THE SUBHUMID STATES.

In the subhumid states, namely, North Dakota, South Dakota, Nebraska, Kansas, and Texas, 66,965 acres, or 104.63 square miles, were irrigated in the census year ending May 31, 1890. The aggregate number of farms upon which irrigation was practiced was 1,552, the average number of acres per farm being 43. The term "subhumid" as applied to extensive areas in the United States includes belts of country on each side of the arid region, these forming the debatable ground between it and the comparatively well watered regions east or west. The western subhumid region is much narrower than that on the east and the states crossed by it lie for the greater part within the arid region. On the other hand, the subhumid region on the east, crossing broad prairies, includes the greater part of the states above named. In this discussion of irrigation by states and territories it becomes a matter of convenience to classify these states under the one designation of subhumid, although their eastern ends are within humid regions, and in the case of Texas, at least, the western prolongation lies far within the arid region.

The following table gives for each of the states under discussion the number of irrigators and other items. This table has been obtained by compilation of the enumerators' returns for each irrigator in these states. Classifying these according to size, it has been found that of the 1,552 irrigated areas 7 were of 640 acres or upward, 12 of from 320 to 640 acres, and 40 of from 160 to 320 acres. These 59 areas contained an average of 341 acres each, or in all 20,146 acres, a little under one-third of the entire amount in the 5 states. The remaining 1,493 irrigated areas, under 160 acres in size, averaged 31 acres each and comprised 69.92 per cent of the total.

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

COMPARISON OF COSTS AND VALUES.

The average first cost of bringing water to the land throughout these 5 states, as estimated from the statements of the farmers, was $4.07 per acre, while the average selling value placed by the irrigators upon their water rights wherever these were transferable was $14.81 per acre. The average annual expense of water rental or of maintaining the ditches was $1.21 per acre, and the average cost of preparing the ground for cultivation, excluding the cost of bringing water to the land, was $4.62 per acre, as given by the farmers.

In the following table the more important of the foregoing statements are compared with those for the adjoining states on the west, namely, Montana, Wyoming, Colorado, and New Mexico:

COMPARATIVE CONDITIONS OF IRRIGATION, SUBHUMID AND OTHER STATES, 1889.

ITEMS.	Montana.	Wyoming.	Colorado.	New Mexico.	Subhumid.
Area irrigated in census year, in acres	350,582	229,676	890,735	91,745	66,965
Number of irrigators	3,706	1,917	9,659	3,085	1,552
Average size of irrigated farms, in acres	95	120	92	30	43
Average size of irrigated farms of 160 acres and upward, in acres	307	494	307	312	341
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated.	50.37	65.18	49.34	21.45	30.08
Average size of irrigated farms under 160 acres, in acres	56	50	55	24	31
Average first cost of water rights per acre	$4.63	$3.62	$7.15	$5.58	$4.07
Average annual cost of water per acre	$0.95	$0.44	$0.79	$1.54	$1.21
Average first cost of preparation for cultivation per acre	$8.29	$8.23	$9.72	$11.71	$4.62

GENERAL DESCRIPTION.

The country under discussion forms part of the Great Plains region lying west of the Mississippi and extending to the base of the Rocky mountains. The surface of this plain rises as a whole toward the mountains, the increase altitude on a line through Kansas and Colorado, for example, being from 1,500 feet up to 5,000 feet in a distance in of 400 miles, or under 9 feet per mile. The Rocky mountains in the northern half of their length in the United States have a decided trend to the northwest, and the plains sweep around far to the west, extending in northern Montana even beyond the meridian of Salt Lake city. Taking any north and south line nearly at right angles to the greatest slope and passing, for example, through western Kansas, it is found that the plains for the most part descend from the south toward the north, the highest points being on the Llano Estacado of Texas, where the general altitude is about 4,000 feet. On going northerly from this locality, and neglecting the river valleys, the surface through western Kansas is found to be at an altitude of about 3,000 feet, continuing, with slight undulations, to South Dakota, where the surface is about 2,000 feet, finally dropping off to or even below 1,500 feet on the north line of Dakota. This gradual northerly slope of the Great Plains counteracts to some extent the differences in climate due to the position farther to the north, so that the contrasts in temperature and in other climatic factors are not as great as might be expected.

The soil of this region, taken as a whole, is as rich as that of any part of the United States, and in almost every respect, save that of moisture, the country is an ideal one as regards agriculture, but unfortunately the lack of rain at critical times during the summer, together with the occasional hot winds so destructive to vegetation, renders doubtful the success of farming by ordinary methods. The amount of rainfall and the time of occurrence vary widely from year to year, decreasing as a whole for a few years and then increasing for longer or shorter periods, the duration of these oscillations being a matter of uncertainty. These nonperiodic oscillations of the annual rainfall are more noticeable in such a country, where in ordinary years there is hardly enough to mature the crops, for in the years when the amount of precipitation during the summer is a little above the average the crop yield may be phenomenally large. On the other hand, during years of scanty rainfall the crops usually fail, reducing the population to the verge of famine.

These changes in the amount of moisture and the consequent success or failure of crops have resulted in great hardship to most of the settlers, who, coming with small means and no experience in farming in such a climate, have lost their property and have been saved from starvation in many instances only through outside aid. Thousands of families have been compelled to leave their homes. Among the special schedules of the Census Office there are hundreds of statements reciting the desperate situation of the people, especially in the year 1890, with many touching appeals for aid. Although a large number of families have left this subhumid area, others are constantly coming in, and the population as a whole does not show the rapid decrease which might be expected from an examination of individual statements. The change in population is perhaps best shown by the statistics for western Kansas, in which state an annual census has been made. Taking, for example, the counties of Norton, Graham, Trego, Ness, Hodgeman, Ford, and Clark, and all those to the west of these, the total population, as shown by the state census was, in 1883, 20,942; in 1884, 23,957; in 1885, 33,758; in 1886, 85,193; in 1887, 138,283; in 1888, 138,717; in 1889, 121,071, and in 1890, according to the Eleventh Census of the United States, 102,394. According to these figures the greatest population was in 1888, this declining in 2 years by 36,323.

In many respects the settler in a subhumid country is less fortunate than one in the arid region, especially if his means are scanty. In order to secure the title to his land he must of necessity expend nearly or quite all of his money, and if his first crop is a failure his situation is desperate. Many a man in spite of this has been induced to endure great hardships in the hope that the succeeding year might be favorable and the crops approach the wonderful yield of which he has perhaps seen examples. More than this, there have been hopes held out of a permanent change in the climate, or that water can be procured in some novel way, or the rainfall increased by mechanical effects. On the other hand, the settler in the arid region knows that there can be no hope of success except by irrigation, and if he secures a water supply he is reasonably certain of success, and is not called upon to endure years of privation while experimenting in methods of agriculture or waiting for a fortunate season.

The fact that there is nearly enough rain to insure the success of crops in the subhumid region is not as great a benefit as is often inferred, for, as stated above, farmers are induced to take chances on the fortunate occurrence of rain at critical times, and in the long run they are disappointed. It is difficult to convince the people in many localities of the necessity of developing to the utmost capacity every possible source of water supply and of maintaining and pushing forward the work even during years of unusual precipitation. There is a tendency to neglect systematic effort in this direction, and schemes projected in one year are sometimes dropped in the next. There are many localities where, in spite of poverty, it would be possible by united and persistent application to save storm water or develop other sources of supply. Each year people are misled by some new theory which promises to increase the available moisture without involving the laborious construction of the class of works which have proved successful in the past. At one time they have been excited by anticipations of securing artesian water, again by hopes of employing the so-called "underflow" or the ultimate success of the rain makers.

In view of the many failures reported from western Kansas and Nebraska, it is surprising to note the large acreage in cereals in this part of the country. According to the agricultural returns for the census year there

were raised in the 32 counties in the western end of Kansas 775,753 acres of cereals. Of this there were in barley 1,850 acres, in buckwheat 188 acres, in corn 523,030 acres, in oats 66,114 acres, in rye 58,324 acres, and in wheat 126,247. In the 25 counties in the western end of Nebraska there were in all 749,871 acres of cereals, and of this there were in barley 5,942 acres, in buckwheat 986 acres, in corn 484,391 acres, in oats 98,537 acres, in rye 19,041, and in wheat 140,974 acres. The population in these counties in Kansas was, as before stated, 102,394 and in the counties of Nebraska 103,188.

Although the area cultivated within counties in and adjoining the subhumid region appears in the aggregate so large, yet on the other hand the yield per acre is relatively small and uncertain. The number of failures can not be ascertained, but in 1889 and 1890 it was so large that the majority of the population were discouraged and impoverished. The possibility of irrigation has been received with great enthusiasm, and most of the easily available sources of water have been employed to a greater or less extent, as shown by the number of irrigators. Is is obvious that only a small proportion of the agricultural land can ever be irrigated, but these relatively small areas upon which valuable crops can be raised with certainty are of the greatest importance in promoting the prosperity of the communities in which they occur. If a farmer can be sure of obtaining from a small area an amount of produce sufficient to furnish food for his family he will be less dependent on the success of his grain crops, or can devote the greater part of his land to cattle raising. The principal obstacles to the introduction of irrigation, besides lack of water, have been the prejudice and ignorance of the people regarding the subject. It has been feared that if it were known that irrigation was necessary or even beneficial the reputation of the country would be injured. The sensitiveness on that point has tended to disappear, owing to the severe effects of the droughts of recent years, and there is a more general demand for the introduction of systems of water supply. For lack of knowledge of the best means of obtaining water and of applying it to the crops progress has been slow.

WATER SUPPLY.

The largest amount of water for irrigation is obtained from rivers which, heading in the Rocky mountains, flow in a general easterly course across the plains, emptying into the Missouri river or farther south into the Mississippi. These have an enormous drainage area and at certain seasons of the year carry a correspondingly large quantity of water. During the hot weather, when water is most needed, their channels, especially within the subhumid region, become nearly or quite dry. This is due both to losses by evaporation and to diversion of water by irrigating canals and ditches near the base of the mountains. Along each of these rivers, notably the Platte and the Arkansas, large canals have been built, receiving occasionally an abundant supply of water. Attempts have been made to increase and render perennial the amount of water in these canals by continuing them up the river and in a general way parallel to it at a grade less than that of the bed of the stream until they have penetrated water-bearing sands or gravel. The amount of water obtained in this way has been relatively small, but being available at a critical time it is valuable.

A source of water supply secondary only to that obtained from the large rivers is found in the springs or streams fed by them. These springs occur in great abundance in many parts of the eastern arid and the subhumid regions, water coming from coarse material, beds of sand and gravel, usually found below the surface marls. A small part of the rainfall finds its way down to these pervious beds, where it is stored, ultimately escaping wherever an opportunity occurs. The streams formed by the union of water from various springs are usually largest near their sources, dwindling in size rapidly from these points unless re-enforced by storm water. Their channels continue in a general easterly direction toward more humid regions, where the amount of water gradually increases, to be finally discharged into one of the larger rivers of the country. Many small ditches have been built, taking water at points a short distance below the springs and carrying it out to one or two farms.

The third source of water supply is from wells drilled or dug through the surface clays or marls down to the water-bearing sands and gravels, usually found at from 50 to 300 feet below the surface. A few of these flow, especially those upon the lower lands, but the great majority must be pumped, wind power being commonly employed. These wells seem almost inexhaustible by the machinery ordinarily used, and furnish water not only for domestic purposes and watering cattle but in many instances for gardens and trees. Their more extensive utilization for irrigation rests on the relative cost of raising the water and the value of the products. A small amount of irrigation has been carried on by means of storm waters held in suitable reservoirs. There are not many places where the topography of the surface is favorable for the construction of these, but all such localities will probably be utilized in the future.

The examination of sources of water supply points to the conclusion that outside of the canals in a few of the large river valleys the development of irrigation depends upon the utilization in each locality of all of the available water, either in large or small quantities and from whatever source it may come, whether from springs, wells, or storms, and that it is impossible to lay down any general scheme applicable to the country as a whole. Each community must ascertain for itself how and where water can be obtained if it is to be had, and having done so, the question as to whether the water can be profitably employed is to be answered only by the results of practical trial.

The average distribution of rainfall by months is comparatively uniform in the four northern states under discussion. Taking all of the rainfall data up to 1889, as furnished by the Chief Signal Officer, it appears that the average annual rainfall at all stations for the time during which observations were made was for the Dakotas 19.30 inches, for Nebraska 27.83 inches, and for Kansas 29.88 inches. These figures apply to the states as a whole, the average precipitation on the eastern side being greater and that on the western less than the figures given. The percentage of rainfall by months, on the contrary, is comparatively uniform across each of these states, to a certain extent, regardless of the total amount of precipitation. The following table gives in round numbers the average rainfall by months for the two Dakotas, Nebraska, and Kansas:

AVERAGE PER CENT OF MONTHLY RAINFALL FOR SUBHUMID REGION.

MONTHS.	Dakotas.	Nebraska.	Kansas.
January	3	3	4
February	4	3	3
March	5	5	5
April	12	11	10
May	15	14	15
June	15	16	14
July	16	16	15
August	12	11	12
September	7	8	8
October	5	7	7
November	3	3	4
December	3	3	3

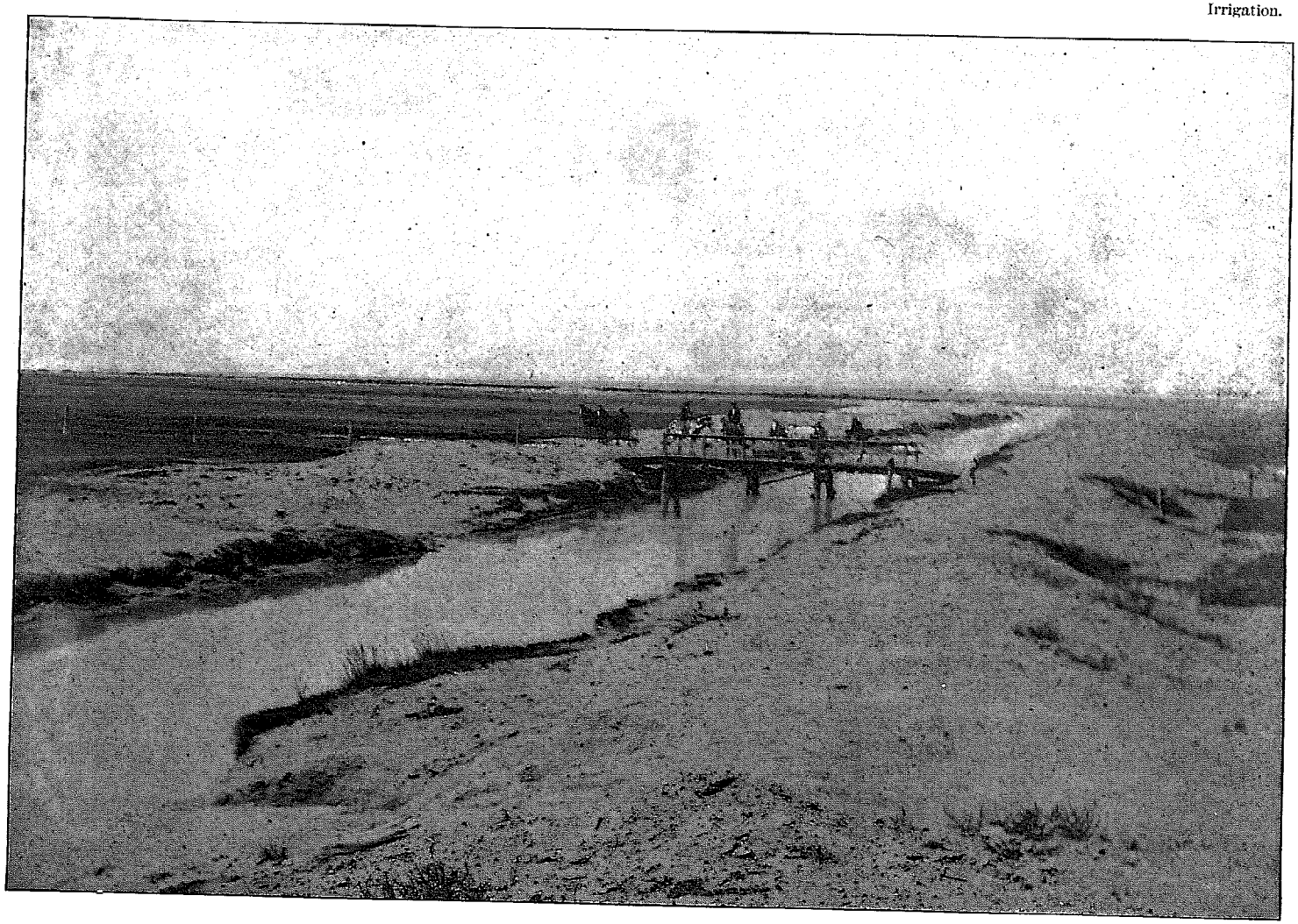
From the above figures it is evident that April, May, June, July, and August are the rainy months, from 66 to 70 per cent of the precipitation occurring during this part of the year. This is peculiarly favorable in many ways to agriculture, rendering it possible to cultivate crops in localities where, judging from the mean annual rainfall alone, their success would appear doubtful. In Texas, as pointed out by General A. W. Greely, there is not the same uniformity throughout the state in the distribution of rainfall by months, there being more than one distinct type. Of the types mentioned by him two of most interest in this discussion are, first, that represented by the precipitation at Forts Sill, Griffin, and Elliott, in or near the "Panhandle" of Texas, and, second, that by the rainfall at Forts Bliss, Davis, and Stockton, in the extreme western prolongation of the state. Taking the average in each of these groups, it appears that the first agrees fairly well with the figures above given; but in the case of the second, the greatest rainfall occurs later in the season, coming in August and September, as shown by the following table:

AVERAGE PER CENT OF MONTHLY RAINFALL IN TEXAS.

MONTHS.	"Panhandle", Texas.	Western Texas.
January	3	2
February	4	3
March	3	4
April	9	3
May	15	7
June	13	9
July	11	14
August	10	20
September	10	20
October	11	9
November	5	5
December	6	4

NORTH DAKOTA.

In North Dakota irrigation was practiced in 1889 on farms in two counties, namely, Buford and Flannery, these being in the extreme northwestern corner of the state, north of the Missouri river. Water from artesian and pumped wells was used to a greater or less extent on gardens and fruit trees in the eastern end of the state, but in this connection these comparatively isolated cases have not been considered. In Buford county the irrigated land is in the vicinity of Williston, the irrigating ditches leading from Muddy creek and its tributaries, and also from Stony creek, both of these flowing into the Missouri. In Flannery county the land is watered from Beaver, Jones, and other short creeks flowing southerly from the high prairies. The ditches have been built by cattle owners mainly for the purpose of raising forage crops and produce for home consumption.



VIEW OF BELMONT CANAL NEAR HEAD, CHEYENNE COUNTY, NEBRASKA.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN NORTH DAKOTA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	7	445	64
Buford	3	180	60
Flannery	4	265	66

GENERAL DESCRIPTION.

In various counties throughout the western part of North Dakota farmers state that although the soil is rich yet no dependence can be placed upon the crops. There is rarely rain enough through the summer to afford sufficient moisture, and in 1890 many of the settlers became completely discouraged and abandoned their homesteads. In Burleigh county, near the center of the state, it is reported that from 1880 to 1890 there were only three good crop years, namely, 1882, 1884, and 1885, the rainfall at other times being deficient, except perhaps in 1888, when the main losses were by frost. In any one county or group of counties it rarely happens that all farmers suffer alike. Usually there are local rains covering small areas, and thus one field or part of a farm may receive a fair amount of moisture while another part is dry.

It is impossible to draw any sharp line between the counties needing irrigation and those which do not, but it is sufficient to say that on the eastern edge of the state there is usually an abundant rainfall, while on the western side "dry" farming rarely succeeds. The water supply is not especially favorable for the growth of irrigation. In the eastern part of the state, in the James River valley and in that of the Red River of the North, are many artesian wells, but these can hardly be counted upon as a large factor in irrigation, being of far greater importance for domestic and municipal supply. Besides, irrigation is not really necessary, although of great benefit in increasing the yield per acre. The Missouri river flows through the state, entering near the northern end of the western side, and trending in a general southeasterly and southerly direction. In this part of its course the river has a fall of only about 1 foot to the mile, and diversion of its waters into short canals is almost if not quite impossible.

Flowing into the Missouri river from the north are a number of creeks, receiving water from springs or from the drainage of the prairie-like divide between the Missouri and Mouse rivers. Most of these streams are comparatively short, and some of them become almost, if not quite, dry during the summer. By means of a proper system of storage several thousand acres could be irrigated in the valley along the Missouri. On the south or west side of the river the opportunities for diverting water are even worse than on the east. Most of the perennial streams have cut deep gorges, in which there is no bottom land, and many of them fluctuate so greatly in quantity of water discharged that irrigation is almost impossible.

DIVERSION OF MISSOURI RIVER.

The practicability of diverting water from the Missouri river by means of a large canal built on a gentle grade has been frequently discussed, and hopes have been entertained that water could be brought over into the valleys of the James and Mouse rivers. It has been ascertained by the United States Geological Survey that the low water level of the water in the Missouri at the mouth of Milk river, Montana, is approximately 2,020 feet; at Fort Buford, at its junction with the Yellowstone, 1,855 feet; at Williston, Buford county, at the mouth of Muddy creek, 1,820 feet, and at Bismarck, Burleigh county, 1,620 feet. The elevations of the lowest points of the divide between the Missouri river and the drainage basins of the James and Mouse rivers have been ascertained to be as follows: north of Dog Den Butte in Church county the lowest points are over 2,100 feet, while south of it the lowest gaps are respectively 2,048 feet, 2,022 feet, 1,950 feet, and 1,923 feet, the last being at the head of Painted Woods creek. Where the Northern Pacific railroad crosses the divide the elevation is 1,870 feet. A ditch starting at the mouth of Milk river, Montana, and constructed on a uniform grade of 6 inches to the mile, would have to be about 450 miles long in order to reach the divide in Sheridan county south of Dog Den Butte. It would then have an elvation of a little under 1,800 feet, or 70 feet lower than the lowest gap mentioned. The line for a ditch on this grade would be at an average distance of about 5 miles from the Missouri for a length of 400 miles, leaving the river at about the northern side of McLean county and passing to the north of Turtle lake. The land below this line is rich and suitable for agriculture, but it is apparent from the above figures that such a project can hardly be considered as feasible.

The country examined in the course of this survey along the northern and eastern sides of the Missouri river is a rolling plateau deeply cut in a few places by coulees and bounded by bluffs along the Missouri river of from

200 to 400 feet in height. The divide between the Missouri and the rivers mentioned above is marked by low, irregular hills, at the base of which are many small lakes or lake beds, some of these being as much as 4 miles in diameter. Most of these lakes have no outlet and as a consequence they are strongly alkaline. From others a small amount of water escapes, but this soon disappears in the dry channel during the summer at least. It is obvious that water can not be held by storage in any of these lakes except by enormously increasing the drainage area and concentrating, if possible, the flowing water at a single point. The lakes fluctuate greatly, water accumulating during some years and then diminishing during several successive summers. The same is true of streams which drain large areas of this prairie country. The Mouse river and streams tributary to James river frequently cease to flow in summer, the water standing in pools in the beds.

The prairies northeasterly from the Missouri have a rich soil, which in years of abundant rainfall produces heavy crops of wheat. Settlement has progressed rapidly near the railroads, but away from these few inhabitants are to be found. There is good grazing over the entire area, and along the streams are a few trees. Most of them, however, have been cut off by the settlers. Attempts have been made to secure artesian water in a few localities. At Bismarck a hole was drilled to the depth of 1,200 feet, but without success. Ordinary dug or drilled wells usually find a supply at from 50 to 100 feet or more.

ARTESIAN WELLS.

Flowing wells have been found in the eastern end of the state in the valley of the James river, and that of the Red River of the North, which forms the boundary line between this state and Minnesota. By far the greater number of wells are in this latter area, there being but a few comparatively deep wells in the James River valley. The most northerly well in this area is that at Devils lake, in Ramsey county, which has reached a depth of 1,511 feet. This is 3.5 inches in diameter at bottom, and delivers water at the rate of 60 gallons per minute.

At Jamestown, in Stutsman county, about 85 miles south of the locality above mentioned, 2 other wells have been drilled, 1 to a depth of 1,523 feet. This is 8 inches in diameter at top and 3.5 inches at bottom. It delivers water at the rate of 167 gallons per minute. Another well has been drilled to the depth of 1,321 feet, but has been abandoned. At Ellendale, in Dickey county, 65 miles south of Jamestown, a well 4.75 inches in diameter was drilled in 1885 to the depth of 1,087 feet, at a cost of $4,000. This discharges at the rate of 1,700 gallons per minute, furnishing water for city purposes. The surplus is conducted for half a mile to a farm, where it is used for irrigation. These wells just mentioned all obtain water from what is known as the Dakota sandstone.

In the valley of the Red River of the North are a large number of flowing wells, both in Minnesota and in North Dakota. These range in depth from 100 to 200 feet as a general rule, though many are shallower or deeper. Taking the counties in order from north to south, these wells are reported in Pembina, Walsh, Grand Forks, Traill, Cass, Richland, and Sargent counties, North Dakota, and in Kittson, Marshall, Polk, Norman, Clay, Becker, Wilkin, and Traverse counties, Minnesota. All, or nearly all, of the wells in these counties obtain water from beds of sand and gravel buried beneath thick, impervious strata of clay, all of these being the result of glacial action followed by the effects of sedimentation from rivers and lakes.

The water from these wells is used almost entirely for household purposes and for watering cattle. The amount from any one well is usually small, and would be almost insignificant for use in irrigation if it were necessary to attempt this method of agriculture. As it is, there is an ample rainfall, and large crops are raised almost every year. The water is usually clear, cool, and agreeable to the taste, although it often contains a notable amount of saline matter. Even when too salty for household use cattle will drink it eagerly. Many of the farmers in North Dakota state that the water from their wells injures or even destroys vegetation, and that it will kill grass and willows in a short time. This effect is possibly due in many instances to the low temperature of the water, and in others to the saline contents.

Within the counties mentioned almost every farmer has his own flowing well, and, if the water is good, he finds it a great convenience. The cost of these wells was formerly $1 per foot for the first 100 feet and $1.50 for the second 100 feet. At a later time the ordinary contract price was 80 cents for the first 100 feet and corresponding rates for greater depths. Nearly all the wells are 2 inches in diameter, although there are a few 4 inches or larger. These are mainly deeper wells, which often have larger flow. For all practical purposes the shallow wells with small flow are as useful as the larger, since even the smallest supplies sufficient water for house and cattle. As a general rule, it may be said that the water from these larger, deeper wells is more liable to be salty and of less value for all purposes.

SOUTH DAKOTA.

Irrigation in South Dakota is practiced mainly in what are known as the Black Hill counties, on the western side of the state, namely, Butte, Lawrence, Meade, Pennington, Custer, and Fall River. In addition to areas in these counties a small amount of land is watered by means of artesian wells in the eastern part of the state. The streams in the counties mentioned rise in the Black Hills, and, flowing outwardly in nearly every direction, finally unite, those on the north forming the north fork and the others the south fork of the Cheyenne river, these streams nearly encircling this mountain area.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN SOUTH DAKOTA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	189	15,717	83
Butte	43	4,282	100
Custer	22	1,754	80
Fall River	5	419	84
Lawrence	65	4,496	69
Meade	9	690	77
Pennington	45	4,076	91

Among the mountains at the altitude at which timber is found there is an abundance of moisture for cereals and grass. These are raised to a considerable extent in the valleys or parks of this area. Lower, among the foothills, the rainfall is usually deficient, and farming without irrigation can hardly be said to be profitable. Whenever the rainfall is more ample than usual wheat, oats, corn, barley, and millet are raised. Many of the farmers in these lower valleys make a living by working part of their time at the mines, and in this way manage to maintain themselves through years of drought. Some of the settlers, failing to raise crops for several years in succession, have abandoned their homesteads.

In the counties easterly from the Black Hills the rivers for the most part flow in deep, narrow channels 100 or more feet below the general surface. During certain seasons of the year they discharge a considerable amount of water, but in summer the streams gradually diminish until they almost, if not quite, disappear. The small amount of water available during the irrigating season, together with the unfavorable topography of the country, renders irrigation by ordinary means impracticable. Beyond the Missouri there are possibly a number of tributaries which, with storage, could be utilized, but at present the hopes of the farmers are centered upon the development of artesian waters.

WATER SUPPLY.

The principal streams used for irrigation in the Black Hills region are Redwater, Hay, Spearfish, False Bottom, Bear, and other creeks rising in the northern end of the mountains and flowing partly through Lawrence and Butte counties. On the east are Rapid and Battle creeks in Pennington and Custer counties, and on the south Beaver, Fall, and Cascade creeks in the southern part of Custer county and in Fall River county. The ditches taking water from the creeks to the land are usually small, having been constructed by individual farmers or by a partnership, each person of which is entitled to a certain proportion of the water.

The water supply is ample for the area now irrigated, but if the greater part of the ditches projected or under construction are completed there will undoubtedly be a deficiency, especially during the hot weather. Most of the streams flow throughout the year, but they become very low during the summer, and a comparatively small diversion of water at that time will leave the channels dry. The greatest development of irrigation is in the vicinity of Rapid, where there are from 8 to 10 ditches, a few of them of relatively large size. In the vicinity of Minnesela and to the south of it are also a number of ditches, and near Buffalo in Custer county. At this latter place a well 6 inches in diameter has been drilled to the depth of 800 feet in the hope of obtaining an artesian flow. Outside of the lower valleys around the Black Hills region are broken plateau and prairie lands stretching far away, upon which grazing is the only industry. Farming has been tried at various places, but with little success, principally on account of the lack of water and of the occasional occurrence of hot winds. The soil on many of these table lands between the streams is good and a few fair crops have been raised.

The Belle Fourche, or north fork of the Cheyenne, which receives the drainage from the northern part of the Black Hills, except in spring, is a small stream, and its banks are so high and the slope is so small that it will be hardly possible to divert any water upon the adjacent land. This, as previously stated, is the prevailing condition of the streams after they leave the foothills. There are a number of places in which reservoirs could be made, but

for the most part these localities belong to individuals whose opposing interests prevent concerted action toward their utilization.

The Westside Water Supply Company has constructed a ditch from Redwater creek, heading about 1.5 miles southerly from the town of Minnesela, in Butte county, and carrying water out on the west side of the creek. It is about 5 miles long, 6 feet wide, and cost $1,500. The ditch was first used in 1890. Heading on the same stream above this ditch is the canal owned by the Redwater Land and Canal Company, taking water out toward the north and east. The total length is estimated to be 35 miles, average width 12 feet, and the cost was about $75,000. The canal was made by enlarging and extending two ditches purchased by the company. Water has been supplied to irrigators at the rate of from $1 to $1.50 per acre each year.

The Little Giant ditch takes water from Rapid creek, in Pennington county, running out on the north side of the valley. It is 4 miles long, about 5 feet wide, and cost about $2,400. It is owned by farmers, who divide the water among themselves. The Lonetree ditch takes water below the Little Giant, the head being about 8 miles southeast of Rapid. This ditch is 5 miles long, about 6 feet wide, and the cost was probably $4,500. In this valley, which is from 1 to 2 miles wide, the ditches are short and take water to comparatively few farms. The creek has a decided fall, and in places crosses from side to side, cutting into the bluffs on one side of the valley and then swinging across to those opposite. The various ditches, of which there are probably 8 in use, already cover the greater part of the farming land from about 3 miles west of Rapid down to a point 12 miles east.

ARTESIAN WELLS.

The flowing wells in this state, as in North Dakota, are found mainly near the eastern end, extending in a broad belt southerly down the James River valley to the Missouri, the greater number being found in the southeastern corner of the state and mainly in the counties of Bonhomme, Yankton, and Clay. A few shallow wells are found near the northeastern corner of the state, in Grant county, these being in all probability similar to those in North Dakota and Minnesota, and marking the southern end of the artesian area of glacial origin.

This state contains wells which have a very large flow. The amount of water from one of these wells compared to that generally coming from artesian sources is enormous. It is, however, usually greatly exaggerated, and it is difficult in a matter of this kind, where local pride enters so largely, to arrive at the exact condition of things. So far as can be ascertained probably the largest well does not deliver continuously over 3,000 gallons per minute, or 6.68 second-feet, although it has often been asserted that 1 or 2 of them flow at the rate of 10,000 gallons per minute. These large wells, in spite of the quantity of water they deliver, show no signs of exhausting the supply, although from analogy it is to be presumed that as the country develops the number of wells will be increased until the discharge begins to show signs of diminution.

Most if not all of the wells obtain water from the Dakota sandstone, which underlies the greater part of this state, as well as of North Dakota. Omitting the minor inequalities, as a whole, the distance from the surface to the Dakota sandstone becomes less in going from north to south or from west to east, so that the shallowest wells are those on the James river and Missouri bottoms in southeastern South Dakota. East of this region of shallow wells, and notably in Minnehaha county, the Dakota sandstone abuts against crystalline rocks, which come to the surface, and in which no flowing water is found, although a well has been sunk to a depth of 600 feet.

It should be noted that nearly all the more important wells, or at least those first drilled, are in or near towns, and that in many counties where wells exist none have been reported as being upon farms. This is due to the fact that the trial borings have been made mainly by municipal corporations or associations of citizens for the purpose of obtaining a domestic supply of water, and it is only in localities where the wells are comparatively shallow and inexpensive that they have been put down to any extent by farmers. It is obvious that the ordinary farmer can not incur the expense of deep drilling unless he has more than usual assurance of success.

Taking the counties in geographical order from north to south, the most northerly wells are in Brown county, which adjoins Dickey county, North Dakota. At Frederick a well over 1,100 feet in depth discharged, when completed, at the rate of 120 gallons a minute, while other wells at Columbia, Aberdeen, and Groton, averaging about 950 feet each, are reported to have discharged from 800 to 1,000 gallons a minute. In Marshall county, on the east, a well at Britton 1,000 feet deep flowed 850 gallons a minute. In Day county, at Andover, south of Britton and east of Aberdeen, a well 1,000 feet deep flowed 250 gallons a minute. In Edmunds county, at Ipswich, 30 miles west of Aberdeen, a well 1,270 feet in depth, is reported as discharging considerable quantities of soft, though slightly brackish, water.

Taking next the counties to the south, the largest number of wells is in Spink county, the depth being about 950 feet. These are found at Mellette, Ashton, Doland, Redfield, and other localities. Wells have also been drilled in Faulk county, to the west, and in Hughes, Hyde, and Hand counties, to the southwest, the well at Miller, in the last named county, being nearly 1,150 feet in depth, and discharging as high as 1,000 gallons per minute, and at Harold, in Hughes county, 1,450 feet deep, and discharging 150 gallons per minute.

In Beadle county, south of Spink, the most notable group of wells is at Huron, where the depth is about 900 feet. The discharge from some of the wells of this county is enormous, and the pressure is sufficient to furnish

short time before the wells at various towns will by success or failure outline the limits of the artesian area. The only drilling in the extreme western part of the state as yet reported is one in Pennington county, 350 feet in depth, from which no water is obtained.

NEBRASKA.

In the following table are given in alphabetical order the counties within which irrigation was carried on during 1889. In the description, however, following the table, these counties, for convenience, have been grouped according to their geographic position. The figures of cereal production of the state show that the total area devoted to the cultivation of cereals in 1889 was 7,961,969 acres. Taking all the counties in the western part of the state lying beyond the one hundredth meridian, it has been found that cereals were raised upon 749,871 acres, over one-half of this area being in Indian corn. Comparing the irrigated acreage with the cereal crop alone in this part of the state, it appears that all of the land upon which crops were raised by irrigation was only 1.57 per cent of the area upon which small grains were produced. In this part of the state, where the climate is semi-arid, the average yield of the cereals per acre was considerably less than in the state as a whole; for example, Indian corn yielding 17.33 bushels against 39.40 bushels per acre for the whole state, and wheat 11.27 bushels against 13.23 bushels per acre.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN NEBRASKA IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of farms irrigated in acres.
Total	214	11,744	55
Banner	4	218	55
Cheyenne	36	3,154	88
Dawes	12	267	22
Deuel	4	125	31
Dundy	4	41	10
Keith	6	295	49
Kimball	11	441	40
Lincoln	37	3,049	82
Redwillow	3	72	24
Scotts Bluff	70	2,753	39
Sheridan	4	13	3
Sioux	23	1,316	57

NORTHWESTERN COUNTIES.

In Dawes and the adjoining counties of Sioux, Boxbutte, and Sheridan, in the extreme northwestern corner of Nebraska, are a few small irrigating ditches taking water out upon low land or meadows along the streams. The water is used mainly upon hay lands and for gardens or small patches of vegetables upon cattle ranches. The principal streams from which water is derived are Hat creek, which flows northerly into the south fork of Cheyenne river; White river, which also flows northerly into South Dakota, and the head waters of Niobrara river, flowing easterly near the state line. The water comes mainly from springs, and the streams do not fluctuate as widely or with the regularity of the snow fed rivers of the Rocky mountains. The supply as a whole is very small and wholly insufficient for the needs of any general system of irrigation. In order to extend the area cultivated in this manner it will be necessary to store all of the water that can possibly be held, utilizing each favorable depression.

The total area devoted to cereals in these four counties in 1889 was 146,163 acres. Of this there were in barley 3,492 acres, in buckwheat 385 acres, in Indian corn 58,365 acres, in oats 37,307 acres, in rye 2,449 acres, and in wheat 44,165 acres, the latter producing an average of 11.43 bushels per acre. There have been a number of years in which crops have failed entirely. In 1887 and 1888 the yield as a whole was good, but the light rainfall of 1889 and 1890 did not furnish sufficient moisture and the crops were almost a complete loss, so that hundreds of farmers were without seed for the following year. The soil throughout this area is rich and with moisture produces abundantly. The hot winds, however, are apt to occur during the summer, and there have been heavy losses from hail. Water for ordinary purposes is obtained from wells of from 50 to 150 feet in depth. One well in Sioux county is reported to be 298 feet deep, and the water is strongly impregnated with oil.

COUNTIES ALONG NORTH PLATTE RIVER.

The counties of Cheyenne, Deuel, Scotts Bluff, Banner, and Kimball form the southwestern corner of the western prolongation of Nebraska. The North Platte river flows diagonally through this portion of the state, and the South Platte crosses a corner of Deuel county, the two streams uniting some distance further to the east. On the south is Lodgepole creek, which flows easterly from Laramie county, Wyoming, through Kimball, Cheyenne, and Deuel counties, entering the South Platte. Throughout these five counties agriculture has been carried on in places since about 1885, but with varying success. In 1886 and 1887 the crops were fairly good, but in 1889 and 1890 the yield was very small and many of the farmers were reduced to poverty.

The total area in these five counties upon which cereals were raised in 1889 was 54,814 acres. Of this there were in barley and buckwheat 423 acres, in Indian corn 43,819 acres, having an average yield of 5.96 bushels per acre, in oats 4,016 acres, in rye 617 acres, and in wheat 5,939 acres, with an average yield of 6.50 bushels per acre. The losses incurred during the years of drought have called attention to the necessity of providing means of irrigation and a number of projects have been undertaken, the principal source of water supply for this part of the state being the North Platte (*a*), a large river, discharging many times as much water as the South Platte.

Even during the dryest part of the year the amount of water in the North Platte appears to be sufficiently great to supply canals of considerable size, and when irrigation has been thoroughly developed it is probable that the available water supply will be somewhat increased by seepage. Beginning at a point in Wyoming above the state line, and extending down through the counties above named, there are many localities favorable for the diversion of water. A number of irrigating ditches and canals have already been built, a few of these being in size comparable to those near the head of the South Platte. Surveys have also been made for great systems of irrigation, for whose construction millions of dollars would be required. The amount of land irrigated in 1889 is almost insignificant in comparison with the area later brought under ditch. In Scotts Bluff county the development has been especially rapid, although Cheyenne and Deuel counties are receiving their share of attention.

Water is diverted mainly upon the valley land along the river. This is bounded by bluffs, in places rising to a height of several hundred feet, rendering it almost impossible to bring water upon the higher plains or plateaus between the streams. The soil on these higher lands is reputed to be better than that in the valleys, since it is less sandy and comparatively free from alkali. If canals succeed in bringing water to this height large areas, embracing thousands of acres of rich soil, can be watered.

Through Scotts Bluff county probably the greater part of the irrigation is carried on along the north side of the stream, where the topography is in places more favorable for the construction of ditches than on the south side. As the river is very shallow and the sand drifts into the headworks, it is usually a matter of difficulty and expense to keep the water flowing into the ditches. Experiments have been made with the use of steam vacuum pumps to raise water, but the expense of running these has been found in many instances to be too great to be profitable. On the bottom lands from the Wyoming line easterly a number of farmers' ditches have been constructed and several large canals projected. The principal ditches are, on the north side, the Farmers, Enterprise, Winter Creek, Minatare, Alliance, Brown Creek, and Lee Creek, and on the south side the Laramie and Scotts Bluff, Mitchell, Castle Rock, Chimney Rock, Belmont, Empire and Logan.

The Farmers canal heads on the north side of the river, 1 mile east of the state line. If constructed as projected it will be 75 miles long. Work was begun in the spring of 1888, and water was used to a small extent in 1890. It is 14 feet wide on bottom, 6 feet deep, and is planned to have a grade of slightly over 1 foot per mile. This canal is owned by a corporation, and with the exception of the Minatare is stated to be the only one selling or

a In 1891 the state engineer of Wyoming made several measurements above the mouth of Laramie river, and in the fall of 1892 the topographers of the United States Geological Survey gauged the river at points in Nebraska. The results of these different measurements are given in the following table:

GAUGINGS OF NORTH PLATTE RIVER.

DATES.	Locality.	Drainage area in square miles.	Discharge in second-feet.
June 3, 1891	Douglas, Wyoming	14,665	10,130
October 13, 1891	Fairbanks, Wyoming	16,775	579
November 5, 1892	Douglas, Wyoming	14,665	595
December 4, 1891	Douglas, Wyoming	14,665	807
September 14, 1892	North Platte, Nebraska	28,250	770
October 8, 1892	Camp Clarke, Nebraska	25,267	335
November 2, 1892	North Platte, Nebraska	28,250	1,070
November 22, 1892	North Platte, Nebraska	28,250	1,370

Fairbanks is some 50 miles or more below Douglas and about 12 miles above the mouth of Laramie river. The town of North Platte, Neb., is near and between the junction of the North and South Platte rivers, and Camp Clarke is about halfway between Fort Douglas, Wyo., and the town of North Platte.

power for machinery, such as printing presses and flouring mills. The largest well probably flows at the rate of nearly 3,000 gallons a minute, or about 6.6 second-feet, and is reported to have thrown a 2-inch stream to the height of 90 feet. One well at least has been put down for irrigation on a farm near Huron. This well is 850 feet in depth, no water, however, coming in below 802 feet. It cost $1,800, is 4 inches in diameter, and discharges at the rate of 600 gallons per minute. In 1890 about 40 acres were irrigated and in the succeeding year approximately 100 acres. The pressure of the water at the surface of the ground is reported to be 120 pounds per square inch.

Southerly from this, in Sanborn county, are many comparatively shallow wells, which supply a small amount of water for ordinary uses. Little if any of this water is used for irrigation, since the amount from any one well is usually too small to be profitably employed. It is stated that the ground around some of these wells where the water is allowed to stand and evaporate becomes coated with alkali, and that plants have been killed by it. At Woonsocket are deep wells notable for their large amount of water and high pressure. One of them is reported to have thrown a 4-inch stream 70 feet in height for a period of over five minutes, and to have a discharge of about 2,700 gallons per minute, or 6.2 second-feet. Such wells as these will be of great value for use in irrigating during years of deficient rainfall.

In Miner county are many shallow wells similar to those of Sanborn county. Some of these wells of 100 feet or more in depth do not flow, although the water rises nearly to the top. In Jerauld county, west of Sanborn, a well has been drilled to the depth of 799 feet, the water obtained, however, being alkaline and carrying a small amount of oil. Other attempts, with possibly better success, have been made. In the next tier of counties to the south many wells have been drilled, those near the western end being the deepest. For example, in Brule county, wells at Chamberlain and Kimball have depths of 1,000 feet or more, and in Aurora, at Plankinton, and in the vicinity of White Lake, depths of about 900 feet, all of these yielding large quantities of water.

In Davison county, south of Sanborn, are comparatively few wells, and most of them are less than 200 feet in depth. Irrigation has been tried by means of water from these wells, and it is stated that the results have in the main been successful. Where failures are reported it is probable that water has not been applied skillfully. In Hanson, east of Davison county, the conditions are very similar, the wells, which are comparatively shallow, being put down primarily for watering cattle and for household uses. Very little of the water has been used for irrigation, and in many instances the surplus water from the wells is regarded as a nuisance, since it occasionally injures vegetation, especially where the ground is already naturally moist.

In McCook county comparatively few flowing wells are reported. There have been a number of failures, the drillers striking, it is stated, the hard crystalline rock, which bars further progress. The water from the successful wells sometimes carries small amounts of iron, sulphur, and other minerals, and a little petroleum. There have been a few crop failures, and the farmers look upon irrigation as occasionally necessary. In Turner and Hutchinson counties, south of McCook, the wells are quite shallow, being generally from 80 to 100 feet in depth. They discharge small quantities of water, none of which, so far as reported, is used for irrigation. In Douglas county, west of Hutchinson, a well has been bored at Armour to a depth of about 750 feet, furnishing water for town purposes at the rate of 1,400 gallons per minute.

In Bonhomme, Yankton, and Clay counties, lying along the north side of the Missouri river, the wells are mainly from 300 to 400 feet in depth and furnish from 100 to 200 gallons per minute. They are found mainly on the lower grounds near the river and in the James and Vermilion valleys. In Clay county they are so common that it may be said that there is one on nearly every farm. For stock and household use there is no question as to the value of the water and the great benefits derived from these wells, but on the subject of irrigation there is a wide range of opinion. A few farmers state that by proper use of water the yield has been remarkable, especially during the first year. Others state that during the second year the results have not been as good: that by too lavish use of the water alkali has developed upon the surface. Still, others state that the water from their wells, if applied to the surface, destroys all vegetation. How far the last mentioned opinion is the result of ignorance in applying the water or of prejudice against its use it is impossible at this time to judge.

The wells in this part of South Dakota, especially on the low grounds, are rapidly and cheaply made. The prices quoted are from $75 for a 2-inch well of a depth of 275 to 300 feet up to $300 for a 3-inch well of from 300 to 350 feet in depth. As a matter of course, the older wells, or those first put down, have in general cost more than would be the present prices for the same work. Upon the prairie, above the valleys, the wells cost more, from the fact that they must of necessity be deeper and are more liable to encounter gravel and stones. Thus the cost is from $250 to $300 for a 2-inch well and from $400 to $1,000 for one 3 or 4 inches in diameter.

The pressure of many of these wells, especially those on the lower ground, is sufficient to operate small machinery, and farmers use water wheels for driving churns and cornshellers and doing other work. In a few instances the wells operate water rams, forcing a small quantity of water to buildings high on the bluffs overlooking the river valleys. In Vermilion valley some of the wells do not flow, the water only rising within 30 feet of the surface. In others the flow has decreased owing to stoppage by sand, and many require frequent cleaning in order to keep the water running.

Attempts to secure flowing water have been made in the western half of the state, but comparatively few of these are successful. Exploration, however, is rapidly going forward, and it is only a question of a comparatively

renting water rights. Enterprise ditch heads 5 miles east of the state line and covers land between the Farmers canal and the river. It is 20 miles in length, and in its course is reported to cover about 8,000 acres.

Winter Creek canal heads at a point nearly north of Gering, covering in turn land under the Enterprise canal. It is 14 miles long, 16 feet wide on bottom for the first 2 miles, then narrowing to 12 feet wide for the remainder of the distance. Stock in the canal is divided into 168 shares or water rights, each of these entitling the holder to 26.5 inches of water. The water duty is estimated to be 1 inch per acre. The company owning this ditch was organized in 1888, and the work of construction was carried on so that irrigation was practiced in 1889 and later with fairly successful results. The Minatare canal heads about 5 miles above the town of that name and covers a narrow strip of land along the north bank of the river. It is owned by a corporation composed mainly of farmers. It is about 10 miles long, the bottom width of the main canal being 30 feet and of the branches 14 feet. Work was begun in 1888, and water was turned into the canal in August of that year. The appropriation calls for 864,000 cubic inches of water, whatever this may be. The capital stock of the company is placed at $50,000, and the par value of a share is stated to be $100. Each share represents 40 inches of water. An 80-acre water right has been sold for $200. It is difficult to estimate the actual cost of this work. In order to maintain and keep the ditch in repair there is an assessment of labor and also a cash levy of about $10 per 80 acres to pay the salary of a superintendent. This is one of the first successful canals in this part of the state, and on this account has attracted considerable attention.

The Alliance, Brown Creek, and Lee Creek ditches head in succession down stream, being wholly within Cheyenne county. The Alliance is about 10 miles long, was built by farmers, and is reported to be highly successful. Brown Creek canal heads east of Camp Clarke. The appropriation calls for 10,000 inches of water, and the work, when completed, is to be 12 miles long, 50 feet wide on bottom, and nearly 3 feet in depth. The Lee Creek is a small private ditch 7 miles long, heading near the lower end of Brown Creek ditch.

Taking the canals on the south side of Platte river in order down stream, the first project of importance is the Laramie and Scotts Bluff canal. On this, however, little if any construction work has as yet been done. It is to head in Wyoming, 6 miles west of the Nebraska line, and as planned is to be 80 miles in length. The surveyed line follows along the bottom of the bluffs or hills of the valley and covers all of the available land in Scotts Bluff county between these and the river. The grade for the first 40 miles is planned to be 0.5 feet per mile and from that point 0.75 feet per mile. It is estimated that the area between this and the other irrigation systems is 48,000 acres.

The Mitchell canal heads in Wyoming, 1 mile west of the state line, and on that account possibly enjoys certain advantages over other irrigating systems taking water at lower points in the state of Nebraska. It is 25 miles long and has a fall of 1.5 feet per mile. When measured in the flume over Horse creek the canal was carrying 24 second-feet, at a time of low water. The stock of the company is divided into 370 shares of a par value of $100 each. A share is understood to entitle the owner to the use of 20 inches of water upon 20 acres of land. The cost of a perpetual water right is also given at $7 per acre, or water is rented at the rate of $2 per acre. The annual cash assessment has been $3.10 per share, together with a work assessment of 2 days' labor per share. Construction work was begun in the fall of 1890, and water was used in the latter part of the following year in order to wet the ground for the following season. The canal is reported to cover 17,000 acres, and assuming that the cost of construction was, as estimated, $34,000, the average first cost of irrigation would be only $2 per acre. The cost of the preparation of the land for cultivation was also estimated to be $2 per acre, an amount lower than in other parts of this district. In comparison with this the land under the canal is stated to be worth $15 per acre and upward. The Central is a small ditch heading near Gering and covering a small area near the town. It is about 4 miles long and is used both for irrigation and milling purposes.

The Castle Rock canal heads about 4 miles east of Gering and extends along the south side of the river for about 17 miles. The bottom width is 16 feet, and the cost is stated to have been upward of $1,000 per mile. Along the course of the ditch is one flume 200 feet in length, but otherwise the work is comparatively simple. The ownership is in shares of $100 each, and the water rights are fixed at 40 inches for 40 acres. The irrigation works commonly known as the Chimney Rock take water from the south side of the North Platte river about a mile west of the Cheyenne county line and 12 miles west of Camp Clarke. The main ditch is 10 miles long, and has a fall of 1.66 feet per mile. It has been built by farmers, and the cost can not be ascertained. Work was begun in 1889, a little irrigation being done in the following year. The crops irrigated are wheat, oats, corn, barley, and flax.

The Belmont Irrigating Canal and Water Power Company has constructed a canal 32 miles long, 40 feet wide on bottom at head, 3 feet deep, and with a grade of 2.6 feet per mile. The head is 4 miles west of Camp Clarke, the canal leaving the river and following along the upper edge of the bottom lands. The notice of appropriation was filed in December, 1889, and construction work was begun in the following year. It covers 26,000 acres, making the average cost of construction $4.75 per acre. A considerable acreage under this canal was devoted to the cultivation of flax, and the yield, 14 bushels to the acre, was considered to be a success. Twenty inches constitute a water right, or water is rented at $2 per acre.

The Empire is a small ditch, heading a short distance below the Belmont, and covering land under that canal. It is 6 miles long, 3 feet wide, and the cost was very low, probably not more than from $1 to $2 per acre covered. The Logan is another small private ditch, about 2.5 miles long, irrigating a small strip along the river bank.

Away from the North Platte a small amount of water is obtained from Lodgepole and other creeks, and also from springs and wells. The wells are usually from 150 to 300 feet in depth, and when complete, including windmill and tank, cost from $300 to $500. The amount of water obtained is large and the supply can rarely be exhausted by windmills. Springs are found in many localities, and the water sometimes forms ponds of considerable size, finally escaping by evaporation. In the northern end of Deuel county the lakes are especially numerous, the waters from some of these probably escaping into Blue river, which flows southerly into the North Platte. In the valleys along Pumpkinseed creek and Lodgepole creek are a number of small private ditches, irrigating gardens, trees, and small areas of field crops, the water being utilized as far as possible without water storage. Lodgepole creek flows from the Laramie hills in Wyoming easterly across the plains, its water usually disappearing into the sandy soil. At places, however, it appears on the surface during a part of the year at least, and can be diverted for irrigation. After crossing the state line into Nebraska the creek furnishes water for several ditches, each taking out apparently all of the water at the point of diversion. As an example of these ditches, may be given that of the North Side Irrigating and Milling Company, heading about 8 miles west of Kimball. It is 4.5 miles long, averages 8 feet in width, and cost $300. It was begun in 1889 and first used in 1890. The cost of water is stated to be about $1 an acre each season.

KEITH, LINCOLN, AND COUNTIES TO THE NORTH.

Keith and Lincoln counties lie northeasterly from Colorado, a corner of the first being adjacent to Sedgwick county, Colorado. Both the North and South Platte flow easterly through Keith county at an average of about 5 miles apart, finally uniting their waters in the eastern half of Lincoln county. To the north are 2 tiers of counties, the first tier containing Arthur, McPherson, and Logan counties, and above these Grant, Hooker, and Thomas. Cherry county, whose area is greater than that of the 6 just mentioned, includes the lands to the South Dakota line and adjoins Sheridan county, which lies on the west. Throughout these 9 counties agriculture is carried on in favorable localities, stock raising, however, being the principal industry. In Keith and Lincoln counties 84,790 acres of cereals were raised in 1889, of this amount 58,421 acres being in Indian corn, with an average production of 22.94 bushels per acre, and 14,102 acres in wheat, averaging 12.06 bushels per acre. In the 7 remaining counties the total area of cereals was 57,578 acres, and of this there were in Indian corn 46,449 acres, producing on an average 17.20 bushels per acre. The experience of several years has convinced the farmers that greater success can be attained only by irrigation.

The Niobrara river, which flows from Sheridan county across the northern end of Cherry county, furnishes a perennial supply of water, the quantity not varying greatly throughout the year. It flows through a narrow valley, canyon like in character, with little if any irrigable land along this part of its course. South of this stream are the North Loup, the Middle Loup, and Dismal river, its principal tributary. All of these streams receive their water from springs, and their discharge, like that of the Niobrara, fluctuates within narrow limits. It is stated that even in the driest weather the rivers do not fall perceptibly, and that after a rain they rarely rise more than a foot or so. The country drained by these streams consists largely of wind sculptured sand hills rising to heights of from 10 to 200 feet and inclosing small valleys. The bottoms of some of these valleys are wet and crops of hay can be cut. The grazing on the sand hills is good, and the springs and lakes furnish water sufficient for the needs of cattle.

The South Loup, rising in Logan county, is less regular in its behavior than the streams named above. It occasionally becomes nearly or quite dry in summer down to the point where it unites with other tributaries. Its waters have been used to a small extent for the irrigation of kitchen gardens and trees. The wells throughout this area are usually from 150 to 300 feet in depth, and, wherever the owner has sufficient means, are pumped by windmills. On the high table-lands between the streams mentioned above are large areas of fertile soil, which would be very productive if water could be had. There does not seem to be any means of securing the needed supply, except in a few localities, by storage of storm waters or by pumping from wells.

Agricultural development of this part of the state by means of irrigation must of necessity be confined to the vicinity of the North Platte. Already a number of ditches, both in Keith and Lincoln counties, have been constructed and others are projected. Besides the river, there are a number of creeks coming from the sand hills north of the river in Deuel and Keith counties which could be made to serve a considerable acreage of land on the north side of Platte valley. The poor crops of 1889 and 1890 stimulated the building of irrigation works. Among the most important of the side streams useful for irrigation are Blue and Birdwood creeks, the former in Deuel county, and the latter about 60 miles below in Keith county.

Blue creek is about 30 miles in length, and, rising in springs among the sand hills, flows southwesterly and southerly into the North Platte. The volume of water carried, as in most of these streams from the sand hills, is remarkably uniform throughout the year, excepting in times of heavy rains, when the flow is somewhat increased.

The discharge, when measured, amounted to 105 second-feet. It heads in what is locally known as the lake region, a country dotted by lakes, some fresh, others alkaline. Along its valley are lands adapted to irrigation, but only one small ditch has been constructed, this being on the west side about 3 miles above the mouth of the creek. A larger ditch could be taken out farther up the creek, covering a considerable area of land in the valley and on the Platte bottoms.

The valley of Platte river eastward from Blue creek has a large and well distributed water supply. Numerous streams discharging from 3 to 5 second-feet during the summer come from the sand hills and have a fall sufficiently great to allow of taking their waters to almost any point desired. Along Otter creek are a few small ditches, aggregating about 4 miles in length, and also along White Tail creek is a ditch which irrigates lands in the open valley. Most of the water of these ditches is used in the production of hay, which, when loaded, is valued at from $7.50 to $9 per ton.

Birdwood creek is probably the largest tributary of the North Platte in western Nebraska. When measured in September it was discharging at the rate of 126 second-feet, the flow not fluctuating greatly throughout the year. Near the junction of the east and west forks, and about 10 miles above the mouth of the creek, work has been begun on a ditch presumably for the purpose of irrigating some of the land now used for grazing. The valley of the creek is, however, narrow, the principal body of irrigable land being near the mouth.

On the south side of the North Platte river, about 3 miles above the mouth of Birdwood creek, is the head of the North Platte canal, covering land between the North and South rivers. The total length of the canal is 23 miles, the average width 16 feet, and the cost is stated to have been $40,000, the laterals being built by farmers at their own expense. Water is diverted by means of a wing dam built of timber and having a length of 1,550 feet. The canal is owned by a corporation, which has sold perpetual water rights at the rate of $6.25 per acre. The annual assessments are not to exceed $10 for 80 acres. The unit of distribution is 1.44 second-feet per 80 acres. This is claimed to be the pioneer ditch of the region, being first used in 1885.

During the summer the South Platte is often dry, and its surface flow can not therefore be depended upon for purposes of irrigation. In the fall the water gradually begins to flow again, and by November the discharge reaches several hundred second-feet. Three measurements of the amount in the stream were made by topographers of the United States Geological Survey shortly after the fall rains. In October the discharge at Julesburg, Colo., was 653 second feet, in early November at the bridge south of the town of North Platte 460 second-feet, and late in November at the same point 645 second-feet. The bed of the stream is very broad, and during the summer after the disappearance of the flowing water the sandy channel, as well as the adjacent low land, remains saturated to within a short distance of the surface. Attempts have been made to draw upon the water thus stored in these pervious beds under or adjacent to the river channel, bringing it out by means of ditches built at a less grade than that of the stream, in order to utilize this during the months of July, August, and September. One of these projects, built by the Ogallala Water Power and Irrigation Company, heads about 10 miles above Ogallala, on the north side of the stream. The ditch is 12 miles long, about 10 feet wide, 1.5 feet deep, and has a grade of 1.5 feet per mile. It empties into a small reservoir covering about 20 acres, and located 1.5 miles northwest of the town. At the head of the ditch is a box culvert 10 feet wide, 3 feet deep, extending for about one-fourth of a mile up the river parallel to the bank, its upper end opening to receive the water whenever there is any in the channel. During the summer, when the bed is dry, it is expected to obtain water by means of an open ditch dug in the bed of the stream extending another fourth of a mile above this culvert. Water seeps into this ditch and culvert and is also collected by means of a small drain or channel extending from the head of the main ditch diagonally across the bed of the river. On October 1 there was found to be about 2 second-feet thus obtained, and at a point 3 miles below the headworks this little stream had increased to nearly 3 second-feet. The drainage channel was first constructed in 1890 during the great drought, but the amount of water obtained at that time was less than had been anticipated. The canal was built by a corporation, but the county, or rather Ogallala precinct, voted to issue bonds to the amount of $35,000 to aid in the work. Little, if any, water has been used for irrigation, and the project is not generally considered as successful.

On the south side of the river is what is known as the Hollingsworth ditch, owned by the South Side Irrigation and Water Power Company. It is about 9 miles long and averages 4 feet in width. It carries water only in times of flood, being used to some extent for irrigation in the early part of the year. When constructed it was supposed that a large perennial supply could be obtained from the ground water saturating the pervious beds of the valley, but as a result of experiments in other localities less confidence has been placed in this.

Along the Platte river east of the junction of the north and south branches are several small ditches and also 2 canals of notable size, both of these being on the north bank. They were constructed, however, mainly for the purpose of obtaining water power, little, if any, of the water being employed in irrigation. The first of these is the Gothenburg canal, in Lincoln county, and east of this the Kearney canal, in Buffalo county. The head of the former is near Brady island, from which point it continues easterly for about 9 miles, swinging back from the river and gradually mounting the lower bluffs to a point north of and above the town of Gothenburg, where it empties into a reservoir. From this the water is taken in large pipes to supply turbines, which in turn furnish power

to dynamos. The system, as well as that at Kearney, furnishes an excellent example of the utilization of water power under what would at first appear to be unfavorable circumstances. In the case of this canal also it was hoped that the summer water supply could be augmented or rendered more constant by drawing upon the ground water, and at the head long trenches were constructed through the marshes and low lands in order to bring out this accumulated water. Tests were also made above the head of the canal in the old river bed of the Platte, and the engineer in charge states that after passing through 15 feet of sand and gravel a hard clayey layer 4 feet in thickness was reached; below this in turn were found sand and gravel, the water in the latter rising to the height of that in the upper layers. Similar trials were made for a distance of 1.5 miles up stream, all giving the same result.

The Kearney canal is of interest more from the side of water power than from that of irrigation. The head is in the vicinity of Elm creek, and from that point it extends easterly for about 15 miles to a reservoir near town. Water is taken directly from the river, and during the summer the various rivulets flowing in the broad sandy channel are brought together and forced over to the north bank by means of a temporary obstruction of sods and sand laid diagonally up stream. Large amounts of money have been spent in excavating and making long trenches in the sands and gravels of the bottom lands. It is claimed that this work was at least partially successful, but apparently this part of the project has been abandoned. In addition to the canals built or projected to take water from Platte river, plans have been made for utilizing the supply in the forks of the Loup river; for example, to cover lands near Brokenbow, in Custer county, and the town of Loup, in Sherman county. Both of these points are east of the one hundredth meridian, which for convenience has been assumed to be the eastern boundary of the irrigated region.

SOUTHWESTERN COUNTIES.

The counties of Perkins, Chase, Hayes, Frontier, Dundy, Hitchcock, and Redwillow are in the southwestern corner of Nebraska, east of Colorado. They lie mainly within the drainage basin of the Republican river, which flows in an easterly direction along the southern boundary of the state. During the census year irrigation was practiced to a very small extent, and at that time most of the farmers indignantly denied that it was necessary. It was only after the unusually severe drought of 1890 that the majority gave up hopes of making a success of "dry farming". The serious losses of crops and the poverty prevailing at that time among the farmers caused many to leave this part of the state, while those who remained eagerly discussed the possibilities of irrigation, the few small ditches already constructed having proved the success of this method of agriculture.

The surface of this part of the state as a whole falls from the Platte river southward toward the Republican, and this, combined with the general easterly slope of the plains, gives the diagonal, southeasterly trend to these streams and allows their head waters to approach to within a few miles of the Platte. It is stated in the report by Samuel Aughey on the physical geography of Nebraska that the Republican receives by seepage a portion of the waters of the Platte. It is probable, however, that the rainfall upon the pervious beds of this part of the state will fully account for the presence of springs supplying the tributaries of the Republican. On the divide between the Platte and the Republican and the numerous tributaries of the latter stream the soil is unusually fertile, and with sufficient rain produces largely. Many farmers state, however, that during 4 or 5 years they have not been able to raise a fair crop, and one person writes that the average yield per acre for 10 years in succession has not been one-third of that in the eastern part of the state. In these 7 counties in 1889 cereals were raised on 406,720 acres, Frontier county containing the greatest area, namely, 101,026 acres. Taking the counties together, there were in barley and buckwheat 1,533 acres, in Indian corn 277,337 acres, averaging 19.65 bushels per acre, in oats 43,473 acres, in rye 12,030 acres, and in wheat 72,347 acres, averaging 11.17 bushels per acre.

The principal water supply of this area is derived from Frenchman creek, which rises in Phillips county, Colorado, flowing easterly through Chase and Hayes counties into Hitchcock county, where it joins the Republican. This creek flows throughout the year without great fluctuations. The Republican river, on the other hand, has been nearly or quite dry during the summer, in that of 1890 no water appearing in the bed, although the sands and gravels beneath the surface remain saturated. In this year construction was begun on a number of canals designed to take water from both of these streams and to carry it out upon the valley lands. The soil of the divides between the rivers might be made fertile as well as that of the lower irrigable ground, but the elevation is too great to render it profitable to conduct the comparatively limited water supply the required distance. The wells on the higher ground are from 100 to 300 feet in depth, depending upon the elevation, water being found at approximately the level of that in the valley streams.

In Chase and Hayes counties ditches have been taken out from the Frenchman and its principal tributary, and farther down the stream are canals covering land in the vicinity of Culbertson. On the Republican are ditches at short intervals from near Wray, in Yuma county, Colorado, taking water out in the vicinity of Haigler, Benkleman, Trenton, Culbertson, McCook, and Cambridge. Apparently some of these have been projected with little regard to the amount of water available, and it is only a question of a short time when, during the dry seasons, there will be a deficiency and only a portion of the land under ditches can be watered. In the case of many of the new

canals dependence is being placed upon the water which remains saturating the sands of the river bed after the stream has dried. The amount of water in these sands, as previously stated, is apparently inexhaustible by ordinary methods of pumping, but for the needs of several irrigating canals it is small. One of the earliest systems of irrigation is the canal of the Haigler Land and Canal Company (formerly the Farmers Colorado and Nebraska Ditch Company), which takes water from the south side of the north fork of the Republican river near the town of Laird, Colo. It is 13 miles long, averages about 8 feet in width, and cost $5,000. Farther east, near the town of Benkleman, are what are known as the Porter ditches, and farther down, near Culbertson, are the works of the Culbertson Irrigation and Water Power Company and of the Cambridge and Arapahoe Irrigation Company, both of these being on the north side of the creek. On the south side of the Republican are the Farmers, Trenton, and Meeker ditches.

The Culbertson canal was begun in 1890, and was planned to be 80 miles in length, 32 feet in width near the head, and to cost $170,000. It is estimated that a supply of 400 second-feet can be obtained, and that the lands can be irrigated at the rate of 200 acres to the second-foot. The Meeker ditch heads at the junction of Frenchman creek and Republican river, south of the town of Culbertson, and from this point continues easterly, covering land south of the river to and beyond McCook. The line as surveyed extends to a point southeasterly from Cambridge, and then swings back from the river to the vicinity of Wilsonville. The amount of water available from the river seems hardly sufficient to supply such a long canal. So far as known, systematic records of the amount of water in these streams have not been kept. Two gaugings, however, were made, showing that the discharge of Frenchman creek in late November was 177 second-feet, and of Republican river above Frenchman creek 209 second-feet. These measurements were made after several days of heavy rains and snow storms, and the quantity of water was greater than during the summer. Judging from the statements of the residents of this locality, the average summer discharge of Frenchman creek is somewhat less than 175 second-feet, and the Republican above this junction possibly discharges about 200 second-feet throughout the winter, the quantity fluctuating widely on account of the irregular floods.

ARTESIAN WELLS.

These wells are principally in the northeastern part of the state, the largest number being in Knox, Cedar, and Dixon counties, on the south side of the Missouri river, opposite Clay and Yankton counties, in South Dakota. There are also a number of shallow wells in the valley of the Elkhorn river, in the southern half of Holt county, about 75 miles southwesterly from the group first mentioned. There are also reported to be a few shallow flowing wells in Seward county, about 30 miles west of Lincoln, the capital of the state. The wells in Cedar and adjoining counties probably receive their water supply from the Dakota sandstone, this being the southern end of the developed artesian area, while the small flowing wells of Holt and Seward counties obtain water from gravels of comparatively recent origin.

In Knox county, at the Santee agency, a well has been drilled to the depth of 604 feet, at a cost of $1,500, the discharge, however, being only 6 gallons per minute. This small amount is accounted for, in part, by the statement that the well is on high ground. The small wells nearer the Missouri river discharge more freely. In Cedar county a large number of wells have been put down in Bow valley and near the Missouri river, these being mainly employed for watering cattle. Little if any of the water has been used for irrigation. Some of the wells have stopped flowing, clogged by sand, or the leakage through the casing is so great that none of the water reaches the surface. In Dixon county the wells are on the bottom lands, near Newcastle. Irrigation has never been tried, although the water is reported to be good, and the excess in a few instances is used for fish ponds.

In Holt county the flowing wells consist simply of a pipe from 1.25 to 2 inches in diameter, driven through the clays, sands, and gravels to a depth of from 50 to 185 feet, or until an ample supply of water is found. The water, which is clear and cold, usually rises to the surface, or even to a height of 5 feet or more above. The temperature is probably too low for the water to be used immediately for irrigation, even if it were desirable to do so. These wells cost, on an average, $48, and can be obtained almost anywhere on the low ground. A deep well 6 inches in diameter has been started at O'Neil, the county seat, the intention being to drill down to the Dakota sandstone, and a depth of about 1,450 feet has been reached. Water, if obtained sufficiently pure and in large quantities, will be used for city purposes.

The wells in Seward county reported to be flowing are at Beaver Crossing. They are very shallow and have been put down for the purpose of obtaining water for stock. East of this locality, at the city of Lincoln, a well has been drilled to the depth of 985 feet, obtaining a large amount of water at various depths, some of this being strongly saline. Still farther to the east, in Otoe and Nemaha counties, which border on the Missouri river, are several borings from which salt water flows. At Unadilla a salt well 280 feet in depth discharges at the rate of 32 gallons an hour. South of Lincoln, in Gage county, a well at Beatrice has been drilled to the depth of 1,200 feet, but without success.

Throughout central and western Nebraska no flowing wells, with possibly one or two exceptions, have been found. Water for domestic purposes and for watering cattle, as a rule, can be obtained only by drilling to a depth

of from 100 to 200 feet, windmills being used to raise it to the surface. In many places springs abound, but these, compared to the needs of the people, are very small and widely scattered. In Boxbutte, Cherry, Cheyenne, and neighboring counties, in the northwestern part of the state, the common wells are reported to be from 35 to 250 feet in depth, and in Deuel county from 140 to 300 feet. In Frontier county, toward the southwestern part of the state, it is stated that water is very scarce, and that the wells, which are upward of 300 feet in depth, are often pumped dry in from 1 to 2 hours. In Custer and Dawson counties, about the center of the state, the wells, notably on the high ground, are 300 or even 400 feet in depth, costing about $1 per foot. None of these, except possibly one or two on the bottom lands, discharge any water. In McPherson county one small well, 28 feet in depth, is reported to discharge a small amount.

KANSAS.

In Kansas, as in Nebraska, the counties are discussed in groups according to geographic position, those in the northern part of the state being considered first and then the group next adjoining on the south. In the 32 counties in the western end of the state in 1889 there were raised 775,753 acres of cereals, the greater part, namely, 523,030 acres, being in Indian corn, the average yield of which was 13.43 bushels per acre, or about one-third the average for the whole state. Second in importance to this was wheat, there being 126,247 acres, averaging 10.23 bushels per acre, while the average yield of the state was 19.21 bushels per acre. The area irrigated is almost insignificant, it being only 2.68 per cent of the acreage producing cereals.

NUMBER OF IRRIGATORS, AREA IRRIGATED, AND AVERAGE SIZE OF IRRIGATED FARMS IN KANSAS IN 1889.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.
Total	519	20,818	40	Kiowa	5	15	3
				Lane	4	48	12
Cheyenne	6	539	90	Logan	9	112	12
Clark	2	550	275	Meade	25	603	24
Decatur	10	248	25	Norton	4	27	7
Finney	162	9,151	56	Pawnee	6	92	15
Ford	116	1,807	16	Rawlins	16	323	20
Gove	3	9	3	Scott	3	24	8
Graham	14	202	14	Seward	3	146	49
Gray	4	266	67	Sheridan	7	23	3
Hamilton	8	1,130	141	Wallace	13	206	16
Hodgeman	6	70	12	Wichita	2	9	5
Kearny	91	5,218	57				

NORTHWESTERN COUNTIES.

Cheyenne, Rawlins, Decatur, Norton, Sherman, Thomas, Sheridan, and Graham counties in the northwestern corner of Kansas are drained for the most part by tributaries of the Republican and Solomon rivers, both of which streams flow easterly and then southeasterly into the Kansas river. Springs flowing throughout the year furnish water to these streams, keeping up a nearly constant supply near the head waters. At some distance below the springs the streams dwindle during the hot weather to a mere thread, and a few of the minor tributaries become dry. A small amount of irrigation has been successfully carried on, as shown by the table above, the water being diverted by a few ditches. The method of applying water more commonly in use in this part of the state is what is known as subirrigation. Dams are built across the small streams, holding the water until it backs up and covers the bottoms, in this way completely saturating the ground, and by percolation moistening a large area of low land in the vicinity. The principal streams employed in irrigation are the south fork of the Republican, Beaver, Sappa, and Prairie Dog creeks, and the north and south forks of Solomon river.

In these 8 counties cereals were raised in 1889 on 534,445 acres. Of this there were in barley and buckwheat 1,126 acres, in Indian corn 374,501 acres, producing on an average 15.68 bushels per acre, in oats 40,379 acres, in rye 36,693 acres, in wheat 81,746 acres, averaging 10.28 bushels per acre. Some of the farmers state that for many years in succession, owing to the deficiency and irregularity of rain, they have not been able to raise a profitable crop, although the soil is remarkably fertile. On account of failures of crops many farms have passed into the hands of loan and trust companies, the owners not being able to pay the interest. The hope of ultimately irrigating the land has prevented many of the farmers from leaving the country.

The rain storms on this level country are often violent, and are therefore not as efficient in wetting the soil as longer and more gentle showers. The country as a whole consists of rolling prairie, but slightly cut by the creeks,

and even where too dry for cultivation it is valuable for stock raising. Water is brought to the surface by means of windmills, from wells of from 50 to 250 feet in depth, and is utilized mainly in watering cattle, a few gardens only being irrigated in this manner. Above St. Francis, in Cheyenne county, is the ditch system, known as the Emerson, taking water from the south fork of the Republican river, the head being near the state line. These ditches are to be continued along the southeastern side of the river, down to St. Francis, passing by one or two reservoirs in which surplus water can be stored for use in time of need. Under these is a ditch known as the Benkleman, heading about 5 miles lower down, and keeping nearer the river.

WEST CENTRAL COUNTIES.

Wallace, Logan, Gove, Trego, Greeley, Wichita, Scott, Lane, Ness, Garfield, and Hodgeman counties include the central portion of western Kansas lying north of counties traversed by the Arkansas river. As in the case of the region farther to the north, small areas scattered through this region are irrigated by water obtained from springs or small creeks formed by springs, or in a few cases by pumping from deep wells. The suppply is not sufficient for general irrigation, but it has enabled experiments to be made in many localities demonstrating the value of artificial watering. The counties lie within the drainage basins of the Saline and Smoky Hill rivers, both of which flow easterly into the Kansas river, and on the south include part of the head waters of Walnut creek and Pawnee fork, flowing into the Arkansas. These streams receive most of their water from springs discharging throughout the year almost without change. During the summer season the creeks shrink to insignificant proportions, and without some method of holding water they are of little importance in irrigation. By diverting the water, near the points where it issues from the ground, and using it before much of it has time to evaporate a larger acreage can be watered than at lower points.

The rainfall is exceedingly irregular, and even if there happens to be plenty for part of the crop at least there is liability of loss by the hot winds occurring in July and August. Some of the farmers state that they have tried year after year, but have not succeeded in raising a profitable crop. They have lost nearly all their possessions in attempting to farm and only remain through hopes of the introduction of irrigation. The total area upon which cereals were raised in 1889 in these 11 counties was 132,426 acres. Of this there were in barley and buckwheat 364 acres, in Indian corn 77,106 acres, averaging 6.84 bushels per acre, in oats 10,145 acres, in rye 15,514 acres, and in wheat 29,297 acres, averaging 11.62 bushels per acre. The total population was 26,014.

The greater part of this area is a gently undulating plain cut in a few places by ravines, or draws, as they are locally called. The surface of the soil is in most places so packed by the tramping of animals that it seems to be impervious. Below this and extending to depths of from 50 to 100 feet or more is a porous material resting upon beds of sand or gravel. This latter deposit is saturated with water, and to ordinary pumping machinery the supply seems almost inexhaustible. Hopes have been entertained that by suitable machinery some of this water can be brought to the surface at a cost so low that it can be profitably used in irrigation. Attempts have been made to secure artesian wells, but unfortunately without success. At Jetmore, Hodgeman county, a hole has been drilled to the depth of 1,000 feet without obtaining flowing water, and at Larned, Pawnee county, salt water has been struck. Water is diverted by means of ditches from Beaver or Ladder creek, from Rose creek near Wallace, and from a number of other streams. Most of these are very short, only about a mile in length. Among the most important of these ditches is that belonging to the Elkader Water Power and Irrigation Company, taking water from Beaver creek. It is 3 miles long and about 3 feet wide. It was begun in 1888 and it was used to a small extent in 1890.

COUNTIES ALONG ARKANSAS RIVER.

Hamilton, Kearny, Finney, Gray, and Ford counties are traversed by the Arkansas river, which flows in a general easterly course from Colorado. Water for irrigation is diverted from this river by means of several large canals, heading in succession from a point near Syracuse down to and beyond Dodge. This stream is about the only source of supply, except in the case of wells from which water is pumped to irrigate a few acres.

Agriculture without irrigation has been attempted in many localities in these counties, but the results have been so discouraging that many farmers have abandoned their homes and with their few movable possessions have gone to other states. The soil on the plains, especially to the north of the river, is fertile, and the climate is favorable to agriculture in all respects except that of moisture. Although many attempts at farming have been made by persons from various parts of the United States and Europe, having all degrees of skill, comparatively few have prospered, the most successful persons being those engaged in raising cattle, the buffalo grass furnishing excellent grazing. The total area upon which cereals were raised in these 5 counties in 1889 was 51,587 acres. Of this there were in barley 410 acres, in Indian corn 33,009 acres, averaging 9.22 bushels per acre, in oats 10,002 acres, in rye 3,056, and in wheat 5,110 acres, averaging 8.60 bushels per acre.

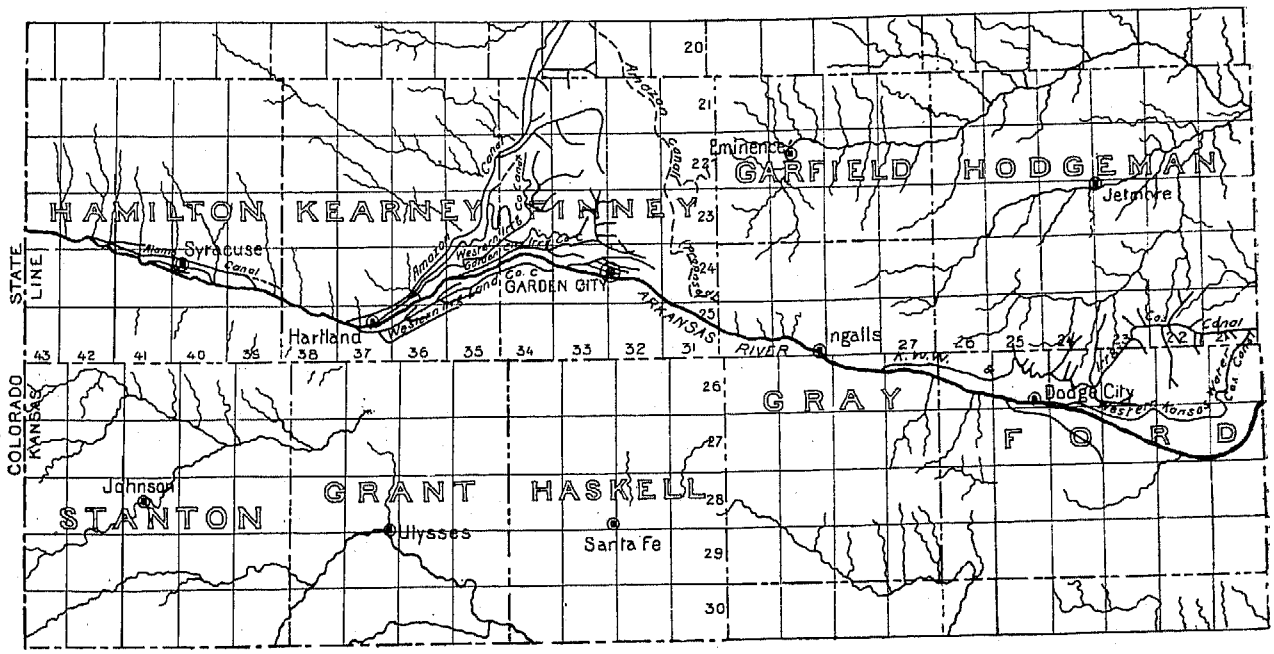
The soil on the so-called table lands or plains is superior to that in the valley of the Arkansas, this latter being more or less sandy and occasionally impregnated with alkaline salts, but the higher land can not be brought

under irrigation except to a small degree by long canal lines or by storage reservoirs. Water for domestic use is obtained by means of wells of from 30 to 300 feet in depth. Some of these are pumped by windmills, but the supply obtained by this means is too small for the irrigation of more than a few acres.

In 1889 a preliminary line was run by engineers of the United States Geological Survey to determine the possibility of diverting the water of the Arkansas upon the high lands in Hamilton and Finney counties. This survey, starting about 10 miles west of the Kansas-Colorado line, followed along the north side of the river, the line passing about 4 miles north of Syracuse and 8 miles north of Kendall. It then turned and passed northerly across the high land. This work showed that if water could be stored in sufficient quantities to supply all the canals it would be possible to bring under irrigation a large part of the land in the counties north of and adjoining the Arkansas in western Kansas. In short, the amount of land which can be watered is only limited by the available supply.

The Arkansas river, although having a large drainage area, is a somewhat unsatisfactory stream for purposes of irrigation. The greater part of the water is diverted for use in Colorado long before the stream reaches the Kansas line, and the channel of the river in the counties named above is occasionally dry, the duration of drought being apparently longer in the lower counties than in those up stream. During June and into July there is usually a period of high water, during which the canals can be filled. There has been general complaint among the farmers regarding the irregularity of water supply and of the methods of canal control. Some of the canals were built with the intention of obtaining a supply of water from what has been termed the "underflow", or water saturating the permeable beds of sand and gravel under or adjacent to the river. The amount of water thus obtained has been too small to repay the outlay. Added to this the fact that many of the farmers are not skilled in irrigation, it results that there is more or less dissatisfaction, intensified by the too sanguine hopes of great benefits to be received from this method of agriculture. The annual cost of water and the uncertainty of obtaining it each year have deterred many farmers under the canals from attempting to irrigate. Those, however, who have received a sufficient supply and have used it to advantage have prospered.

MAP OF IRRIGATING CANALS ALONG ARKANSAS RIVER IN WESTERN PART OF KANSAS.



The principal canals in order from the Colorado line easterly are on the north side of the river, the Alamo, Amazon, Southwestern, Kansas, Garden City, Eureka, and Pawnee canals, and on the south the Western canal and South Dodge. The Alamo canals take water out on the north side of the Arkansas river, canal No. 1 heading about 6 miles below Coolidge and canal No. 2 about 5 miles lower down, being above Syracuse. Both of these flow in a general parallel course to and beyond Syracuse. The total length is 20 miles, the average width 15 feet, and the total cost was $17,000. The canals were begun in 1888 and used to a small extent in the succeeding year. The company does not sell water rights, but delivers the water each year for about $1.50 per acre.

The Amazon canal of the Syndicate Lands and Irrigation Company was projected to take water from below the bed of the river by means of a deep trench heading about 3 miles above Hartland in Kearny county, the canal continuing to a length of upwards of 100 miles. Water first used from the canal was diverted from the river by means of a temporary wing dam of sods, the permanent inlet not having been constructed. No perpetual water rights are sold, but the charge for water has been $2 an acre.

The Southwestern canal, owned by the Southwestern Irrigation Company, heads about a mile above Hartland, Kearny county, and follows along the river on the north side in a general northeasterly direction. It is 40 miles long and 20 feet wide. Below this are the Kansas and Garden City canals, both belonging to the Garden City Irrigation Company. The length of the first is 20 miles and the average width 16 feet, and the length of the second is 12 miles and width about 12 feet. Both of these cover land in the vicinity of Garden City. Water is delivered to the land at the rate of $1.25 per acre, no rights being sold. Under many of these canals there has been considerable difficulty in persuading the farmers to use the water in a proper way or even to employ it at all, and as a rule more water has been turned on to the fields than can be properly used.

The canal of the Kansas Water Works and Irrigation Company, formerly known as the Eureka, takes water from a trench on the north side of the Arkansas, west of Ingalls, Gray county. The total length of the canal is 96 miles, the average width 30 feet, depth about 4 feet, and the cost is stated to have been $2,000,000. It was begun in 1884, used in 1887, and finished in 1889. The first 40 miles consist of a series of heavy cuttings in rock and earth, no flumes being used. The grade of this part of the canal is about 20 inches to the mile, while the average fall of the Arkansas river here is 7 feet per mile. Thus in the neighborhood of Dodge the canal has attained a height of about 100 feet above the river, and, having reached the top of the bluffs, continues to Spearville and Kinsley, being for the greater part of the way on a low table-land or plateau, where the topography is such that water can be taken out by laterals on each side. The canal is owned by a corporation, which sells water to farmers, water rights being valued at $15 per acre, subject to an annual assessment of $1 per acre. It is considered that 1 miner's inch per acre under a 4-inch pressure is sufficient.

It was the original intention to divert water by means of a dam in the Arkansas, but the structure built for this purpose was washed away by a flood in 1890. This attempt having failed, a trench, known as the gathering channel, was excavated parallel to the river at a depth of about 10 feet below the level of the stream and for a length of nearly 2 miles. It is proposed to lift water from this gathering channel or reservoir into the canal by means of four centrifugal pumps, each capable of delivering 16,000 gallons of water per minute, or 35.65 second-feet, and all driven by 2 engines of 40 horse-power each. It is claimed that when the water is lowered from 4 to 5 feet by means of the pumps the inflow is so great that the supply appears to be inexhaustible by such means.

The South Dodge canal, owned by the Western Kansas Water Works, Irrigation, and Land Company, is on the south side of the Arkansas, the headworks being about 6 miles west of Dodge. It continues in a general southeasterly course and at a distance of about 3 miles from the river, ending at Mulberry creek, near Ford. The total length when completed will be 30 miles, and the average width about 20 feet. It is proposed to supply water during the summer to this canal by means of 2 centrifugal pumps drawing from a gathering channel similar to that on the north side of the stream.

The canal of the Western Irrigation and Land Company heads on the south side of Arkansas river about 1.5 miles west of Hartland. The main canal is 25 miles in length, and has a width of from 30 to 35 feet near the upper end. The company has also constructed 35 miles of laterals of from 8 to 12 feet in width. The total cost is stated to have been $100,000.

COUNTIES SOUTH OF ARKANSAS RIVER.

Stanton, Grant, Haskell, Morton, Stevens, Seward, Meade, and Clark counties include the area in the southwestern corner of the state south of the Arkansas river. These are for the most part situated within the drainage basin of the Cimarron river, or creek, which cuts across the southeastern corner of Colorado and flows in a northeasterly direction through Morton, Stevens, and Grant counties, then turns nearly at a right angle and continues through Seward and Meade counties, finally crossing the south end of Clark county. This stream and some of its tributaries are the principal source of water supply south of the Arkansas. It is a small, shallow stream, hardly more than a brook, at some parts of its course flowing throughout the summer and at others the water during the hot weather occasionally disappearing through evaporation. (*a*) A few ditches have been constructed at various points along the banks of the Cimarron, and surveys have been made in order to determine in a general way the feasibility of larger irrigating systems depending for their water supply in part at least upon storage.

Many farmers state that they have tried for at least five years to raise crops, but have failed in nearly every season. The rain is very irregularly distributed, and while some farms may receive it in one year, others do not. All crops and fruit trees do well in the early months of the year, but during the long, dry summer, with its hot winds, they wilt and die unless a rain storm happens to occur at the critical moment. In these 8 counties cereals were raised in 1889 on 57,295 acres. Of this there were in barley and buckwheat 138 acres, in Indian corn 38,414 acres, yielding 8.30 bushels per acre, in oats 5,588 acres, in rye 3,061 acres, and in wheat 10,094 acres, the average yield of wheat being 6.60 bushels per acre.

The largest ditch in use in 1889 was that of the Claremount Land and Irrigation Company, taking water from the Cimarron river, the head of the ditch being near the northeast corner of Beaver county, Oklahoma, 3 miles

a When measured on October 23, 1892, by topographers of the United States Geological Survey the discharge was found to be a trifle less than 15 second-feet at a point one-half mile below Arkalon, Kan.

south of the Kansas line and a short distance west of the one hundredth meridian. The total length of the ditch, which ends in Clark county, Kansas, is 8.5 miles, average width 15 feet, and the cost was $6,500. The ditch was built to water the Claremount ranch, there being very little demand for water along the line of the ditch in Oklahoma. The supply is not sufficient for the land under the ditch, especially during the summer. The water is used mainly to irrigate crops sown in the fall, namely, wheat, rye, and barley, it having been found that one irrigation in fall, winter, or spring insures a crop. In Beaver county, Oklahoma, are other ditches taking water from the Cimarron, and also one ditch from Paladora creek, in Grand valley, this stream receiving its water from springs.

ARTESIAN WELLS.

In Kansas there are two small groups of artesian wells in the southwestern corner of the state, in Meade and Hamilton counties, and also several deep wells in various parts of the state, some of which discharge small quantities of water, this being, however, usually saline. In Meade county the wells range from 50 to 210 feet in depth, averaging 153 feet, and with a flow of 49 gallons per minute. Nearly all of them are only 2 inches in diameter, and consist simply of a pipe forced through the unconsolidated clays and sands. The water is reported to be pure and sweet and suitable for all uses. It is employed in irrigation as far as possible, since there are many seasons in which no crops can be successfully raised without the application of water. The first flowing wells were sunk in 1887, and since that time, with the number increased each year, no decrease in the supply has been noted.

In these wells great trouble is frequently experienced on account of the fine sand which flows in and rapidly fills the pipe. This comes with great rapidity at times and in almost inexhaustible quantities. There appears to be little regularity in the stratification of these wells, and it is reported that water is struck at irregular depths, a well on high ground frequently reaching a flow at less depth than one on lower ground.

In Hamilton county, along the Arkansas river, near Coolidge, and also over the line in Colorado, are a few deep wells flowing from 10 to 50 gallons per minute. One of these, 275 feet in depth, 5 inches in diameter, flows at the rate of 20 gallons per minute. The owner has built a reservoir in which to store the water to be used for irrigation. In Morton county, in the extreme southwestern corner of the state, a well was drilled in 1888 to the depth of 700 feet. This is reported to deliver water at the rate of 30 gallons per minute, irrigating a garden containing vegetables, corn, and trees. In other parts of this county water is pumped from shallow wells by means of windmills. At Santa Fe, in Haskell county, a well has been drilled to the depth of over 1,000 feet, but it has been abandoned, although water is reported to have risen to within 50 feet of the surface.

Northerly from this locality, particularly in Logan county, wells are put down to the depth of 300 feet and over in order to obtain water. This usually rises to within 100 feet of the surface. In Trego county, about the center of the western half of the state, a well was sunk to the depth of 650 feet at Gibson, obtaining only a little water at the bottom. Southeasterly from this latter locality, in Pawnee county, on the Arkansas river, at Larned, a well 910 feet deep, 8 inches in diameter, drilled in 1888, at a cost of about $3,500, yields a small amount of water carrying a notable amount of mineral matter. This is reported to flow to the height of 10 feet or more above the surface and to be highly medicinal in character. Near Great Bend, in Barton county, brine has been encountered. At Jetmore, in Hodgeman county, 45 miles westerly from Larned, there is reported to be an unsuccessful well 1,000 feet in depth.

In Reno county, easterly from Pawnee, ordinary water wells are obtained at depths of from 10 to 30 feet, water being brought to the surface by pumps usually driven by windmills. The prevalence of a large amount of water saturating the porous beds beneath the surface has given rise in this part of the state to certain ideas concerning what is called the "sheet water", popularly supposed to be flowing beneath the surface. The structure and character of the unconsolidated layers beneath the surface promote the retention in considerable quantities of the water which falls as rain or snow throughout that part of the state, so that wells dug or pipes driven down to these porous layers receive an ample supply.

In the northeastern part of Kansas several deep wells have been drilled. For example, in Marshall county, at Marysville, a hole was bored for coal to the depth of 1,360 feet, encountering 4 water bearing strata. The casing has been pulled, and the water, saline in character, now flows in a small stream. Westerly from Marshall county, near Jamestown, in Cloud county, there is reported to be a flow of brine. About 50 miles east of Marysville, at Sabetha, in Nemaha county, the railroad company has drilled a well to the depth of 200 feet, the water, it is reported, flowing to the surface.

In the eastern end of the state water is pumped from wells 100 feet or more in depth, and in Miami county are a number of gas wells which have encountered salt water at depths from 200 to 300 feet. South of here, in Bourbon county, near the southeastern corner of the state, are deep wells, some put down for gas, a few of which are reported to discharge a little water. Southeasterly, in Neosho county, it is stated that mineral water is obtained at depths of 100 feet, and in Montgomery county there are probably a few flowing wells on low land.

TEXAS.

PANHANDLE COUNTIES.

In the following discussion of the condition of irrigation in Texas during the census year the counties are taken up in groups according to their geographic position, those in the northern extremity, known as the "Panhandle" of Texas, being mentioned first. Included in this area are the counties of Lipscomb, Hartley, Hutchinson, Hemphill, Oldham, Carson, Donley, Collingsworth, Hall, Floyd, and Motley, where there were in all 22 irrigators and 566 acres upon which crops were raised by the artificial application of water. These counties and the adjoining counties are mainly upon the Staked Plains, where the rainfall is usually sufficient to produce good crops of wheat, oats, barley, potatoes, and grass. The soil throughout this region is very fertile, and with sufficient moisture the yield is always large. Irrigation may be regarded as exceptional, being practiced in only a few localities where water can be readily had.

In Hartley county is a small ditch from Romero spring, and in Hutchinson county another from a creek tributary to the Canadian. South of this, in Carson county, water can be obtained only from wells, this county being on the high divide between the Canadian and Red rivers. Here all kinds of stock, both in summer and winter, find feed on the wild grasses. Water for stock is obtained by means of wells of from 200 to 350 feet in depth, and is raised by windmills, no flowing wells being reported. In a few instances steam power has been introduced for the purpose of pumping water, the supply of which at the depths given is apparently inexhaustible. In Hemphill county, farther down the Canadian river, a little irrigation is practiced. above the town of Canadian by means of water from Clear creek. Farther south, in Childress county, water is obtained from wells of from 40 to 150 feet deep, none of these flowing. South of the Red river, in Hardeman and Wilbarger counties, test wells have been drilled, in the former to the depth of 1,200 feet without success, and in the latter reaching salt water at 320 feet.

TRANSPECOS COUNTIES.

In El Paso and the adjacent counties of Jeff Davis, Reeves, Ward (*a*), Presidio, and Pecos there were 178 irrigated crop areas, having a total of 8,039 acres. These counties lie in the extreme western end of Texas, south of New Mexico and north of the Rio Grande. The surface of the greater part of this region, known as Transpecos Texas, is composed largely of short mountain ranges having a general northwesterly and southeasterly trend and rising abruptly from the plains which surround them. These plains are composed of light materials washed or blown from the mountain masses, and the soil is rich and highly productive whenever irrigated. Various nutritious grasses, the most valuable of which is known as gama grass, are to be found on the plains and hill slopes, furnishing excellent pasturage for cattle. The water supply, however, is so deficient that during a great part of the year there is not enough for cattle to drink, and thus vast areas are rendered useless.

Irrigation is carried on at a number of places along the Rio Grande from El Paso down to Presidio both in Texas and in Mexico. There is a large canal heading at El Paso and carrying water of the Rio Grande to Ysleta, San Elizario, and other small towns down to Fabens. This canal is reported to be 40 miles long and 60 feet wide at the head. Besides this large canal, lately completed, each town has its own acequia, which has been in use for a century or more. The supply of water in the Rio Grande is ample in most years excepting in the months of August and September. In 1889 and 1890 the river ceased flowing about the latter part of July and the bed remained dry until late in the fall, so that the necessities of water-storage were more clearly seen than ever before.

Above the town of El Paso is a suitable locality where, by the construction of a dam at the narrow pass near the town, an enormous amount of water can be held for use during the dry months. This locality has been carefully examined by the United States Geological Survey, and it has been found that by the construction of a dam 60 feet high above the river bed a lake about 14 miles long and 4 miles wide would be created. This lake would contain over 500,000 acre-feet, and of this amount at least 200,000 acre-feet could be made available, an amount sufficient to increase the area under cultivation along the river by at least ten times. The water supply at this point is discussed under the head of Donna Ana county, New Mexico. Among the high mountains there are unquestionably many localities at which flood water can be held in storage reservoirs. In a land utterly devoid of perennial streams, waterworks of this kind have more than usual value, from the fact that they render available vast areas of pasture land, and in some instances render possible the development of the mineral wealth of the country.

In Jeff Davis county, in the vicinity of Fort Davis, a small amount of land is irrigated. Also in Pecos county areas of considerable size in the vicinity of Fort Stockton and to the north of this, toward the Pecos river, are cultivated by means of water from springs. These springs form small creeks, of which the principal are Comanche, Leon, Santa Lucia, and Santa Rosa. A number of ditches take the water from these creeks and bring it out upon the ranches near the southern edge of the Pecos valley.

In Pecos valley some land was cultivated in 1889 by means of water from the Pecos river taken out by the Hardman canal, Pecos River canal, and other ditches. The principal canal, however, is farther up the river, in

(*a*) Ward county is included in this grouping, although east of the Pecos river.

Reeves county. This is the Pioneer canal, heading about 10 miles northerly from Pecos and carrying water out on the west side of the river in Reeves county. The main ditch is 3.75 miles long and 30 feet wide. Water is to be diverted by means of a brush and stone dam, raising the level about 2.5 feet. At its lower end the main canal branches, the East Valley canal being carried across the Pecos river into Ward county, and the West Valley canal continuing down to and beyond Pecos. When completed there will be about 30 miles of branch or distributing ditches covering the lands between Pecos and Barstow. The cost of the water right is about $10 per acre and the annual assessment $1.50 per acre. The canal is rapidly approaching completion, allowing the cultivation of large areas. Throughout this part of Texas small patches of land are cultivated wherever sufficient water can be found. Corn, wheat, oats, and barley, beans, cotton, and fruit are thus raised. It may be said that planting and harvesting go on continually throughout the year. Often two crops of corn are raised on the same land, or one crop of wheat followed by one of corn; three or four crops of peas are obtained each year, and vegetables are to be had at all seasons if there is sufficient water.

The method of irrigation along the Rio Grande is in general that peculiar to old Mexican settlements. Water is usually applied to the land by flooding within small borders or ridges of earth, these borders being a foot or more in height and about 18 feet apart, dividing the land into squares or rectangles. Water is allowed to flow from one square to another until the surface of the ground is completely saturated. This method requires a large amount of personal attention and care on the part of the irrigator. Attempts have been made in various parts of this region to find water by deep wells.

Along the Texas and Pacific railroad, through western and transpecos Texas, wells have been drilled in nearly every county, but often without success. In Mitchell county, at Colorado city, the well, 1,120 feet in depth, reached salt water, while that to the west, in Howard county, passed through salt water for about 300 feet. In Midland county a hole 350 feet in depth did not reach flowing water, and in Ector county, at Odessa, a well 830 feet in depth was a failure. At Pecos, however, in Reeves county, artesian water has been found, but farther to the west the deep wells have not been successful so far as flowing water is concerned. In El Paso county a well at Torbert 1,100 feet in depth has been abandoned. Another, at Sierra Blanca, 943 feet deep obtains plenty of brackish water, but does not flow. At Finlay a well 1,080 feet deep did not reach good water and was abandoned, and at El Paso no water was reached at 800 feet.

COUNTIES NEAR THE HEAD WATERS OF BRAZOS RIVER.

In the counties lying on or near the head waters of the Brazos river 31 irrigators were reported, having an irrigated crop area of 185 acres. These counties are Taylor, Jones, Shackelford, Young, Baylor, Wichita, Wise, together with the neighboring counties of Hood and Somervell. Nearly all of this land is irrigated by water from wells, either flowing or raised by windmills. At Abilene, Taylor county, a small acreage is irrigated by a ditch from Cedar creek and also by windmills. Nearly all crops can be raised in ordinary seasons without irrigation.

In several instances farmers have constructed reservoirs to hold rain and flood waters. In Young county, for example, a reservoir is being built by a farmer, the dam for which is 700 feet long, 140 feet wide at base, and 40 feet at top. Water is to be brought to this in part by a ditch running around the hillside to enlarge the drainage area tributary to the reservoir. When full about 5 acres will be covered to a depth of from 8 to 10 feet. This water will be distributed by means of pipes and open ditches. In Somervell county nearly all the irrigation is being done by artesian wells, although in the valleys large areas could be covered by ditches taken from perennial streams. In the vicinity of Glenrose there are at least 60 artesian wells, from 200 to 400 feet in depth. The cost ranges from $150 to $500 each. The water has been successfully used to irrigate cotton, Indian corn, ribbon cane, and garden vegetables. It is asserted that there are 200 of these wells in the Paluxy valley.

TOM GREEN AND ADJOINING COUNTIES.

In Tom Green and other counties on the head waters of the Colorado river and extending to and including Lampasas county there were 159 irrigated crop areas, having a total of 5,531 acres. These counties, named in order are, Martin, Midland, Irion, Tom Green, Concho, Menard, McCulloch, Coleman, Brown, San Saba, and Lampasas. Water for irrigation is taken principally from the small tributaries near their heads, comparatively little being diverted from the main streams at points where they have attained a size sufficiently great to be called rivers. The more southerly of these counties, especially San Saba and Lampasas, are noted for the large springs which form the main source of supply for the creeks. A few of these springs discharge as much as 5 second-feet and are so situated that the water can be used for running machinery, such as flouring mills. Many of these, however, have not been utilized in any way and the water runs to waste.

The Concho river and many of the creeks supplying it rise in the edge of the Staked Plains and flow in a general southeasterly course nearly parallel with the Red fork of Colorado river, with which it finally unites. All of these streams can be utilized for irrigation, since it would be a matter of comparatively small expense to divert water upon the fertile valleys or even upon the plateaus bounding these. The Concho especially offers opportunities

for irrigation, the discharge being probably more constant than that of the other rivers and the lands to be irrigated at a relatively low altitude.

In Menard county the greater part of the area irrigated is covered by the ditch of the Vaughan Agricultural and Mechanical Company, taking water from the south side of the San Saba river. This stream is fed mainly by springs and flows throughout the year. The head of the ditch is 4 miles west of Menardville. The length is about 9 miles, average width 8 feet, and the cost was $20,000. The annual charge for water is $2 per miner's inch, 100 miner's inches being the quantity discharged through a box 10 inches square under a head of 2 inches. Under this canal small grain is irrigated at intervals of from 12 to 15 days, corn at from 15 to 20 days, and cotton at from 18 to 25 days.

The value of irrigation in this locality may be judged from the fact that land worth $1.50 per acre before being brought under irrigation is after the introduction of this method of agriculture valued at $50 an acre at least. By thorough watering it is reported that from 1 to 2 bales of cotton per acre are raised, while on the same land without water less than one-fourth bale can be raised. The annual charge to the irrigators is $2 per miner's inch a year, an inch being supposed to water an acre. Water is applied to the cotton by running it in furrows, and to small grain by flooding.

In Irion county, in the vicinity of Sherwood, are a number of small ditches, of which the principal are the Lackey and McDonald ditches, taking water from Spring creek, and Stetson ditch, taking water from Dove creek, both of which creeks are tributaries of Concho river, one of the branches of the Colorado river. The water, as in the case of the other streams, comes mainly from springs, and there is an amount ample for all present needs. Alfalfa, grass, wheat, oats, and other grains are irrigated by flooding, while the corn, potatoes, and gardens are kept wet by means of furrows. It is reported that cotton is becoming a favorite crop for irrigated land, 1.5 bales or more to the acre being raised. At localities away from the streams water is obtained at depths of from 50 to 100 feet and is raised to the surface by means of windmills. The Sherwood irrigating ditch takes water from Spring creek, 2 miles west of Sherwood, and carries it out on the south side of the creek for a total distance of about 3.5 miles. The width is 6 feet, and the cost when built, in 1884, was $1,000. Water is diverted from the river by a dam of rock and planks. In 1889 about 300 acres were irrigated, this area being largely in oats and sweet potatoes, together with gardens. In 1890 cotton was tried for the first time, three-fourths to one bale per acre being raised.

East of Irion county, and farther down the stream, in Tom Green county, are a few small ditches irrigating land above San Angelo, the principal crops being corn, cotton, oats, beans, pease, and minor vegetables. Farther up the Concho river, in Martin and Midland counties, a small amount of irrigation is carried on by means of water pumped from wells of a depth of 10 to 100 feet. On the Staked Plains wells of this latter depth seldom fail to find ample water, and the wind movement is sufficient to keep mills in active operation. The water is carefully controlled and allowed to flow into small basins around each fruit tree, or run in furrows to vegetables, so that a comparatively small amount is sufficient for a large area. At Marienfield projects for greatly increasing the fruit area have been started, and there is probability that the acreage will increase rapidly.

TRAVIS AND NEIGHBORING COUNTIES.

In Travis and the adjacent counties of Williamson, Burnet, Coryell, Bell, Falls, and Milam there were 19 irrigators and a total irrigated crop area of 364 acres. In these counties irrigation is exceptional, since crops are raised each year without the artificial application of water. A few small farms, however, scattered here and there are irrigated by means of little ditches from springs, by flowing wells, or by water pumped by windmills. The yield per acre is greatly increased by this means, and vegetables are raised at nearly all seasons.

In Travis county, about 15 miles northwest of Austin, a small ditch is taken out of Cypress creek, which receives its water mainly from springs, and market gardens are irrigated. In Coryell county, on Leon river, 5 miles southeast of Gatesville, the Sheridan ditch takes water from Fort Gates creek. This stream generally furnishes ample water, but becomes dry perhaps once in 12 or 15 years. Corn, cotton, and sweet potatoes are irrigated, as well as various garden vegetables. For sweet potatoes and cabbage water is used from the middle of April to the middle of September at intervals of about 15 days, and for cotton from the 15th of June to the 1st of October at the same intervals.

BEXAR AND NEIGHBORING COUNTIES.

In Bexar and other counties lying southwest of Colorado river and south of San Saba river, one of its branches, there were 139 irrigated areas, having a total of 1,009 acres. These counties in order from north to south are Mason, Llano, Kimble, Gillespie, Blanco, Kerr, Kendall, Hays, Bandera, and Bexar. As in the case of the other areas described, a large part of the irrigation is carried on by water from springs. At San Antonio, in Bexar county, however, water is obtained directly from San Antonio river by means of two ditches, one on each side of the stream. These ditches were constructed by the early Mexican settlers, and have been controlled largely according to customs instituted by the first inhabitants. There are two commissioners, whose duty it is to

superintend the ditches on the east and west side of the river, to keep them clean and in repair, and to see that all parties entitled to the water receive their proper share. Crops are raised in the vicinity without irrigation, but this method of agriculture possesses the advantage of enabling market gardeners to raise vegetables throughout the year. There are also in the vicinity of San Antonio a number of artesian wells.

In Hays county some water is taken from Cypress fork of Blanco river by two or more small ditches, one of which is used mainly for supplying power for a mill. In this county there is reported to be a flowing well of a depth of 131 feet 5 inches in diameter, flowing at the rate of less than a gallon a minute. In all of these counties the small irrigating ditches are occasionally not used for weeks at a time, since the ground often receives sufficient moisture from rains. Some of the farmers speak unfavorably of irrigation, saying it robs the soil of its richness, and that a heavy application of fertilizers is necessary. This perhaps is because the spring water used is generally very clear, and if employed in excess it washes away valuable mineral salts.

In Kimble county attempts have been made to divert water from the South Llano river at a point 4 miles above Junction by means of a dam 7 feet high. This, however, has been injured by spring freshets, so that irrigation on a considerable scale has not been possible. There is a large amount of fine, rich valley land, and usually ample water in Little Llano river. Corn, oats, wheat, sorghum, cane, and potatoes are now raised without irrigation. Where water can be had four crops of alfalfa are obtained.

VALVERDE AND NEIGHBORING COUNTIES.

In Valverde and the neighboring counties of Edwards, Kinney, Uvalde, Medina, Maverick, Zavalla, Dimmit, and Lasalle were 75 irrigated crop areas, having a total of 2,547 acres. These counties lie along and northeast of the Rio Grande, extending from the mouth of the Pecos to the head waters of tributaries of Nueces river, which flows in a general southwesterly direction, parallel to the Rio Grande, into the Gulf of Mexico. Over a great part of these counties crops can be raised without irrigation, but with it the yield is larger, and there is greater assurance of success.

All of the irrigation is done by means of water from springs or from small creeks formed by these. The water is usually clear, since it comes from limestone strata, and does not carry in suspension the fine sediment so valuable for fertilizing purposes. In this it differs from water from the Rio Grande, which is remarkably rich in silt. Great care, therefore, must be used in applying this water in order that it may not wash away valuable salts already contained in the soil. The principal crops are corn, cotton, sugar cane, sorghum, wheat, oats, and hay. Whenever water is abundant these are irrigated at short intervals throughout the year unless there happens to be an unusual amount of rain.

At the town of Del Rio, in Valverde county, lands are watered by means of ditches from San Felipe creek. Water is turned into the laterals of shareholders for from 2 to 5 hours per share at intervals of 15 days. It is applied to the land usually in the old Mexican method, and since many of the laborers are unreliable or unskilled, the results are not always satisfactory, the lands sometimes being washed or injured by careless application. Irrigated land, however, is quoted as selling at $100 per acre. In general 2 crops of corn are planted, the first in February or March, and the second in June. It is stated that the June corn, coming probably from Mexico, does better than the earlier corn. Three or sometimes 4 crops of sorghum are raised, mainly for feed. At this town there is a well sunk to a depth of about 430 feet. Water rises within 45 feet of the top, but it is reported to be heavily charged with mineral matter.

In Zavalla county water is taken from the west side of the Leona river by the ditch of the Comanche Irrigation Company. This stream is a tributary of Frio river, which flows into the Nueces. It is fed by springs, is rarely dry, but is subject to occasional floods from local rains. The ditch is 3 miles long, about 8 feet wide, and carries approximately 6 second-feet. Water is diverted by a permanent dam of wood, brush, and stone. Water is distributed to those entitled to it, each person using the full stream for as many hours as he has acres in cultivation. The first cost of water right was about $12 per acre, and the annual assessment 50 cents an acre. Crops in this county are raised without irrigation, but the farmers state that they can not be sure of more than 2 crops in 3 years.

In Frio county, east of Zavella, are several flowing wells. On one farm about 20 miles southeast of the center of this county, on San Miguel creek, are three, 160 feet, 266 feet, and 391 feet in depth, respectively, flowing at the rate of 5 gallons, 8.5 gallons, and 6.5 gallons a minute. The third well is on higher ground, and though much deeper discharges less water than the second. In no case does the water rise more than 7 or 8 feet above the surface of the ground. The cost of such wells is usually $1 a foot for the first hundred feet, $1.50 a foot for the second hundred feet, and so on, 50 cents per foot being added for each increase of 100 feet. These wells are usually cased with pipe from 3 to 6 inches in diameter, costing from 25 to 75 cents per foot. Still farther to the east, in Atascosa county, is a well 315 feet deep, in which the water rises to the top.

In the counties of southern Texas, south of the Colorado river, flowing wells are found irregularly distributed from about the vicinity of San Antonio down to the coast. The wells in Hays, Bandera, and Gonzales counties are small and shallow, yielding only enough water for cattle. In Bexar county the wells are mainly at San

Antonio. These are upward of 800 feet in depth. In Medina county a well 1,000 feet in depth did not reach fresh water. In Uvalde county, west of Medina, the water obtained from flowing wells is reported to be impregnated with mineral matter, but, on the contrary, south of this locality, at Carrizo Springs, in Dimmit county, the water from artesian wells is sufficiently pure to be used for irrigation. In Webb county, south of Dimmit, at Laredo, on the Rio Grande, there have been repeated failures in the attempt to secure flowing water. To the eastward, near the coast, fresh water has been obtained in Victoria county from wells 825 to 946 feet in depth. This water will rise to a height of 50 feet above the surface. At Corpus Christi, in Nueces county, a well 1,700 feet in depth contains water highly charged with mineral matter.

ARTESIAN WELLS.

In the preceding description a number of flowing wells have been mentioned, mainly in connection with their use in irrigation. In the following paragraphs, however, mention is made of the artesian wells which were enumerated without special regard to the way in which their waters were utilized. These wells are as a whole found mainly near the center of the state, scattered over a broad belt extending in a general north and south direction between the ninety-sixth and ninety-ninth meridians, the greater number being in the vicinity of the cities of Dallas, Fort Worth, Waco, and towns farther to the south. The position of these wells is governed by the peculiar geologic structure of the state, the largest number of wells being located in such position that they reach a thick sandstone at the base of the cretaceous, known as the Trinity sands. This sandstone, as described by R. T. Hill, comes to the surface in an irregular line extending from Cooke county southwesterly and southerly through Montague, Wise, Parker, Erath, Comanche, Mills, Lampasas, Burnet, and Blanco counties. From this line of outcrop the sandstone dips easterly or southeasterly, at a gentle angle, toward the Gulf, the dip being slightly greater than the fall of the surface, so that the bed is found at a greater and greater depth as borings are made to the eastward.

The principal flowing wells of the state are found within the belt of country about 80 miles in width lying to the east of this outcrop, but this area by no means includes all of them. There are other sandstones lying above the Trinity sands which also slope toward the Gulf faster than the land descends, and at localities in southeastern Texas, where the Trinity sands are buried too deep to be reached by the drill, these overlying porous layers are frequently pierced, yielding artesian flows. The wells, however, receiving water from these sandstones do not as a rule yield as large a quantity, and there is less certainty of success in the deep borings for water.

West of the line where the Trinity sands come to the surface, as above described, is a group of rocks which belong mainly to the coal measures and dip toward the west and northwest, having in general a basin-like structure. Flowing wells have been obtained near the edge of this basin, but the water is generally saline in character or so heavily charged with mineral matter as to be unfit for most purposes.

In the following descriptions the counties will be taken up in general order from north to south. The most northerly well is probably in Grayson county, 16 miles northwest of Sherman, and was bored in the search for coal. This is 480 feet in depth, and is reported to have passed through 3 water-bearing strata at 140, 160, and 180 feet from the surface, respectively. A pure water, pleasant to the taste, now flows from the lowest water bearing sandstone. The well is situated in heavily timbered creek bottom land, and the water has been of little use. At Paris, in Lamar county, 75 miles east of this point, a well has been drilled to the depth of nearly 450 feet, but without obtaining flowing water. In Denton county, southwest of Grayson county, the wells on the low ground, averaging 350 feet in depth, discharge small quantities of water, while those on the higher land are pumped for the purpose of furnishing water for cattle.

In Jack county, about 60 miles west and therefore outside of the area underlaid by the Trinity sands, there are reported to be a number of flowing wells of a depth of about 100 feet. These wells and others now pumped by windmills were drilled for the purpose of obtaining water for stock. Southwesterly from this locality, in Palo Pinto, Stephens, and Eastland counties, which, as in the case of Jack county, are within carboniferous areas, a number of wells have been drilled in order to prospect for coal. At Strawn a well 546 feet deep, and costing $700, discharges mineral water which comes from a depth of 321 feet beneath the surface. At Graham, in Young county, a well 300 feet deep reached salt water only. In Stephens county wells averaging 130 feet in depth discharge from 3 to 10 gallons per minute of water suitable for cattle. In one instance irrigation has been successfully tried on a small scale, but the amount of water available is too small to be economically handled. At Breckenridge, in this county, a well was drilled to the depth of 1,400 feet, but without success, and in Eastland county, at the town of the same name, about 25 miles south of Breckenridge, a well 1,300 feet deep is reported to be a failure. Another well at Cisco, about 7 miles west, was drilled to the depth of 1,680 feet, passing through strata bearing salt water.

In Parker county, east of Palo Pinto, there are several shallow flowing wells discharging a small amount of water. At Weatherford a hole was drilled to the depth of about 500 feet, the principal amount of water, however, being found near the surface. In Tarrant county, still farther to the east, are a larger number of deeper flowing wells, delivering on an average about 10 gallons per minute of good, soft water. The average depth of these wells

is 207 feet. At Fort Worth, however, 2 wells have been drilled to a greater depth, one being over 750 feet deep and discharging a small stream, while the other, 950 feet deep, is reported to flow at the rate of 140 gallons per minute. In Dallas county there are also a large number of flowing wells similar to those near Fort Worth, the water being used, as in the case of the other counties, mainly for cattle, irrigation not being necessary. Many of these wells are not tubed or cased except for a short distance near the top, and doubtless a great deal of water is lost in the porous strata.

In the counties of the next tier to the south, namely, Hood, Somervell, Johnson, and Ellis, wells are mainly from 80 to 300 feet in depth, and do not differ essentially from those previously mentioned. In one instance, at least, the water has been used for irrigating cotton, corn, cane, and vegetables in an experimental way with marked success. It is stated that in Hood county a large number of the wells have from one cause or another ceased flowing. At Cleburne, in Johnson county, 4 wells, each of about 360 feet in depth, did not obtain flowing water. In Ellis county instances are given of the irrigation of a few trees, but otherwise the water was not used except for cattle and household use. At Hillsboro, in Hill county, 25 miles southeasterly from Cleburne, a well was drilled to the depth of 500 feet without success. West of this, in Bosque county, however, are many flowing wells from 400 to 600 feet in depth. The water from these is generally soft and palatable, although there are statements to the effect that it is occasionally impregnated with salt, and that, while stock will drink it, it is not suitable for irrigation. Several of the wells have stopped flowing, owing possibly to defects in casing.

West of Bosque county, at Lanham, wells were drilled nearly 500 feet in depth without success, and at Brownwood, in Brown county, still farther to the west and outside the area underlaid by Trinity sands, a well 1,100 feet in depth obtained only salt water. In Coleman and McCulloch counties, however, wells drilled in the carboniferous rocks are stated to yield water nearly if not quite fresh. The strata in these counties dip gradually to the west or northwest, and the water evidently comes from rainfall in the counties toward the east and south.

South of Bosque county, in Coryell, McLennan, and Bell counties, are groups of wells yielding water in general suitable for stock. In one or two cases it is reported that irrigation has been tried, but that the water was found to be too heavily charged with mineral matter. At Belton a well 1,000 feet deep is stated to yield 160 gallons a minute. At Waco are a number of deep wells, put down by water companies and having a depth of upward of 1,800 feet. These are stated to flow at the rate of from 300 to 700 gallons per minute, or from 0.67 to 1.56 second-feet, and the water is excellent for city purposes. In Burnet county, west of Bell, the wells are shallow, less than 100 feet in depth, and discharge small quantities of water, used in cooking and drinking.

In the counties of Robertson, Brazos, and Burleson, along the valley of the Brazos river, the wells are mainly from 300 to 500 feet in depth, and in the aggregate they yield a large amount of water. None of it has been employed for irrigation, except possibly in an experimental way, for there is usually a rainfall ample for the crops of that country, which consist mainly of cotton and corn. In Robertson county especially a considerable proportion of the wells do not flow, but are pumped in order to obtain water for cattle. At Bremond a well 1,500 feet in depth does not discharge, although the water rises toward the surface.

In Washington county, at Brenham, a well was drilled to the depth of 600 feet, but without success. From this point southerly and southeasterly to the coast there are comparatively few flowing wells, although many attempts are being made to obtain them. At Houston, however, are a number of great value to that city. In Galveston county borings have been made through the coast clays, and artesian water has been found in several localities at depths of from 400 to 700 feet or more. A well at Hitchcock delivers about 100 gallons per minute, and another at Highland flows at the rate of 8 gallons a minute. Some of the water from these wells is used on vegetables and strawberries, but these are about the only attempts at irrigation.