DEPARTMENT OF THE INTERIOR,
CENSUS OFFICE.

ROBERT P. PORTER,
Superintendent.
Appointed April 20, 1889; resigned July 31, 1893.

CARROLL D. WRIGHT,
Commissioner of Labor in charge.
Appointed October 5, 1893.

REPORT

ON

AGRICULTURE BY IRRIGATION

IN THE

WESTERN PART OF THE UNITED STATES

AT THE

ELEVENTH CENSUS: 1890.

F. H. NEWELL,
SPECIAL AGENT.

WASHINGTON, D. C.:
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DEPARTMENT OF THE INTERIOR,
CENSUS OFFICE,
WASHINGTON, D. C., May 31, 1894.

SIR:

I have the honor to transmit herewith the Report on Agriculture by Irrigation in the western part of the United States, prepared by Mr. Frederick Haynes Newell, special agent, under the general direction of Mr. John Hyde, formerly special agent in charge of the division of agriculture.

Very respectfully,

CARROLL D. WRIGHT,
Commissioner of Labor in charge.

Hon. HOKE SMITH,
Secretary of the Interior.

INTRODUCTION.

BY F. H. NEWELL.

This report shows the relative importance of irrigation under the general heads of the Arid region, where irrigation is essential, and the Subhumid region, where the rainfall in some seasons tempts the agriculturist to depend upon a supply that fails to develop his crops in other seasons.

In the first, or arid region, are embraced part or the whole of certain states and territories, namely: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

In the subhumid region are embraced parts of certain states, namely: North Dakota, South Dakota, Nebraska, Kansas, and Texas.

The following condensed tables present the number of persons who irrigate their farms, aggregating 52,584; the acres irrigated, aggregating 3,564,416; the average size of irrigated farms for the regions treated, 68 acres; the average value of products per acre for the arid region, $14.89, first distributed by states and territories for the arid region, and next by states for the subhumid region.

TOTAL NUMBER, TOTAL AREA, AVERAGE SIZE, AND AVERAGE VALUE OF PRODUCT PER ACRE OF IRRIGATED FARMS IN THE ARID REGION.

STATES AND TERRITORIES.	Number of irrigators in 1889.	Area irrigated in 1889, in acres.	Average size of irrigated farms, in acres, in 1889.	Average value of products per acre in 1889.
Total	52,584	3,564,416	68	$14.89
Arizona	1,075	65,821	61	13.92
California	13,732	1,004,233	73	19.00
Colorado	9,650	890,735	92	13.12
Idaho	4,323	217,005	50	12.93
Montana	3,706	350,582	95	12.96
Nevada	1,167	224,403	192	12.92
New Mexico	3,085	91,745	30	12.80
Oregon	3,150	177,944	56	13.90
Utah	9,724	263,473	27	18.03
Washington	1,046	48,799	47	17.09
Wyoming	1,917	229,676	119	8.25

The table for the subhumid region does not show the value of products per acre.

TOTAL NUMBER, TOTAL AREA, AND AVERAGE SIZE OF IRRIGATED FARMS IN THE SUBHUMID REGION.

STATES.	Number of irrigators in 1889.	Area irrigated in 1889, in acres.	Average size of irrigated farms, in acres, in 1889.
Total	1,552	66,965	43
North Dakota	7	445	64
South Dakota	189	15,717	83
Nebraska	214	11,744	55
Kansas	519	20,818	40
Texas	623	18,241	29

The area irrigated by artesian wells was but 1.429 per cent of the irrigated land. The number of wells, the area they irrigated in each state and territory, with various details, appear in the following table:

ARTESIAN WELLS ON FARMS IN JUNE, 1890.

STATES AND TERRITORIES.	Total number.	Average depth in feet.	Average cost per well.	Average discharge in gallons per minute.	WELLS USED IN IRRIGATION.		Acres irrigated per well.	Total acreage irrigated.
					Per cent.	Computed number.		
Total	8,097	210.41	$245.58	54.43	48.54	3,930	13.21	51,896
California	3,210	243.00	425.00	104.00	64.17	2,060	18.63	38,378
Colorado	596	251.00	221.00	39.00	57.85	345	18.01	6,213
Idaho	28	83.00	53.00	11.00	50.00	14	13.21	185
Kansas	59	202.00	175.00	44.00	41.37	24	13.71	329
Montana	14	366.00	473.00	28.00	42.85	6	3.00	18
Nebraska	91	247.00	173.00	13.00	7.40	7	1.00	7
Nevada	33	215.00	607.00	6.00	60.60	20	1.00	20
North Dakota	461	196.00	265.00	21.00	2.17	10	2.00	20
Oregon	6	70.00	250.00	15.00	50.00	3	4.00	12
South Dakota	527	216.00	158.00	51.00	13.46	71	6.68	474
Texas	534	292.00	359.00	19.00	27.32	146	3.00	438
Utah	2,524	146.00	78.00	26.00	48.49	1,224	4.74	5,802
Washington	9	127.00	312.00	89.00	....	....	....	....
Wyoming	5	210.00	456.00	8.00	....	....	....	....

IRRIGATION IN THE WESTERN PART OF THE UNITED STATES.

NUMBER OF FARMS AND AREA IRRIGATED.

The area irrigated within the arid and subhumid regions in the western part of the United States during the census year ending May 31, 1890, aggregated 3,631,381 acres, or 5,674.03 square miles, approximately four-tenths of 1 per cent of the total land area west of the one hundredth meridian. Of this irrigated area very nearly two-thirds was devoted to the raising of various kinds of forage. The total number of irrigators was 54,136, or, more correctly, this was the aggregate number of farms or agricultural holdings upon which crops were raised by means of irrigation. In this connection it may be well to note that the definition of a farm adopted for the purposes of the census includes "all considerable nurseries, orchards, and market gardens, owned by separate parties, which are cultivated for pecuniary profit and employ as much as the labor of one able-bodied workman during the year". "A farm is what is owned or leased by one man and cultivated under his care. A distant wood lot or sheep pasture, even if in another subdivision or district, is to be treated as a part of the farm, but wherever there is a resident overseer or a manager there a separate farm is to be reported". Under this classification a person can have but one farm, unless the estate is so large as to require a resident farmer upon each tract.

The following table gives the items mentioned above for each state and territory lying within the arid region, and also for the states largely within the subhumid region on the east, the statistics for these latter being grouped under the single designation "subhumid region":

NUMBER OF IRRIGATORS, AREA IRRIGATED, AVERAGE SIZE OF IRRIGATED FARMS, AND AVERAGE VALUE OF PRODUCTS PER ACRE IN EACH STATE AND TERRITORY IN 1889.

STATES AND TERRITORIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	Average value of products per acre.
Total	54,136	3,631,381	67	$14.89
Arizona	1,075	65,821	61	13.92
California	13,732	1,004,233	73	19.00
Colorado	9,659	890,735	92	13.12
Idaho	4,323	217,005	50	12.93
Montana	3,706	350,582	95	12.96
Nevada	1,167	224,403	192	12.92
New Mexico	3,085	91,745	30	12.80
Oregon	3,150	177,944	56	13.90
Utah	9,724	263,473	27	18.03
Washington	1,046	48,799	47	17.09
Wyoming	1,917	229,676	120	8.25
Subhumid region	1,552	66,965	43	....

The average size of such portions of farms as were actually irrigated was 67 acres. This is the result obtained by dividing the total area irrigated by the total number of holdings. This acreage was large, from the fact that in many of the states of the far west large areas of hay lands were flooded, little care or attention being bestowed upon them. This was notably the case in Nevada and Wyoming, and to a less extent in Montana and Colorado.

The average value of products per acre from this irrigated land was $14.89, this being the quotient obtained by dividing the total value of all products "sold, consumed, or on hand in 1889" by the number of acres irrigated. There was a tendency apparent from many of the returns received from farmers to underestimate the value of products and to overestimate the acres irrigated. As a result the value of products per acre obtained in this way was far less than has been popularly supposed was obtained from irrigated lands.

The term "subhumid" is generally understood as applying to a portion of the Great Plains lying to the east of the arid region, and is so used in this report upon irrigation. As a matter of course there is on the western side of the arid region a strip of country which may be designated as subhumid, but this area, on account of the diversified topography, is comparatively narrow and restricted, since the arid region extends on the southwest to the shores of the Pacific ocean and on the northwest to the Cascade range. For purposes of discussion the subhumid region is therefore considered as extending in a broad belt lying across the country in a north and south position and including portions of the states of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. The western extremity of Texas lies far within the arid region, but since the greater part of Texas is subhumid, the irrigation statistics for the whole state have been placed in this category.

The following table gives for these subhumid states the principal facts relating to irrigation, namely, the number of irrigators or holdings, the acreage irrigated, and the average number of acres in each holding. The average value of products has not been ascertained, since in these states, where some crops were raised by irrigation and others without the artificial application of water, it has been impossible to discriminate between the products raised by these two methods of agriculture. The table shows in a general way an increase in the number of irrigators and in acreage irrigated from north toward the south, which is due largely to the fact that conditions of summer aridity increase with lower latitudes, and also to the greater density of population and more easily available water supply toward the south.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN THE SUBHUMID STATES IN 1889.

STATES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	1,552	66,965	43
North Dakota	7	445	64
South Dakota	189	15,717	83
Nebraska	214	11,744	55
Kansas	519	20,818	40
Texas	623	18,241	29

The relative position of these irrigated areas in both arid and subhumid regions is shown on the accompanying plate, the small green patches, mainly along the streams, indicating the principal places where crops were raised by the artificial application of water. In size these patches of color are not comparable among themselves, as on the scale of the map it is impossible to represent them in their true proportion, and where a number of small holdings or groups of holdings are near together they have been run into one spot whose size is relatively too large.

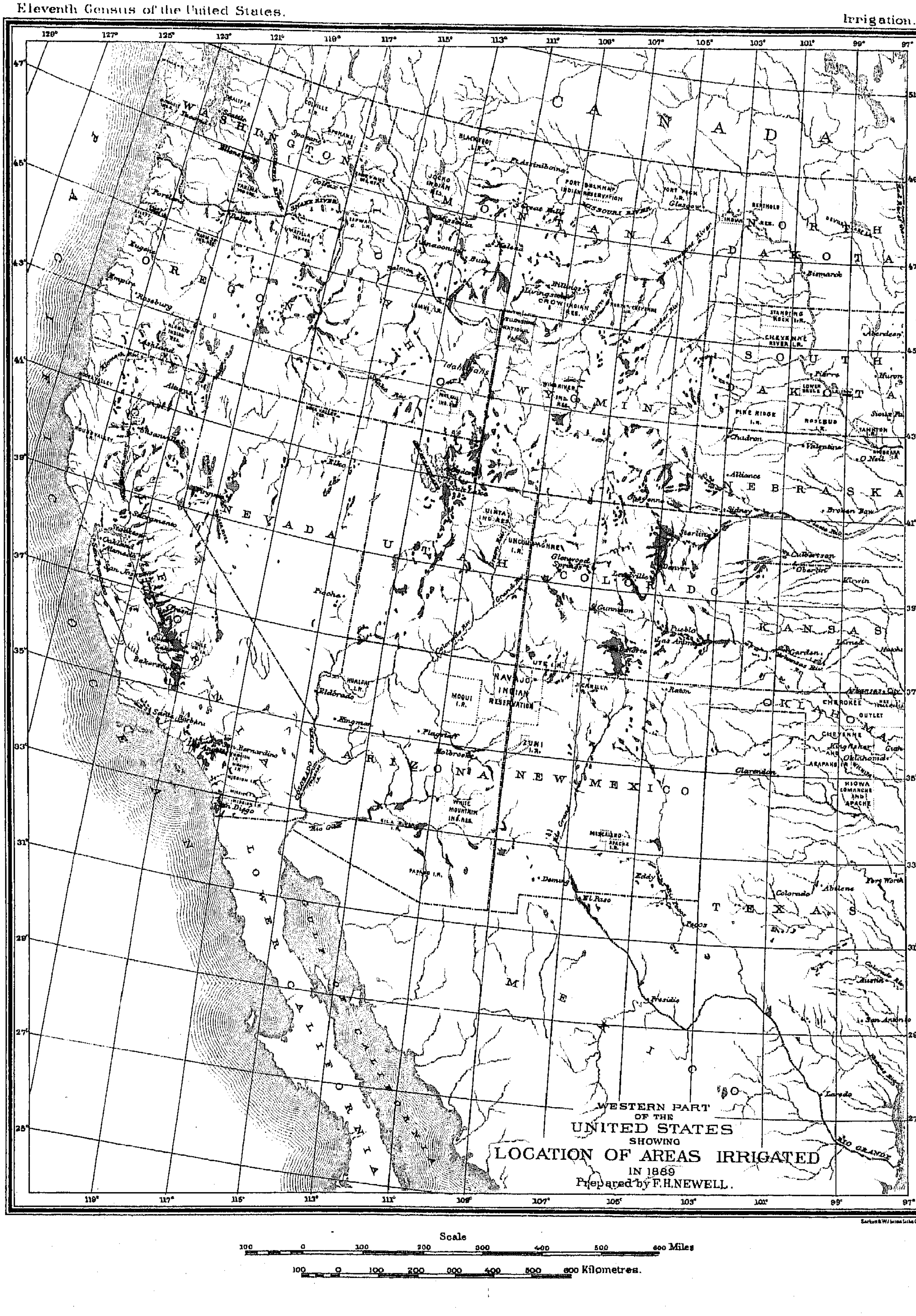
PERCENTAGE OF LAND-SURFACE IRRIGATED.

The relative number of agricultural holdings on which irrigation was practiced and the proportion of these as regards area are shown in the appended table. Omitting the subhumid states, in which irrigation may be considered as exceptional, the total area irrigated was 3,564,416 acres, or 5,569.40 square miles. This is almost exactly one-half of 1 per cent of the total land area of the states and territories within which irrigation was commonly practiced. In this comparison the area of 13 eastern counties of Washington and 16 eastern counties of Oregon has been taken instead of the total for the two states. The largest percentage by states was found in Colorado, reaching 1.34 per cent, and the smallest percentage irrigated among arid states and territories was in Arizona, where the area was less than one-tenth of 1 per cent.

AREA IRRIGATED IN STATES AND TERRITORIES WHOLLY OR PARTIALLY WITHIN THE ARID REGION.

STATES AND TERRITORIES.	AREA IRRIGATED.		Total number of farms enumerated.	HOLDINGS CONTAINING IRRIGATED AREAS.			
	Acres.	Per cent of entire land surface of state.		Total number.	Per cent of number of farms in state.	Total area in acres.	Per cent of total area irrigated.
Total	3,564,416	0.50	123,143	52,584	42.70	17,199,925	20.72
Arizona	65,821	0.09	1,426	1,075	75.39	152,345	43.21
California	1,004,233	1.01	52,894	13,732	25.96	5,622,000	17.86
Colorado	890,735	1.34	16,389	9,659	58.94	2,865,000	31.09
Idaho	217,005	0.40	6,603	4,323	65.47	832,000	26.08
Montana	350,582	0.38	5,603	3,706	66.14	1,520,853	23.05
Nevada	224,403	0.32	1,277	1,167	91.39	1,587,700	14.13
New Mexico	91,745	0.12	4,458	3,085	69.20	510,177	17.98
Oregon (a)	177,944	0.39	10,159	3,150	31.01	1,120,000	15.89
Utah	263,473	0.50	10,517	9,724	92.46	1,196,000	22.03
Washington (b)	48,799	0.23	10,692	1,046	9.78	287,000	17.00
Wyoming	229,676	0.37	3,125	1,917	61.34	1,506,850	15.24

a Sixteen eastern counties only. b Thirteen eastern counties only.


WESTERN PART
OF THE
UNITED STATES
SHOWING
LOCATION OF AREAS IRRIGATED
IN 1889
Prepared by F.H.NEWELL.
CANADA
WASHINGTON
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
OREGON
IDAHO
WYOMING
NEBRASKA
NEVADA
UTAH
COLORADO
KANSAS
CALIFORNIA
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
MEXICO
LOWER CALIFORNIA
GULF OF CALIFORNIA
PACIFIC OCEAN
RIO GRANDE
Scale
100 0 100 200 300 400 500 600 Miles
100 0 100 200 300 400 500 600 Kilometres.

Considering the counties of these states in the order of the percentage of total area irrigated, Boulder county, Colo., leads the list with 14.04 per cent of its entire area cultivated by means of irrigation in 1889. Next comes the county south of this, namely, Jefferson, with 7.42 per cent. Both of these are in the vicinity of Denver and at the eastern front of the Rocky mountains, where the water supply is unusually large and convenient. The following 10 counties contain the largest proportions of lands upon which crops were raised by irrigation in 1889:

	Per cent.		Per cent.
Boulder county, Colo	14.04	Salt Lake county, Utah	5.06
Jefferson county, Colo	7.42	Tulare county, Cal	4.71
Davis county, Utah	6.93	Custer county, Colo	4.56
Orange county, Cal	6.72	Cache county, Utah	4.43
Weber county, Utah	5.13	Weld county, Colo	4.30

PERCENTAGE OF NUMBER OF FARMS IRRIGATED.

The total number of farms enumerated in the 11 western states and territories named in the preceding table was 123,143, omitting certain western counties of Oregon and Washington. In comparison therewith it has been found that 52,584, or 42.70 per cent, of these farms contained irrigated areas; that is to say, within the arid region, or at least within the area bounded by state and county lines, and including the greater part of the arid region, irrigation was practiced upon less than one-half of the holdings, which under the census classification were designated as "farms". Of the remaining farms, on which irrigation was not practiced, by far the greater number were what are commonly known as cattle ranches, while on others crops were raised by dependence upon the rainfall.

The largest proportion of irrigated farms to the total number was found in Utah, where over nine-tenths of the agricultural holdings contained irrigated areas. The smallest proportion was in Washington, the 13 eastern counties of which, although regarded as being in part, if not wholly, within the arid region, contained relatively a small number of irrigated areas, aggregating in fact less than one-tenth of the total number of farms. Arranging the states and territories in the order of the importance of irrigation as shown by this classification, the results obtained are:

STATES AND TERRITORIES IN THE ORDER OF THE PROPORTION OF THE NUMBER OF FARMS IRRIGATED TO THE TOTAL NUMBER OF AGRICULTURAL HOLDINGS.

	Per cent.		Per cent.
1. Utah	92.46	7. Wyoming	61.34
2. Nevada	91.39	8. Colorado	58.94
3. Arizona	75.39	9. Oregon (*a*)	31.01
4. New Mexico	69.20	10. California (*b*)	25.96
5. Montana	66.14	11. Washington (*c*)	9.78
6. Idaho	65.47		

a Sixteen eastern counties only. *b* Including the whole state. (See following paragraph.) *c* Thirteen eastern counties only.

Considering this table as a whole, it may be said that in the states and territories in the upper part of the list irrigation was the rule, while in those toward the foot it had less importance, and in the case of Washington it may be considered as almost exceptional. The relative position of California requires explanation, for in that state, with its enormous area and great diversity of topography, irrigation plays a peculiar part. In the northern and southern counties irrigation was practiced on a great majority of the farms, while in the counties near the center of the state, especially those bordering upon the bay of San Francisco or the Pacific ocean, it has been exceptional, there being but few counties in the state where it is not practiced to a greater or less extent. If the bay and coast counties, 14 in number, are deducted, California takes a position above Oregon, thus standing ninth in the list instead of tenth, with a percentage of 48.65 of the farms irrigated.

PERCENTAGE OF FARM AREA IRRIGATED.

The total area of the 52,584 agricultural holdings of which a part was irrigated, as shown by the preceding table, was 17,199,925 acres, or an average of 327.09 acres each. The total area irrigated was 3,564,416 acres, or 20.72 per cent of the total area of these farms. In other words, in these 11 states and territories less than half of the farms contained irrigated areas, and of this latter number one-fifth of the area was successfully irrigated. If now it is assumed that the average size of the agricultural holdings, 327.09 acres, derived as above from less than half of the farms, applies to the whole, 123,143 farms, the total acreage of these agricultural holdings would be 40,278,844 acres.

In comparison with this total farm area of 40,278,844 acres the 3,564,416 acres of irrigated crop formed evidently only 8.85 per cent of the land owned by farmers within the states and territories designated. This is a significant fact, especially in comparison with the water supply, for it has been found upon a detailed examination of each county and locality that as a rule the greater part if not all of the easily available water supply has been utilized, and in 1888 and 1889 the losses through drought were enormous, yet less than one-tenth of the land belonging to the farmers actually produced a crop by means of irrigation. It must be borne in mind, however, that a portion of the remaining nine-tenths, especially in the state of California, does not require irrigation, and that a still greater portion is unquestionably above the reach of water; but from a careful consideration of these figures it would seem as though all of the water supply of the arid region must be needed to properly irrigate the lands already owned by farmers and not fully utilized, provided that these lands are so situated as to be susceptible of irrigation.

Comparing the states and territories among themselves as regards the completeness of irrigation of the area of the farms which were wholly or in part cultivated in this manner, it is seen that Arizona stood at the head, with a percentage of 43.21, while Nevada came last, with only 14.13 per cent of the area of each farm irrigated. Arranging these in the order of this relation, the following result is obtained:

STATES AND TERRITORIES IN THE ORDER OF THE PROPORTION OF LAND IRRIGATED TO THE TOTAL AREA OF LAND IN FARMS WHOLLY OR PARTLY IRRIGATED.

	Per cent.		Per cent.
1. Arizona	43.21	7. California	17.86
2. Colorado	31.09	8. Washington	17.00
3. Idaho	26.08	9. Oregon	15.89
4. Montana	23.05	10. Wyoming	15.24
5. Utah	22.03	11. Nevada	14.13
6. New Mexico	17.98		

In Wyoming and Nevada the agricultural holdings were generally very large, being used chiefly for stock raising, and, therefore, as might be expected, the irrigated portions from which crops were cut were but a small percentage of the whole area. Thus, although irrigation was essential, these divisions came near the bottom of the list.

In the case of the subhumid states any comparison of the area of crop irrigated with the total area of the state would have little value, as irrigation is exceptional and is practiced in widely scattered localities. The following table shows the relation between the irrigated area and the total size of the agricultural holdings on which this method of agriculture was practiced. Taking the 5 subhumid states as a whole, only 6.40 per cent of the farms owned by men who practiced irrigation was actually cultivated in this manner. In comparing the percentages for the states, it is to be seen that these diminish in order from north to south, ranging from 34.77 in North Dakota, the highest, to 2.43 in Texas, the lowest. The small percentage in the latter state was due partly to the fact that irrigation was largely carried on by means of water from springs or wells, small areas of garden, fruit and shade trees, and forage crops being watered on each farm, even where field crops were raised by dependence upon rainfall.

TOTAL AREA OF FARMS IN SUBHUMID STATES ON WHICH IRRIGATION WAS PRACTICED, TOGETHER WITH AREA AND PERCENTAGE IRRIGATED IN 1889.

STATES.	Total area in acres.	Area irrigated in acres.	Per cent irrigated.
Total	1,045,993	66,965	6.40
North Dakota	1,280	445	34.77
South Dakota	52,466	15,717	29.96
Nebraska	81,305	11,744	14.44
Kansas	161,020	20,818	12.93
Texas	749,922	18,241	2.43

CHARACTER OF CROPS AND PROPORTION IRRIGATED.

The character of the crops raised by irrigation is shown in a broad way by the table on the following page, in which a classification has been made into two great groups, comprising the cereals on the one hand and the forage and miscellaneous crops on the other, forage forming by far the greater part of this latter group. This table serves to show that over one-third of the area irrigated was devoted to cereals, namely, wheat, oats, Indian corn, barley, rye, and buckwheat, the importance of these products being in the order named. Of the remainder of the crop over 60 per cent consisted of forage, including various native and cultivated grasses, alfalfa or lucern, and other clovers, also wheat, oats, and related cereals cut before maturity for forage purposes. The widespread practice of using the cereals for hay, especially when owing to scarcity of water a fair crop of grain could not be produced, has introduced considerable confusion in the returns, and in some instances caused the products per acre and their values to appear remarkably small. The irrigated areas devoted to fruits are included with miscellaneous crops, since, although of great value, they form but a relatively small percentage.

GENERAL CHARACTER OF CROPS IN THE ARID REGION IRRIGATED IN 1889, BY STATES AND TERRITORIES.

STATES AND TERRITORIES.	Total acreage irrigated.	FORAGE AND MISCELLANEOUS CROPS.		CEREALS.	
		Per cent.	Acres.	Per cent.	Acres.
Total	3,564,416	65.31	2,328,016	34.69	1,236,400
Arizona	65,821	65.82	43,321	34.18	22,500
California	1,004,233	47.22	474,233	52.78	530,000
Colorado	890,735	70.25	625,735	29.75	265,000
Idaho	217,005	70.97	154,005	29.03	63,000
Montana	350,582	78.61	275,582	21.39	75,000
Nevada	224,403	93.32	209,403	6.68	15,000
New Mexico	91,745	36.78	33,745	63.22	58,000
Oregon	177,944	69.99	124,544	30.01	53,400
Utah	263,473	56.35	148,473	43.65	115,000
Washington	48,799	57.99	28,299	42.01	20,500
Wyoming	229,676	91.73	210,676	8.27	19,000

Throughout the arid region as a whole over 80 per cent of the crop area, including as a matter of course the forage plants, was irrigated, but at the same time there were counties lying well within this great region where as high as from 20 to 40 per cent of the area cultivated was utilized without the artificial application of water. Examples of this were found in northern Utah, where, as in the Cache and Malade valleys, large areas were profitably cultivated by what is known as "dry farming". The large size of the counties and the restricted areas in which agriculture has been conducted render figures somewhat misleading in detail, as, for example, in the southeastern corner of California, in San Diego, San Bernardino, and adjoining counties, in which the statistics obtained apply only to the regions near the coast, where from 20 to 60 per cent of the crop areas were irrigated. The greater portion of these counties, that lying east of the mountains near the coast, can produce nothing without water artificially applied. On both sides of the main body of arid lands, as might be inferred, there were counties in which the greater part of the crop area was not under irrigation, and beyond or adjacent to these the areas in which this method of agriculture was not in use. Along the border and even well within the arid region there were localities where it was impossible to draw the line sharply between areas irrigated and those not watered, especially where on one farm part of a given crop was irrigated and the other part not. Many farmers have learned that thorough cultivation will often compensate for scantiness of precipitation, and when, as was the case in 1889, droughts were general and water was difficult to obtain, portions of the fields were dry farmed.

VALUE OF LAND AND CROPS.

The average value of the land upon which crops were raised by irrigation, and the average value of the products per acre are shown in the table on the following page, these averages being obtained by dividing total values by the number of acres for which values were given; that is to say, in cases where the returns of farm values of products were deficient, the acreage was omitted in order to obtain the averages, it being assumed that these few cases did not differ materially from the mean of all others. For the 11 states and territories given the average value of the irrigated land, including improvements, such as fences and buildings, was $83.28 per acre, ranging from $31.40 per acre in Wyoming up to $150 per acre in California. The total value of this irrigated land and its improvements thus obtained was $296,850,000.

The average value of products for the 11 states, $14.89 per acre (to nearest figure), multiplied into the number of acres, gives in round numbers a total of $53,057,000. This average value has been obtained, as above stated, by taking all the cases in which definite returns were made and assuming that they represent the general condition. In the case of the states and territories where crops are raised on the same farm both with and without irrigation it is exceedingly difficult and not unfrequently impossible to discriminate between them.

VALUE OF IRRIGATED LANDS IN ARID REGION IN 1890 AND OF THEIR PRODUCTS IN 1889.

STATES AND TERRITORIES.	Area irrigated in 1889 in acres.	VALUE OF FARMS ON JUNE 1, 1890.		VALUE OF PRODUCTS IN 1889.	
		Average value per acre.	Total value, estimated.	Average value per acre.	Total value, estimated.
Total	3,564,416	$83.28	$296,850,000	$14.89	$53,057,000
Arizona	65,821	48.68	3,204,000	13.92	916,000
California	1,004,233	150.00	150,635,000	19.00	19,080,000
Colorado	890,735	67.02	59,696,000	13.12	11,686,000
Idaho	217,005	46.50	10,091,000	12.93	2,806,000
Montana	350,582	49.50	17,354,000	12.96	4,544,000
Nevada	224,403	41.00	9,200,000	12.92	a2,899,000
New Mexico	91,745	50.98	4,677,000	12.80	1,174,000
Oregon	177,944	57.00	10,143,000	13.90	2,473,000
Utah	263,473	84.25	22,198,000	18.03	4,750,000
Washington	48,799	50.00	2,440,000	17.09	834,000
Wyoming	229,676	31.40	7,212,000	8.25	1,895,000

a The actual value of farm products for the state of Nevada as returned on the agricultural schedules was $2,705,660. The excess of the estimate in the above table is probably accounted for by the omission of valuations from many irrigated farms in which the only crop was alfalfa and other forage eaten by cattle, and which were not reported to the enumerators.

SIZE OF FARMS.

In a comparison of the relative size of irrigated holdings in various localities the fact brought out most prominently by a study of the census returns is the large size of the areas devoted mainly to the raising of forage crops, as, for example, in Nevada, Montana, and Wyoming. On the other hand, in those localities where irrigation was highly advanced, and the products were of more than usual value, the irrigated holdings were small. The condition of the water supply, and the density of settlement entered often to modify this generalization, the irrigated areas being large where water was abundant and the population was scattered.

In order to examine into the average size of the majority of irrigated areas, and to eliminate the results produced by the existence of large tracts of land owned by a few men, the table showing "relative number and size of irrigated farms" has been prepared, in which the irrigated holdings have been classified according to size. The larger areas have been placed by themselves, thus allowing the far greater number of moderate sized holdings to be considered independently. For this classification 160 acres, or a quarter section, has been taken as the basis, and for simplicity, all irrigated holdings or parts of holdings under 160 acres in area have been called throughout this report "small farms", and those of 160 acres or over have been designated as "large farms", it being understood that these terms apply only to the areas irrigated and not to the total holding of each individual, so that if a farmer owned 640 acres and irrigated 40 acres, the latter number was the one considered and it was classed as a small farm.

Out of the 54,136 holdings upon which crops were raised by irrigation in the census year there were 4,595 in which the area irrigated was 160 acres or upward, the total of the same being 1,802,605 acres, or 49.64 per cent of the whole amount irrigated; that is to say, 4,595 persons, or 8.49 per cent of those irrigating, owned very nearly one-half of the total area irrigated. The great majority of irrigators, 91.51 per cent, irrigated 1,828,776 acres, or an average of nearly 37 acres each, against an average of 392 acres upon which crops were raised by irrigation by the few large owners.

RELATIVE NUMBER AND SIZE OF IRRIGATED FARMS.

STATES AND TERRITORIES.	UNDER 160 ACRES.				160 ACRES AND UPWARD.			
	Number.	Total irrigated area in acres.	Average size in acres.	Per cent of total area.	Number.	Total irrigated area in acres.	Average size in acres.	Per cent of total area.
Total	49,541	1,828,776	37	50.36	4,595	1,802,605	392	49.64
Arizona	996	43,165	43	65.58	79	22,656	287	34.42
California	12,595	382,850	30	38.12	1,137	621,383	547	61.88
Colorado	8,227	451,215	55	50.66	1,432	439,520	307	49.34
Idaho	4,110	159,528	39	73.51	213	57,477	270	26.49
Montana	3,130	174,009	56	49.63	576	176,573	307	50.37
Nevada	823	47,812	58	21.31	344	176,591	513	78.69
New Mexico	3,022	72,069	24	78.55	63	19,676	312	21.45
Oregon	2,896	101,788	35	57.20	254	76,156	300	42.80
Utah	9,641	237,616	25	90.19	83	25,857	312	9.81
Washington	994	31,943	32	65.46	52	16,856	324	34.54
Wyoming	1,614	79,962	50	34.82	303	149,714	494	65.18
Subhumid region	1,493	46,819	31	69.92	59	20,146	341	30.08

GENERAL DISCUSSION.

All the cases in which 160 acres or upward of crop (large farms) were irrigated, have been tabulated (see t following) under three headings, namely, those of from 160 to 320 acres, those of from 320 to 640 acres, and t of 640 acres and upward, these figures, as before stated, applying not to the total acreage of the agricult holding, but only to that portion upon which crops were raised by the artificial application of water.

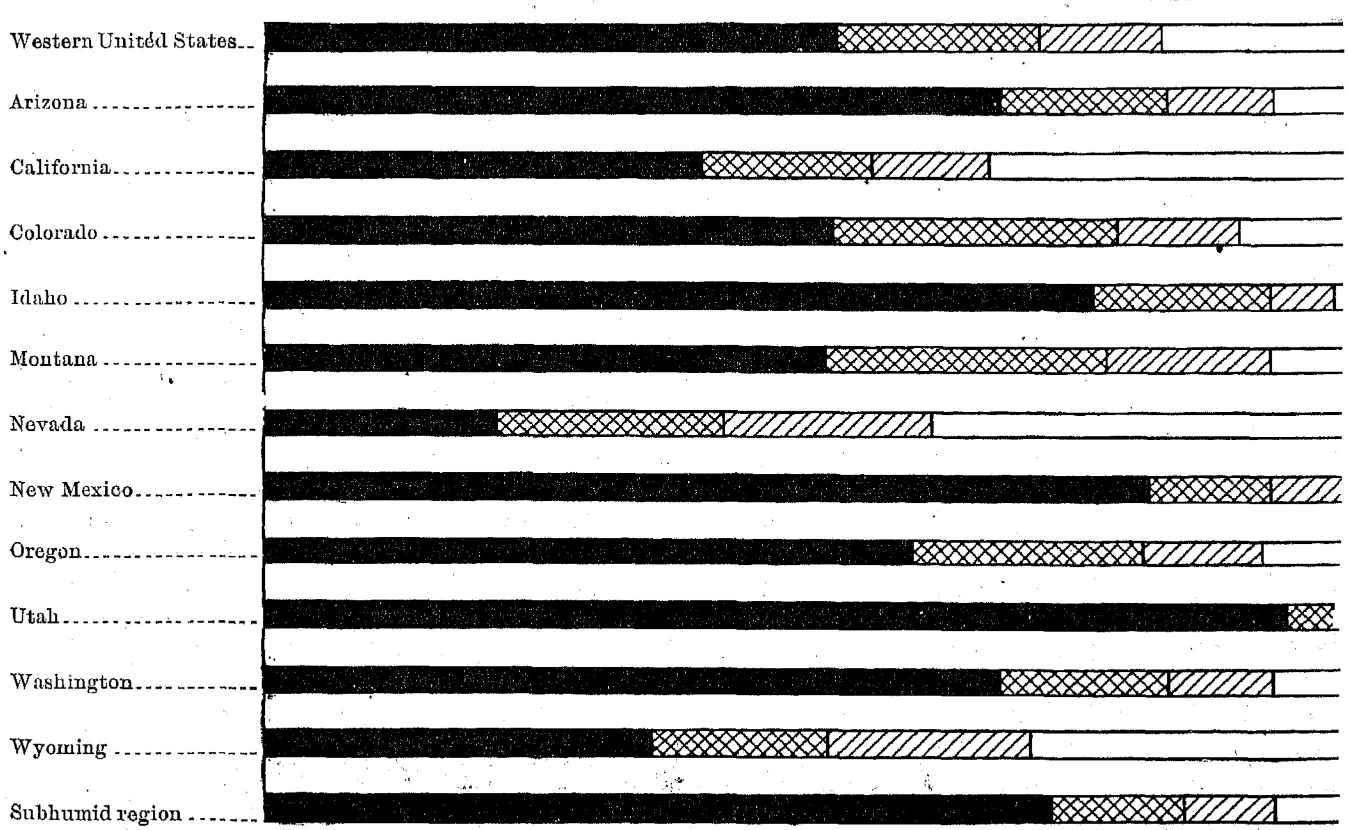
Taking the irrigated areas of 640 acres and upward, the following table shows that they numbered 411, wit aggregate area of 724,147 acres, or an average of 1,762 acres each. The 411 individuals or corporations ow these irrigated lands constituted three-fourths of 1 per cent (0.76) of the number of irrigators and held 19.9 cent of the total area.

RELATIVE NUMBER AND SIZE OF LARGE IRRIGATED FARMS (160 ACRES AND UPWARD).

STATES AND TERRITORIES.	160 TO 320 ACRES.			320 TO 640 ACRES.			640 ACRES AND OVER.		
	Number.	Total irrigated area in acres.	Average size in acres.	Number.	Total irrigated area in acres.	Average size in acres.	Number.	Total irrigated area in acres.	Average size in acres.
Total	3,242	671,151	207	942	407,307	432	411	724,147	1,762
Arizona	57	10,454	183	15	6,516	434	7	5,687	812
California	738	152,542	207	243	103,488	426	156	365,353	2,342
Colorado	1,113	224,518	202	244	103,845	426	75	111,157	1,482
Idaho	172	34,751	202	34	14,036	413	7	8,690	1,241
Montana	421	88,994	211	123	51,986	423	32	35,593	1,112
Nevada	201	46,556	232	91	41,494	456	52	88,541	1,703
New Mexico	46	10,202	222	14	6,460	461	3	3,014	1,005
Oregon	192	38,736	202	49	21,110	431	13	16,310	1,255
Utah	65	13,234	204	13	5,555	427	5	7,068	1,414
Washington	36	7,599	211	11	4,615	420	5	4,642	928
Wyoming	161	35,370	220	93	42,780	460	49	71,564	1,460
Subhumid region	40	8,195	205	12	5,423	452	7	6,528	933

The facts given in the two preceding tables are exhibited graphically in the following figure, which give percentage of total area of farms of each class to the area of all farms irrigated. The black portion of eacl indicates the percentage which the total area of irrigated farms of under 160 acres each bears to all the irrigated. For example, in Utah, New Mexico, and Idaho the small irrigated farms predominated, their aggr being in excess of that of the larger farms. On the contrary, in Nevada, Wyoming, and California the irrigated farms, though being as a matter of course less in number, surpassed in aggregate area those unde

DIAGRAM ILLUSTRATING CLASSIFICATION OF IRRIGATED FARMS ACCORDING TO SIZE.



acres in size. The doubly crosshatched portion of each line or bar shows the percentage of area of farms of from 160 to 320 acres each, and the single crosshatching the percentage of those of from 320 to 640 acres each, while the open portion gives the proportion of those of 640 acres or upward. In Nevada, for example, the 52 large irrigated farms surpassed in area those of any other of the classes above enumerated, being considerably over a third of the total irrigated area.

COST OF IRRIGATION.

The statistics concerning acreages and value of land and products were taken from the enumerators' returns for each agricultural holding. Other facts now to be discussed have been obtained by direct correspondence with farmers by means of special schedules addressed to each irrigator. These schedules contained questions intended to cover facts concerning the location of irrigated land, the character of the water supply, the cost of irrigation, methods of using the water, necessity of irrigation, the use of artesian wells and pumps, also the location of canals or irrigating ditches, size and cost, and methods of distributing the water. In all about 30,000 replies have been received, and from these, after proper tabulation, certain averages have been drawn, the principal of which are shown in the following table:

AVERAGE COST OF IRRIGATION AND CULTIVATION.

STATES AND TERRITORIES.	Average first cost of water rights per acre.	Average value of water rights per acre in 1890.	Average annual cost of water per acre.	Average first cost per acre of preparation for cultivation.
Total	$8.15	$26.00	$1.07	$12.12
Arizona	7.07	12.58	1.55	8.60
California	12.95	39.28	1.60	17.48
Colorado	7.15	28.46	0.79	9.72
Idaho	4.74	13.18	0.80	9.31
Montana	4.63	15.04	0.95	8.29
Nevada	7.58	24.60	0.84	10.57
New Mexico	5.58	18.30	1.54	11.71
Oregon	4.64	15.48	0.94	12.59
Utah	10.55	26.84	0.91	14.85
Washington	4.03	13.15	0.75	10.27
Wyoming	3.62	8.69	0.44	8.23
Subhumid region	4.07	14.81	1.21	4.62

As shown above, the average first cost of bringing water to the land throughout the entire arid and subhumid regions has been $8.15 per acre. This average was derived from the statements of all persons who have constructed ditches, or have purchased water rights from others. It included all cases from those, on the one hand, where the farmers dug or plowed small ditches leading from the river or creek to their land, to those, on the other, where the irrigator purchased the right to take water from some large canal, and embraced all the intermediate conditions where water was obtained through co-operation of neighboring landowners or through partnerships of farmers. The fact that a person has used water upon a certain number of acres entitles him in many localities to certain rights or privileges. It has become customary to term property of this kind a "water right", and the first cost of applying the water to the land can be considered as the cost of this "water right".

In the different states and territories there was a wide range in this average first cost of applying water to the land, or of the water right. The highest average was in California, where the most thorough and expensive systems for saving and distributing water have been constructed. The lowest was in Wyoming, where enormous areas have been covered with water by means of ditches quickly and cheaply constructed by means of plow and scraper, the average cost in this latter state having been a little over one-fourth of that given for California.

The average value per acre of these water rights, wherever they could be considered independent of the value of the land, was $26. This was the average of the values given to this privilege or property by the owners of water rights or of independent ditches. In many localities, however, owing to the scarcity of water or to other causes, the water right can not be taken from the land without depriving the latter of its entire value, for without a water supply the land is worthless. In such cases the entire value inheres in the water right, and if it is assumed that the average value of the land was $83.28 per acre, at least $80 of this, and possibly more, must be attributed to the water right. Taking those cases in which water rights were transferable and were sold or treated like other pieces of property, the apparent enhancement to the creator of these rights has been the difference between $26 and $8.15, or $17.85 per acre.

Besides the first cost of water, namely, the expense of constructing ditches from the stream or the cost of shares in some irrigating canal, the irrigator must pay annually a small amount or must expend some labor in order to repair the ditches and keep them in good order, the amount being often only a few cents per acre. Where he takes water from some larger canal, especially one owned by a corporation, he may be compelled to pay a larger sum, that will not only cover the cost of keeping the canal in repair, but will also pay interest on the investment, salaries of officers, and other items of expense. In the aggregate this often amounts to $3 or even more per acre. Averaging all the statements as to the annual cost of water, the result for the entire arid and subhumid regions was $1.07 per acre.

Since the greater part of the irrigators owned the small ditches used for bringing water from the streams to the land, having built such ditches at points where the conditions were most favorable for construction and maintenance, the annual cost of keeping them in repair has been small, much less than it would have been under other conditions. For example, with the construction of larger irrigating works designed to carry water to land farther away from the streams and to overcome more or less serious obstacles, the first cost of irrigation was usually greater, as was also the annual cost, on account of the heavy interest upon the original investment, and also from the fact that salaries and other items of expense not entering into the operation of the small ditches were included.

The average cost of bringing the land under cultivation beyond the expense for water, but including fencing, was, according to the statements of the farmers, $12.12 per acre, ranging from $4.62 per acre in the case of the subhumid states to $17.48 per acre in California, the difference being due both to the configuration and character of the ground and to the amount of labor spent in preparing it for the various kinds of crops. For example, in most of the states where the cost of cultivation was low the ground originally was nearly barren, and there were no plants, except, perhaps, sagebrush, to be removed. In cases where the expense of preparing the ground for cultivation was great, either the ground was rough and uneven, requiring more or less leveling in order that the water might be applied economically, or it was covered with willows and other small trees, requiring considerable labor before the fields could be brought into arable condition. Where fruit trees and vines were to be planted great expense has often been incurred, especially in California.

TOTAL INVESTMENT AND ENHANCED VALUE.

By making use of the averages of cost and value as given in the preceding table and applying them, with proper modifications, to the acreage irrigated, it is possible to arrive at certain conclusions as to the amount invested in irrigation works and in lands cultivated by irrigation, also as to the value of the same and the enhanced value realized by the owners of lands and water rights. The results obtained are shown in round numbers in the three following tables. In the cases of Nevada and Wyoming a mean value has been substituted for the average first cost of water for each state, from the fact that the average first cost of bringing water to the land in Nevada, owing to peculiar circumstances, applied to the land which was under a comparatively high state of cultivation, and not to the hay lands, while in Wyoming the reverse was the case.

In the table on the following page, under the head of "Cost", is given the total first cost of bringing water to the land irrigated during the census year, that is to say, this is in round numbers the sum of the amounts obtained by multiplying the acreage irrigated by the average first cost of obtaining water, or of water rights, as given by the irrigators. It may also be considered as the investment in time and money in the construction of irrigating systems in use during the census year, under the broad assumption that each system was employed to its full capacity. In such cases, however, as those in which a canal furnished water to only a small proportion of the irrigable lands, only a portion of the total cost of the canal would be represented in the totals shown.

The total first cost of irrigating the designated land was for the entire arid and subhumid regions $29,611,000, this being the amount, as stated above, presumably invested in productive irrigation works. The total value of the works or of the rights thus created, assuming that the statements of the farmers apply to all cases, was $94,412,000, showing an apparent increase of $64,801,000, or 218.84 per cent. As to the total cost of the irrigation works or the expenditures for irrigation upon lands which for one reason or another were unproductive, it is impossible to obtain reliable estimates. Statements and conjectures have been made by interested parties, but they have no foundation so far as can be ascertained beyond the personal impressions of the individuals making the statements.

TOTAL APPROXIMATE COST OF PRODUCTIVE IRRIGATION SYSTEMS AND THEIR VALUE IN 1890.

STATES AND TERRITORIES.	Cost.	Value in 1890.	Increase.
Total	$29,611,000	$94,412,000	$64,801,000
Arizona	465,000	828,000	363,000
California	13,005,000	39,446,000	26,441,000
Colorado	6,369,000	25,350,000	18,981,000
Idaho	1,029,000	2,860,000	1,831,000
Montana	1,623,000	5,273,000	3,650,000
Nevada	1,251,000	3,714,000	2,463,000
New Mexico	512,000	1,679,000	1,167,000
Oregon	826,000	2,755,000	1,929,000
Utah	2,780,000	7,072,000	4,292,000
Washington	197,000	612,000	415,000
Wyoming	1,281,000	3,801,000	2,520,000
Subhumid region	273,000	992,000	719,000

The results shown in the foregoing table apply to irrigation constructions or rights considered apart from the land. As a matter of fact, in the vast majority of cases, it is practically impossible to separate land values in the arid region and assign to them a certain sum, for the value of the land is inseparably bound up with the question of water supply.

In considering what may have been the first cost of the irrigated land upon which crops were raised in the census year it is necessary to assume a sum representing the purchase price of the wild or desert land, the cost of bringing water to the land, and that of cultivating the soil, building fences, and performing other necessary operations. The following table gives in round numbers the acreage under discussion multiplied by the probable first cost of the three items per acre. It also shows the total value of this same land, as given previously, and the difference or increase in value to the farmer or owner of these irrigated areas. From the table it appears that the total first cost of this land, excluding the subhumid states, was $77,490,000, and the value, as derived from the statements of a majority of the owners, was $296,850,000, showing an increase of $219,360,000, or 283.08 per cent.

FIRST COST OF IRRIGATED AREAS IN THE ARID REGION, INCLUDING WATER RIGHTS, AND THEIR VALUE IN 1890.

STATES AND TERRITORIES.	First cost.	Value on June 1, 1890.	Increase.
Total	$77,490,000	$296,850,000	$219,360,000
Arizona	1,114,000	3,204,000	2,090,000
California	31,814,000	150,635,000	118,821,000
Colorado	16,140,000	59,696,000	43,556,000
Idaho	3,320,000	10,091,000	6,771,000
Montana	4,968,000	17,354,000	12,386,000
Nevada	3,905,000	9,200,000	5,295,000
New Mexico	1,701,000	4,677,000	2,976,000
Oregon	3,288,000	10,143,000	6,855,000
Utah	7,022,000	22,198,000	15,176,000
Washington	759,000	2,440,000	1,681,000
Wyoming	3,459,000	7,212,000	3,753,000

The total amount expended each year in maintaining systems of irrigation may be assumed, for purposes of comparison, to be represented by the total acreage irrigated multiplied by the average expenditure per acre as reported by the irrigators. This is given in round numbers in the table on the following page, and the total value of products as previously shown is placed in comparison with it. The difference represents a net value of products from the irrigated land, or the sum by which the irrigator must reimburse himself for his labor and expenses and for interest on the capital invested. This table shows that $3,794,000 was the probable amount expended during the census year at least for maintenance of canals and ditches, or 12.81 per cent of the amount previously assumed as the first cost of these systems.

TOTAL COST OF WATER AND OF MAINTAINING DITCHES IN THE ARID REGION IN 1889-1890, AND TOTAL VALUE OF PRODUCTS OF IRRIGATED LANDS IN 1889.

STATES AND TERRITORIES.	Total cost of water.	Value of products.	Difference.
Total	$3,794,000	$53,057,000	$49,263,000
Arizona	102,000	916,000	814,000
California	1,607,000	19,080,000	17,473,000
Colorado	704,000	11,686,000	10,982,000
Idaho	174,000	2,806,000	2,632,000
Montana	333,000	4,544,000	4,211,000
Nevada	188,000	2,899,000	2,711,000
New Mexico	141,000	1,174,000	1,033,000
Oregon	167,000	2,473,000	2,306,000
Utah	240,000	4,750,000	4,510,000
Washington	37,000	834,000	797,000
Wyoming	101,000	1,895,000	1,794,000

COST OF IRRIGATING CANALS.

Classifying irrigating canals and ditches according to their widths, it has been found that for those averaging less than 5 feet in width the expense of construction, including headworks, flumes, and other adjuncts, was $481 per mile; for those 5 feet in width and under 10 feet, $1,628 per mile; and for those 10 feet or more in width, $5,603 per mile. The greater number of the irrigating systems of the country have been constructed under such conditions that the owners can not give even an approximate estimate as to what they really cost. Many of them have been built by the efforts of a few farmers, acting originally in partnership, and have been enlarged from year to year as more land was brought under cultivation and population increased. Farmers as a rule have not kept account of the amount of labor or money expended on such works, and in cases where they owned the irrigating ditches they have not taken into consideration the labor expended upon the ditches at times when farm work was not pressing.

The average cost per mile of the three classes of irrigation works is given for each state and territory in the following table, which exhibits the variations in cost due to difference in topography, thoroughness of construction, and accidental circumstances. California heads the list as to cost. The differences in cost were due largely to the condition of development of irrigation, the states where the methods were crude and simple generally showing a less average expenditure, although the existence of one or two great works has introduced apparent departures from this rule.

AVERAGE COST PER MILE OF CONSTRUCTING IRRIGATING CANALS AND DITCHES

STATES AND TERRITORIES.	Under 5 feet in width.	5 to 10 feet in width.	10 feet and over in width.
General average	$481	$1,628	$5,603
Arizona	471	1,674	5,274
California	885	5,957	15,511
Colorado	380	1,131	5,258
Idaho	205	810	1,320
Montana	325	800	2,300
Nevada	200	1,150	....
New Mexico	310	581	6,666
Oregon	260	1,000	1,300
Utah	493	1,025	3,072
Washington	285	1,236	2,571
Wyoming	....	837	3,884
Subhumid region	303	447	1,884

WATER SUPPLY.

Facts concerning the water supply for irrigation have been ascertained in a general way by correspondence with irrigators and owners of canals and ditches, mainly by means of special irrigation schedules sent to all parts of the west. Obviously it is not possible in this way to obtain exact statements, for data as to the amount of water available or utilized for irrigation can be obtained only by means of measurements made by engineers skilled in such matters. The average irrigator has very indefinite notions concerning the amount of water flowing in streams, especially in those of considerable size, and in fact it is almost impossible for any person who has not made a specialty of such matters even to approximate such quantities with success.

As a general statement it may be said that throughout the arid region there is hardly a stream of small size from which water can be conducted readily upon arable land that has not been utilized to its full capacity during the summer season. To increase the area under irrigation it will be necessary either to use greater economy in employing the water, so that it will cover larger areas, or to store the flood and waste waters of the nonirrigating season. A great increase in the acreage cultivated can come also by the construction of expensive works to divert the water of large rivers upon lands which can not be watered except by the expenditure of a large amount of capital. Taking the country as a whole, there are very few localities, if any, where, as in the past, a farmer can divert water unclaimed by others, and by means of a simple ditch constructed by himself and his neighbors bring his farm under irrigation.

From the replies of irrigators throughout the country, it is apparent that in 1888 and 1889 there was a deficiency of water supply for the land then under cultivation along most of the streams. By a comparison of all the facts it is evident that, taking the past decade as a whole, there was an unusually large amount of water in the streams in 1885 and 1886, and that this amount decreased year by year, although by no means constantly in all localities. Thus it happened that while the area under irrigation was rapidly increasing, the water supply as a whole decreased, and during the years of drought, namely, 1888 and 1889, and in some localities 1890, there was a general loss of crops upon irrigated lands, due to the fact that a larger acreage was tilled than could be irrigated by the methods in use.

Not only was there loss of crops in many counties, but the areas which were irrigated and from which crops were obtained did not in many instances receive a sufficient amount of water to produce large or satisfactory results. Many statements have been made that, owing to insufficiency of water during the last part of the season, some of the cereal plants were cut for forage or were hardly worth the gathering.

The simple fact that the area which can be irrigated is dependent upon the amount of water flowing in the streams is often ignored in general discussions of irrigation and its possibilities. It is often taken for granted that because along some river there are vast areas of fertile land, some of which has been irrigated profitably, larger and larger areas will, with the progress of settlement, be brought under cultivation to an indefinite extent, the assumption being tacitly made that since the river drains a large area its waters must be proportionately abundant. It is unfortunately the case that many of the rivers of the arid region occupying a prominent place upon the map carry a very small amount of water for a part of the year, and this water is all utilized or needed for the land now wholly or in part under cultivation.

DUTY AND VALUE OF WATER.

The duty of water is the term used to express the relation between the quantity of water used in irrigation and the area upon which it is employed. If a given stream flowing at the rate of 10 second-feet irrigates throughout the season 1,000 acres, it is said that the duty of water is 100 acres to the second-foot. A second-foot of water is the quantity represented by a stream 1 foot wide and 1 foot deep flowing at the average velocity of 1 foot per second. The duty, as might be inferred, differs very widely with the character of the water supply, the methods of employing it, the character of the soil and crops, and perhaps more than all with the skill and experience of the irrigator. It is necessary, however, to assume certain averages in order to ascertain the value of flowing water.

The average duty of water most widely accepted is that originally taken by Powell (*a*) as 100 acres to the second-foot. In practice some irrigators undoubtedly reach a higher value and others a lower one. Throughout the arid region there is a popular expression of "1 inch to the acre"; that is to say, water flowing in a stream of moderate size will irrigate at the rate of 1 miner's inch to the acre. The miner's inch is a variable quantity, depending upon the method of measurement and the character of the aperture through which the water flows. In many of the states most of the details of measurement are defined by statute, but even then there is often uncertainty. For practical purposes, however, it may be assumed that in California 50 miner's inches equal 1 second-foot, and in Colorado and adjoining states 40 miner's inches, or even less, are equivalent to the same. This rate of 1 miner's inch to the acre, therefore, would give an extremely low duty of only 40 or 50 acres to the second-foot, but it is probable that in many localities where there is an ample water supply it is used as freely as this. The saying is so common that the majority of the irrigators who have formed any opinion on the subject have given this as the common practice. Nevertheless there can be little doubt that a higher duty is generally obtained.

Upon the new lands of Utah, Idaho, and Montana it is probable that the duty of water averages about 70 acres to the second-foot, and that it can be readily brought up to 100 acres. In California, in localities where water is scarce and great care is taken in using it, the duty has been found to be 200 acres or more, in exceptional cases rising to 500 acres or over, this high water duty being obtained usually in the case of orchards, in which the water is conducted by pipes to each tree. The state engineer of Colorado in the fifth biennial report estimates the duty of water of certain streams at from 168 to 424 acres per second-foot, using in this connection the acreage estimated by the water commissioners. By substituting the acreage from which crops were obtained as shown by this census,

a Report on the lands of the arid region of the United States, with a more detailed account of the lands of Utah, by J. W. Powell. Second edition, Washington, 1879, page 8.

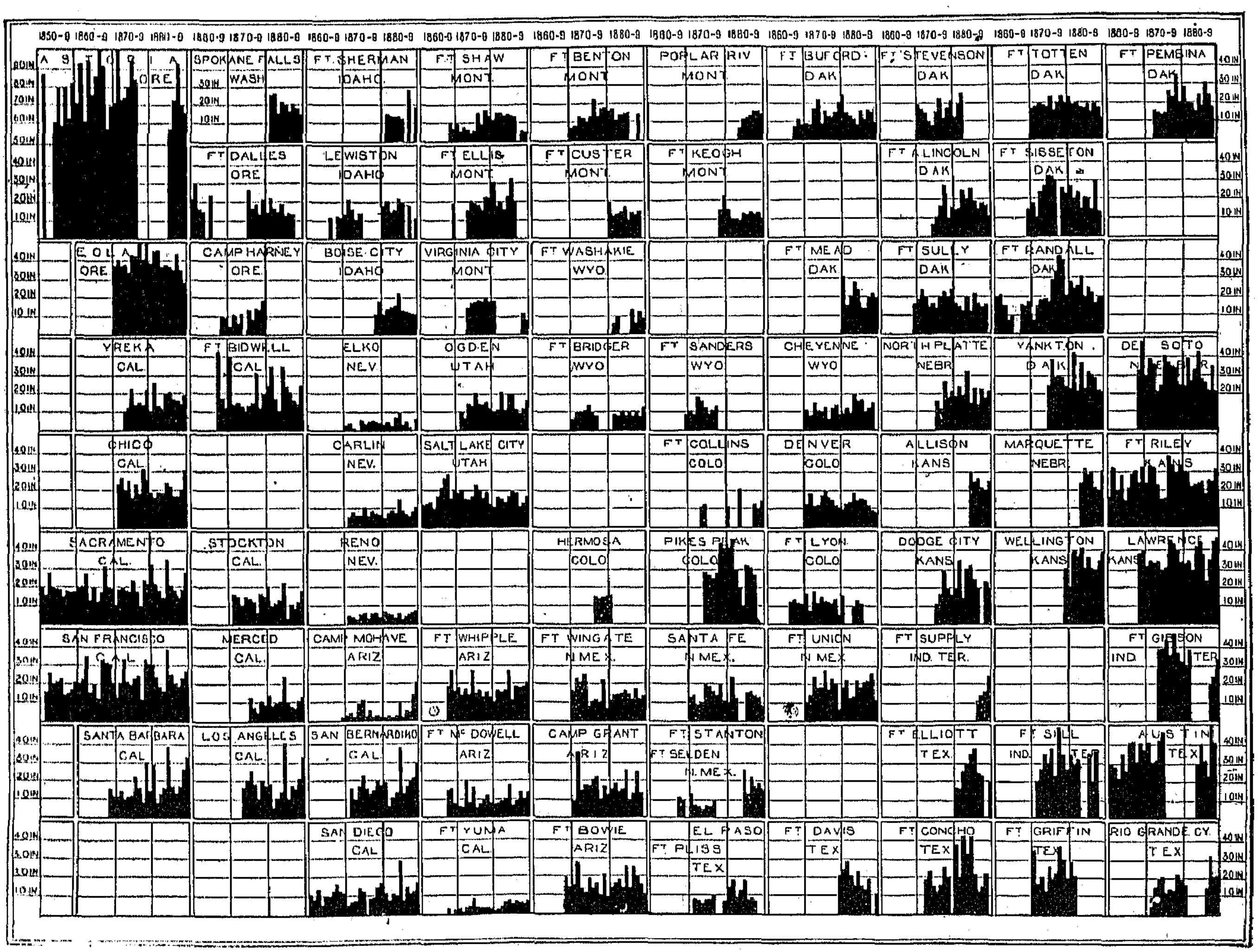
the duty has been found to be from 90 to 200 acres to the second-foot. This high duty of water is unquestionably due to the fact that some of the water returns by seepage to the stream and is used a second time. As a conservative estimate, as well as a convenient one, 100 acres to the second-foot may be considered as the average duty which has been obtained under favorable conditions and by the employment of ordinary skill on the part of the irrigator.

By taking a definite quantity to represent the duty of water, viz, 100 acres to the second-foot, and by ascertaining the average value of this water to the land, it is possible to obtain some conception of the value of the water resources of the country. Taking the average value of the water right as $26 per acre and the average first cost as $8.15 per acre, the difference, $17.85, can be considered as the value of the flowing water to each acre. If then 1 second-foot irrigates 100 acres, its value under these assumptions is $1,785. Thus, for example, a small river or creek carrying throughout the irrigating season 100 second-feet should be worth at least $178,500.

RAINFALL.

In any discussion of irrigation it is essential to make reference to the quantity and character of precipitation, for this governs not only the questions as to necessity of artificially applying water, but also throws some light upon matters of water supply. The data concerning rainfall have been so carefully collected and published by the United States Signal Service that it is sufficient to refer to its reports. In order to show in concise manner some of the principal facts several diagrams have been prepared giving graphically the annual and mean monthly rainfall at various points in the western half of the United States. The first of these, entitled "Annual rainfall at important stations in the western part of the United States", exhibits by a series of vertical lines the relative depth of rain at different points through a series of years. These are arranged in a rude geographic order, the stations given

DIAGRAM OF ANNUAL RAINFALL AT IMPORTANT STATIONS IN THE WESTERN PART OF THE UNITED STATES.



on the left hand side of the sheet being those near the Pacific coast and those on the right hand on the great plains of the Mississippi basin. The great fluctuations year by year are shown by the varying heights of these vertical lines or columns and also the irregularity or lack of uniformity. It is possible to pick out one or two years during which there was unusually large or small precipitation at most of the stations, but these are rather exceptional than otherwise. In 1884, for instance, the precipitation at a number of places was above the average and in 1885 less; but taken as a whole the plate illustrates the fragmentary character of even the best of the data and the great irregularity in annual rainfall.

The next plate, on the contrary, is characterized by a great uniformity, since it has been constructed from averages of from 15 to 20 years. It exhibits the average rainfall by months, the stations being arranged, as in the other plate, with regard to their geographic position. A prominent fact seen on this plate, as on the preceding, is the small amount of rainfall at the stations well within the arid region, but perhaps the most striking feature is the gradual change in distribution of rainfall throughout the year found in proceeding from one side of the diagram to the other. On the east, in the Great Plains region, the greatest rain occurs in the summer months, while in the west, near the Pacific ocean, the summer is the time of diminishing rainfall, succeeded by the annual drought. In the center, as, for example, at Fort Bridger, the rainfall is fairly evenly distributed or somewhat irregular. It is also interesting to compare the minimum rainfall shown at Yuma, Ariz., with that at Portland, Ore.

General A. W. Greely, Chief Signal Officer, has classified the distribution of rain according to months under a number of curves (*a*) typical of certain portions of the country. These curves, placed one above the other, bring out clearly the great difference in the distribution of precipitation between California and Colorado, and show that although in some points in California there may be a greater annual rainfall, yet the quantity of rain which falls during the summer is exceedingly small, and in order to save the trees and vines it becomes as necessary to irrigate as in regions of less annual precipitation.

In the present report, under the description of states, the quantity and distribution of the rain will be further discussed. Throughout the greater part of the arid region there have been relatively few points where rainfall measurements have been made, and these have been mainly in the vicinity of cities and towns of considerable size. Concerning the precipitation on the great mountain areas, from which the important streams come, little is known.

ARTESIAN WELLS.

A small amount of water used for irrigation is obtained from artesian wells, and therefore the census enumerators were instructed to include these within the agricultural schedule. By a tabulation of the returns it has been found that in the states and territories forming the western part of the United States there were 8,097 artesian wells upon farms in June, 1890. The artesian wells southeast of Minneapolis, supplying many cities and towns of Wisconsin and northern Illinois, as well as points more distant, do not enter into this discussion. The wells considered were in Kansas, Nebraska, North Dakota, South Dakota, Texas, and the states and territories west of them. Out of this total number of 8,097 wells, statistics concerning the depth, cost, discharge, and other features were obtained for 2,971, or 36.69 per cent. From this latter number of wells, fairly distributed in each state and county, averages have been drawn, which, when applied to the whole number, give the results shown in the following table:

ARTESIAN WELLS ON FARMS IN JUNE, 1890.

STATES AND TERRITORIES.	Total number.	Average depth in feet.	Average cost per well.	Average discharge in gallons per minute.	WELLS USED IN IRRIGATION.			
					Per cent.	Computed number.	Average area irrigated per well in acres.	Total area irrigated in acres.
Total	8,097	210.41	$245.58	54.43	48.54	3,930	13.21	51,896
California	3,210	248.00	425.00	164.00	64.17	2,060	18.63	38,378
Colorado	596	251.00	221.00	30.00	57.89	345	18.01	6,213
Idaho	28	83.00	53.00	11.00	50.00	14	13.21	185
Kansas	59	202.00	175.00	44.00	40.68	24	13.71	329
Montana	14	366.00	473.00	28.00	42.86	6	3.00	18
Nebraska	91	247.00	173.00	13.00	7.69	7	1.00	7
Nevada	33	215.00	607.00	6.00	60.61	20	1.00	20
North Dakota	461	196.00	265.00	21.00	2.17	10	2.00	20
Oregon	6	70.00	250.00	15.00	50.00	3	4.00	12
South Dakota	527	216.00	158.00	51.00	13.47	71	6.68	474
Texas	534	292.00	359.00	19.00	27.34	146	3.00	438
Utah	2,524	146.00	78.00	26.00	48.49	1,224	4.74	5,802
Washington	9	127.00	312.00	89.00	....	....	....	....
Wyoming	5	210.00	456.00	8.00	....	....	....	....

a Some of these are shown diagrammatically in his report upon irrigation and water storage, published as House Executive Document No. 287, Fifty-first Congress, second session.

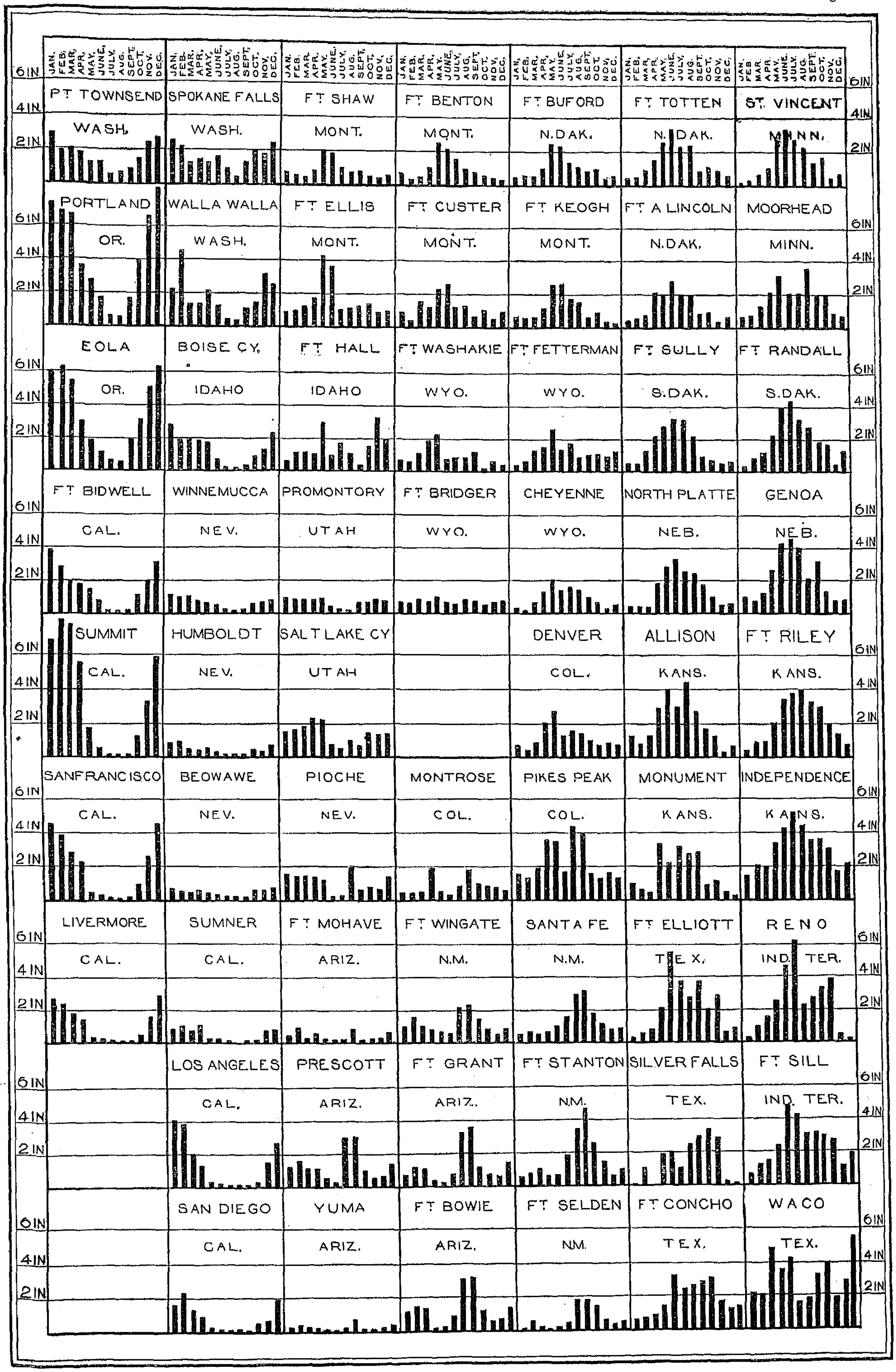


DIAGRAM ILLUSTRATING AVERAGE MONTHLY PRECIPITATION AT IMPORTANT STATIONS IN THE WESTERN PART OF THE UNITED STATES.

This table shows that 3,930 wells, or 48.54 per cent of the total number on farms, were employed in irrigation, watering 51,896 acres, or an average of 13.21 acres per well. Over one-half of these wells were in the state of California, irrigating 38,378 acres, or 73.95 per cent of the total area irrigated by flowing wells. The average discharge of the whole number of wells was 54.43 gallons per minute, or 0.121 cubic foot per second or second-foot. This gives a water duty of 1 second-foot to 109.17 acres; that is, the water flowing from these wells has irrigated on an average 109.17 acres per second-foot. The average depth of these wells was 210.41 feet, and the average cost was $245.58, or $1.17 per foot for all depths and conditions. Taking as the average discharge 54.43 gallons per minute, or 0.121 second-foot, the cost of the water would be $4.51 per gallon per minute, or $2,029.59 per second-foot. Taking the figures just given for the duty of water, namely, 1 second-foot for 109.17 acres, the average cost of irrigating an acre has been $18.59. The average cost of water per acre by ordinary means of irrigation, as derived from the statements of irrigators throughout the entire country, was $8.15, or 43.84 per cent of the cost by artesian wells. This, it should be borne in mind, is the average cost of water from successful wells. To arrive at the actual cost due allowance should be made for many attempts, aggregating perhaps thousands, to obtain flowing water without success. The total number of these can not be ascertained, for failures in this line are soon forgotten, but the amount expended annually by individuals, cities, towns, and corporations in fruitless attempts must be very large.

At an average cost of $245.58 per well, the 8,097 wells represent an aggregate investment of $1,988,461.26. The total depth drilled or bored in making these flowing wells was 1,703,689.77 feet, or 322.67 miles. The total amount discharged by all these wells was 440,719.71 gallons per minute, or 981.93 second-feet, nearly four-fifths of the discharge of the Rio Grande at Del Norte, Colo., for 1890, and a trifle less than that of the Weber river above Ogden, Utah, for the same year.

The amount of water discharged by artesian wells is so small that it has been found convenient to employ a smaller unit of measurement than in the case of rivers and creeks. The quantities in the latter case are usually expressed in cubic feet per second or second-feet. For artesian wells the far smaller unit often employed in regard to city supply, the gallon per minute, is used. A gallon per minute equals 0.002228 second-foot, and, conversely, 1 second-foot is equivalent to 448.831 gallons per minute, 1 cubic foot being equal to 7.48052 United States standard gallons. A third unit of flowing water is in popular use, namely, the miner's inch, but this, as previously stated, is an indefinite quantity, varying according to the method by which it is measured, in some localities 40 and in others 50 miner's inches making a second-foot. In this discussion the gallon per minute, since it is in common use, is employed.

An artesian well flowing at the rate of 100 gallons per minute, or 0.2228 second-foot, will in 1 day discharge 0.4419 acre-foot; that is, it will cover 0.4419 of an acre 1 foot in depth, or 1 acre that fraction of a foot in depth, and in 1 year will discharge 161.29 acre-feet. In other words, if all this water could be saved, this number of acres would be covered 1 foot in depth. At the average discharge of 54.43 gallons per minute a well during 24 hours discharges 0.2405 acre-foot, and in 1 year will discharge 87.79 acre-feet. All of the wells at this rate in 1 year would discharge a total of 710,835.63 acre-feet.

In the following table the number of wells in each county is given, together with the depth of the deeper and shallower wells, the average depth, cost, and discharge in gallons per minute of those wells for which statistics were obtained:

ARTESIAN WELLS, DEPTH, COST, AND FLOW, BY STATES AND TERRITORIES AND COUNTIES.

CALIFORNIA.

COUNTIES.	Total number.	DEPTH IN FEET. Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	3,210	....	....	248	$425	164
Alameda	34	40	450	195	401	62
Butte	3	....	....	800	2,000	4
Colusa	2	....	....	1,000	....	....
Contra Costa	1	....	....	....	....	1
Fresno	47	72	1,200	502	1,170	....
Inyo	1	....	....	20	....	....
Kern	89	300	1,100	551	1,489	1,072
Lake	45	50	160	81	90	59
Lassen	2	200	394	297	355	4
Los Angeles	627	20	600	187	394	192
Merced	112	170	700	326	431	65
Modoc	12	56	280	143	295	15
Monterey	60	60	189	136	152	3
Orange	640	26	450	147	209	110
Plumas	159	60	1,132	550	165	40

CALIFORNIA—Continued.

COUNTIES.	Total number.	DEPTH IN FEET. Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Sacramento	4	....	....	75	$25	....
San Benito	117	29	329	111	188	157
San Bernardino	301	65	700	191	403	283
San Diego	60	108	389	212	353	112
San Luis Obispo	11	74	124	101	84	4
San Mateo	50	80	252	170	505	106
Santa Barbara	22	75	147	112	112	7
Santa Clara	460	50	740	280	555	316
Santa Cruz	33	80	184	137	307	139
Shasta	1	....	....	209	543	4
Sierra	40	45	1,130	458	136	47
Siskiyou	1	....	....	700	1,500	133
Solano	1	....	....	250	....	....
Sonoma	2	76	315	195	532	6
Stanislaus	1	....	....	408	800	2
Tulare	139	50	1,060	587	1,302	409
Ventura	115	15	225	149	287	73

ARTESIAN WELLS, DEPTH, COST, AND FLOW, BY STATES AND TERRITORIES AND COUNTIES—Continued.

COLORADO.

Counties.	Total number.	Depth in feet.			Average cost.	Average flow in gallons per minute.
		Shallow.	Deep.	Average.		
Total	596			251	$221	39
Arapahoe	185	136	858	400	420	13
Boulder	3	249	600	416	775	120
Conejos	184	40	478	146	70	23
Costilla	70	30	500	250	117	26
Douglas	5					
Jefferson	7			558	1,100	
Pueblo	2			772	1,800	
Rio Grande	50	76	235	136	103	21
Saguache	90	110	426	267	265	140

IDAHO.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	28			83	53	11
Bingham	15	90	150	120	37	13
Oneida	13	50	100	77	58	10

KANSAS.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	59			202	175	44
Bourbon	7	163	620	442	753	14
Hamilton	6			275	400	20
Meade	44	50	210	153	46	49
Morton	1			700	825	30
Nemaha	1			14	20	

MONTANA.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	14			366	473	28
Cascade	2			160	350	6
Custer	12			400	488	26

NEBRASKA.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	91			247	173	13
Cedar	36	255	550	388	261	14
Dixon	4	170	300	254	92	45
Holt	42	50	185	99	48	7
Knox	8	400	604	491	686	17
McPherson	1			28	35	

NEVADA.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	33			215	607	6
Churchill	2			300	1,750	7
Douglas	2			150	175	3
Lander	20	64	750	200	258	3
Ormsby	5	100	150	125	150	8
Washoe	4					

NORTH DAKOTA.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	461			196	265	21
Cass	100	35	514	169	235	6
Dickey	1			1,087	4,000	1,700
Grand Forks	20	40	217	142	205	34
Pembina	12	120	175	154	180	14
Ramsey	1			1,511		60
Richland	104	34	450	121	192	12
Sargent	2	125	610	367	962	1
Stutsman	1			1,523		167
Traill	170	96	440	212	277	11
Walsh	50	101	298	175	201	7

OREGON.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	6			70	$250	15
Crook	2			104	150	
Gilliam	1			21		10
Harney	2					
Wasco	1			51		20

SOUTH DAKOTA.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	527			216	158	51
Beadle	1			850	1,800	600
Bonhomme	6	512	736	655	1,172	219
Clay	150	205	500	311	120	55
Davison	10	97	288	172	188	3
Grant	12	30	117	59	83	17
Hanson	50	70	315	174	160	260
Hutchinson	11	3	154	83	92	26
Jerauld	2			709	625	3
Lincoln	12	32	70	47	23	3
McCook	11	85	195	133	105	41
Miner	66	60	284	133	94	16
Sanborn	92	60	600	110	124	89
Turner	30	24	340	82	47	18
Yankton	74	225	645	375	219	38

TEXAS.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	534			202	359	19
Bandera	1			104	80	
Bell	10	128	500	268	192	2
Bexar	10			575	800	100
Bosque	22	180	780	434	762	34
Brazos	15	228	470	330	407	4
Burleson	12	400	600	500	138	4
Burnet	2	87	97	92	92	1
Coryell	27	240	330	325	325	5
Dallas	66	65	262	153	200	3
Denton	32	134	684	350	387	3
Dewitt	6	55	100	67	88	11
Dimmit	10	98	165	151	284	2
Ellis	27	165	276	217	200	3
Galveston	5			400	800	40
Gonzales	3			284	548	2
Grayson	1			180	275	60
Hays	1			131	200	1
Hood	16	200	240	222	222	43
Jack	5	50	200	105	129	4
Johnson	8	70	272	171	166	20
Lavaca	1			435	1,700	24
McLennan	6	456	640	552	743	2
Palo Pinto	3			546	700	
Parker	11			70	60	
Reeves	1			185	350	60
Robertson	120	165	750	464	189	11
Somervell	48	93	350	211	221	36
Stephens	10	115	156	130	100	6
Tarrant	49	80	273	207	288	10
Uvalde	3	103	110	106	200	10
Victoria	3	825	946	896	2,333	120

UTAH.

Counties.	Total number.	Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	2,524			146	78	26
Boxelder	34	54	203	115	53	27
Cache	73	33	410	157	112	12
Davis	492	30	425	160	76	29
Juab	7	85	90	88	93	10
Millard	26	132	250	153	83	4
Salt Lake	501	27	320	116	107	32
Sanpete	233	33	215	103	39	20
Sevier	14	60	100	69	31	11
Summit	1			165	150	
Tooele	133	40	580	135	120	38
Utah	495	30	432	145	65	30
Weber	515	50	330	167	73	22

ARTESIAN WELLS, DEPTH, COST, AND FLOW, BY STATES AND TERRITORIES AND COUNTIES—Continued.

WASHINGTON.

Counties.	Total number.	Depth in feet. Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	9	....	....	127	$312	89
Spokane	1	....	....	130	230	14
Whitman	8	....	....	126	352	100

WYOMING.

Counties.	Total number.	Depth in feet. Shallow.	Deep.	Average.	Average cost.	Average flow in gallons per minute.
Total	5	....	....	210	$456	8
Albany	4	8	510	151	414	15
Sheridan	1	....	....	500	625	1

The artesian areas are widely scattered, and individually they are of small size, excepting those in North Dakota, South Dakota, and California, where the artesian conditions extend over several hundred square miles. Each of these areas will be discussed or mentioned in its appropriate place in the following pages.

By far the greater number of the artesian wells in the west have been put down within the last decade, there being comparatively few which have been in existence for 10 years. In California, however, cases are reported where wells have been flowing for 20 or even 30 years, the discharge not having decreased except through the interference of other wells. The success attained in sinking wells in some of the valleys of California and Colorado led to a widespread interest in such matters, and since 1884 attempts have been made to secure flowing water in the majority of counties of the western part of the United States.

Many cities and towns have devoted money to experimental drillings, and in a few instances state governments have favored such works by legislation or by direct appropriation. The national government in the early part of the past decade paid for the sinking of two wells upon the Great Plains, both of which were without success so far as flowing water was concerned. Perhaps the largest amount of experimental work has been done by railroads, whose need for pure water for locomotives has led to drilling a number of deep wells along their lines. Owners of cattle also, both as individuals and corporations, have spent large amounts of money in putting down deep wells in remote parts of the country in the hope of obtaining water for stock. In the aggregate a vast amount of experimental work has been done, and from the knowledge obtained in this way and by study of the geological structure the extent of conditions favorable for artesian wells is fairly well known.

The geological conditions favoring the existence of artesian wells are found in nearly every state considered, although in restricted areas. The most notable basins are in North Dakota, South Dakota, California, Texas, Colorado, and Utah; their importance as regards area and amount of water delivered being approximately in the order named. These areas, outlined by successful wells, are small compared to the total land surface of each state, a possible exception to this rule being in the case of North Dakota and South Dakota, where artesian water can apparently be obtained over perhaps one-fourth of these states, providing that wells are drilled to a depth sufficiently great.

Comparatively few artesian wells have been put down for irrigation alone, and the utilization of the water in raising crops has been what may be termed an afterthought of the owners. The greater number of the wells were drilled primarily for the purpose of obtaining drinking water, but since the amount consumed in this way must be small, even insignificant, the large surplus is available for other uses. Thus it is that, although the expense of irrigation from artesian wells is in many instances so great as to appear to be prohibitory, yet as other more important purposes are served and the water otherwise would be wasted, it results that irrigation by this method is profitable, especially for intensive agriculture.

The advantages of artesian water for irrigation lie mainly in the matter of convenience and independence of the owner. Having a well on his own land, subject to his exclusive control, the irrigator can employ the water when he pleases without waiting for his turn, as in the case of the farmer taking water from a company ditch. On the other hand, however, although he can obtain the water at all times, it comes, except in the case of a few remarkable wells, in a very small stream, so small that it requires great care and patience to conduct it from point to point. The dry soil drinks up this little stream with a rapidity almost as great as that with which it comes, so that many instances are reported where the farmer has been unable to carry the water more than 200 feet from the well. The temperature of the water, especially from the shallow wells, is usually low, from 40 to 50 degrees fahrenheit, varying very slightly throughout the year. On a hot summer's day this water, if applied at once, might injure the vegetation.

For these reasons, namely, the small size of the stream and the low temperature of the water, it has been found advantageous wherever possible to build small reservoirs in which the water from the well can accumulate and become warmed by the sun. By this means a large quantity of water, warmed nearly to the temperature of the air, can be turned at once upon the fields in a stream sufficiently large to force its way from point to point, rapidly wetting the surface with comparative uniformity. In considering the cost of irrigation by artesian wells, therefore, the expense of constructing and maintaining a small reservoir should not be overlooked. Unfortunately, in many cases reservoirs are not feasible, either on account of peculiarities of the surface or because the water from the well does not rise to a height sufficiently great.

Artesian water is generally regarded as having less value for irrigation than water from rivers and creeks, from the fact that the latter usually contains a large amount of silt, which is believed to enrich the land. Well water, on the other hand, is almost always clear, although it sometimes carries a large amount of mineral salts in solution; the artesian waters ranging from those almost as soft as rain water to the strongest brine. When water, although containing but a small amount of saline matter, is used for irrigation, the salts left by evaporation gradually become concentrated, and may reach a point, especially if great care is not taken, where they completely destroy vegetation. This also is the case with many river waters, and may be obviated to a certain extent by thorough cultivation of the soil and proper management.

The majority of artesian wells are upon low grounds, the water only rising slightly above the level of the bottom lands of the valleys. This, as regards irrigation, is especially unfortunate, from the fact that these lower grounds are often below irrigating canals and are to a greater or less extent wet by the seepage from the canals or from the rivers. Wherever the pressure is sufficient to lift the water to lands upon the benches or sides of the valley above irrigating ditches the water has unusual value, but these cases are rare. In spite of this fact, however, flowing wells even in countries covered with a network of canals are valuable, from the fact that they furnish throughout the year a continuous supply of water suitable for domestic purposes and for cattle. During the winter time especially, when the water is turned out of the irrigating ditches, the artesian wells prove of great service.

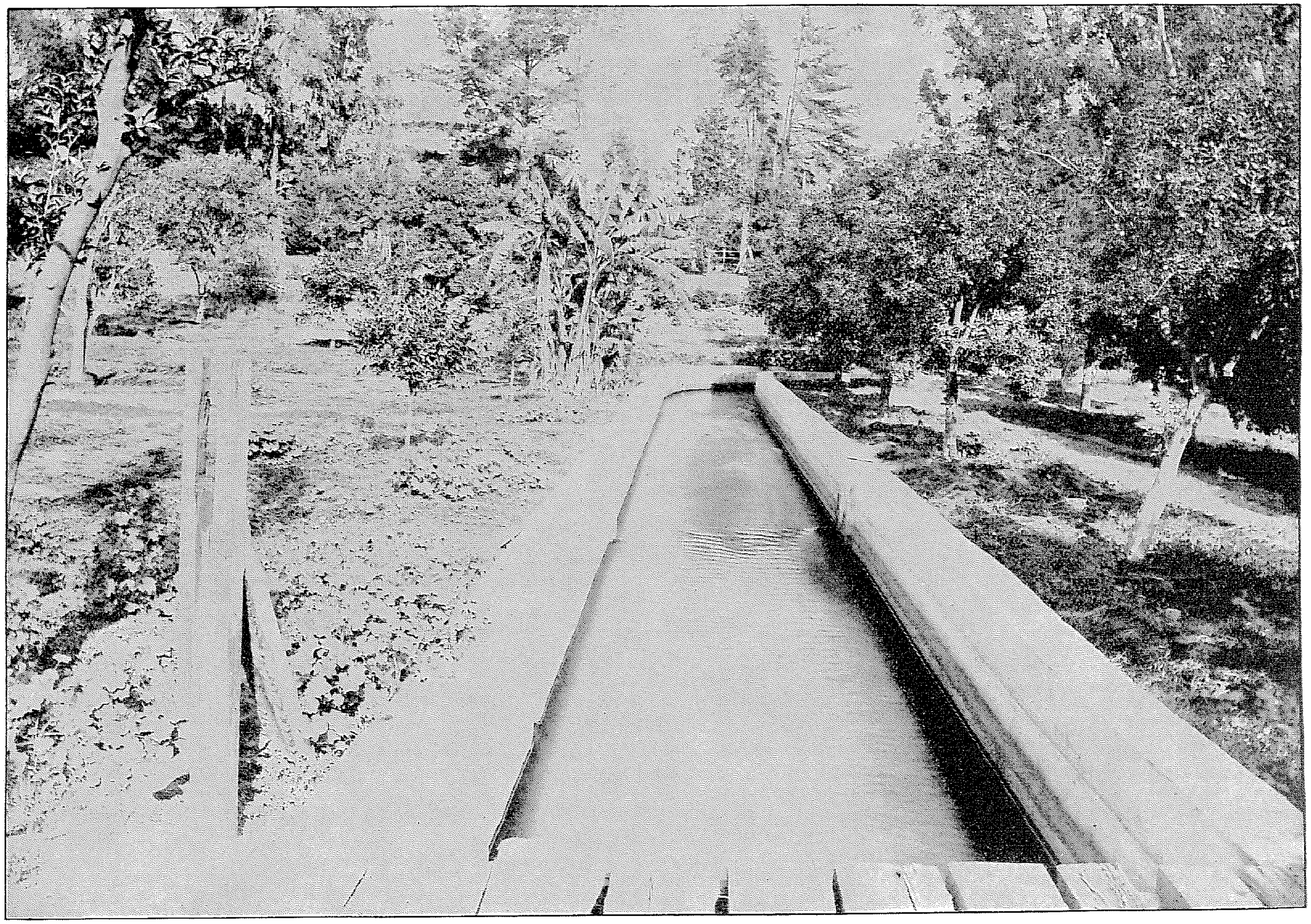
The development of the known artesian areas by the sinking of new wells has proceeded rapidly. The examination of statements from the owners of artesian wells demonstrates unmistakably, however, that the majority of wells show a gradual decrease in the amount flowing from them. Many wells do not exhibit a perceptible change in this regard, but the number in which shrinkage has occurred is sufficiently great to justify an examination into the causes prevailing in each basin or at each group of wells. This decrease in discharge has often resulted from mechanical imperfections in the construction of the well, which end in clogging or injury of the tubing or casing or in filling the lower part of the well with fine sand.

A more serious cause of diminution of flow is that due to loss of hydrostatic pressure resulting from an increase in the number of wells or from pumping one or more of them. The water in the pervious sands or gravels can never be completely exhausted by artesian wells or even by pumping, but it is comparatively easy to make the openings so numerous and large that water no longer has an opportunity of accumulating in the higher parts of the bed to an amount sufficient to exert great pressure at points lower on the dip of the beds.

Examples of the injury or even total destruction of artesian wells by increase in the number, or by reckless drilling through the confining strata, are to be seen in many parts of the country. The decrease of flow or complete stoppage of many wells of the Denver basin is well known. In California, along the coast south of San Francisco, are a number of small artesian areas where wells have been flowing for many years. The result of putting down new wells within the second half of the past decade has been that many of the older wells have stopped flowing except at times of high tide or during the rainy season. In fact, it is comparatively easy to find wells in any of the older basins which flow only during the winter. Legislative protection against interference with this valuable class of property is in many states essential in order to prevent its complete destruction.

The largest and probably the most permanent artesian areas of the country, namely, those of North Dakota, South Dakota, and Texas, lie east of the arid region and within that part of the debatable ground known as the subhumid, where irrigation is rarely necessary, although often of great benefit. On account of the fact that good crops are often raised by dependence upon rainfall, it has been difficult to convince the farmers within these artesian areas that irrigation can be made profitable or practicable from these wells. Even within the arid region few artesian wells have been put down by farmers primarily for irrigation, and it is doubted whether this can be profitably done except in instances where it has already been proved beyond a doubt by neighboring wells that a large artesian flow can be obtained. The risk and cost involved are often too great to justify the experiment. In unexplored territory the chances of striking flowing water are against the prospector, for even if the geological structure is favorable, the beds may be comparatively impervious to water, or it may not rise to the surface, or, as is often the case, it may be strongly saline. The expense of maintenance also in the case of wells delivering pure water is occasionally a notable amount, owing to the necessity of keeping them clean or of repairing accidental injuries.

The efficiency for irrigation of the water from artesian wells varies widely with the character of the crops, soil, and climate. The greater part of the water is used upon small gardens in the vicinity of houses, and for fruit and shade trees, for watering lawns, and for raising grass either for pasturage or for hay. Toward irrigating the ordinary field crops, such as wheat, rye, oats, and corn, water from this source has been employed to only a small extent. As will be seen by examining the figures previously given, the number of acres irrigated per well in each



VIEW OF CEMENT LINED CANAL NEAR SANTA ANITA, LOS ANGELES COUNTY, CALIFORNIA, ILLUSTRATING IMPROVED METHOD OF CONDUCTING WATER.

state is by no means proportional to the discharge. In California and Colorado, for instance, approximately the same number of acres per well are irrigated, although in the case of the former the average discharge is over four times as great as in the latter. This difference is traceable to the character of the soil and surrounding circumstances, the discrepancy arising from the fact that in the San Luis valley in Colorado the wells irrigated large areas of land in the immediate vicinity of canals, where the ground water stood comparatively near the surface, and thus the small amount from an artesian well was very effective, while in some of the other states the ground in the vicinity of the well was dry to such depths that it drank up the water with astonishing rapidity.

RESERVOIRS.

In various parts of the country attempts have been made to increase the amount of water available during the irrigating season by means of storage works holding a portion of the flood waters until most needed. Great interest has been shown in the development of these works, and their necessity is attested by the popular discussions of the advantages to arise from their construction. There is hardly a county in the whole arid region in which there are not a number of sites at which it has been proposed at one time or another to construct a reservoir. Unfortunately, however, experience has proved that the natural advantages for the profitable construction of storage reservoirs are not widely distributed, and there are few places in any one state where under present conditions it will pay to hold water. As a usual thing the localities pointed out are deficient in storage capacity or are so located that a perfectly safe dam can not be constructed with reasonable outlay. Progress therefore in the increase of water supply by this means has been and must continue to be slow, relative to the development of systems for distributing water. In certain parts of the country, for example, in Colorado, many small reservoirs have been built by farmers for the purpose of holding water for individual use, but the aggregate capacity of these is almost insignificant.

The best known storage works of the country are probably the Sweetwater reservoir of the San Diego Land and Town Company; the Cuyamaca reservoir of the San Diego Flume Company; the Bear Valley reservoir, belonging to the Bear Valley Company (these three being in southern California); Lake Yosemite, near Merced, Cal., and the Castlewood reservoir, near Denver, Colo. In addition to these there are a number of other works in process of construction or projected, notable among these being the Hemet Valley dam, the Arrowhead works of southern California, and the Pecos dam, in southern New Mexico.

Besides the reservoirs mentioned above, which are wholly artificial, there are throughout the west a number of lakes used to a certain extent as storage works. In the case of the larger of these lakes the natural fluctuations of water level are almost beyond control, and the evaporation from the surface is usually far greater than the amount of water utilized. The largest of these are Utah lake, in Utah; Bear lake, in Utah and Idaho; Lake Tahoe, in California and Nevada; Clear and Eagle lakes, in California. It is probable, also, that Goose lake, in Oregon and California, could be used, as well as Klamath lake, by the construction of suitable outlets. A comparison of these large bodies of water with the wholly artificial reservoirs is hardly possible, since the area of the former is nearly 100 times as great.

METHODS OF CONDUCTING WATER.

Water is usually brought from the running stream or reservoir by means of open ditches or canals built on a grade such that it shall flow freely. Many considerations have to be taken into account in determining the fall of the ditch. As a general rule, the less the grade the more land the ditch will command at a given number of miles from the head, but, on the other hand, a canal of gentle grade requires a larger cross section than one of more decided slope, and if the velocity of the water is small the channel may be entirely choked by aquatic plants. Too great a slope, however, results in the washing away of the banks and bed, requiring constant care and expenditure. Little attention was given to details of this kind in the laying out of the older ditches and canals. As experience has been gained and larger and more expensive enterprises have been entered upon, engineering skill has been called into practice, and the open channels and flumes have been improved upon in various ways. In many instances the open earth ditches have been replaced, in whole or in part, by conduits less wasteful of water. In southern California especially, where, owing to the absence of frost, there is less liability of destruction, cement has been largely used in various ways. For example, some of the open ditches have been lined with stone and a coating of cement placed upon this, making the sides and bottom of the ditch smooth and impervious, thus at the same time increasing the capacity while diminishing the loss by seepage.

In various parts of the country pipes of wood or of iron are being employed to a considerable extent to prevent loss of water, especially at points where it is difficult to maintain an open channel. The wooden pipes are made of strips of plank, with their edges carefully beveled or fitted together. These strips run lengthwise of the pipe, and no two terminate at the same point, so that the pipe when complete is practically continuous. The pieces are bound together and held in place by iron hoops at short intervals. The iron pipes generally employed are made of sheet iron put together in various ways, usually, however, in short lengths. Many styles of pipe are on the market, as single and double riveted, spiral, double cemented, and coated. Cast iron is used to only a small extent, owing to its heavy cost. Where frosts are not feared cement or stoneware pipes are often employed, especially in connection with the cement ditches mentioned above, the water in these pipes being submitted to slight pressure. Taking the arid region as a whole, however, the open earth ditch is the rule and such devices are exceptional, marking perhaps the beginning of better things.

METHODS OF APPLYING WATER.

The methods of applying water to the soil in use in different parts of the arid region depend largely upon the character of the soil and crop, the quantity of water usually available, the slope of the ground, and the degree of skill on the part of the average irrigator. The grasses and other forage crops, notably alfalfa, when growing upon nearly level ground, are usually flooded by cutting the side of the distributing ditch, constructed along the highest parts of the field. The opening in the side of the ditch is usually made by a shovel or hoe, and is filled in again after the adjacent portion of the field has been irrigated. Sometimes, however, small gates or openings through the side of the ditch provided with suitable sliding doors are placed permanently, so that the quantity of water can be regulated with some degree of care. From the openings in the side of the ditch the water is allowed to find its way in all directions, and unless the surface is perfectly level some portions receive far more than others. Thus fields slightly undulating will often show bare spots where the plants have not received sufficient moisture. Where the supply of water is ample, especially on the edge of some broad valley, enormous areas of the native grasses are thus flooded, little care being taken to distribute the water evenly, since the yield per acre is at best small.

On very gently sloping lands what is known as the check system has been largely in use, especially in California. This consists in raising low ridges of earth, about 1 foot in height and 10 feet or more in width at the bottom, these being built along contours and thus meandering across the fields as required by the slope of the ground. The space between the distributing ditch and the first check or small levee, which may be at a distance of from 100 to several hundred feet, is first filled with water, and the soil being saturated the low levee is cut in one or more places and the surplus water, together with an additional supply from the distributary, is allowed to fill the second checks or levees. These checks are so broad and low that they do not interfere with cultivation, the farming machinery passing over them without difficulty. Among the Mexicans this system of checks is carried to an extreme. They are placed very near together and consist of sharp, narrow ridges, inclosing patches of grain or vegetables often not more than 20 feet square. Each of these in turn is made into a pond by turning water in from the nearest ditch.

The cereals and other field crops are irrigated by means of furrows, whose distance apart varies with the character of the soil. In Utah and many other parts of the arid region, after the grain is planted, what is known as a marker is run over the field, rolling or digging small furrows 18 inches to 2 feet apart, through which the water is allowed to flow two or three times during the growing season. Vegetables and corn are wet by turning water into the furrows between the hills or rows, these having previously been plowed in a direction such that there shall be a continuous gentle fall from the distributing ditch to the far end of the field. The irrigation of plants on land having a decided fall requires considerable care and skill on the part of the farmer in order to prevent the washing away of the soil and the unequal distribution of water. For this end furrows are plowed, winding along the ground in such a manner as to reduce the fall, and small quantities of water are used at a time in order that it may not break away and cut channels down the slopes. For fruit trees and vines the water is usually applied by furrows; the water seeping from these furrows saturates the soil uniformly, and the quantity is easily regulated.

In many cases steeply sloping lands which have been considered as useless for agriculture have been found to possess a soil and climate especially adapted to fruit culture. These lands have in many instances been terraced and the water allowed to flow in channels along each of the benches thus made, erosion being prevented by conducting the water from terrace to terrace by wooden, metallic, or stone conduits. The fruit trees receive moisture by percolation from the channels or furrows or by the complete saturation of the surrounding soil from small pools formed on the surface. This latter method of applying water has been largely practiced by fruit growers, but is perhaps falling into disuse. It consists in surrounding each tree with a ridge of earth, forming a basin, into which water is let from the distributing ditch. This basin system, which is similar to the methods practiced by the Mexicans, is used either upon sloping or level ground. Among the disadvantages of the use of basins are those arising from the fact that the high ridges render cultivation difficult and expensive, and from a tendency to apply too much water to a restricted area. For these reasons orchardists are gradually learning to apply water by means of furrows, which can be quickly made after each cultivation.

In order to reduce the length of these furrows and to conduct the water with as little loss as possible, small wooden flumes, placed on or above the ground, are sometimes built through an orchard leading from the distributing ditches to the furrows. In this flume openings 1 inch square are cut at intervals of from 2 to 5 feet or more, each of these being closed by a small metallic slide. When ready to irrigate, the small flume is filled with water,

VIEW OF ORANGE ORCHARD, SHOWING METHOD OF APPLYING WATER BY BASINS ON TERRACES.

and a number of the small shutters are drawn out, allowing the water to escape into furrows, which in turn conduct it to the trees or other plants. These wooden flumes can be laid on uneven ground or carried over steeply sloping surfaces by introducing vertical drops from time to time, thus making it possible to irrigate the hillsides.

The most economical method of distributing the water applicable in the case of orchards and vineyards is that by means of pipes laid under ground. This is, of course, very expensive, and can be only adopted where the value of products is high, as in the case of citrus and other fruits. Attempts have been made to deliver water to trees and vines through porous earthenware pipes, but this, though theoretically perfect, in practice has not been successful, owing to the clogging of the pipes by roots and other causes. Where water is brought to each tree or group of trees by means of pipes it is customary to provide a small hydrant, through which water rises to the surface and is conducted away over a small adjacent area.

ARIZONA.

Total population (average per square mile, 0.53)		59, 620
Number of owners of farms (2.39 per cent of population)		1, 426
Number of irrigators (75.39 per cent of farm owners, 1.80 per cent of population)		1, 075
Area of territory, land surface (112,920 square miles)	acres	72, 268, 800
Area irrigated in census year	do	65, 821
Area of all farms, 8.03 per cent improved	do	1, 297, 033
Cereals raised in census year, including 29 acres in rye	do	22, 701
Barley, average production 23.77 bushels per acre	do	10, 644
Corn, average production 19.06 bushels per acre	do	4, 331
Oats, average production 23.10 bushels per acre	do	1, 472
Wheat, average production 16.12 bushels per acre	do	6, 225
Alfalfa	do	19, 945
Total value of all farms, including land, fences, and buildings		$7, 222, 230
Estimated total value of the irrigated farms, as above		$3, 204, 000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889		$1, 045, 970
Estimated value of production, as above, from farms irrigated in whole or in part		$916, 000
Average size of irrigated farms	acres	61
Average size of irrigated farms of 160 acres and upward	do	287
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated		34. 42
Average size of irrigated farms under 160 acres	acres	43
Average first cost of water right per acre		$7. 07
Average annual cost of water per acre		$1. 55
Average first cost per acre of preparation for cultivation		$8. 60
Average value of irrigated land, including buildings, etc., in June, 1890, per acre		$48. 68
Average annual value of products per acre in 1889		$13. 92

The above table gives in condensed form the principal statistics concerning irrigation in Arizona, showing its importance to agriculture and affording a means of comparison with other branches of industry. In order to make plain the development of irrigation in this territory relative to that of other great political divisions, it should be stated that the assumption has been made that the arid regions are bounded by certain arbitrary lines, embracing Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, 16 eastern counties of Oregon, Utah, 13 eastern counties of Washington, and Wyoming. As a matter of fact, however, portions of the areas above named are far from being arid. On comparison with these states and territories it appears that in number of irrigators and in acreage irrigated Arizona in 1889 stood next to the bottom of the list, coming above Washington, this latter state having the least number of irrigators and the smallest area irrigated. In average size of irrigated farms it was sixth, in this respect standing between California and Oregon. In average value of products per acre in 1889 it was number 4, California, Utah, and Washington exceeding it.

In comparing the areal extent of irrigation it appears that a smaller proportion of the entire territory was irrigated (less than one-tenth of 1 per cent of the entire land surface) than in any other state or territory. This is because Arizona embraces an enormous extent of the deeply eroded plateau country traversed by the Colorado river and also of the desertlike region adjoining the republic of Mexico, both of which areas are almost uninhabitable. Although the number of farms and of irrigators was small, yet, the proportion of farms irrigated was large, 75.39 per cent of the total number using water. In this respect Arizona stood third, Utah and Nevada exceeding it. On the other hand, in comparing the extent to which irrigation was practiced on these farms and the relative area actually irrigated, Arizona stands at the head of the list, 43.21 per cent of the total farm area owned by irrigators being irrigated, a percentage over twice as great as that prevailing throughout the arid region. In average value per acre of land irrigated, including improvements, $48.68 per acre, Arizona was number 8, while, as previously stated, in average value of products, $13.92 per acre, it was number 4. In first cost of water rights the territory was fifth, and in average annual cost of water per acre, $1.55, it was second, being exceeded only by California.

By reference to the map of the western part of the United States it will be seen that the irrigated areas lie mainly in the central and southwestern half of the territory. The high plateaus of the northern part of the territory are bounded by a series of great escarpments, the face of these extending diagonally across the center of the territory and facing the plains of the Gila basin. The winds from the west sweeping across the low plains are deflected upward by the abrupt slopes and mountain masses bordering the plateau, and a portion of their moisture is precipitated, forming almost innumerable creeks which unite to form the Verde, Salt, and other tributaries of the Gila, and thus render possible a large amount of irrigation in the valleys, especially on the Gila and Salt plains near the point where the waters leave their canyons. On the edge of the plateau country and among the mountains at elevations of from 6,000 to 8,000 feet, agriculture is successfully carried on without irrigation, in connection usually with stock raising or in the immediate vicinity of mining towns. For the greater part of the territory, however, it may be said that irrigation is practiced or needed during the entire year. In the lower lying plains the temperature is such that crops grow and mature at any season, providing there is a supply of moisture. Crop follows crop in succession, depending only upon the abundance or scarcity of water in the ditch or of the summer rains. During the winter and in the early spring and late fall the water is used on the alfalfa and hay crops, of the former of which from 3 to 6 cuttings or even 7 are made, the average number for the whole territory being 5. Usually two waterings are given for a cutting, and thus the total amount of water used is in excess of that required by any other crop. Later in the spring, when the rivers begin to decline and the water supply becomes scanty in most ditches, the alfalfa is neglected, all the water being needed for other crops, and still later, before the floods begin, in many places the whole flow is employed upon the trees and vines.

The water is applied in most cases by flooding, as, for instance, on lucern and grain, or through furrows laid off at regular intervals, no especial care being taken in the preparation of the fields. The Mexicans still practice the old method of flooding in small "pools" or rectangular areas separated by ridges of earth. The farmers in many localities look forward to better methods of distributing and applying water. Since the soil and local conditions vary so widely, there is no rule as to the number of waterings or time required for the different products. There is a general impression that in many cases too much water has been used and that in the future better crops can be matured by using the water more sparingly, as a result increasing the acreage. Shortage of water and loss of crops on irrigated land were reported by many of those whose rights to water were secondary to those of older claimants. The latter stated that as a rule there was ample water for their needs, excepting from the middle or latter part of June through July, August, and into September. Many of the field crops should have matured before this time, so that what little water remained could be used for orchards, vineyards, and alfalfa. The improved lands of the territory are too valuable to be given up to the ordinary field crops and cereals, but could be utilized to a greater extent in the production of high grades of semitropic fruits or of plants which, while flourishing in Arizona, are less successful elsewhere. Especially is this the case if water storage is to be utilized to any great extent, for the capital invested in such enterprises must necessarily be so great that the ordinary field crops can hardly be remunerative. Many projects of this character are on foot, but progress has been slow, since large capital is required, and there has been very little definite information upon which to base engineering computations.

DEEP WELLS.

In this territory no flowing wells were reported upon farms in June, 1890. Deep wells have been drilled in various places, but so far as reported without success. At Phenix a well has been drilled to the depth of 700 feet, and on the plains of the Gila water at various depths has been sought. On the road between Mesaville and Florence is a well several hundred feet in depth, from which water is drawn by horse power. In the Verde valley, in the central part of the territory, it is claimed there is a flowing well, but the facts concerning it have not been ascertained.

Near Pima, in Graham county, a well was drilled to the depth of 420 feet without success, and in Pima county, at Calabasas station, a well is said to have been drilled 700 feet, but no water ever flowed from it. At various points along the Southern Pacific railroad are comparatively deep wells, from which water is pumped by steam or by windmills. At Yuma are wells from 75 to 100 feet in depth, pumped in this manner, the water being used to a very small extent for irrigation. None of these wells flow, but it is reported that in one case at least the water comes to within 20 feet of the surface.

RAINFALL.

The table on the following page gives the principal data concerning the amount and distribution of precipitation in Arizona. It shows the mean monthly and annual rainfall at stations where measurements have been made for two years or more. (*a*) According to this table the mean annual rainfall at stations in the territory varied from 3.06 inches at Yuma up to 25.57 at Goodwin, in Graham county, a number of localities in the mountains showing a mean annual rainfall of 20 inches and over.

a Report by the Chief Signal Officer of the army (Fifty-first Congress, second session, House of Representatives, Executive Document No. 287, Irrigation and Water Storage in the Arid Regions, February 28, 1891).

MEAN MONTHLY AND ANNUAL RAINFALL AT STATIONS IN ARIZONA.

[T. indicates a trace of rain, less than 0.01 inch.]

LOCALITIES.	Altitude in feet.	Length of record. Yrs.	Length of record. Mos.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Apache county:																
Holbrook	5,047	3	10	0.54	0.71	0.72	0.67	0.16	0.12	1.51	1.40	1.18	0.68	1.08	0.72	9.29
Fort Apache	5,050	18	10	1.34	1.80	1.65	0.84	0.47	0.72	4.04	4.20	1.54	1.34	1.17	1.93	21.04
Fort Defiance	6,500	*a*9	2	0.98	0.70	0.84	0.67	0.52	0.72	2.44	2.73	1.86	0.70	1.16	0.87	14.19
Cochise county:																
Wilcox	4,164	*a*9	9	0.89	0.90	0.92	0.08	0.12	0.21	2.37	2.70	1.21	0.67	0.44	0.84	11.35
Benson	3,580	9	10	0.50	0.45	0.51	0.02	0.09	0.29	1.77	2.23	0.71	0.50	0.24	0.75	8.06
Fort Bowie	4,781	23	2	1.11	1.77	1.27	0.19	0.28	0.69	3.28	2.90	1.34	0.57	0.74	1.27	15.41
Fort Huachuca	4,785	4	8	0.80	1.27	0.97	0.11	0.15	0.39	4.29	2.92	2.61	0.94	1.02	0.95	16.42
San Simon	3,611	*a*8	5	0.27	0.28	0.53	0.02	0.11	0.04	0.55	1.64	0.22	0.30	0.24	0.39	4.59
Gila county:																
Fort San Carlos	3,456	*a*9	3	1.22	1.63	1.38	0.31	0.22	0.24	1.85	2.43	0.91	0.75	0.67	1.85	13.46
Graham county:																
Fort Thomas	2,700	10	6	0.84	1.18	1.08	0.35	0.45	0.26	2.03	2.31	0.93	0.63	0.48	1.30	11.84
Camp Goodwin	2,650	*a*3	11	2.41	1.82	1.04	1.30	T.	0.69	3.35	5.78	3.80	1.39	1.18	2.81	25.57
Fort Grant	4,860	*a*17	2	0.92	1.24	1.13	0.38	0.29	0.65	3.86	3.22	1.84	0.94	0.86	1.52	16.85
Maricopa county:																
Fort McDowell	1,250	*a*23	10	1.06	1.24	0.74	0.42	0.13	0.12	1.26	1.48	0.94	0.42	0.81	1.76	10.38
Phenix	1,068	12	9	0.56	0.87	0.67	0.32	0.12	0.09	0.72	1.02	0.65	0.57	0.54	1.25	7.38
Burkes	......	3	0	0.10	0.68	0.18	0.11	0.07	T.	0.02	1.44	0.57	0.02	0.41	0.28	3.88
Wickenburg	1,400	*a*8	1	1.07	1.10	0.80	0.52	0.30	0.02	0.81	1.99	0.66	0.18	0.51	1.89	9.85
Pima county:																
Fort Lowell	2,400	*a*19	5	1.14	1.15	0.83	0.28	0.10	0.30	2.47	2.79	1.38	0.45	0.52	0.96	12.37
Fort Buchanan	5,330	3	11	1.47	1.51	0.20	0.60	0.14	0.82	5.25	6.16	2.03	1.16	1.09	1.15	21.58
Camp Crittenden	2,000	4	10	0.55	1.09	0.65	0.26	0.05	0.31	6.01	4.70	0.85	0.19	0.28	1.57	16.51
Pinal county:																
Breckenridge	3,800	*a*6	10	1.00	0.76	0.45	1.21	0.10	0.50	4.64	4.08	1.95	0.06	1.19	1.09	17.03
Maricopa	1,190	13	8	0.44	0.46	0.69	0.14	0.07	0.06	0.40	0.91	0.47	0.34	0.35	0.84	5.17
Yavapai county:																
Camp Date Creek	3,726	*a*6	3	0.92	1.58	0.95	1.03	0.13	0.24	3.19	3.39	0.29	0.46	0.64	1.40	14.22
Whipple Barracks (Prescott)	5,389	23	11	1.45	1.78	1.68	0.98	0.58	0.17	3.03	2.88	1.18	0.66	0.82	1.85	17.06
Yuma county:																
Yuma	141	14	11	0.39	0.45	0.18	0.12	0.06	T.	0.13	0.40	0.13	0.21	0.35	0.64	3.06
Texas Hill	355	*a*11	0	0.58	0.27	0.27	0.10	0.03	....	0.08	0.45	0.34	0.61	0.26	0.48	3.47

a Record broken.

CONDITION OF IRRIGATION IN EACH COUNTY.

The following table gives some of the fundamental data of irrigation during the census year in each of the counties of the territory. Upon an examination of the figures it will be noticed that in general the value of products per acre increased as the average size of farm diminished. For example, in Maricopa county the average size, 108 acres, was the greatest in the territory, while the value of product, $9.26 per acre, was the least. Next comes Yuma county, with 93 acres per farm and products averaging $10.50 per acre, then Pinal, with 60 acres per farm and products of $11.25 per acre. In other words, the large irrigated farms were not as closely tilled as were the smaller, and a lower priced crop resulted.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN EACH COUNTY IN ARIZONA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS. (*a*) Total number.	OWNERS OF FARMS. (*a*) Per cent of population.	IRRIGATORS. Per cent of farm owners.	IRRIGATORS. Per cent of population.	Area of county in acres.	FARM AREA. Acres.	FARM AREA. Per cent improved.	Cereals in acres.	Alfalfa in acres.	AREA IRRIGATED. Per cent of area of county.	AREA IRRIGATED. Per cent of total farm area.	AREA IRRIGATED. Per cent of land owned by irrigators.	Average value of products per acre.
Total	1,075	65,821	61	1,426	2.39	75.39	1.80	72,268,800	1,297,033	8.03	22,701	19,945	0.09	5.07	43.21	$13.92
Apache	182	5,545	30	253	5.01	71.94	4.25	13,478,400	1,085,535	0.73	3,693	856	0.04	0.51	32.56	13.36
Cochise	52	2,372	46	192	2.77	27.08	0.75	3,842,560	31,513	19.65	242	614	0.06	7.53	31.75	26.93
Gila	18	815	45	18	0.89	100.00	0.89	2,055,680	3,080	22.53	375	23	0.04	26.46	26.46	23.85
Graham	199	7,556	38	201	3.54	99.00	3.51	3,937,280	23,533	38.55	4,823	1,741	0.19	32.11	37.33	16.06
Maricopa	327	35,212	108	336	3.06	97.32	2.98	6,330,880	61,888	78.79	9,216	12,193	0.56	56.90	60.14	9.26
Mohave	....	....	....	14	0.97	....	....	7,252,480	1,781	21.45	10	202	....	....	....	....
Pima	85	3,085	36	114	0.90	74.56	0.67	6,781,440	31,852	16.24	643	891	0.05	9.69	33.17	30.36
Pinal	115	6,910	60	124	2.92	92.74	2.71	3,392,000	20,804	40.39	2,066	1,534	0.20	33.26	37.09	11.25
Yavapai	91	3,762	41	161	1.85	56.52	1.05	18,711,040	32,417	52.34	1,025	1,716	0.02	11.61	26.22	31.00
Yuma	6	555	93	13	0.49	46.15	0.22	6,487,040	4,630	12.63	8	175	0.01	11.99	15.50	10.50

a Includes owned and hired farms, assuming one farmer to each.

APACHE COUNTY, located in the northeastern corner of Arizona, is second in size in the territory and sixth in the whole United States. The Navajo and Moqui Indian reservations cover the northern end of the county, and the White Mountain Indian reservation is located partly in the southern end, while between these are the railroad grants, leaving relatively little land open for settlement. The Little Colorado flows across the center of the county, and then turning northwesterly flows through narrow canyons to the Colorado. The principal towns are along the Little Colorado and its tributaries entering from the south, where there are areas of good agricultural lands. As a rule irrigation is required, although, especially at altitudes of 7,000 feet and upward, some dry farming is reported to be successful. The water supply is somewhat limited, scarcity being felt especially in June, July, and August.

A number of small irrigating ditches have been reported at Show Low, Taylor, Snowflake, and other points on Silver creek; also at Springerville, St. Johns (the county seat), Woodruff, St. Joseph, and other points on Little Colorado river. The principal crops irrigated were corn, oats, alfalfa, and beans. In the vicinity of Taylor are the ditches covering both sides of the valley and irrigating lands in the vicinity of Taylor and Snowflake. These ditches are from 3 to 4 miles long, and have cost in all about $25,000. Work was begun in 1877, and the ditches were practically completed within a few years. Water rights have cost from $12 to $15 per acre, and the annual assessment has been from 90 cents to nearly $5 per acre, the latter large amount owing to injuries by flood. It is stated that it is usual to give 3 good waterings to wheat and oats, 2 for a crop of corn, and 1 or 2 irrigations for each cutting of alfalfa.

At Springerville, south of St. Johns and on the headwaters of Little Colorado river, are several ditches on both sides of the stream. The principal ones were begun in 1872 and used in the following year. They are owned mainly by private parties, who share the expense. This is estimated to be annually about $1.25 per acre. At St. Johns the main ditch is known as the Gibbons or Mill ditch. It is about 4 miles long, 6 feet wide, and has cost probably $10,000. The principal crops irrigated are wheat, corn, barley, and oats. The St. Joseph ditch heads about 12 miles from Holbrook and covers land on the north side of Little Colorado river. It is about 7 miles long, 6 feet wide, and with the dam has cost about $45,000. This latter, it is stated, has been replaced 8 times within 14 years. The first cost of water right was about $7 per acre, but the annual assessments, the greater part of which have been for repairing the dam, have been from $2 to $5 per acre.

Attempts have been made to obtain flowing wells, and the board of supervisors of the county, in compliance with an act of legislature, has offered a reward of $2,000 to any person who should first obtain a flowing stream of water of not less than 17,500 gallons per day, such well, however, not to be upon military or railroad lands nor within 10 miles of any other flowing artesian well nor within a mile of any permanent flowing stream of water.

COCHISE COUNTY is in the southeastern corner of the territory bordering upon New Mexico and the republic of Mexico. In general altitude it ranges from 3,000 to 6,000 feet and upward. Agricultural lands are to be found in nearly all of the valleys or broad plains, the principal irrigated areas being on the western side of the county along San Pedro creek and its tributaries, mainly in the vicinity of Hereford, Fairbanks, Benson, and Tres Alamos. This stream furnishes the greater part of the water supply of the county, the other rivers and creeks being of such an intermittent character that irrigation is exceedingly difficult. Even in the case of the San Pedro there is far more land than the water will supply, and as a result litigation has arisen concerning the water rights. During periods of drought the entire amount of running water is diverted by the various dams across San Pedro creek, some water reappearing in the channel to be again taken out at points below.

Around the edge of Sulphur Spring valley, which occupies the center of the county, a small amount of irrigation has been practiced, mainly for the purpose of raising hay or for increasing the area of grazing lands. It is reported that in many localities wells reach water at from 10 to 40 feet, and it is probable that some of this can be brought to the surface with profit by means of pumping machinery. Deep wells have been drilled in the hope of obtaining artesian water, but so far as can be ascertained these have not been successful. Among the higher mountain valleys small crops have been raised without irrigation, but as a whole it may be said that this method of cultivation is essential throughout the county, and especially so for fruits. With an ample supply of water, orchards and vineyards are exceedingly profitable.

GILA COUNTY, the smallest in the territory, occupies a position largely within the drainage basin of the Salt river, on the south crossing the mountains and reaching to the Gila river. On account of its position it is comparatively well watered, but the valleys are narrow and there is little arable land. The White Mountain Indian reservation covers the greater portion of the county, leaving only a narrow strip of land on the western side. The tilled land is principally along the Salt river, between Pinal and Tonto creeks, or in their vicinity. Among the headwaters of Tonto creek and in the Tonto basin, at an elevation of from 6,000 to 7,000 feet, corn and potatoes are raised without irrigation if the land is carefully tilled. Other crops require the artificial application of water.

GRAHAM COUNTY lies to the southeast of Gila, between Apache and Cochise counties, filling in the eastern side of the territory. It is thus in or near the headwaters of the Gila river, and, like Gila county, is largely mountainous. The principal area of agricultural land is in the Pueblo valley, extending from a canyon above Solomonsville for about 30 miles to Fort Thomas, the principal settlements being, in order, Solomonsville, Safford, Central, and Pima. The Gila is the source of supply for the valley. A number of dams are placed across it at intervals of 2 miles or more. When the flow of the stream diminishes in May and June the dams of logs, brush, and stone are tightened so as to turn all the water into the canals. Below each dam, however, the water begins to rise in the bed of the stream, so that by the time the next dam is reached there is apparently as much water as before. If the summer rains fail the river may become entirely dry in July and August, loss of crops resulting.

At present the acreage under cultivation is not greatly in excess of the usual water supply, and the losses are not such as to call for immediate water conservation. In view of future extensions, it is already recognized that active steps must soon be taken. There appears to be no comprehensive system of water distribution, and the present needs point to a consolidation of the various small ditches into a few high-line canals, both to reduce the expenses and to effect a greater economy in the use of the water. The river, occupying a wide sandy bed, is unstable, and during freshets is liable to cut new channels, leaving the dams on dry land. Some cultivation by irrigation is successful in the valleys south of the river at the foot of the mountains, where small streams or springs issue. The greater portion of this water is lost for lack of facilities for holding the spring flow until later in the season.

As examples of the irrigating ditches brief descriptions may be given as follows: the Union irrigation canal heads about 1.5 miles northwest of Solomonsville. It is 13 miles long, 12 feet wide, and has cost $15,000. The Graham ditch heads about 2 miles east of Safford, taking water out on the north side of the river. It is 4 miles long, about 6 feet wide, and has cost over $2,000. The work was begun in 1879, and it has been enlarged since that time. It is owned by farmers, who divide the water and share the annual expenses, which are estimated to have been about $2 per acre. The principal crops irrigated are wheat, barley, oats, corn, beans, Irish and sweet potatoes, and garden vegetables. The Montezuma and neighboring ditches also cover land in the vicinity of Safford, water being diverted from the Gila by means of dams built of wood, stones, and brush. These dams are often washed out, increasing largely the annual expenditures. The ownership in most of the irrigation works is divided into shares, each entitling the owner to a certain proportion of the water. A water master, appointed by the irrigators, calls upon each when necessary to make repairs, or hires labor, which is paid for by a cash assessment.

In the vicinity of Pima are a number of ditches owned by asssociations of irrigators, who share the work and expense necessary to keep them in repair. The principal expense in these ditches is in rebuilding the diverting dams. The crops irrigated are alfalfa, barley, beans, and potatoes. Alfalfa is watered after each cutting, and the cereals receive 2 or 3 irrigations. Garden vegetables require irrigation every 8 or 10 days, orchards 5 or 6 wettings during the year, and vineyards 3. Difficulty has been experienced in obtaining sufficient water on account of the small size of some of these canals, although there is usually sufficient in the river. The owners are generally men of small means and are not able to construct or maintain the works in the most economical manner, and the water supply is not utilized as thoroughly as in the case of better equipped systems of supply.

MARICOPA COUNTY, in value and extent of irrigation, as well as in agricultural development, leads the others in the territory. It contains over one-half of the irrigated land and the greater number of the irrigating canals. The amount of land actually utilized in the census year was small in comparison with the area under these canals, and formed an almost insignificant part of the vast extent of arable land which with water could be rendered valuable. The results attained have shown that the lands of this county, especially those within the Salt river valley, when properly wet, can produce enormous crops, and when planted with trees and vines have the requisites for the successful cultivation of many of the most valuable fruits, rivaling in this respect favored portions of California. In some particulars the Salt river valley and the lands along the Gila are claimed to have advantages for fruit growing in that they are nearer the markets of the east, so that the green fruit is not only hauled a less distance, but also is saved a day's journey through the hot desert. It is asserted also that grapes and other fruits ripen earlier in the season and can be put on the market far in advance of the California products.

The principal irrigated areas are in the vicinity of Phenix, the territorial capital, and also near Mesa and Tempe, extending along both sides of Salt river from below the Verde and the Salt River Indian reservation westerly at intervals to and even below Gila Bend. The water supply is derived mainly from Salt river, large canals heading also on the Gila itself below the mouth of the first named stream. Taken as a whole, the water supply is large, but fluctuates greatly, having far less regularity than in the case of rivers farther to the north. Measurements of the amount flowing in the Verde and Salt have been made at various points by the United States Geological Survey, the most important of these being shown by the following tables:

VERDE RIVER, NEAR FORT MCDOWELL, ARIZONA.

(Drainage area 6,000 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET. Maximum.	Minimum.	Mean.	Total for month in acre-feet.	RUN-OFF. Depth in inches.	Second-feet per square mile.
1889.						
August 14 to 31	480	154	207	12,730	0.04	0.03
September	340	140	192	11,424	0.03	0.03

SALT RIVER, 50 MILES ABOVE PHENIX, ARIZONA.

(Drainage area, 5,880 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET. Maximum.	Minimum.	Mean.	Total for month in acre-feet.	RUN-OFF. Depth in inches.	Second-feet per square mile.
1890.						
May 28 to 31	520	523	520	31,980	0.10	0.09
June	520	193	298	17,731	0.06	0.05
July	375	185	215	13,222	0.04	0.04
August	2,200	600	1,362	83,763	0.27	0.23

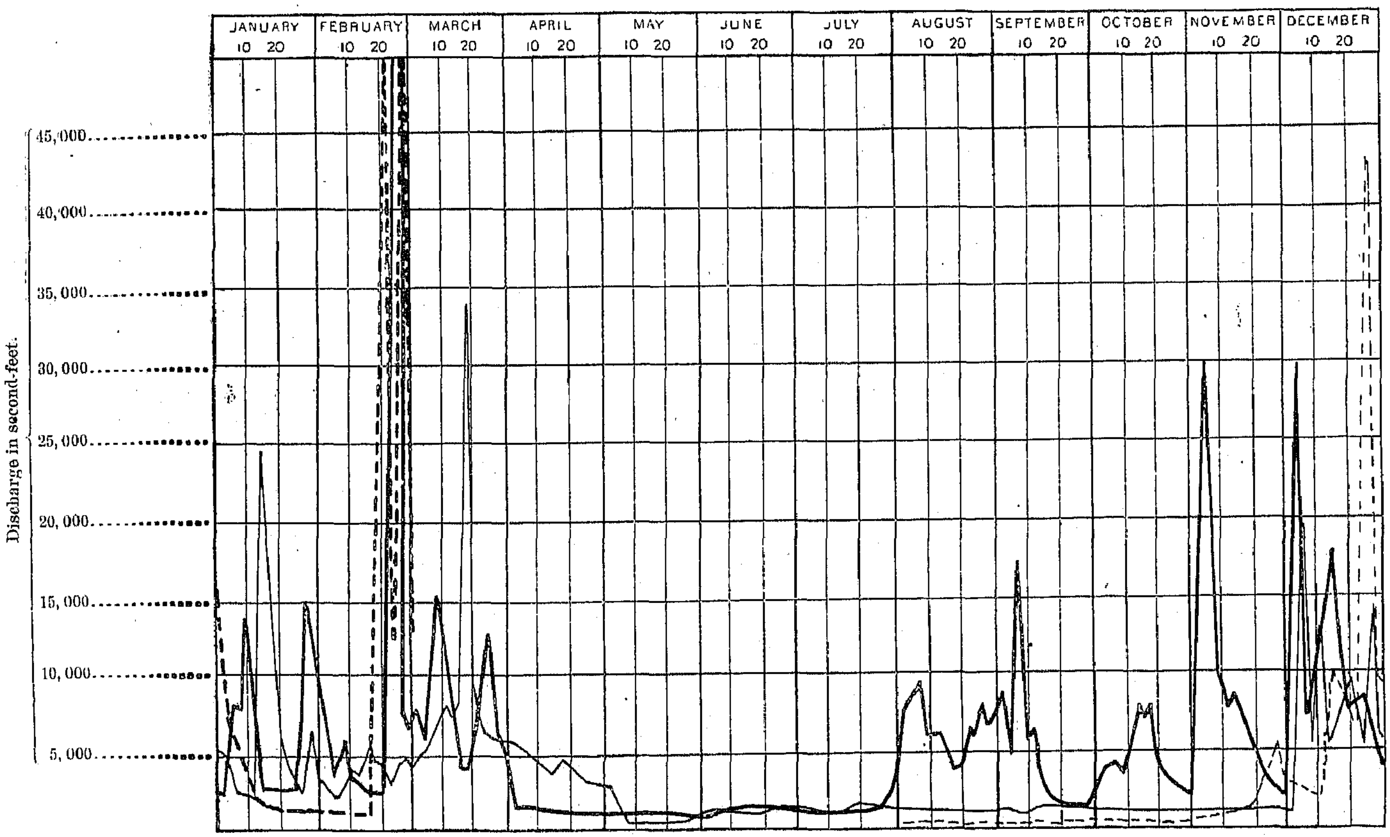
The longest series of observations have been carried on under the direction of Samuel A. Davidson at the headworks of the Arizona canal, of which he has been engineer. The results are shown by the table and diagram on the following page. On this diagram the discharge for 1888 is indicated by the lighter broken line, that for 1889 by the lighter continuous line, that for 1890 by the heavier continuous line, and for the following two months by the heavier broken line.

SALT RIVER AT ARIZONA DAM, ARIZONA. (*a*)

(Drainage area, 12,260 square miles.)

Months.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Run-off. Depth in inches.	Second-feet per square mile.
1888.						
August	....	....	350	21,525	0.03	0.03
September	....	....	350	20,825	0.03	0.03
October	350	300	331	20,356	0.03	0.03
November	5,760	425	842	50,099	0.08	0.07
December	43,489	1,665	6,698	411,927	0.63	0.55
1889.						
January	24,953	1,665	5,947	365,740	0.56	0.58
February	3,940	1,534	2,605	144,577	0.22	0.22
March	33,794	3,563	8,745	537,817	0.82	0.71
April	5,559	2,406	3,975	236,512	0.36	0.32
May	1,784	622	1,039	63,898	0.10	0.08
June	615	356	470	27,965	0.04	0.04
July	1,311	334	495	30,522	0.05	0.04
August	755	389	417	25,645	0.04	0.03
September	1,172	389	521	31,000	0.05	0.04
October	704	319	440	27,060	0.04	0.04
November	629	532	576	34,272	0.05	0.05
December	25,371	557	5,086	349,689	0.53	0.46
Per annum	33,794	319	2,576	1,874,697	2.86	0.21
1890.						
January	15,750	1,376	4,982	306,393	0.47	0.40
February	143,288	1,045	10,097	560,383	0.86	0.82
March	17,228	2,566	6,421	394,891	0.60	0.52
April	2,077	1,369	1,840	109,480	0.17	0.15
May	1,369	630	914	56,211	0.09	0.08
June	672	397	511	30,404	0.05	0.04
July	872	397	524	32,226	0.05	0.04
August	7,734	1,114	3,885	238,927	0.37	0.32
September	3,685	725	2,339	139,170	0.21	0.19
October	7,465	753	2,768	160,232	0.25	0.23
November	30,507	766	4,717	280,661	0.43	0.38
December	30,366	1,110	6,259	384,928	0.59	0.51
Per annum	143,288	397	3,771	2,693,906	4.14	0.31

DIAGRAM OF DAILY DISCHARGE OF SALT RIVER AT ARIZONA DAM, MARICOPA COUNTY, ARIZONA.



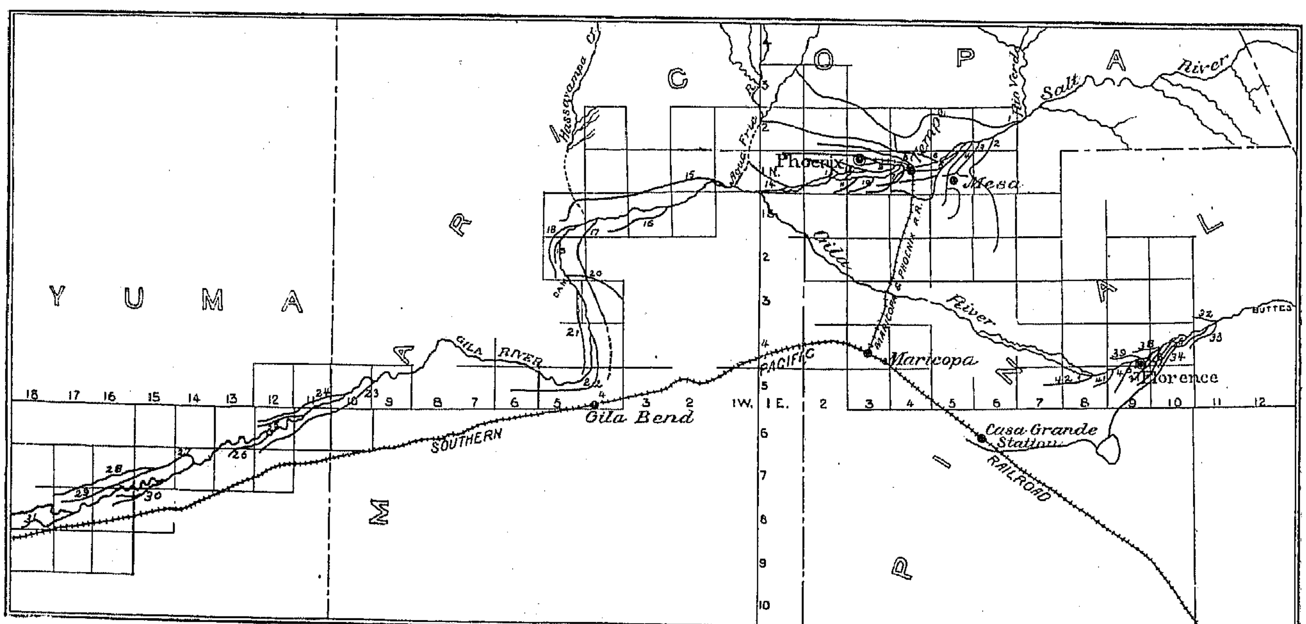
a Measurements of Salt river at Arizona dam were abruptly broken by the great flood of February, 1891. This flood, which reached an estimated maximum of 300,000 second-feet, seriously injured the dam and headworks of the Arizona canal and carried away nearly all the dams, bridges, and other obstructions in or near the river banks. The flow for two months in 1891 (estimated for February) was:

Months.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Total for month in acre-feet.	Run-off. Depth in inches.	Second-feet per square mile.
1891.						
January	17,127	1,060	3,416	210,084	0.32	0.28
February	300,000	825	39,201	2,175,055	3.32	3.10

Comparing the flow of this river with that of many of the other rivers discussed in this report, the most notable difference is the low water during April, May, and June, months when the streams of the rest of the country reached their highest. The suddenness with which these floods come and go in the Gila and its tributaries is in striking contrast to the slow rise and fall of the snow fed rivers upon which most of the irrigation in the United States depends.

The location of most of the more important canals of this and adjoining counties is shown on the accompanying map. Taking these along the Salt river in order downstream, the highest on the north side of the river is the Arizona, and below this the Grand, Maricopa, and Salt river valley, these 4 canals forming one system and covering lands north of and around Phenix. Farther downstream, below Phenix, are the Griffin, Farmers, St. John, and other ditches. On the south side of the river, and heading a short distance below the Arizona, is the Highland, whose general direction is nearly south, covering lands east of Mesa city. Below this come the Mesa, Utah, and Tempe canals, the latter irrigating lands immediately adjacent to the town of Tempe. Below this in order are the San Francisco, French, and Broadway. Below the junction of the Salt and Gila are a number of important canals projected and partially constructed. The first of these is the Buckeye, on the north side of the river, heading near the junction of the channel of the Agua Fria. About 25 miles west of this stream the channel of the Hassayampa enters from the north; the Gila swings to the south for about 20 miles and then again to the west, forming what is known as Gila Bend. Near the junction of the Hassayampa, on the right bank of the river, are the headworks of the Gila river and the Monarch canals, and about 8 miles below is the head of the Enterprise canal. On the left bank of the Gila river, halfway between Agua Fria and Hassayampa creeks, is the head of Rumberg's canal, and below this the proposed St. Louis canal. About 8 miles below Hassayampa is the dam of the Gila Bend Reservoir and Irrigation Company, one of the largest projects in the territory, the canal for diverting the water coming out toward the east and south. Below this is the Lower Gila Bend or Palmer canal.

MAP OF IRRIGATION CANALS IN THE GILA VALLEY, ARIZONA.



The figures near each canal line indicate the name of the canal, as shown by the following list:

1. Arizona.
2. Highland.
3. Mesa.
4. Utah.
5. Tempe.
6. Grand.
7. San Francisco.
8. Maricopa.
9. Salt River Valley.
10. French.
11. Broadway.
12. Griffin.
13. Farmers.
14. St. John.
15. Buckeye.
16. Rumbery's.
17. St. Louis.
18. Gila River.
19. Monarch.
20. Gila Bend Reservation and Irrigation Company.
21. Enterprise.
22. Lower Gila Bend.
23. South Gila.
24. Farmers.
25. Purdy.
26. Contreres.
27. Mohawk.
28. North Branch of Mohawk.
29. South Branch of Mohawk.
30. South Mohawk.
31. Antelope.

The Arizona canal diverts water from Salt river by means of a weir or dam over 900 feet long, located about a mile below the mouth of the Verde. The canal follows the bank of the river for a short distance and then gradually turns toward the northwest. Near the head the bottom width is 36 feet, narrowing to 30, and the estimated capacity nearly 1,000 second-feet, the grade being 2 feet per mile. For the first 3.5 miles the canal was excavated in rock or gravel, the expense of construction being heavy. Work was begun in 1883 and water was first used in 1887. The total length of the main ditch was 41 miles, and the cost, including the dam, about $600,000. After leaving the

Indian reservation lateral ditches run south toward Phenix covering every section. Water rights have been sold at the rate of $12.50 per acre, the annual assessment being $1.25 per acre.

It has been found that 1 second-foot of water was sufficient to produce crops of all kinds on 80 acres of land. For economical use a stream flowing at the rate of 2 second-feet is to be preferred, and with this quantity of water 10 acres of grain or alfalfa or 20 acres of fruit trees can be irrigated in 24 hours. The corporation owning this canal has purchased also the Grand, Maricopa, and Salt river canals, covering land under the Arizona, and which are now used largely as distributaries. The Grand canal is 27 miles in length and has an estimated capacity of 200 second-feet. The Maricopa is about 26 miles long, from 16 to 18 feet wide on bottom, and has a capacity of 140 second-feet. The Salt river canal, heading on the river at the same point as the Maricopa, these together being known as the Consolidated, has a width of 22 feet, a length of 26 miles, and capacity of about 160 second-feet. These are connected with the Arizona canal by means of a crosscut having a capacity of 375 second-feet.

The Mesa canal, heading on the south side of the river about 5 miles below the Arizona dam, takes water out in the vicinity of the town of Mesa. The total length of the main ditch is approximately 10 miles, the average width 15 feet, and the cost is placed at $75,000. Work was begun in 1878, and the canal was used in the following year. The diversion dam is of brush and stone and has been replaced after several floods. The works are owned by a corporation consisting of farmers, the property being held in 400 shares, each of these entitling the holder to a proportional part of the water. The cost of the water right was originally about $15 per acre, and the annual tax is about $1 per acre. It is estimated that water was used under this canal at the rate of 1 second-foot to 80 acres, although the theoretical water duty is far higher. This, as well as the adjacent canals, is being rapidly extended, bringing more land into use for fruit and alfalfa.

The Tempe canal is 24 miles long, about 25 feet wide, and has cost over $120,000. Work was begun in 1870 and water used in the following year. It is owned by an association, each share entitling the holder to 100 inches or about 2.5 second-feet, this amount being considered sufficient for 160 acres. The first cost of the water right was estimated to have been $10 per acre, and the annual assessment has varied from 20 cents to 30 cents per acre.

The Buckeye canal takes water from the Gila about 4 miles below the junction of the Salt, carrying it out on the north side. The river at this point as a rule flows the year round, but is stated to have been dry in extraordinary seasons. The total length of the main ditch is 28 miles, the average width 12 feet, and the cost was estimated to be $120,000. Work was begun in 1885 and water used in 1888. The ownership is divided into shares, each of these representing 80 miner's inches. The annual assessment is $1 per miner's inch. It is usually calculated that 80 inches will furnish sufficient water for 160 acres.

The dam of the Gila Bend Reservoir and Irrigation Company is located about 45 miles southwesterly from Phenix and 22 miles north of Gila Bend station. The canal from this is being constructed along the left bank of the river and southerly toward Gila Bend station, it being proposed to continue this along and across the Southern Pacific railway, thus covering an immense area of fertile land. The Lower Gila Bend canal heads about 10 miles below the dam of the canal just mentioned and covers a narrow strip of land on the same side of the river. The total length of the main ditch is 15 miles, the average width 11 feet, and the cost was $25,000. The canal was begun in 1884 and first used in 1885. Water is diverted by means of a dam of brush and stone replaced in whole or part each year. The works are owned by farmers and held in 36 shares, each entitling the holder to a proportional part of the water.

MOHAVE COUNTY occupies the extreme northwestern corner of the territory, adjoining Utah and Nevada. An exceedingly small amount of cultivation was reported, the total area in cereals being only 10 acres of wheat and the total production 25 bushels. Cattle raising was about the only industry of importance. During and before the census year attempts at farming were made along Sandy creek, but the floods of 1889 are reported to have washed away more than half the farming land, and apparently it was only a question of a short time before the rest would be destroyed. Taking the county as a whole there is plenty of agricultural land, but the difficulty of obtaining water stands in the way of development. Hay and grain for the mining camps have been brought from California, and butter, eggs, bacon, and similar supplies from Kansas. The Colorado river forms a portion of the western boundary of this county and carries at all times a large amount of water. Little, if any, of this can be utilized on account of the depth to which the river has cut below the arable lands. The difficulties of taking out the water of this river appear to be almost insurmountable, although it is possible that by the expenditure of large sums lands in the southeastern part of California may be reclaimed. A few measurements of the actual quantity of water in the Colorado were made in 1875 and 1876, showing that the discharges at the times of observation varied from 8,000 to 18,000 second-feet, and probably reached during flood 50,000 second-feet.

PIMA COUNTY is situated along the central part of the extreme southern border of the territory adjoining Mexico. Agriculture is confined to the eastern end, near Cochise county, where the elevations range from 2,500 feet upward. The Santa Cruz and Sonoita and their tributaries are the only sources of water supply, with the exception of a few springs among the foothills of the mountains. The amount of water is small in comparison to the acreage already under cultivation, and crops are frequently lost during the dry season. A number of ditches are taken out in succession along the Santa Cruz from Calabasas down to Tucson. In the vicinity of Crittenden is the Pennsylvania Ranch ditch, 7 miles long and 3 feet wide, receiving its water mainly from the springs of Sonoita creek, corn, alfalfa, and barley being irrigated. At the junction of the Sonoita with the Santa Cruz, about 8 miles north of Nogales, is a ditch 4 miles long and 3 feet wide, which is stated to have cost $800. Among the ditches farther down on the Santa Cruz is one on the west side, taking water out in the vicinity of San Xavier, 4 miles in length and from 2 to 8 feet in width. The annual cost of water is estimated to be 50 cents per acre. Farther north, in the vicinity of Tucson, is the Goodwin ditch, covering land on the east side of the river. It is 3.5 miles long, about 3 feet wide, and has cost $2,500. Water is obtained from an open cut, penetrating the bed of the river to a depth of about 6 feet. The Davidson canal takes water from Rillito creek, a stream usually dry on the surface for about one-half of the year, the sandy channel, however, being saturated with water. Work was begun about 1887, and the cost before completion had already reached $25,000. It is proposed to draw the water from a depth of 14 feet beneath the surface by means of a drain or aqueduct 4 feet 6 inches wide and 3 feet 6 inches high at the sides. This is to be so protected that floods will pass over it without injuring it. The object sought is to secure a permanent supply of water in order to guarantee the success of orchards and vineyards. The ordinary surface ditches are not always sure of receiving water, and while annual crops can be raised, vineyards and orchards have been lost or injured by total failure of supply.

PINAL COUNTY includes a portion of the Gila valley above the mouth of Salt river, and in some respects possesses advantages for irrigation as great as those had by the lands in the vicinity of Phenix. The agricultural land now utilized is mainly in the vicinity of Florence, along the river below the point where it cuts through a transverse range of hills or mountains. Above this point, along and below the mouth of San Pedro creek, is a second district in which irrigation is practiced, water being obtained from the creek at various points above the town of Dudleyville and also from the river in the valley below that place. The cereal most cultivated is barley, next in importance to this is wheat. Large acreages have been devoted to alfalfa, and each year the area in orchards and vineyards steadily increases.

The quantity of water available has been measured for one year only. The gauging station on the Gila was located about 15 miles above the town of Florence, at the Buttes, being thus above the head of canals and where, owing to the character of the channel, the best results could be obtained. The following table gives the computed discharge. This was a year of prevailing low water, and there were few of the sharp, sudden floods so characteristic of the stream. One of these occurred in August, 1890, just previous to the abandonment of the station. (a)

GILA RIVER AT BUTTES, ARIZONA.

(Drainage area 13,750 square miles.)

MONTHS.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.		MONTHS.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.		Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.							1890.						
August 26 to 31	124	110	115	7,072	0.009	0.008	January	2,100	310	680	41,820	0.057	0.049
September	210	90	128	7,616	0.010	0.009	February	1,514	405	578	32,079	0.044	0.042
October	210	140	157	9,655	0.013	0.014	March	710	300	387	23,805	0.032	0.028
November	250	156	212	12,614	0.017	0.015	April	333	158	238	14,161	0.019	0.017
December	890	124	275	16,912	0.023	0.020	May	150	35	87	5,350	0.007	0.006
							June	35	27	28	1,666	0.002	0.002
							July	3,112	11	130	7,995	0.011	0.009
							August	6,330	1,115	3,137	192,925	0.262	0.228

San Pedro creek was gauged for a time during the summer of 1890, and discharges were computed, as shown in the table on the following page. As previously stated, the low water prevailed during this year and little irrigation was possible from the waters of this stream. Above the point of measurement there were at the time a number of ditches, mainly of from 1 to 2 miles in length, taking out water, so that, omitting the small floods which occasionally occurred and lasted for a few hours, the quantity measured may be considered perhaps as representing the seepage water. Although this stream has a large catchment area, the run-off, like that from adjacent basins, is exceedingly small.

a The greatest flood known in years happened in February, 1891, the total amount of which, however, has not been approximated.

SAN PEDRO, AT DUDLEYVILLE, PINAL COUNTY, ARIZONA.

(Drainage area 2,819 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1890.						
April 9 to 30	21	5	14	833	0.005	0.005
May	9	5	6	369	0.002	0.002
June	5	1	3	179	0.001	0.001
July	225	1	13	800	0.005	0.005
August	507	102	295	18,140	0.121	0.105

The necessity of water storage is perhaps as well appreciated in this county as in any part of the territory. During the census year there was unprecedented scarcity of water, due not only to a diminution of river flow, but to an increased diversion on the part of all the ditches, most of which had been gradually enlarged from time to time. Surveys have already demonstrated the feasibility of holding flood waters at various points, particularly in the valley above the Buttes, 15 miles from Florence.

The principal ditches on the north side of the Gila river are Moore, McLellan, Stiles, and Swiss; on the south side, Brash, the Florence canal, Montezuma, Holland, Alamo Amarilla, Brady, Adamsville, White, and Walker. Nearly all of these are owned by individuals, the principal exceptions being the Florence canal and the Montezuma and Alamo Amarilla ditches. The McLellan ditch heads about 10 miles above Florence, covering lands on the north side of the river. It is over 5 miles in length, 4 feet in width, and the cost was probably $5,000. Work was begun in 1871, and the ditch was finished in 1872. Water is diverted by means of a dam composed of triangular cribs loaded down with rock and covered with brush and stone. There is generally an ample supply, but need of water is sometimes felt in June, July, and August. The first crop raised consists mainly of barley, wheat, beans, and early corn, and the second crop of beans, corn, sweet potatoes, pumpkins, watermelons, and sugar cane. Water is usually turned into the ditch in October and November, and used until the end of the spring floods. It is stated that the water in this part of the river has been diminishing for 6 years, owing probably to diversions from the San Pedro and from the Gila near Solomonsville and other towns. The Swiss ditch takes water from the north side of Gila river in the vicinity of Florence. It is about 4 miles long, 10 feet wide, and probably cost about $2,500. It was begun in 1872 and used in the same year. The water supply at this point is often insufficient, generally on account of the fact that it is diverted at points above by other canals having prior rights. The need is felt most in May, June, and July, and sometimes in August. The principal crops irrigated are alfalfa and grain, the latter being cut sometimes for hay, and besides these, garden vegetables and fruit trees are watered regularly.

The Florence canal heads about 12 miles above the town of that name and, coming out of the south side of the river, it is continued beyond the town in a southwesterly and southerly course nearly to the Southern Pacific railroad. The total length is reported to be upward of 50 miles, the average width 20 feet, and the cost was placed at $400,000. Work was begun in 1886, and water was first used in 1888. The diverting dam is of brush and is replaced each year. The canal is owned by a corporation which sells water rights at the rate of $8 per acre above the reservoir and $12.50 per acre below the reservoir. The annual assessment is $1.25 per acre. A reservoir has been constructed about 25 miles from the head of the canal, having an area of 1,800 acres and an estimated storage capacity of 6,000,000,000 gallons. Besides this it is proposed to construct another reservoir at the Buttes, about 3 miles above the head gates.

YAVAPAI COUNTY, the largest in the United States (*a*), comprises about one-fourth the area of Arizona. The county contains an exceedingly small proportion of irrigable land, since it includes that part of Arizona adjoining Utah which contains the greater portion of the grand canyons of the Colorado. These stupendous gorges cut the great plateau to the depth of from 3,000 to 6,000 feet. The minor lateral canyons, in which flow the tributaries of the Colorado, are also cut to a great depth, which decreases toward their head waters. Thus the water of the northern part of the territory, though large in amount, is wholly useless, lying as it does hundreds and thousands of feet below the level of the arable lands. It is only toward the southern portion of the county, where the great plateau begins to break off and the valleys are less deep and narrow, that agriculture has been seriously attempted. Along the line of the Atlantic and Pacific railroad, which crosses the county from east to west, at an elevation of from 5,000 to 7,000 feet, some crops, especially for forage, are raised without irrigation. For example, at Flagstaff, at an elevation of about 7,000 feet, corn, potatoes, and vegetables, as well as a little wheat, oats, and barley are thus cultivated, the cereals being generally cut for forage purposes. The same is true of Prescott, although near that place irrigation has been employed wherever practicable. On the head waters of the Agua Fria, at an elevation of about 4,500 feet, there is also a little dry farming.

a Since 1890 Yavapai county has been divided, the northern portion, with Flagstaff as the county seat, being set off under the name of Coconino.

The principal bodies of irrigated lands are along the Verde river and its tributaries, Oak, Clear, Beaver, and other creeks, both above and below Camp Verde, where a number of small ditches have been built by farm owners. On Walnut creek, which heads west of Prescott and flows northerly into Big Chino valley, and on Granite creek to the east, all the available waters are utilized and the irrigators are discussing the feasibility of water storage. On the head waters of Hassayampa river, a short distance southerly from Prescott, two dams have been built, mainly for the purpose of supplying water for hydraulic mining. The upper of these, that at Oro Fino, was built about 1885, the height being about 20 feet. It is located near the mouth of the upper canyon, below which is the farming land of Walnut Grove valley. This is about 7 miles in length and from 1 to 3 miles in width. At the foot of this valley the Walnut Grove Water Storage Company built the dam the destruction of which by a great flood in February, 1890, caused large loss of life and property. This dam was 420 feet long on top, 138 feet wide at bottom, 15 feet wide at top, and 110 feet in greatest height. It was planned to use the water both for placer mining and purposes of stock raising on the plains of the valleys below.

YUMA COUNTY, occupying the southwestern corner of the territory, comprises lands having the lowest altitude and the hottest climate of Arizona. In these respects it is surpassed by the desert regions of San Bernardino and San Diego counties, California, portions of which are far below sea level. This area possesses the advantage of having a fair water supply from the Gila, which flows westerly through it into the Colorado, which forms the boundary between Arizona and California. Along the Gila are several places where water can be brought out by means of canals, and the lands thus irrigated are capable of producing semitropical fruits. The Colorado itself, as previously stated, probably can not be used to any great extent for irrigation in this territory, owing to the almost insurmountable difficulties of diverting water. Small bodies of land are being brought under irrigation by means of pumps, raising water to lands upon or above the flood plains. This method of obtaining the water supply, although expensive, can probably be made profitable, owing to the value of the fruits produced.

Along the Gila the principal canals projected or constructed are, on the north side, the Farmers, Purdy, and Mohawk, and on the south side the South Gila, Contreres, South Mohawk or Saunders, and Antelope, the relative location of these being shown on the map. (*a*) The Saunders is probably the oldest canal along this part of the river, having been used first about 1868, but not completed until 1884. It is 10 miles long, 8 feet wide, and has cost $25,000. It is owned by a company which uses the water upon its own land. The annual cost for water is about 50 cents per acre. The principal crops are alfalfa and barley, for the former of which almost constant irrigation is considered necessary.

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a Some of these schemes for diverting water were abandoned or modified, owing to the disastrous flood of 1891, which carried away much of the preliminary work along the banks.