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Estimates of Water Use in the Western United States in 1990 and Water-Use Trends 1960-90: Report to the Western Water Policy Review Advisory Commission

Wayne B. Solley

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**Estimates of Water Use in
the Western United States
in 1990 and Water-Use
Trends 1960 -90**

Wayne B. Solley
U.S. Geological Survey
Reston, Virginia

**Report to the Western Water
Policy Review Advisory Commission**

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August 1997

The Western Water Policy Review Advisory Commission

Under the Western Water Policy Review Act of 1992 (P.L. 102-575, Title XXX), Congress directed the President to undertake a comprehensive review of Federal activities in the 19 Western States that directly or indirectly affect the allocation and use of water resources, whether surface or subsurface, and to submit a report of findings to the congressional committees having jurisdiction over Federal Water Programs.

As directed by the statute, the President appointed the Western Water Policy Review Advisory Commission. The Commission was composed of 22 members, 10 appointed by the President, including the Secretary of the Interior and the Secretary of the Army, and 12 members of Congress serving *ex-officio* by virtue of being the chair or ranking minority member of the 6 congressional committees and subcommittees with jurisdiction over the appropriations and programs of water resources agencies. A complete roster is provided below.

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This is an Independent Report to the Commission

The report published herein was prepared for the Commission as part of its information gathering activity. The views, conclusions, and recommendations are those of the author(s) and are not

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This report is published to share with the public the information and ideas gathered and considered by the Commission in its deliberations. The Commission's views, conclusions, and recommendations will be set forth in the Commission's own report.

Additional copies of this publication may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia, 22161; phone 703-487-4650.

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Abstract

Freshwater withdrawals in the western United States, including Alaska and Hawaii, were estimated at 179 million acre-feet during 1990—about the same as the estimate in 1985 and 0 percent more than the estimate in 1960. Water used for agriculture (irrigation and livestock), the largest use category in the western States, was estimated at 140 million acre-feet during 1990, percent less than the estimate in 1985, 8 percent less than the estimate in 1980, and 19 percent more than the estimate in 1960. During 1990, domestic and commercial use was estimated at 17.5 million acre-feet; industrial and mining, 5.6 million acre-feet; and thermoelectric power, 16.2 million acre-feet.

A comparison of water use by category indicates that agriculture still is the dominant water use in the western States, accounting for 78 percent of withdrawals in 1990, compared to 86 percent in 1960. Domestic use accounted for 8 percent of withdrawals in 1990 compared to 5 percent in 1960. The increase in domestic use was caused by an increase in population of 75 percent from 1960 to 1990 and an increase in domestic per-capita use from 129 gallons per day in 1960 to 160 gallons per day in 1990. Water used for thermoelectric power generation accounted for 9 percent of total water use in 1990 compared to 4 percent in 1960. Water used for hydroelectric-power generation, the only instream use discussed in this paper, was estimated at 1,730 million acre-feet during 1990. This is about the same as during 1985, and more than double the estimate of 752 million acre-feet during 1960.

Estimates of withdrawals by source indicate that during 1990, ground-water withdrawals in the western States were 58.9 million acre-feet, or 5 percent more than during 1985, and surface-water withdrawals were 120 million acre-feet, or 2 percent less than during 1985. The withdrawal of ground water peaked around 1975 and the withdrawal of surface water peaked around 1980, even though population consistently increased from 1960 to 1990. The general declines in ground-water withdrawals since 1975 and agricultural withdrawals since 1980 are in response to the use of more water-efficient irrigation systems, introduction of crops that use less water, and fewer acres irrigated by ground water in some areas because of declining water levels.

The use of reclaimed wastewater was estimated at 504 thousand acre-feet during 1990, or 25 percent more than during 1985. Total freshwater consumptive use was estimated at 81.7 million acre-feet during 1990, or 1 percent more than during 1985. Consumptive use by agriculture accounted for the largest part of total consumptive use, and was estimated at 75 million acre-feet. Consumptive use in the western States was about 46 percent of the freshwater withdrawn in the West, and accounted for about 78 percent of the Nation's total consumptive use.

The human population in the West increased 75 percent between 1960 and 1990, nearly double the national population growth rate. From 1960 to 1975, total withdrawals increased 35 percent, whereas population increased 29 percent; from 1975 to 1990, withdrawals decreased 2 percent, while population increased another 35 percent. Withdrawals for irrigation and livestock increased 28 percent from 1960 to 1975 and decreased 7 percent from 1975 to 1990. These patterns show that the rate of change in total water withdrawals in the West is more closely linked to irrigation, the dominant use, rather than to population.

Introduction

Water management in the western United States traditionally has focused on manipulating the abundant supplies of freshwater to meet the needs of users. This "supply management" approach has resulted in the building of large dams and conveyance systems. The era of building large dams to meet water demand in the United States is drawing to a close as shown in figure 1 (Ruddy and Hitt, 1990). Increasing development costs, capital shortages, government fiscal restraint, diminishing sources of water supply, polluted water, and a growing concern for the environment have forced water managers and planners to rethink traditional approaches to management and to experiment with new ones. Experts on the subject of water (supply and demand) agree that the western United States is in transition from an era of water-supply development to an era of water-demand management and conservation. "New" water supplies likely will come from the construction of small reservoirs, water conservation, improved water-use efficiency, recycling and reuse, ground-water development, changing water-use patterns, and increased use of reclaimed wastewater. Quantitative assessments derived from compilations, such as contained in this paper, can be used to evaluate the effectiveness of alternative water-management policies and conservation activities, and to make projections of future demands.

Purpose and Scope

The purpose of this paper is to present consistent estimates of water use by category, State, and water-resources region for the western United States, including Alaska and Hawaii. See figure 2. Estimates of freshwater withdrawn from ground- and surface-water sources, consumptive use, and instream use during 1990 are presented along with trends from 1960 to 1990.

Terminology

The term "offstream use" represents all water diverted or withdrawn from a surface- or ground-water source and conveyed to a place of use. "Instream use" refers to uses taking place within the river channel itself. The quantity of water used for a given category is the combination of self-supplied withdrawals and public-supply deliveries. "Consumptive use" refers to that part of the water withdrawn that is evaporated, transpired, incorporated into products and crops, consumed by humans or livestock, or otherwise removed from the immediate water supply. Reclaimed wastewater is treatment plant effluent diverted for beneficial use before it reaches a natural waterway or aquifer.

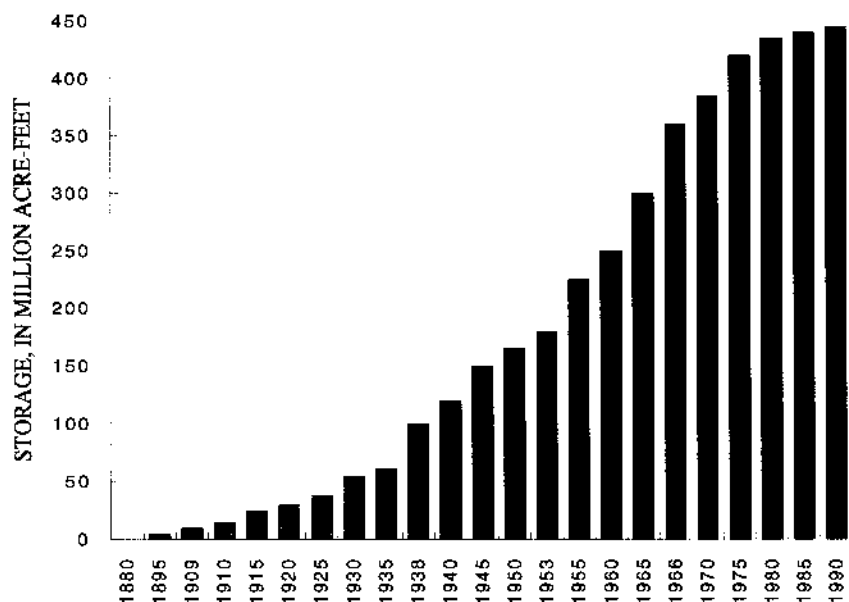
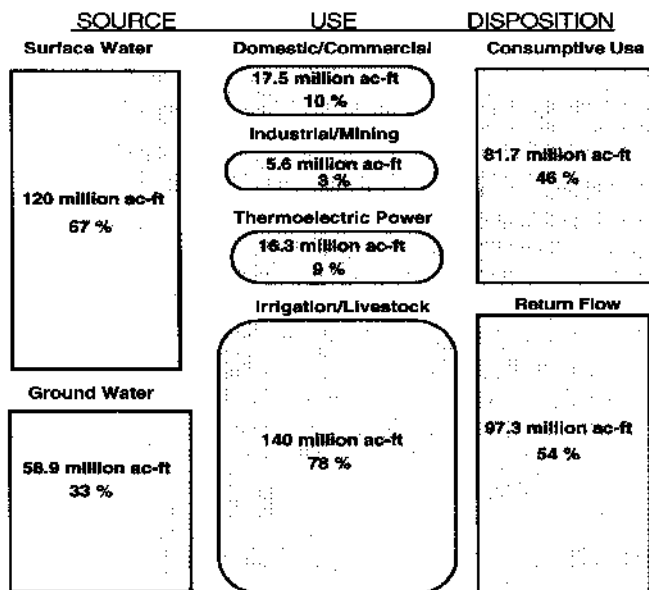


Figure 1.—Cumulative reservoir storage in the United States, 1880-1990.



Western United States

Figure 2.—Source, use, and disposition of freshwater (179 million acre-feet) in 1990 in the western United States.

Sources of Data

The U.S. Geological Survey (USGS) has compiled national water-use estimates every 5 years since 1950 and the reports used to develop trends of water use in this analysis were from 1960 to 1990 (MacKichan and Kammerer, 1961; Murray, 1968; Murray and Reeves, 1972, 1977; and Solley and others, 1983, 1988, 1993). The reports for 1950 and 1955 were not used because of inconsistencies in the reported data. Water-use estimates for 1995 currently are being compiled and are not available for this analysis.

Total Water Use

Fresh ground- and surface-water withdrawals in the western United States during 1990 are shown by State in table 1 and by water-resources region in table 2. Total withdrawals were estimated at 179 million acre-feet for all offstream water-use categories (domestic and commercial, irrigation and livestock, industrial and mining, thermoelectric power), and were about the same as total withdrawals estimated for 1985 (Solley and others, 1988, table 24, p. 59). A comparison of withdrawals by State indicates that of the 19 States in the West, 10 States had less water withdrawn for offstream uses during 1990 than during 1985 (Solley and others, 1993, p. 8). California (39.3 million acre-feet) accounted for the most water withdrawn for offstream use, followed by Texas (22.5 million acre-feet) and Idaho (22.1 million acre-feet). The use of reclaimed wastewater was estimated at 504 thousand acre-feet, or 14 percent more than during 1985 (Solley and others, 1988, table 24, p. 59). Conveyance losses totaled 30 million acre-feet; in addition, total consumptive use was estimated at 81.7 million acre-feet during 1990 (fig. 2), or 1 percent more than in 1985 (Solley and others, 1988, table 24, p. 59).

The Pacific Northwest, California, and Missouri Basin represent the largest water withdrawals by water-resources region (table 2). Over one-third of the population of the West resides in the California region. Surface water is the major source of water in all the water-resources regions in the West except for the Souris-Red-Rainy and Arkansas-White-Red Basins.

For an overview of how the 179 million acre-feet of freshwater withdrawn in the western United States during 1990 was used, the source, use (with-drawals, deliveries), and disposition of freshwater for each category of

Table 1.—Total water use by State in the western United States, 1990
[Figures may not add to totals because of independent rounding. Figures in thousand acre-feet except for per-capita use, in acre-feet]

State	Population, in thousand \$	Per-Capita Use	Ground Water	Surface Water	Total	Reclaimed Waste Water	Conveyance Losses	Consump- tive Use
Alaska	550	0.58	72	248	320	0	0	29
Arizona	3,665	2.01	3,070	4,290	7,360	205	1,130	4,880
California	29,760	1.32	16,400	23,000	39,300	149	1,750	23,400
Colorado	3,294	4.31	3,100	11,100	14,200	4	3,350	5,880
Hawaii	1,108	1.20	660	673	1,330	7	142	703
Idaho	1,007	21.95	8,510	13,600	22,100	0	8,030	6,830
Kansas	2,478	2.75	4,890	1,930	6,820	67	164	4,940
Montana	799	13.02	230	10,200	10,400	0	5,180	2,340
Nebraska	1,578	6.34	5,370	4,650	10,000	0	2,420	4,740
Nevada	1,202	3.11	1,190	2,560	3,740	0	689	1,890
New Mexico	1,515	2.57	1,970	1,930	3,900	0	661	2,310
North Dakota	639	4.69	158	2,850	3,000	0	7	256
Oklahoma	3,146	0.51	742	852	1,590	0	6	739
Oregon	2,842	3.33	860	8,590	9,450	13	1,420	3,540
South Dakota	696	0.95	281	382	664	0	70	387
Texas	16,986	1.32	8,270	14,200	22,500	63	740	10,100
Utah	1,723	2.84	1,080	3,820	4,900	44	700	2,500
Washington	4,867	1.82	1,620	7,240	8,870	0	1,120	3,170
Wyoming	454	18.72	430	8,070	8,500	0	2,410	3,060
Total	78,309	2.29	58,900	120,000	179,000	553	30,000	81,700

Table 2.—Total water use by water-resources region in the western United States, 1990
[Figures may not add to totals because of independent rounding. Figures in thousand acre-feet]

Region	Population, in thousands	Ground Water	Surface Water	Total	Reclaimed Waste Water	Conveyance Losses	Consumptive Use
Souris-Red-Rainy	388	86	58	144	0	0	82
Missouri Basin	7,050	9,140	27,600	36,700	3	10,100	13,300
Arkansas-White-Red	5,850	7,460	6,180	13,600	12	842	7,990
Texas-Gulf	15,226	6,140	8,990	15,100	57	383	6,630
Rio Grande	2,229	2,400	4,320	6,720	1	1,200	3,880
Upper Colorado	625	142	7,790	7,930	1	1,800	2,780
Lower Colorado	4,747	3,450	5,230	8,680	208	1,210	5,610
Great Basin	2,182	2,210	5,860	8,070	58	1,530	3,860
Pacific Northwest	8,912	11,000	29,700	40,700	14	10,800	13,600
California	29,442	16,200	23,500	39,700	144	1,960	23,300
Alaska	550	71	248	319	0	0	29
Hawaii	1,108	660	673	1,330	7	143	703
Total	78,309	58,900	120,000	179,000	553	30,000	81,700

water use are summarized in figure 2. The source column indicates that surface water was the source of 120 million acre-feet of freshwater, or 67 percent of total freshwater withdrawn. The use column shows total freshwater use for each category and the percentage each category represents of total offstream use. The use data indicate, for example, that domestic and commercial water use totaled 17.5 million acre-feet (including public uses and losses in the public-supply distribution system), or 10 percent of the total. The disposition column shows the quantity of consumptive use and return flow. Return flow includes 30 million acre-feet of conveyance losses. Consumptive use in the western States was 46 percent of the freshwater withdrawn in the West, and accounted for about 78 percent of the Nation's total consumptive use (Solley and others, 1993, table 2, p. 11). The higher consumptive-use rates in the West are the result of irrigation being dominant and irrigation accounting for the largest part of total consumptive use.

Table 3 shows total water use (self-supplied withdrawals, public-supply deliveries) by water-use category and the percentage each category represents of the total water use in the State. Irrigation still is the dominant water-use category in all but two states (Alaska, North Dakota) in the West and irrigation and livestock account for 78 percent of total withdrawals. Idaho (98 percent), Wyoming (95 percent), and Colorado (92 percent) are the states with the highest percentage of irrigation and livestock use. Industrial and mining is the major use category in Alaska, and thermoelectric power is the dominant use in North Dakota.

Figure 3 shows withdrawals ranked by State and the percentage each State represents of total withdrawals in the West. California accounts for the largest withdrawal of ground- and surface water and accounts for 22 percent of withdrawals in the West, nearly equal to the sum of the withdrawals of the next two states (Texas, Idaho). During 1990, surface-water withdrawals exceeded ground-water withdrawals in all States in the West except for Kansas, Nebraska, and New Mexico.

Total withdrawals in the western States accounted for 47 percent of the Nation's total withdrawals during 1990, (Solley and others, 1993, table 2, p. 11), whereas two-thirds of the Nation's ground-water withdrawals occurred in the West.

Table 3.—Total water use by water-use category and State in the western United States, 1990
 [Figures may not add to totals because of independent rounding. Use data in thousand acre-feet]

State	Domestic/ Commercial Use		Irrigation/ Livestock Use		Industrial/ Mining Use		Thermo- electric Use		Total Use
	Use	Percent	Use	Percent	Use	Percent	Use	Percent	
Alaska	110	35	1	0	172	54	35	11	320
Arizona	760	10	6,040	82	446	6	116	2	7,360
California	6,590	17	31,700	81	719	2	290	1	39,300
Colorado	722	5	13,100	92	216	2	143	1	14,200
Hawaii	314	24	854	64	58	4	107	8	1,330
Idaho	292	1	21,600	98	233	1	7	0	22,100
Kansas	413	6	4,820	71	128	2	1,460	21	6,820
Montana	168	2	10,200	97	71	1	37	0	10,400
Nebraska	351	4	6,990	70	230	2	2,450	24	10,000
Nevada	464	12	3,170	85	69	2	39	1	3,742
New Mexico	335	9	3,400	87	113	3	56	1	3,740
North Dakota	96	3	211	7	17	1	2,680	89	3,000
Oklahoma	503	32	820	51	169	11	102	6	1,590
Oregon	1,300	14	7,710	82	411	4	17	0	9,450
South Dakota	105	16	487	73	68	10	4	1	664
Texas	3,330	15	9,780	43	1,430	6	8,020	36	22,500
Utah	557	11	4,060	83	189	4	98	2	4,900
Washington	1,020	12	6,800	76	669	8	374	4	8,870
Wyoming	104	1	8,050	95	138	2	207	2	8,500
Total	17,500	10	140,000	78	5,550	3	16,200	9	179,000

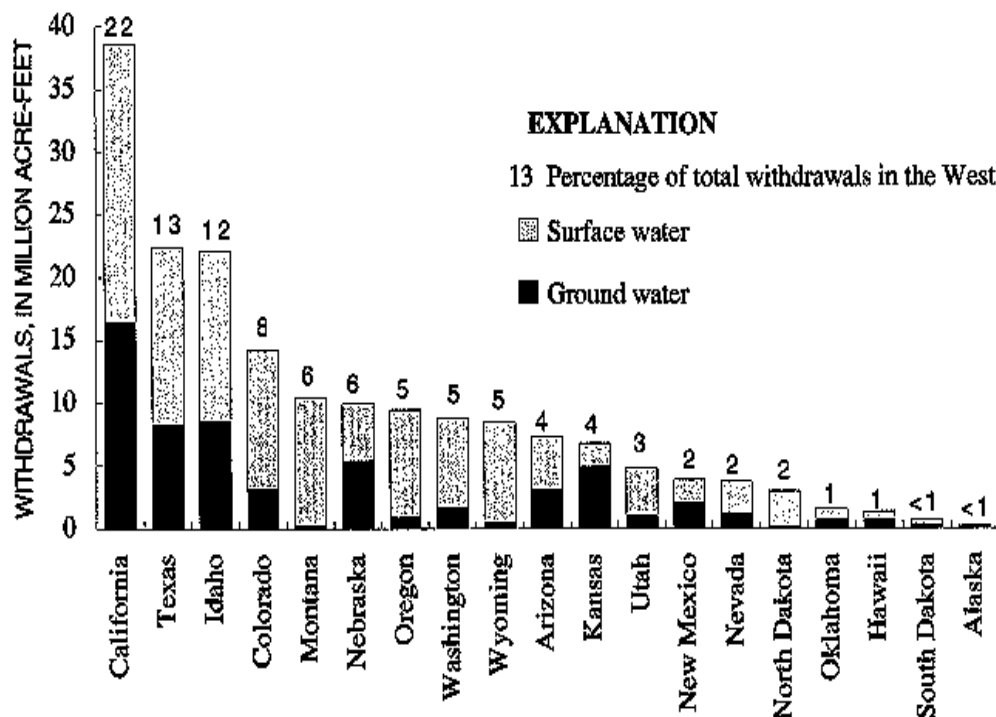


Figure 3.—Ground- and surface-water withdrawals in the western States, ranked by State, 1990.

Domestic and Commercial

Domestic and commercial water use (withdrawals, deliveries, distribution losses) in the western United States during 1990 was an estimated 17.5 million acre-feet (fig. 2, tables 4, 5). California and Texas, the most populated states, have the largest domestic and commercial use.

Public suppliers delivered about 13 million acre-feet of water to domestic and commercial users (tables 4, 5). About 2.2 million acre-feet of water was lost in the distribution system (tables 4, 5) or used for public uses such as street washing, municipal swimming pools, and fire fighting. The California region has the most population by region (table 2) and accounts for the largest domestic and commercial use.

Table 4.—Domestic and commercial water use by State, 1990
[Figures may not add to totals because of independent rounding. Figures in thousand acre-feet]

State	Ground-Water Withdrawals	Surface-Water Withdrawals	Public-Supply Deliveries	Distribution Losses	Total Use	Consumptive Use
Alaska	17	11	70	12	110	10
Arizona	55	0	702	2	760	369
California	301	317	5,080	888	6,590	1,170
Colorado	30	1	615	76	722	175
Hawaii	53	2	211	47	314	105
Idaho	71	0	167	54	292	5
Kansas	35	0	301	77	413	165
Montana	17	1	114	36	168	60
Nebraska	53	0	211	87	351	134
Nevada	19	18	367	60	464	161
New Mexico	45	1	260	29	335	179
North Dakota	14	0	64	19	96	22
Oklahoma	52	2	366	84	503	98
Oregon	72	798	351	85	1,300	111
South Dakota	23	5	69	8	105	19
Texas	161	12	2,720	435	3,330	967
Utah	10	2	473	73	557	151
Washington	147	0	745	131	1,020	128
Wyoming	10	1	80	13	104	32
Total	1,180	1,170	13,000	2,220	17,500	4,060

Table 5.—Domestic and commercial water use by water-resources region, 1990
 [Figures may not add to totals because of independent rounding. Figures in thousand acre-feet]

Region	Ground-Water Withdrawals	Surface-Water Withdrawals	Public-Supply Deliveries	Distribution Losses	Total Use	Consumptive Use
Souris-Red-Rainy	9	0	34	13	56	11
Missouri Basin	127	7	1,040	241	1,415	425
Arkansas-White-Red	97	2	764	189	1,052	280
Texas-Gulf	141	12	2,440	220	2,811	868
Rio Grande	47	1	388	189	626	208
Upper Colorado	17	1	113	14	146	44
Lower Colorado	67	9	1,020	80	1,180	492
Great Basin	22	13	584	76	695	201
Pacific Northwest	293	758	1,300	268	2,622	266
California	301	354	5,010	866	6,527	1,150
Alaska	17	11	70	12	110	10
Hawaii	53	2	211	47	314	105
Total	1,180	1,170	13,000	2,220	17,500	4,060

Irrigation and Livestock

The quantity of water withdrawn for agriculture (irrigation and livestock) in the western United States during 1990 was estimated at 140 million acre-feet, (fig. 2, tables 6, 7), about 2 percent less than during 1985 (Solley and others, 1988, table 8, p. 25) and 19 percent more than during 1960 (MacKichan and Kammerer, 1961, table 5, p. 16). The Pacific Northwest region accounted for the most water withdrawn for irrigation in the West. The quantity of water withdrawn for total livestock purposes (livestock, animal specialties) in the West during 1990 was an estimated 2.3 million acre-feet, (Solley and others, 1993, table 18, p. 41). Agriculture still is the dominant water-use category in the West.

Industrial and Mining

Industrial and mining water use (withdrawals, deliveries) during 1990 in the western United States was estimated at 5.6 million acre-feet (fig. 2, tables 8, 9). Public suppliers delivered an estimated 1.4 million acre-feet of water to industrial users. Texas ranks among the top industrial water-using states in the Nation and Texas reported the second largest quantity of reclaimed wastewater used by industries (Solley and others, 1993, table 20, p. 45). The Pacific Northwest and the Texas-Gulf are the dominant water-resources regions for industrial and mining water use. Public supply is the major source of water for industrial and mining use in the California region.

Total Water Use

Table 6.—Irrigation and livestock water use by State, 1990
[Figures may not add to totals because of independent rounding. Use data in thousand acre-feet]

State	Land Irrigated, in 1,000 acres	Ground Water	Surface Water	Total	Reclaimed Waste Water	Conveyance Losses	Consumptive Use
Alaska	1	0	1	1	0	0	1
Arizona	1,348	2,330	3,710	6,040	202	1,130	4,010
California	9,481	12,200	19,500	31,700	148	1,750	22,100
Colorado	3,552	2,890	10,200	13,100	4	3,350	5,600
Hawaii	127	228	626	854	7	143	592
Idaho	3,413	8,050	13,500	21,600	0	8,020	6,820
Kansas	3,119	4,560	258	4,820	6	163	4,660
Montana	1,933	119	10,000	10,200	0	5,180	2,230
Nebraska	6,863	5,000	1,990	6,990	0	2,420	4,550
Nevada	729	977	2,190	3,170	12	690	1,640
New Mexico	984	1,560	1,840	3,400	0	661	2,010
North Dakota	168	103	108	211	0	7	190
Oklahoma	503	592	228	820	0	6	572
Oregon	2,036	635	7,080	7,710	12	1,420	3,380
South Dakota	396	177	310	487	0	69	353
Texas	6,225	6,380	3,400	9,780	38	740	8,240
Utah	1,294	600	3,460	4,060	44	699	2,170
Washington	1,980	870	5,930	6,800	0	1,120	2,960
Wyoming	1,944	281	7,770	8,050	0	2,410	2,920
Total	46,097	47,600	92,200	140,000	474	30,000	75,000

Table 7.—Irrigation and livestock water use by water-resources region, 1990
[Figures may not add to totals because of independent rounding. Use data in thousand acre-feet]

Region	Land Irrigated, in 1,000 acres	Ground Water	Surface Water	Total	Reclaimed Waste Water	Conveyance Losses	Consumptive Use
Souris-Red-Rainy	71	50	25	75	0	0	68
Missouri Basin	12,710	8,270	19,900	28,100	3	10,100	12,600
Arkansas-White-Red	5,285	6,900	1,950	8,860	10	842	7,420
Texas-Gulf	4,392	4,510	1,380	5,890	34	383	4,990
Rio Grande	1,387	1,830	4,130	5,970	1	1,200	3,600
Upper Colorado	1,559	42	7,480	7,520	1	1,800	2,520
Lower Colorado	1,522	2,550	4,360	6,910	205	1,210	4,600
Great Basin	1,936	1,610	5,490	7,100	58	1,530	3,500
Pacific Northwest	7,491	9,460	26,800	36,300	12	10,800	13,200
California	9,617	12,100	20,100	32,200	143	1,960	22,000
Alaska	1	0	1	1	0	0	1
Hawaii	127	228	626	854	7	143	592
Total	46,097	47,600	92,200	140,000	474	30,000	75,000

Table 8.—Industrial and mining water use by State, 1990
 [Figures may not add to totals because of independent rounding. Figures in thousand acre-feet]

State	Ground-Water Withdrawals	Surface-Water Withdrawals	Public-Supply Deliveries	Total	Reclaimed Wastewater	Consumptive Use
Alaska	11	142	20	172	0.0	15
Arizona	186	172	88	446	3	383
California	155	12	552	719	1	118
Colorado	68	125	23	216	0	62
Hawaii	24	26	8	58	0	4
Idaho	191	38	4	233	0	8
Kansas	84	5	39	128	1	45
Montana	36	34	1	71	0	11
Nebraska	45	148	37	230	0	35
Nevada	62	5	3	69	0	58
New Mexico	92	5	16	113	0	70
North Dakota	6	8	3	17	0	14
Oklahoma	6	36	127	169	0	15
Oregon	35	285	91	411	2	44
South Dakota	22	37	9	68	0	14
Texas	264	882	286	1,430	24	624
Utah	128	36	24	189	0	81
Washington	119	445	104	669	0	83
Wyoming	91	40	6	138	0	43
Total	1,620	2,480	1,440	5,550	30	1,730

Table 9.—Industrial and mining water use by water-resources region, 1990
 [Figures may not add to totals because of independent rounding. Figures in thousand acre-feet]

Region	Ground-Water Withdrawals	Surface-Water Withdrawals	Public-Supply Deliveries	Total	Reclaimed Wastewater	Consumptive Use
Souris-Red-Rainy	1	10	2	13	0	4
Missouri Basin	205	259	86	550	0	137
Arkansas-White-Red	94	312	275	681	2	149
Texas-Gulf	252	725	160	1,137	22	537
Rio Grande	85	3	21	109	1	64
Upper Colorado	47	16	5	68	0	30
Lower Colorado	211	173	90	475	3	400
Great Basin	172	39	24	235	0	125
Pacific Northwest	382	786	197	1,365	2	143
California	157	13	555	725	1	122
Alaska	11	142	20	172	0	15
Hawaii	24	26	8	58	0	4
Total	1,620	2,480	1,440	5,550	30	1,730

Thermoelectric Power

The quantity of water used for thermoelectric-power generation during 1990 in the western United States was about 16.2 million acre-feet (fig. 2, tables 10, 11) and accounted for 9 percent of total freshwater use for all offstream categories in the West. Thermoelectric-power plants furnish most of their own water; less than 0.1 percent is obtained from public supplies.

Consumptive use of water for thermoelectric-power generation in the western States was about 935 thousand acre-feet, or 6 percent of withdrawals. Texas is by far the largest user of water for thermoelectric-power generation, accounting for 49 percent (8.0 million acre-feet) of thermoelectric power water use in the West. The Missouri Basin and Texas-Gulf regions use the most water for thermoelectric power.

Hydroelectric Power

Water use in the western United States for hydroelectric-power generation, the only instream water use discussed in this paper, was estimated at 1,730 million acre-feet during 1990 (tables 12, 13), or about the same as during 1985 (Solley and others, 1988, table 20, p.47).

Table 10.—Thermoelectric power water use by State, 1990
[Figures may not add to totals because of independent rounding. Figures in thousand acre-feet]

State	Ground-Water Withdrawals	Surface-Water Withdrawals	Public-Supply Deliveries	Total	Consumptive Use	Power Generated, in million kWh
Alaska	5	29	1	35	4	3,820
Arizona	47	69	0	116	112	55,900
California	5	270	15	290	7	80,100
Colorado	23	105	15	143	46	30,000
Hawaii	107	0	0	107	2	8,320
Idaho	7	0	0	7	2	0
Kansas	14	1,440	1	1,460	71	33,700
Montana	0	37	0	37	37	15,100
Nebraska	7	2,440	2	2,450	25	20,500
Nevada	13	25	1	39	39	19,100
New Mexico	11	45	0	56	51	28,300
North Dakota	0	2,680	0	2,680	29	26,900
Oklahoma	2	98	2	102	54	41,500
Oregon	0	17	0	17	12	8,040
South Dakota	0	3	0	4	0	2,490
Texas	61	7,930	24	8,020	277	224,000
Utah	0	98	0	98	97	31,600
Washington	4	370	0	374	10	13,500
Wyoming	1	205	0	207	60	35,800
Total	308	15,900	61	16,200	935	680,000

Table 11.—Thermoelectric power water use by water-resources region, 1990
 [Figures may not add to totals because of independent rounding. Figures in thousand acre-feet]

Region	Ground-Water Withdrawals	Surface-Water Withdrawals	Public-Supply Deliveries	Total	Consumptive Use	Power Generated, in million kWh
Souris-Red-Rainy	0	0	0	0	0	0
Missouri Basin	19	6,660	7	6,690	174	112,000
Arkansas-White-Red	31	2,990	29	3,050	140	92,600
Texas-Gulf	51	5,230	8	5,290	232	192,000
Rio Grande	18	2	0	20	14	7,780
Upper Colorado	0	199	0	199	185	91,400
Lower Colorado	52	70	1	123	120	54,000
Great Basin	8	26	0	34	34	17,300
Pacific Northwest	11	387	0	398	24	21,600
California	5	270	15	290	7	80,100
Alaska	5	29	1	35	4	3,820
Hawaii	107	0	0	107	2	8,320
Total	308	15,900	61	16,200	935	680,000

Table 12.—Hydroelectric power instream water use by State, 1990
 [Figures may not add to totals because of independent rounding.
 Water use in thousand acre-feet]

State	Water Use	Power Generated, in million kWh
Alaska	2,010	980
Arizona	35,600	8,180
California	84,100	23,900
Colorado	4,660	1,320
Hawaii	296	89
Idaho	76,000	7,450
Kansas	1,460	12
Montana	74,900	10,700
Nebraska	14,500	833
Nevada	3,910	1,620
New Mexico	1,080	215
North Dakota	12,300	1,720
Oklahoma	53,700	2,870
Oregon	539,000	40,800
South Dakota	46,100	4,270
Texas	17,700	1,570
Utah	2,110	481
Washington	751,000	87,300
Wyoming	4,880	611
Total	1,730,000	195,000

Table 13.—Hydroelectric power instream water use
by water-resources region, 1990
[Figures may not add to totals because of independent
rounding. Water use in thousand acre-feet]

Region	Water Use	Power Generated, in million kWh
Souris-Red-Rainy	0	0
Missouri Basin	112,000	11,400
Arkansas-White-Red	57,100	3,310
Texas-Gulf	13,600	953
Rio Grande	3,950	569
Upper Colorado	13,300	4,760
Lower Colorado	38,900	6,640
Great Basin	2,640	284
Pacific Northwest	1,410,000	142,000
California	77,400	23,700
Alaska	2,010	980
Hawaii	296	89
Total	1,730,000	195,000

The 1990 estimate is more than double the estimate of 752 million acre-feet in 1960 (MacKichan and Kammerer, 1961, table 13, p. 23). Water used to generate hydroelectric power accounts for about 10 times the quantity of water withdrawn for all offstream uses. Washington and Oregon together account for 75 percent of hydroelectric power water use in the West. Therefore, the Pacific Northwest water-resources region is the dominant area for hydroelectric-power generation.

Trends in Water Use, 1960-90

Trends in fresh ground- and surface-water withdrawals in the western United States are shown in figure 4. Total withdrawals of ground water and surface water increased from 1960 to 1975. Withdrawals of surface water were higher in 1980 than in 1975, whereas withdrawals of ground water were lower in 1980 than in 1975. Withdrawals of ground water also were lower in 1985 than in 1980. The withdrawal of ground water was slightly higher in 1990 than in 1985. Surface-water withdrawals remained fairly constant during 1980, 1985, and 1990.

The general declines in ground-water withdrawals since 1975 and surface-water withdrawals since 1980 are in response to use of more water-efficient irrigation systems, changing crop patterns, such as the introduction of crops that use less water, and reduction in acreage irrigated by ground water in some areas because of declining water levels. The increase in population has resulted in an increase in ground-water use in urban areas and the conversion of agricultural land to urban use. The quantity of surface water withdrawn in the West generally is about twice the quantity of ground water withdrawn.

Withdrawals for most water-use categories showed a general increase from 1960 to 1990 with the exception of industry (fig. 5). The large decline in industrial withdrawals from 1980 to 1985 partially is the result of conservation measures and how industry is categorized—some of the withdrawals included in the industry category were included in the livestock category beginning in 1985. Freshwater withdrawals for domestic use and public supply more than doubled from 1960 to 1990 (fig. 5). This is due in part to the large population increase of 75 percent between 1960 and 1990 as shown in figure 6. Domestic per-capita use has remained about the same for the last decade (160 gallons per day) as the result of active conservation programs in many states that include the installation of water meters and water-conserving plumbing fixtures.

From 1960 to 1975, total withdrawals increased 35 percent, whereas population increased 29 percent; and from 1975 to 1990, total withdrawals decreased 2 percent, whereas population increased another 35 percent (fig 6). Withdrawals for irrigation and livestock increased 28 percent from 1960 to 1975 and decreased 7 percent from 1975 to 1990. A corresponding pattern occurred in land irrigated in the western States, which steadily increased by 32 percent from 1960 to 1975 and decreased by 3 percent from 1975 to 1990. These patterns show that the rate of change in total water withdrawals in the western States is more closely linked to irrigation, the dominant use, than to population.

A comparison of water use by category indicates that agriculture still is the dominant water-use category in the western United States, accounting for 78 percent of freshwater withdrawals in 1990, compared to 86 percent in 1960, as shown in figure 7. Domestic use accounted for 8 percent of withdrawals during 1990 compared to 5 percent during 1960. The increase in domestic use is the result of an increase in population of 75 percent from 1960 to 1990 and an increase in domestic per-capita use from 129 gallons per day in 1960 (MacKichan and Kammerer, 1961, table 3, p. 15) to 160 gallons per day in 1990 (Solley and others, 1993, table 12, p. 29). The increase in per-capita use probably is the result of more modern water appliances in the homes, such as dish washers and clothes washers. Water used for thermoelectric-power generation accounted for 9 percent of withdrawals in

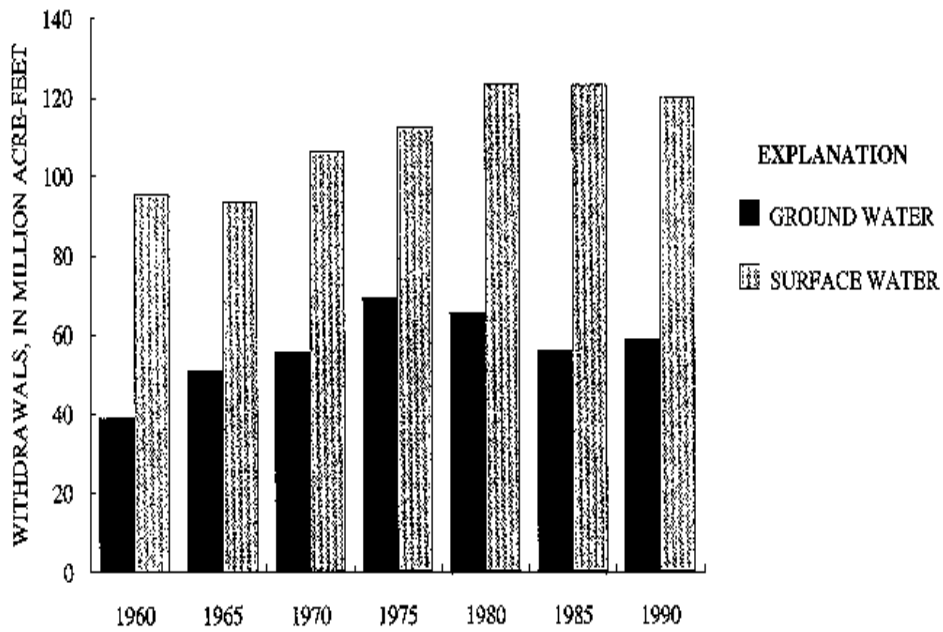


Figure 4.—Fresh ground- and surface-water withdrawals at 5-year intervals in the western States, 1960-90.

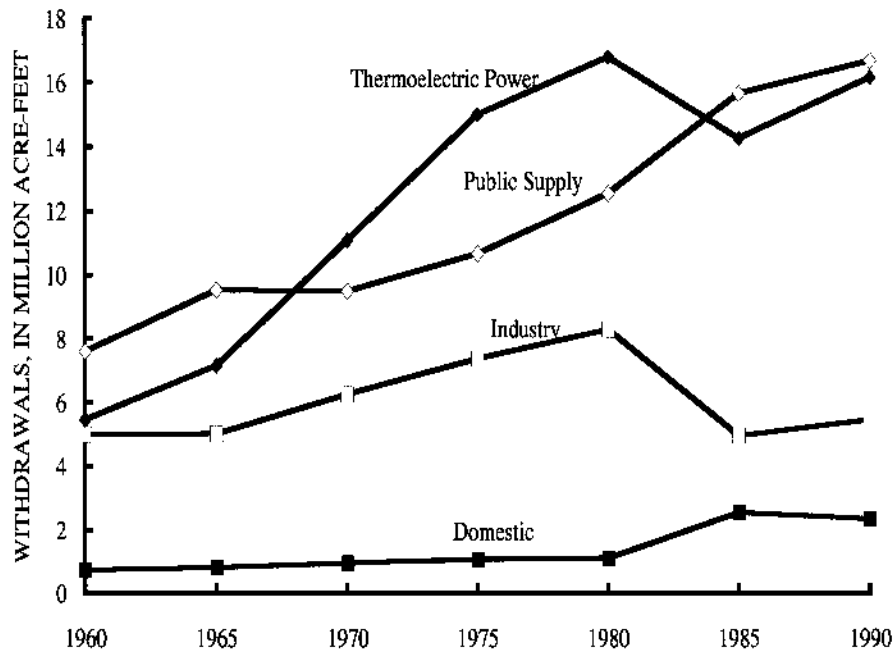


Figure 5.—Water withdrawals by water-use category in the western United States, 1960-90.

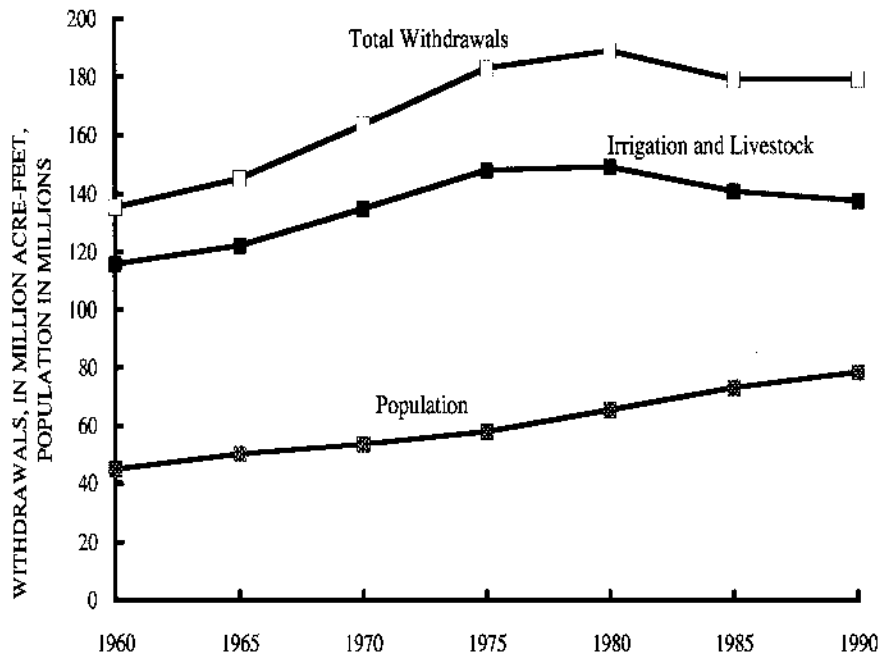


Figure 6.—Water withdrawals and population in the western United States, 1960-90.

1990 compared to 4 percent in 1960. Industrial use in figure 7 includes the mining and commercial water-use categories and accounted for about the same proportion of total water use in 1990 as it did in 1960. The domestic and thermoelectric power categories are expected to continue to increase as population increases in the West, thus intensifying the competition on agriculture's share of total water use.

Summary

Freshwater withdrawals in the western United States were estimated at about 179 million acre-feet during 1990—about the same as the estimate in 1985, and 30 percent more than the 1960 estimate. Agriculture (irrigation and livestock) still is the dominant water use in the western States, accounting for 78 percent of withdrawals in 1990 compared to 86 percent in 1960.

Estimates of withdrawals by source indicate that during 1990, ground-water withdrawals in the western States were 58.9 million acre-feet, or 5 percent more than during 1985, and surface-water withdrawals were 120 million acre-feet, or 2 percent less than during 1985. The withdrawal of ground water peaked around 1975 and the withdrawal of surface water peaked around 1980, even

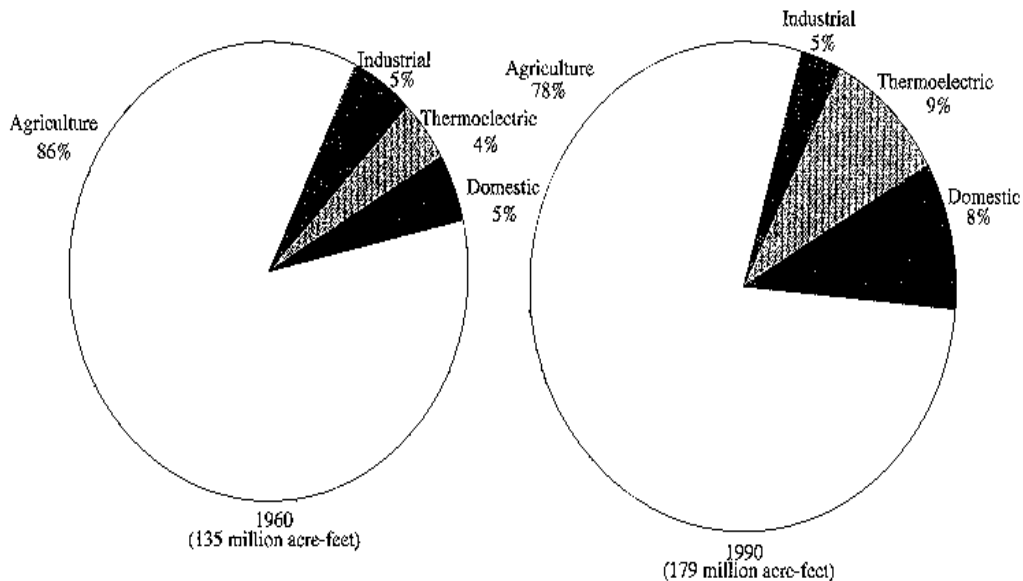


Figure 7.—Freshwater withdrawals by water-use category in the western States, 1960 and 1990.

though population steadily increased from 1960 to 1990.

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