240	4,602	1,600
Vermont	11	23	34	8	4	12	0	1.1	0	1.1	12	0	55	0	0	67	114	16,000
Virginia	10	200	210	33	12	45	.43	6.7	0	7.13	100	0	1,200	450	0	1,750	2,012	24,000
Washington	150	360	510	28	20	48	230	4,800	0	5,030	180	0	540	98	0	818	6,406	110,000
West Virginia	18	65	83	17	9	26	0	.82	0	.82	110	0	3,900	0	0	4,010	4,120	27,000
Wisconsin	140	190	330	84	20	104	2.6	64	0	9.0	120	0	4,500	0	0	4,620	5,063	84,000
Wyoming	25	12	37	9	10	19	28	11,000	4.2	11,032.2	5	0	55	0	0	60	11,148	2,300
United States	4,700	12,000	17,000	1,800	690	2,400	30,000	80,000	100	110,000	9,200	650	83,000	18,000	70	110,000	240,000	1,500,000

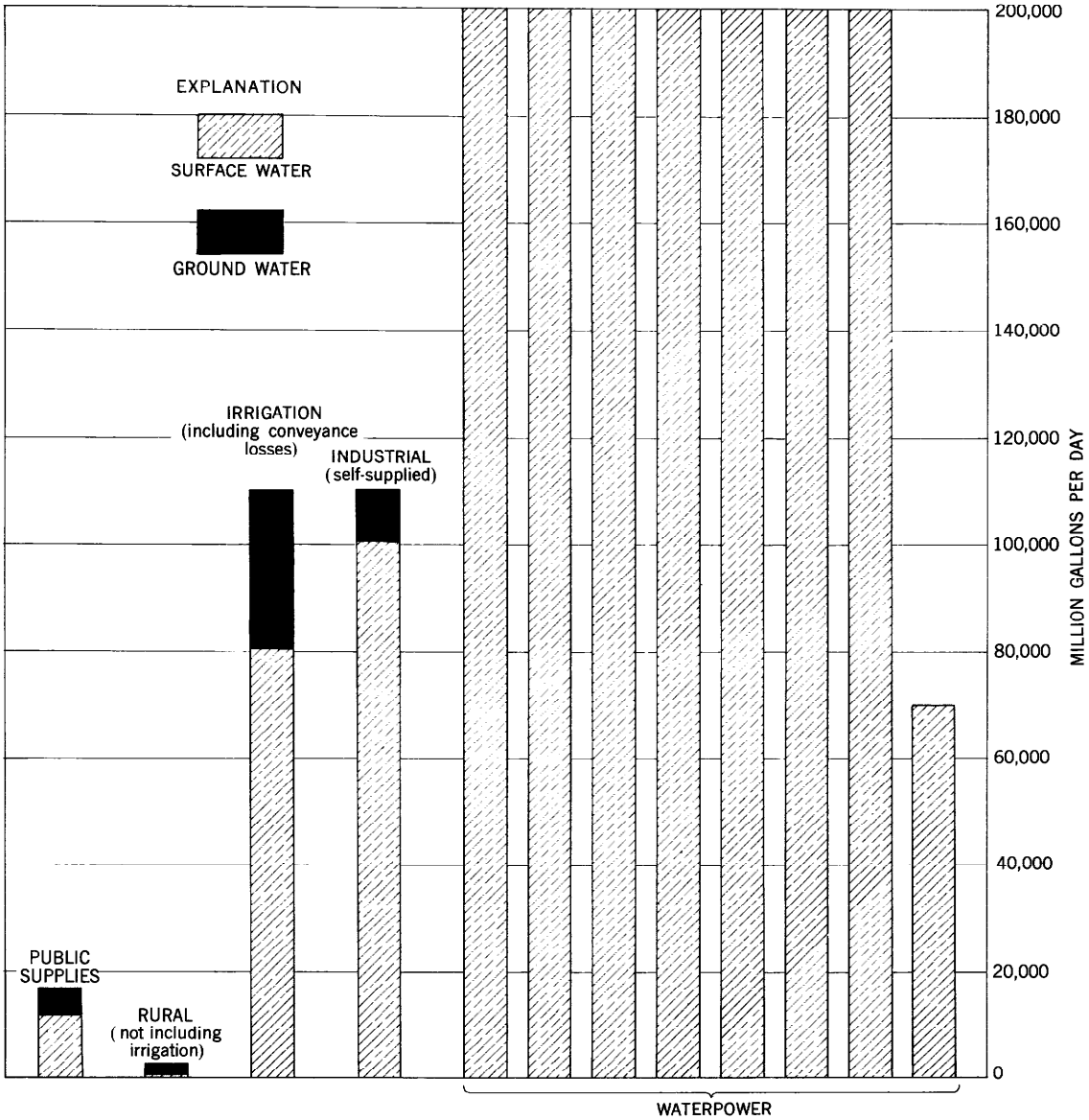

Figure 5. —Water withdrawn in the United States during 1955.

Consumption of Water Not Withdrawn

In addition to the consumption of part of the water withdrawn, large quantities of water stored for withdrawal and nonwithdrawal uses are consumed. Storage in farm ponds and reservoirs increases the water surface area and consequently the evaporation. If the pond or reservoir was created or enlarged to serve a use, then the increased evaporation can logically be charged to consumption rather than natural loss. Consumption of water not withdrawn has not been determined, however, it must be large.

The surface area of reservoirs gives an indication of the quantity of water evaporated. In 1954, there were 1,300 reservoirs and lakes in the United States having a capacity greater than 5,000 acre-feet and storing water for navigation, irrigation, power, water supply, flood control, and other uses (Thomas and evaporation from an area of this size would amount to more than the quantity of water withdrawn for public supplies. In addition to the larger reservoirs reported by Thomas and Harbeck, the U. S. Fish and Wildlife Service (1956) estimates there are more than $1\frac{1}{2}$ million farm ponds averaging an acre each. The aggregate annual evaporation from these ponds exceeds that withdrawn for rural use exclusive of irrigation.

CHANGE IN WITHDRAWALS SINCE 1950

This survey is comparable to the 1950 survey, except that it includes irrigation conveyance losses not given in the 1950 survey, and it probably is a little more accurate. Of the increases in water withdrawals since 1950, the greatest increase, 43 percent, was in self-supplied industrial water (table 10). Rural use declined between 1950 and 1955, because of the de-

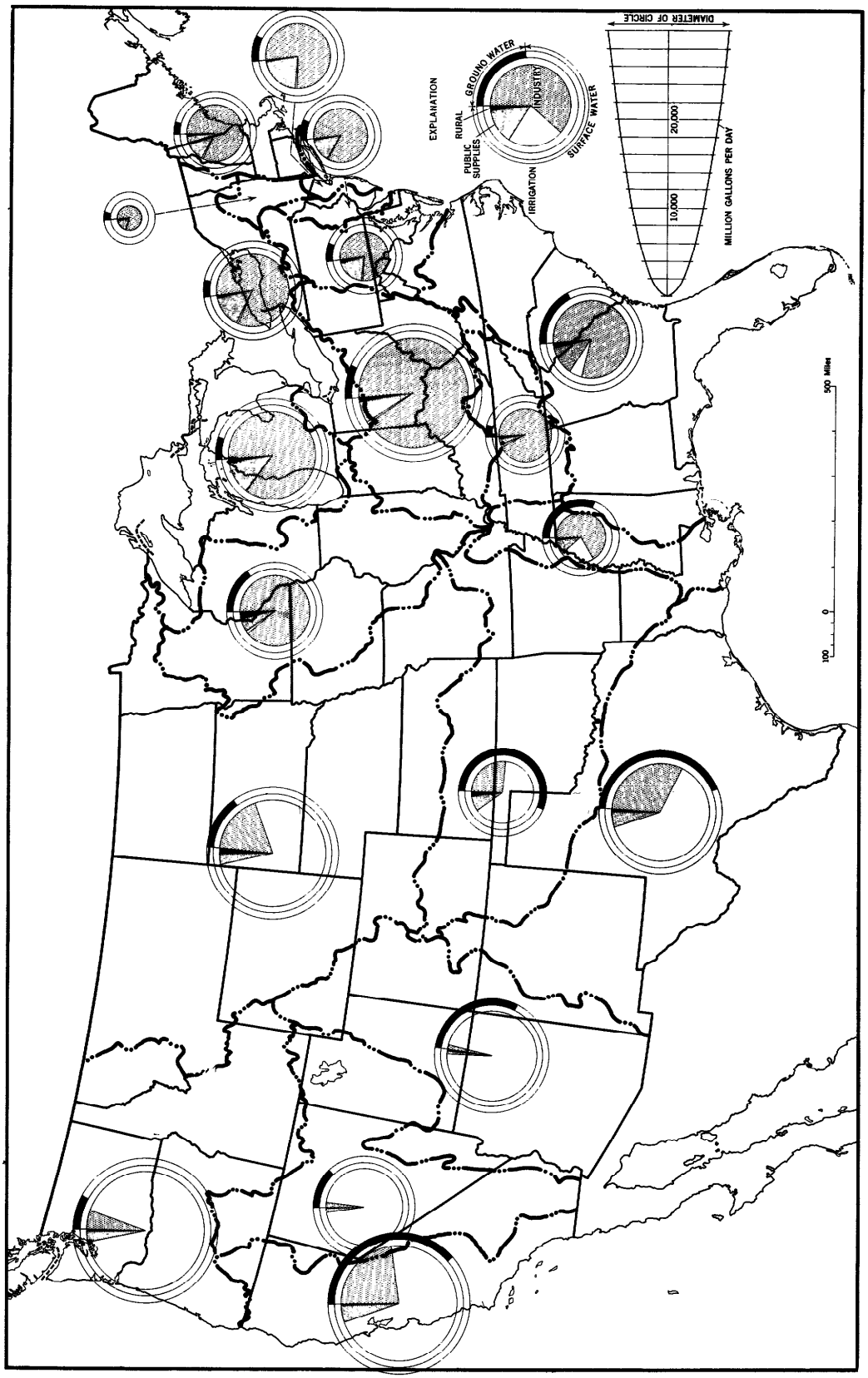

Figure 6.—Water withdrawn during 1955 for rural use, public supplies, irrigation, and self-supplied industrial use, by regions.

Table 10.—Change in withdrawals, 1950-55

	Water used (mgd)		Percent change
	1950	1955	
Waterpower	1,100,000	1,500,000	+36
Rural	3,600	2,500	-31
Public supplies	14,000	17,000	+21
Self-supplied industrial.	77,000	110,000	+43
Irrigation (except conveyance losses).	79,000	81,000	+3
Total, other than waterpower.	173,600	210,500	+21

Although the increase in surface water used, exclusive of that for waterpower, was 26,000 mgd and that of ground water was 11,000 mgd, the greater percentage increase was in water from ground-water sources, 37 percent as compared with 18 percent in surface water.

SUPPLY

Much of the withdrawn water is not consumed and therefore the supply is not depleted by the amount withdrawn. For this reason the quantity of withdrawn water is not directly comparable with the supply and, in fact, may exceed the total supply owing to repeated use. On the other hand, water that is consumed by use is no longer available; consequently, consumptive use can be compared with supply.

The long-term average runoff of a river basin, with few exceptions, is the upper limit of possible production of the combined surface- and ground-water resources of the basin. The exceptions are in the narrow fringes along the coasts where some water that percolates underground directly into the ocean could be used without affecting runoff, provided such use does not cause contamination by sea water. Runoff is the total flow of a stream including outflow from ground-water storage through springs and seeps as well as the overland flow that follows hard rains.

The runoff of all streams in the United States average 1,164,000 mgd, but it is not uniformly distributed throughout the Nation (table 11). The average annual runoff ranges from less than one-fourth inch in several places in the Southwest to more than 80 inches at some places along the Pacific Coast. In addition to this great areal variation in average annual runoff, runoff varies widely from day to day and year to year in any one locality. Therefore, a substantial part of the runoff cannot be used economically because it occurs as flood flow in such large volumes that storage is not feasible. The amount that can be used, however, could be increased by the use of above-ground and underground storage.

Table 11.—The Nation's water supply

Region	Area (thousand square miles)	Water supply 1/	
		Inches per year	Million gallons per day
North Atlantic	59	24	67,000
Upper Hudson	13	22	14,000
Lower Hudson and coastal area.	6	21	6,000
Delaware	12	21	12,000
Chesapeake	57	19	51,000
Eastern Great Lakes and St. Lawrence.	47	18	40,000
Western Great Lakes	81	11	42,000
Upper Mississippi	182	7.2	62,000
Southeast	279	16	212,000
Tennessee-Cumberland.	59	21	59,000
Ohio	145	16	110,000
Missouri-Hudson Bay	580	1.9	52,000
Lower Mississippi	64	16	49,000
Arkansas-White-Red	270	7.0	90,000
Western Gulf	341	3.2	52,000
Colorado	258	1.1	13,000
Great Basin	200	1.1	10,000
Pacific Northwest	257	13	159,000
South Pacific	112	12	64,000
United States	3,022	8.5	1,164,000

1/ Adapted from Langbein (1949) by James K. Searcy.

CONSERVATION OF WATER

Our water supply is a renewable resource because it is replenished frequently by precipitation. As water is a renewable resource, it cannot be hoarded ordinarily by nonuse. There are two important exceptions: stored ground water that is being mined and ground water that is being pumped at such a rate as to allow saline water encroachment to cause permanent contamination.

Mining water is the withdrawal of water accumulated over a long period of time, in the same sense that any other mineral resource is mined. For example, ground water that has accumulated for many centuries in the High Plains of Texas now is being used for irrigation with the full knowledge that, once the ground-water reservoir is depleted, it may be centuries before it can be filled again. Mining is a good conservation practice if the present use of the water results in the greatest foreseeable benefit.

Reducing or preventing contamination of ground water by saline waters or industrial wastes conserves water. In some places fresh ground water has been replaced or contaminated by encroaching saline water. This occurs when fresh water is

pumped from wells in large quantities allowing adjacent saline water to flow into the aquifers from which the fresh water was removed. The saline water may come from other aquifers below or above the fresh-water aquifer, by seepage or through improperly constructed or corroded well casings, or from the sea in coastal areas.

Water can be conserved in many other ways. Reservoirs can be built to hold back flood waters until they are needed. Better use can be made of the large ground-water reservoirs. Also, where geologic conditions permit, water can be stored in ground-water reservoirs by means of artificial recharge. Artificial recharge averaged at least as much as 700 mgd in 1955 (table 12). Most artificial recharge was practiced in California using surface water. Return water from air conditioners, industrial waste, and sewage are also sources of water for artificial recharge.

Water can be conserved by keeping permanent waste to a minimum. This can be accomplished by constructing reservoirs where the evaporation from its water surface is as small as possible and by reducing the growth of phreatophytes. We can obtain more service from our water supply by using water of inferior quality where it is possible to do so, such as for condenser cooling, in order to leave purer water for a use requiring a water of better quality. Recirculating water in industrial plants and preventing or reducing pollution from domestic sewage and industrial wastes are other conservation measures.

Table 12.—Summary of known artificial recharge during 1955, in million gallons per day

Region	Air-conditioning return	Industrial wastes	Surface water	Public water supplies	Other	Total
North Atlantic	0	0	4.0	0	0	4.0
Upper Hudson	0	0	0	0	0	0
Lower Hudson and coastal area	24	31	49	2	0	106
Delaware	1	1	2	0	0	4
Chesapeake	.3	0	0	0	0	.3
Eastern Great Lakes and St. Lawrence	4.1	0	0	0	0	4.1
Western Great Lakes	6.0	3.5	0	0	0	9.5
Upper Mississippi	0	1.0	6.4	0	0	7.4
Southeast	2.0	.25	0	.1	0	2.35
Tennessee-Cumberland	.5	0	0	0	0	.5
Ohio	.5	2.6	30	0	0	33.1
Missouri-Hudson Bay	0	0	.5	0	0	.5
Lower Mississippi	0	0	0	0	0	0
Arkansas-White-Red	0	4.2	0	0	0	4.2
Western Gulf	0	0	0	0	0	0
Colorado	.2	0	0	0	0	.2
Great Basin	2.7	0	0	0	0	2.7
Pacific Northwest	0	5.8	71	8.8	.2	85.8
South Pacific	0	0	375	60	0	435
United States	41	49	540	71	0.2	700

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