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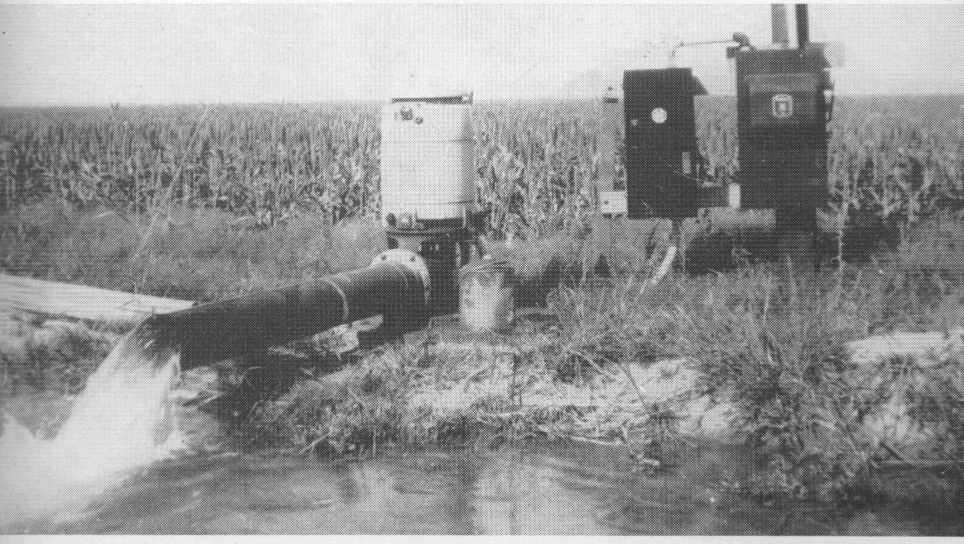
Use of Irrigation Water

on the High Plains



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The TEXAS AGRICULTURAL AND MECHANICAL COLLEGE SYSTEM

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DIGEST

Irrigation from wells has greatly increased the stability of agriculture on the High Plains. An average annual rainfall of less than 20 inches and variations in its quantity and distribution from season to season have resulted in extreme fluctuations in crop yields and, consequently, in farm incomes. Through irrigation, levels of yield are more than doubled and year-to-year variations in yields greatly reduced. Irrigation makes possible the production of some crops such as alfalfa, sugar beets and Irish potatoes, which have high water requirements and cannot be grown successfully without irrigation.

The advantage of supplementing natural rainfall with irrigation is attested by the large and rapid increase in the number of wells and in the acreage of irrigated crops. Since 1934, the number of wells has increased from 300 to more than 16,000 and the acreage irrigated from 35,000 to more than 2 million.

The State Board of Water Engineers and the U. S. Geological Survey have estimated the available supply of water in the ground water reservoir (Ogallala formation) to be approximately 150 million acre-feet. This supply of water is largely dead storage with very little annual replacement by infiltration. The present rate of use is in excess of 2 million acre-feet a year and may be expected to increase.

Other information which may be obtained from this bulletin includes: the demand for water; the amount of water used an acre for each of the principal crops and on the average for all crops; the effects of irrigation on cropping systems; the effect of differences in soil type and in well yields on cropping systems and on rates of watering; methods of spreading water; and the effect of irrigation on crop yields.

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Use of Irrigation Water on the High Plains

C. A. Bonnen, W. C. McArthur, A. C. Magee and W. F. Hughes*

THIS BULLETIN REPORTS the results of a study of the use of ground water for irrigation on that part of the High Plains in Texas south of the Canadian River. Bulletin 745, issued in February 1952, dealt with the cost of water for irrigation. The data on which both of these publications are based were obtained as part of a broad study of management problems on irrigated farms during 1947-49. An average of 154 farms and 203 irrigation wells contributed to the data. The average depth of these wells was around 200 feet. The average depth to the water table was 75 feet and the lift, or pumping level, was 112 feet. An average of 70 farms were on sandy loam soils and 84 were on clay and clay loam soils. In this report, these two soil groups will be referred to as sandy soils and heavy soils, respectively.

As few of the cooperating farms grew sugar beets or potatoes, a group of 35 farms in Deaf Smith county were included in the study in 1949 to obtain information on the irrigation and production practices for these crops. All of these farms were on heavy soils.

Questions for which the answers may be obtained, in part at least, from this bulletin pertain to: the available supply of water; the demands on this supply; the amounts of water used an acre for each of the principal crops and on the average for all crops; the effects of irrigation on cropping systems; the effect of differences in soil types and in well yields on cropping systems and on rates of watering; methods of spreading water; and the effect of irrigation on crop yields.

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*Respectively, professor, assistant agricultural economist and associate professor, Department of Agricultural Economics and Sociology, Texas Agricultural Experiment Station; and agricultural economist, Bureau of Agricultural Economics, U. S. Department of Agriculture.

Table 1. Monthly distribution of rainfall at Lubbock, 1932-51[1]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1932	.93	1.09	.04	1.84	2.37	5.66	1.90	3.15	3.41	1.29	T	2.48	24.16
1933	.37	.95	.02	.06	2.97	.21	1.36	2.19	.71	.42	.99	.06	10.31
1934	.06	.06	1.98	1.08	1.26	.28	.65	1.66	1.86	.28	.55	T	9.72
1935	.15	.60	.89	.04	3.49	2.57	1.25	1.69	3.02	1.22	2.04	.33	17.29
1936	1.08	.02	.59	.92	5.86	.92	1.05	.13	13.93	1.52	.74	.21	26.97
1937	.26	.01	1.81	2.01	4.00	3.12	1.32	2.06	3.85	3.22	.07	.52	22.25
1938	.91	1.18	.49	.14	1.99	5.89	4.01	.47	.63	.51	.27	.03	16.52
1939	2.45	.19	.09	.28	1.82	.67	1.73	2.75	.01	.94	.18	.60	11.71
1940	.23	1.97	T	1.84	1.74	2.06	T	1.57	.73	1.07	2.35	.20	13.76
1941	.55	.61	3.56	2.23	12.69	4.13	3.68	1.85	4.47	5.89	.17	.72	40.55
1942	.04	.18	.51	3.25	.35	1.74	2.58	4.97	7.61	3.39	.01	2.80	27.33
1943	.04	.02	.25	.53	2.71	2.37	3.17	T	1.16	.10	.62	1.87	12.84
1944	1.28	1.36	1.09	.84	3.03	1.75	2.93	2.37	3.73	.80	1.72	1.64	22.54
1945	.69	.39	.10	.46	.46	.36	3.08	2.17	2.22	2.26	.27	.32	12.78
1946	1.18	.15	.76	.07	1.49	2.72	.58	3.55	3.59	4.67	.44	1.04	20.24
1947	.73	.02	.69	1.06	6.35	1.56	1.06	.06	.08	.37	1.43	.52	13.93
1948	.11	1.59	.22	.48	1.91	1.36	1.22	.31	1.08	1.09	.02	.10	9.49
1949	3.67	.38	.78	1.78	6.95	4.62	2.47	2.36	4.87	1.02	.00	.39	29.29
1950	.23	.07	.00	.68	2.51	.77	2.67	1.40	2.24	.29	.03	.02	10.91
1951	.21	.72	.61	.55	2.61	1.91	1.92	3.93	.50	.64	.13	.00	13.73
Av.	.76	.58	.72	1.01	3.33	2.23	1.93	1.93	2.98	1.55	.60	.69	18.32

[1]Data from Weather Bureau, U. S. Department of Commerce.

THE PROBLEM

Lack of soil moisture has been the principal factor limiting production on the High Plains. Average annual rainfall at Lubbock is slightly more than 18 inches. This is near the lower limit for successful dry-land farming. Equally significant are the year-to-year variations in rainfall. During the past 20 years (1932-51), the total annual rainfall at Lubbock has ranged from 9.49 inches in 1948 to 40.55 inches in 1941 (Table 1). Annual rainfall was less than 15 inches during 10 of these years. The range has not been so wide at Plainview (Table 2). During years of below-average rainfall the disadvantage may be offset to a large extent by good distribution. For row-crop production, this usually means sufficient rainfall during May and June to get the crop up and well established. In years of normal or above-normal rainfall, much of its effectiveness may be lost because of poor distribution.

Much of the rain that falls comes in the form of local showers. This is particularly true of summer rains. A consequence of this is much variation in the amount of rainfall and in its timeliness from farm to farm. For example, some farms in northwest Hale county received in the neighborhood of 9 inches of annual rainfall during both 1947 and 1948, while farms in northeast Hale county received about 15 inches, according to data obtained from the Soil Conservation Service, U. S. Department of Agriculture. Much of this difference occurred during May, June and July when row crops were being established. Such variations explain in part some of the farm-to-farm differences in the quantity of irrigation water used.

At Lubbock, for the 3-year period, 1947-49, some rainfall was reported during 326 days but in 80 percent of these cases the amount was less than a quarter inch. Of the remaining 20 percent (65 days), a quarter inch or more fell, and during 9 days only, an average of 3 days per year, more than 1 inch fell. At Plainview, the precipitation was a quarter inch or more on 28 percent of the 253 days during which some rainfall was reported. But here again on only 9 days during the 3-year period, as much as 1 inch of rain fell. A high percentage of the moisture that falls in these light showers is lost quickly through evaporation and contributes little to the effective moisture supply.

These conditions have resulted in wide variations in production and in farm incomes. To overcome these difficulties, farmers have turned to irrigation. Fortunately, this part of the High Plains has an underlying thick layer of high-yielding

Table 2. Monthly distribution of rainfall at Plainview, 1932-51[1]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1932	1.28	.46	.02	2.16	.75	5.11	1.19	3.70	3.66	.96	T	2.23	21.52
1933	.40	.81	1.05	.38	3.03	.22	1.91	6.40	2.60	.62	1.71	.03	19.16
1934	.10	.08	2.02	2.94	4.32	.40	.07	1.72	1.16	T	.94	.00	13.75
1935	.18	.53	.43	.05	5.56	4.55	2.09	2.63	.91	1.18	1.90	.31	20.32
1936	1.35	.15	.10	.59	4.59	.50	2.80	.38	7.08	.61	.10	.51	18.76
1937	.27	.09	1.25	.61	5.16	4.64	1.89	2.45	3.34	1.77	.05	.48	22.00
1938	.39	1.18	1.33	.84	1.33	6.42	4.10	1.15	1.11	.87	.10	.07	18.89
1939	1.92	.14	.80	.82	1.89	3.22	.65	2.75	.02	.85	.08	1.02	14.16
1940	.32	1.91	.00	1.68	2.57	.57	1.40	1.51	.82	1.45	3.09	.11	15.43
1941	.27	1.00	2.30	1.34	7.07	6.03	4.35	2.28	3.65	5.34	.14	.58	34.35
1942	.10	.41	.60	4.15	.23	2.01	2.13	4.04	3.29	4.03	.02	2.71	23.72
1943	.05	T	T	1.54	3.66	.28	6.67	.03	2.38	.16	.80	2.32	17.89
1944	2.22	.99	.20	.76	2.49	4.88	2.14	1.22	3.34	.65	.97	1.87	21.73
1945	.66	.54	.16	1.68	.71	.65	2.06	2.74	1.20	1.94	T	.34	12.68
1946	1.71	.35	.95	.39	1.41	1.74	1.30	2.94	3.87	4.60	.71	2.82	22.79
1947	.82	.30	1.39	1.35	7.03	2.23	.64	.22	.05	.14	1.12	.56	15.85
1948	.61	1.32	.76	1.22	2.57	2.66	1.03	2.87	1.25	.57	.34	.42	15.62
1949	3.89	.68	.61	3.11	3.24	2.07	2.02	2.73	2.61	1.48	.00	.26	22.70
1950	.28	.02	T	.92	.65	1.49	5.30	3.72	5.50	.14	.00	.03	18.05
1951	.34	1.04	.39	.51	6.91	1.59	2.88	1.35	3.40	1.47	.26	.18	20.32
Av.	.86	.60	.72	1.35	3.26	2.63	2.33	2.34	2.56	1.44	.62	.84	19.48

[1]Data from Weather Bureau, U. S. Department of Commerce.

water-bearing materials sufficiently near the surface for economic use for irrigation. Although the first irrigation well was drilled in 1911, there was very little development before the middle thirties. The extreme drouth of that period and the rapidly rising farm prices during the war, coupled with the development of more efficient pumps and power units, resulted in increased interest in irrigation. Despite wartime limitations, the number of wells increased from about 300 in 1934 to 4,300 in 1945. With the removal of wartime restrictions and the continuation of favorable price relationships, the rate of development increased. An estimate by the U. S. Geological Survey placed the number of wells in use on the High Plains on January 1, 1951 at 14,000. No official estimate of the number has been made, but all indications suggest that more than 16,000 irrigation wells were in operation in 1952, from which more than 2,000,000 acres of cropland were irrigated.

SUPPLY OF GROUND WATER

This rapidly increasing demand for water for irrigation naturally raises questions relative to the adequacy of the supply. The U. S. Geological Survey and the State Board of Water Engineers have been studying the ground waters of the High Plains since 1936.

Progress Report No. 7 issued in March 1949 by the Board of Water Engineers gives their conclusions as to the available supply of ground water and the conditions affecting it. They may be summarized partly as follows:

1. The thickness of the water-bearing materials ranges greatly but averages about 210 feet.

2. The available supply of water is about 150 million acre-feet. Two-thirds, or 100 million acre-feet, is within 200 feet of the surface.

3. For all practical purposes, water pumped from the reservoir may be considered as coming from storage.

The average annual recharge of the ground water reservoir is hardly more than the annual loss through springs and seeps. It is estimated that 99 percent of the average annual rainfall of about 20 inches is lost through evaporation and transpiration.

The ground water reservoir (Ogallala formation) has been hydrologically isolated by erosion. Therefore, additions to the ground-water supply is from infiltration of water precipitated on the area itself.

On the basis of these conclusions, it logically follows that the supply of water available for irrigation on the High Plains can in time be exhausted by continued heavy use. Also, owing to physical limitations of the wells or to changes in price-cost relationships, it may become unprofitable to operate many of the wells long before the supply of water is exhausted.

TOTAL USE OF GROUND WATER

Based on the number of irrigation wells reported, the average yield of the 203 wells measured during the 3-year period and the average rate of use of water per acre, the present (1952) total annual use of ground water for irrigation is about 2 million acre-feet. The annual requirements for all other uses—domestic, public and industrial—is estimated by the U. S. Geological Survey and the State Board of Water Engineers to be approximately one-tenth acre-foot per capita. At this rate, the total demand for these other purposes would be hardly more than 35,000 acre-feet per year.

Throughout this bulletin, the quantities of water reported as used mean the total pumpage for the particular purpose with no allowance made for losses between the well and the field.

At the present rate of withdrawal, more water will be used for irrigation during the next 3 years (1952-54) on the Texas High Plains than was pumped during the 10-year period, 1939-48. Since wells are still being drilled at a rapid rate, it is safe to assume that the rate of withdrawal in the future will increase rather than decrease.

So far, the effect on water levels has been serious only in limited parts of the irrigated portion of the High Plains. The Board of Water Engineers and the Geological Survey estimated (Bulletin 5104) that the water level declined 5 feet or less over 78 percent of the reservoir from March 1938 to January 1951. The decline was less than 10 feet over 90 percent and 10 or more feet over 10 percent of the reservoir. Close spacing of wells and heavy pumping have resulted in declines up to 45 feet in the water level in certain limited areas (see also Figure 1).

USE OF WATER PER ACRE

The amount of irrigation water used per acre varies with seasonal conditions and with the crops grown. During the 3-year period, 1947-49, the average amount of water

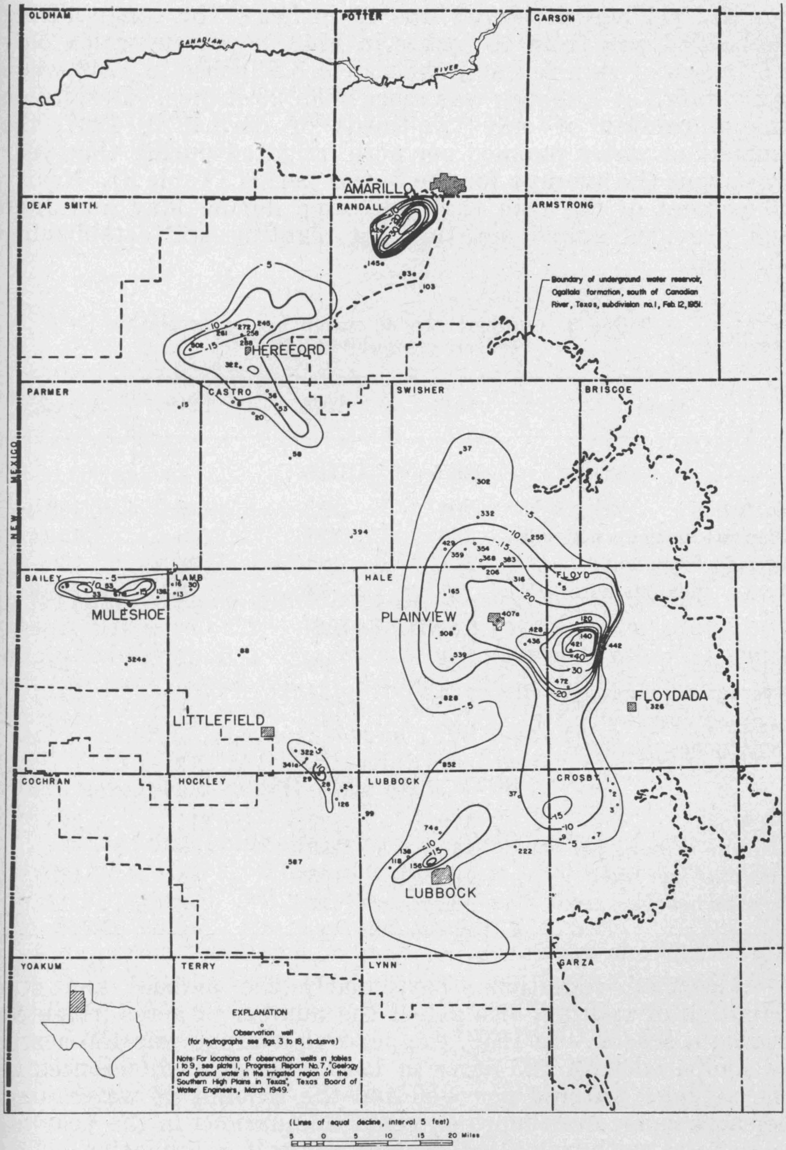

Figure 1. Approximate decline of the water table in the area studied, March 1938—January 1951. Adapted from Figure 1, Bulletin 5104, Texas Board of Water Engineers in cooperation with the U. S. Geological Survey.

pumped per acre irrigated was 11 inches. The range during the period was from 13 inches in 1948, a year in which only 9.5 inches of rain fell at Lubbock, to 8.5 inches in 1949 when the rainfall at Lubbock was more than 29 inches. Despite an annual rainfall of only two-thirds of normal in 1947, the amount of water pumped per acre irrigated during that year was about the average for the 3-year period (Table 3). Nearly 60 percent of the rain that fell came during May and June and provided ample moisture for planting and establishing the crop.

Table 3. Annual use of water by years and by soil groups, 1947-49

Item	1947	1948	1949	Average
HEAVY SOILS				
No. wells	91	121	116	109
Average acreage per well	138	175	138	151.4
Acre-feet per well	127	189	93	138
Acre-inches per acre	11	13	8.1	10.9
SANDY SOILS				
No. wells	88	99	95	94
Average acreage per well	124.5	134.1	109	121.1
Acre-feet per well	114	141	82	113
Acre-inches per acre	11	12.9	9.1	11.1
BOTH SOIL GROUPS				
No. wells	179	220	211	203
Average acreage per well	131.4	155.3	125	138
Acre-feet per well	120	168	88	126
Acre-inches per acre	11	13	8.5	11

Seasonal conditions, particularly the amount and distribution of rainfall, also affect the number of acres irrigated during a season. In 1948, the per-well average was 155 acres, as compared with 125 acres in 1949. Seasonal differences in the acreage watered per well and the amount of water used per acre cause even more extreme fluctuations in the year-to-year total withdrawal of ground water for irrigation. The total amount of water pumped per well in 1948 was almost double that of 1949 and about 40 percent more than in 1947.

Another factor which affected the amount of water used per acre was the yield rate of the wells. In addition to irrigating fewer acres per well, farmers with weak wells (delivering 500 gallons or less) used on the average only slightly more than 7 acre-inches, as compared with an average of 11 inches for all wells. As the yield of the wells increased, the tendency was to irrigate more acres and to apply more water per acre (see also Table 4).

Table 4. Relation of well yield to the amount of water pumped per acre

Well yield group	Number of wells	Acres irrigated per well	Acre-inches per well	Acre-inches per acre
500 gallons and under	65	105.6	756	7.2
501-750 gallons	250	134.6	1,425	10.6
751-1,000 gallons	241	142.8	1,696	11.9
1,001 gallons and over	54	167.7	2,060	12.3

There was no significant difference in the overall use of water per acre on the two main soil groups—the sandy soils and the heavy soils. The amount used per acre was 11.1 inches on the sandy soils and 10.9 inches on the heavy soils. The total amount of water pumped per well, however, was 25 acre-feet greater on the heavy soils (138 feet) than on the sandy soils (113 feet). With this additional water, approximately 30 more acres were watered per well.

These differences mainly reflect the effect of soil type on cropping systems. They also reflect a somewhat higher rate of yield per well, 780 gallons a minute on heavy soils and 699 on sandy soils. The average cropping systems during the 3-year period for farms on each soil group are shown in Table 5. Although the amount of cropland per farm averaged about 90 acres more on the heavy soils, the proportion irrigated was about the same in each case. The main difference is found in the kind and proportion of the different crops grown. On the sandy soils, almost 70 percent of the irrigated acres were planted to cotton and 21 percent to sorghum. No other crop occupied as much as 2 percent of the land.

Cropping systems on the heavy soils were much more diversified. Sorghum led all other crops, occupying more than 39 percent of the irrigated acreage. Cotton and wheat each accounted for about 22 percent. The only other crop of importance was alfalfa. These four crops made up more than 90 percent of the irrigated acreage.

On the nonirrigated portions of these farms, the situation was reversed. A wider range of crops was grown on the sandy soils. Cotton and sorghum in about equal proportions accounted for 75 percent of the acreage. Small grains, mainly wheat, occupied 12.5 percent. Sudan pasture was the only other crop of importance. On the heavy soils, wheat and summer fallow made up 83 percent of the total dry-land acreage. Cotton and sorghum accounted for another 9 percent.

This greater diversity of cropping systems on heavy soils is reflected also in the number of farms reporting each of the four major crops. On the sandy soils, 87 percent of the farms irrigated cotton, 70 percent sorghum, 12 percent wheat and 22

Table 5. Average cropland organization on sandy and heavy land farms, 1947-49

Item	Total acres	Irrigated land		Dry land	
		Acres	Percent [2]	Acres	Percent [3]
		SANDY SOILS			
Total	270.9	176.7	——	94.2	——
Percent [1]	100.0	65.2	——	34.8	——
Cotton	158.8	123.1	69.7	35.7	37.9
Grain sorghum	66.0	33.9	19.2	32.1	34.1
Forage sorghum	7.2	3.9	2.2	3.3	3.5
Wheat	13.5	2.6	1.5	10.9	11.6
Oats and barley	3.4	1.7	.9	1.7	1.8
Alfalfa	3.0	2.8	1.6	.2	.2
Rotation pasture	7.4	3.0	1.7	4.4	4.7
Permanent seeded pasture	2.4	2.2	1.2	.2	.2
Fallow	3.6	——	——	3.6	3.8
All other	5.6	3.5	2.0	2.1	2.2
		HEAVY SOILS			
Total	361.5	229.1	——	132.4	——
Percent [1]	100.0	63.4	——	36.6	——
Cotton	55.7	51.3	22.4	4.4	3.3
Grain sorghum	89.2	82.9	36.2	6.3	4.7
Forage sorghum	8.9	7.6	3.3	1.3	1.0
Wheat	135.5	52.7	23.0	82.8	62.5
Oats and barley	7.2	3.4	1.5	3.8	2.9
Alfalfa	15.6	15.5	6.8	.1	.1
Rotation pasture	5.0	2.8	1.2	2.2	1.7
Permanent seeded pasture	5.7	4.8	2.1	.9	.7
Fallow	28.9	.2	.1	28.7	21.7
All other	9.8	7.9	3.4	1.9	1.4

[1]Percent of total cropland.
[2]Percent of irrigated cropland.
[3]Percent of nonirrigated cropland.

percent alfalfa. On the heavy soils, 49 percent of the farms irrigated cotton, 89 percent sorghum, 66 percent wheat and 51 percent alfalfa.

The greater diversity of the cropping systems on heavy soils distributes the demand for water more uniformly throughout the pumping season. Consequently, all wells on heavy soils were pumped an average of 83 hours more per year than were wells on sandy soils. As will be shown later, cotton and sorghum make moderate use of irrigation water and wheat rather light use, while alfalfa, irrigated pastures, potatoes and sugar beets make heavy use of water. Most of the pumping for cotton and sorghum occurs during April, July and August, whereas alfalfa, root crops and pastures are irrigated frequently throughout the growing season. The light use of water on wheat is offset by the heavy use on the other crops to give an average use per acre similar to that on sandy soils, on which cotton and sorghum are the only crops grown extensively.

The effect of differences in cropping systems on the two soil groups is partly offset by greater use of the practice of preplanting irrigation on sandy soils.

RELATION OF WELL YIELD TO CROPPING SYSTEMS

Attention has been called to the effect of well yields on the amount of water used per acre and on the number of acres irrigated per well. The effect also may be noted in the cropping systems, particularly on the sandy soils. As shown in Table 6, farmers having the higher yielding wells tended to specialize to a high degree in cotton production and to produce little other than cotton and sorghum on the sandy soils. The wells producing 500 gallons and less per minute were associated with a cropping system on the land on which the irrigated part had 55 percent in cotton and a total of 83 percent in cotton and sorghum. In the case of wells yielding more than 1,000 gallons, cotton occupied almost 84 percent of the cropland, and with sorghum accounted for almost 97 percent of the land irrigated.

In the case of the heavy soils, any difference in cropping systems between well yield groups was slight. Proportionately less sorghum was produced and the difference was made up by slight increases in the acreage of cotton and of crops other than those listed in Table 6.

The effects of differences in well yields may suggest something of the effects of proration or limiting the amount

Table 6. Cropping patterns and rates of water use as affected by well yield, average 1947-49

Yield rate of wells	Number of wells	Acres irrigated per well	Inches pumped per acre	Percent of irrigated cropland in				
				Cotton	Sorghum	Wheat	Alfalfa	Total
			SANDY SOILS					
500 gallons and under	42	96.7	8.3	55.4	27.8	3	4	90.2
501-750 gallons	118	121.9	11.3	66.6	23.3	2	1	92.9
151-1,000 gallons	108	127.2	12.0	72.8	20.3	1	1	95.1
1,001 gallons and over	14	152.5	10.7	83.6	13.2	——	——	96.8
Average all wells	282	121.7	11.1	69.6	21.3	1.5	1.5	93.9
			HEAVY SOILS					
500 gallons and under	23	122.0	5.5	20.8	46.7	21.4	3	91.9
501-750 gallons	132	145.9	10.1	18.7	39.7	24.2	7.4	90.0
751-1,000 gallons	133	155.4	11.8	24.6	38.6	19.6	6.1	88.9
1,001 gallons and over	40	173.0	12.8	22.1	36.2	25.5	5.8	89.6
Average all wells	328	151.4	10.9	22.3	39.4	21.9	6.7	90.3

of water used per acre of cropland. If confronted with this problem, farm operators generally would be faced with some of the same problems now faced by the owners of weak wells. With less water to distribute they would have to decide whether to irrigate large acreages lightly or a limited portion of the farms more heavily. A decision for either extreme would mean substantial adjustments in cropping systems.

METHODS OF SPREADING WATER

On most farms, irrigation water is pumped into open earthen ditches which have sufficient slope to convey the water to the fields.

The well is normally located near the highest point on the farm or the point from which the largest acreage may be reached by gravity. This acreage may be increased by building up the main ditches across depressions to the next high point from which additional acres may be reached. Irregularities in the slope of the land also may be overcome through the use of underground pipe or metal or canvas tubes.

When the water reaches the field, it is distributed by running it down the lister furrow or between the rows in the case of row crops, and down the slope between borders or furrows in the case of close-seeded crops. It is now common practice to move the water from the ditch to the row or start it down the slope by means of plastic or metal siphon tubes. More uniform distribution of water is obtained from this practice than from the old method of cutting the ditch bank to distribute the water. Also less labor is involved and less land is wasted and eroded.

Differences in the slope of the land and in the texture of the soil may greatly affect practices followed in spreading irrigation water. The coarser textured sandy soils absorb water more rapidly than do the more dense clays and clay loams. The slope, in turn, affects the rate at which the water moves down the ditch or across the land. This contributes to the difficulty of obtaining uniform distribution of water in the field. The problem is intensified in the case of a low-yield well. To offset these differences, farmers may vary the length of run and the number of rows watered per set. When a small head of water moves down the row slowly, a disproportionate share of the water is absorbed at the upper end of the row, and to a lesser extent at the lower end where water tends to collect after the set is moved. This difficulty is partly overcome through increasing the head of water by using more siphons to the row and by regulating the length of run. On the other hand, irrigating the land rapidly by using more tubes to the row and by shortening the run has the disadvantage of increasing the labor cost of irrigating, as the set would be moved more frequently. When labor is a limiting factor, some farmers like to regulate the rate of irrigation so that the sets may be moved at longer intervals and at such times as to interfere the least with other work. In such cases, it seems more important to save labor than to conserve water. On the farms cooperating in this study, the number of tubes used per row usually ranged from 1 to 4. The length of run in irrigating both cotton and sorghum—the two crops most common to both soil groups—averaged 125 yards longer on clay soils (481 yards) than on sandy soils (356 yards).

The loss of water from the open ditch by seepage, evaporation and transpiration through weeds is an important factor affecting the amount of water that actually reaches the crop and contributes to its growth. The extent of this loss is not known but has been estimated to be as much as 30 percent on sandy loam soils. This loss may be greatly reduced through the use of underground pipe but at a cost which would about double the investment in the irrigation system. The water thus saved would permit the operator to irrigate more rapidly, reach more acres or irrigate more intensively.

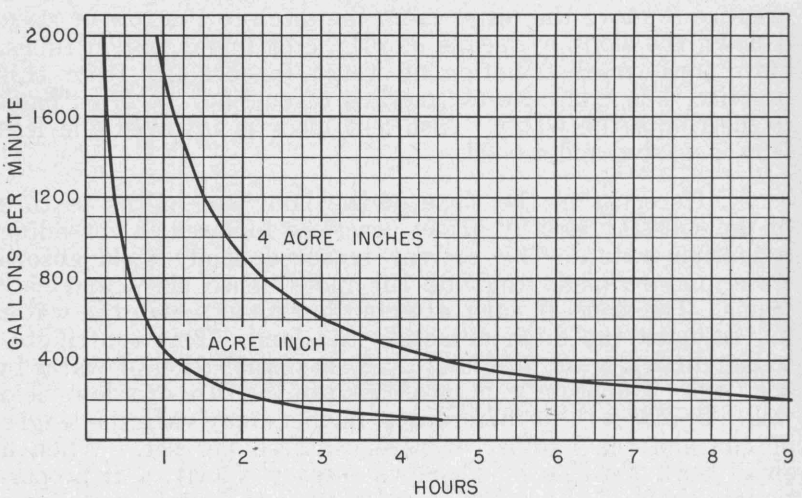

Figure 2. Time required to pump an acre-inch and 4 acre-inches of water at different rates of discharge from wells.

A few operators have attempted to overcome the disadvantage of steep slopes and extremely sandy soils through the use of sprinkler systems. These have the advantage of providing an even distribution of water on land difficult to water by other means. The practice has not been widely adopted partly because of a greatly increased investment, higher pumping costs, the additional labor involved in moving the system over the land, the difficulty of applying water rapidly enough especially during periods of high temperatures, and the uneven wetting of the soil during periods of windy weather.

The time required to pump an acre-inch of water from wells of widely different yields is shown in Figure 2. The time required to pump 4 acre-inches, which approximates an average application of water, is also shown. These were obtained by dividing gallons of water involved by an assumed range of well yields.

This chart provides a means of determining quickly the time required to irrigate a field of given size at a desired rate per acre from a well of known yield. For example, the chart shows that at the rate of 800 gallons a minute, it takes 2¼ hours to pump 4 acre-inches of water. This means that 90 hours would be required to pump 4 acre-inches of water for a 40-acre field.

USE OF WATER ON INDIVIDUAL CROPS

There is a wide range in the amount of water used by different crops. Since the supply of water available to a farm is limited to the yield of the well or wells serving the farm, differences between crops in the quantity of water used are an important factor to be considered in planning for the best use of the available water.

Cotton

Around 40 percent of the water pumped by cooperating farmers during the 3-year period was used to irrigate cotton. On sandy soils where cotton occupied nearly 70 percent of irrigated cropland (Table 5), roughly two-thirds of all water pumped was used on cotton. This compares with 20 percent of the water pumped on heavy soils where cotton made up only 22 percent of the acreage irrigated.

The average amount of water used on cotton was 10.8 inches per acre on sandy soils and about 9.5 inches on heavy soils. Amounts of water used on cotton ranged widely from year to year, varying with the amount and distribution of rainfall. As shown in Table 7, the heaviest pumping was in

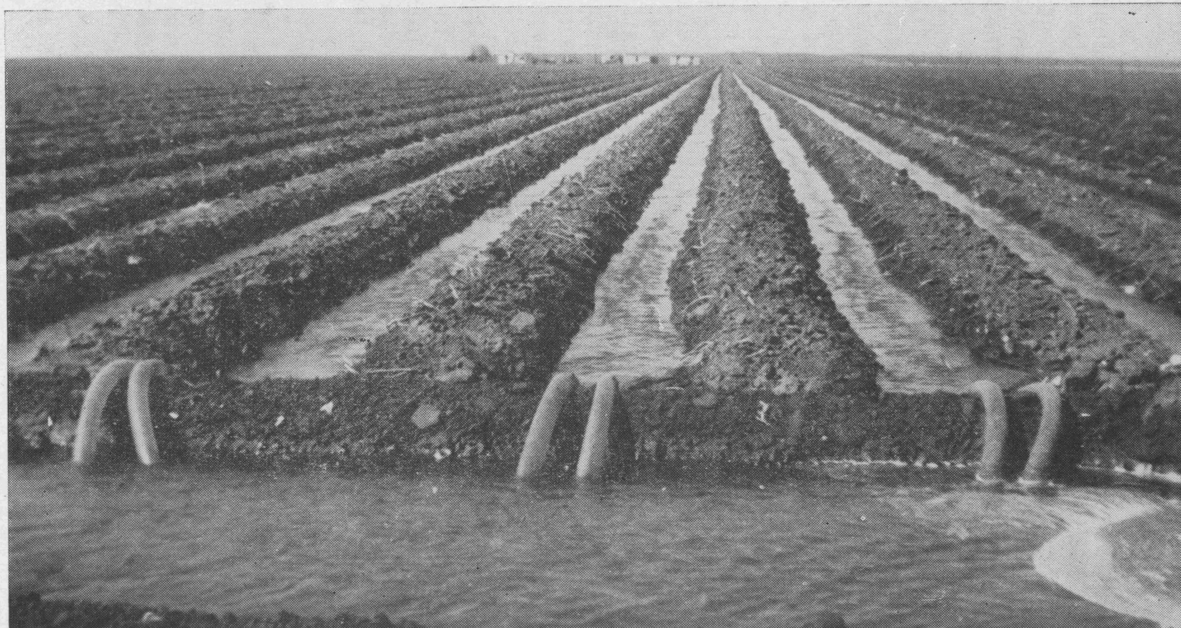

Figure 3. Preplanting irrigation showing water being moved from the irrigation ditch to lister furrows through siphon tubes.

1948, an extremely dry year, and the lightest in 1949, a year of above-normal and well-distributed rainfall. Although the rainfall in 1947 was only 70 percent of normal, the amount of water pumped was below the average, primarily because about 60 percent of the total rainfall came in May and June when moisture is most needed to get the crop up and firmly established. The difference between the two soil groups in the amount of water pumped for cotton may be explained by the fact that sandy soils absorb water more rapidly than do heavy soils. This means that water losses will be greater on sandy soils owing to more loss from ditches and to uneven distribution of water where length of run and the number of rows watered per set are not properly adjusted to the difference in soils and slope and to the rate of well yield. This difference in soils has its effect on all phases of irrigation practice but is reflected mainly in the number of irrigations and in the amount of water pumped per irrigation.

The total acreage of irrigated cotton was watered an average of 2.5 times on sandy soils and 2.3 times on heavy soils (Table 7). The difference was largely in the amount of preplanting irrigation. Seventy-four percent of the cotton on sandy land and 46 percent of the cotton on heavy land received a preplanting irrigation. Competition with wheat and alfalfa for water at that season of the year probably contributed to this difference (see also Figure 5). The number of seasonal irrigations averaged around 1.8 on both soil groups. Year-to-year variations reflect differences in rainfall and its distribu-

Table 7. Number of irrigations, amount of irrigation water and percentage of cotton acreage watered each irrigation, 1947-49

Year	Average number of irrigations	Acre-inches pumped		Percentage of land watered each irrigation				
					Seasonal			
		Each irrigation	Per Year	Pre-planting	1st	2nd	3rd	4th
				SANDY SOILS				
1947	2.5	4.1	10.2	64	100	68	15	1
1948	3.1	4.3	13.9	95	100	83	26	4
1949	2.0	4.3	8.9	62	100	45	1	—
Av.	2.5	4.3	10.8	74	100	65	14	1
				HEAVY SOILS				
1947	2.2	4.0	8.9	15	100	75	35	1
1948	2.8	4.4	12.4	80	100	77	24	1
1949	1.8	4.0	7.3	44	100	40	1	—
Av.	2.3	4.1	9.5	46	100	59	16	1

Figure 4. Irrigating cotton. By using several tubes per row, water is moved more rapidly and distributed more uniformly, but the sets are moved more often and labor requirements are increased.

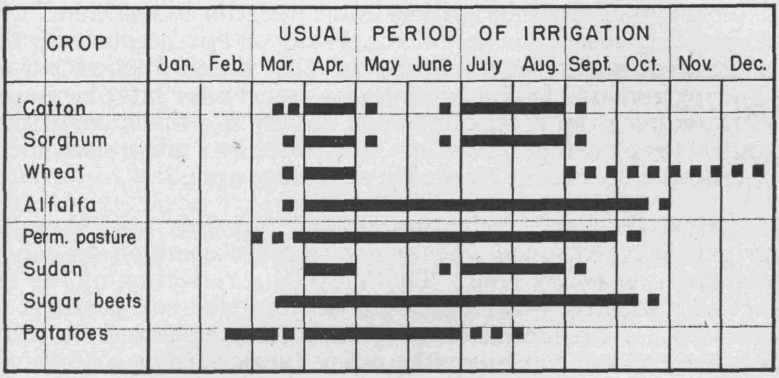

Figure 5. Usual periods during which irrigation water is applied to the more important crops grown on the High Plains.

tion. The greatest number of irrigations occurred in 1948, an extremely dry year, when cotton was irrigated slightly more than 3 times, on the average, on sandy soils and 2.8 times on heavy soils. Also, there was more preplanting irrigation that year. Almost all of the sandy land on which cotton was planted had been irrigated, as had 80 percent of the heavy land. The other extreme was in 1949, a year of above-normal and well-distributed rainfall, when an average of only slightly more than 2 irrigations was applied on the sandy soils and 1.8 on the heavy soils.

The average amount of water pumped for each irrigation of cotton during the 3-year period varied slightly (Table 7). The pumpage was a little greater on sandy soils (4.3) than on heavy soils (4.1). The difference may not be significant, owing to the greater transmission losses incurred on sandy soils.

Farm-to-farm variations in the amount of water pumped per irrigation were quite wide. The usual range was from 2.5 to 6 acre-inches. Some farmers irrigate heavier than others as a common practice, but differences in the slope of land, length of run, soil texture, climatic conditions at time of irrigating and in the capacity of irrigation wells are all contributing factors.

The time of irrigating cotton follows a very distinct pattern. With few exceptions, preplanting irrigation occurs during April. Irrigation at this time increases soil moisture to such an extent that a relatively small amount of rain at planting time will be sufficient for the germination of cotton. In case of a particularly dry spring, a preplanting irrigation may be used to supply the moisture needed for germination.

In either case, early irrigation can contribute to the timeliness of planting which, with cotton, is important because of the short growing season. Much of the water applied before planting remains in the subsoil as a reserve for later crop use. With its deep tap root, cotton can readily use moisture of this kind. Preplanting irrigation is, therefore, more commonly practiced with cotton than with any other crop.

Most seasonal irrigation is done in July and August. Irrigation of cotton in September is more common on sandy land than on heavy land. This may be a reflection of the effect of a slightly longer growing season on sandy portions of the area. Late irrigation of cotton (usually any time after September 1) is considered by many farmers to be a questionable practice. It usually means excessive plant growth, the formation of bolls too late to mature before frost and, consequently, a lower quality of cotton. Harvesting difficulties also may be intensified. It is doubtful if the increase in yield, if any, offsets the extra costs of irrigating and harvesting, and the loss in market price.

In preplanting irrigation, the lister furrows are flooded after the land has been bedded. It is done as near planting time as is practical to insure as nearly as possible the deep moisture which, aided by spring showers, is required to carry the crop through the early stages of development. The first seasonal irrigation then is normally applied between the rows after the first or second cultivation. Subsequent irrigations, if any, follow at short intervals between cultivations. The timing of each, as well as their number, depends to a large extent on the amount and distribution of rainfall.

An exception to this pattern may occur during extremely dry years in which available moisture is not sufficient to carry the crop through its first cultivation. At such times, a light emergency irrigation is applied by running the water down the row or planter furrow. This practice is followed only under extreme conditions; it tends to produce rapid vegetative growth and a shallow root system.

Sorghum

Sorghum ranks next to cotton in the use of irrigation water. During the 3-year period, 1947-49, around 31 percent of the water pumped was used on sorghum. Sorghum was the principal irrigated crop on heavy soils and was second only to cotton on the sandy soils (Table 5). Around 90 percent of the sorghum acreage was harvested for grain. Whether harvested for grain or forage, irrigation practices were the same.

The difference in the amount of water used on sorghum and cotton was slight. Disregarding soil differences, slightly more than 10 inches was used on each crop during the 3-year period. But on sandy soils cotton received, on the average, around an inch more water an acre than sorghum. On the heavy soils, the situation was reversed, sorghum receiving about an inch more water than cotton (Tables 7 and 8). The determining factor seems to be that the major crop on sandy soils is cotton, and on heavy soils, sorghum. In each case, the major crop was given preference in pumping time.

Year-to-year differences in the amount of water used on both cotton and sorghum largely reflect the amount of rainfall and its distribution. About the same amount of water was used on sorghum in both of the dry years 1947 and 1948, but pumping was relatively light in 1949. More water was applied to sorghum grown on heavy soils than on sandy soils during the two dry years, whereas during 1949, a relatively wet year, more water was applied to sorghum grown on sandy soils.

More than half of the sorghum acreage on sandy soils received a preplanting irrigation, whereas only about one-fifth of the acreage on heavy soils was so irrigated. As in the case of cotton, the amount of preplanting irrigation varied from season to season with the amount and distribution of the rainfall.

Table 8. Number of irrigations, amount of irrigation water and percentage of sorghum acreage watered each irrigation, 1947-49

Year	Average number of irrigations	Acre-inches pumped		Percentage of land watered each irrigation				
					Seasonal			
		Each irrigation	Per year	Pre-planting	1st	2nd	3rd	4th
				SANDY SOILS				
1947	2.3	4.4	10.2	50	100	63	18	1
1948	2.4	4.3	10.4	70	96	59	10	1
1949	2.1	4.2	8.9	50	91	52	19	—
Av.	2.3	4.3	9.8	57	96	58	16	1
				HEAVY SOILS				
1947	2.9	4.2	12.1	5	100	94	69	20
1948	2.7	4.5	12.2	47	100	85	35	4
1949	1.8	3.9	7.1	10	100	58	17	1
Av.	2.5	4.2	10.5	21	100	79	40	8

Figure 6. Irrigating sorghums while in the boot stage assures heavy yields of grain.

Most of the preplanting irrigation of both cotton and sorghum is done in April. Wheat and alfalfa also are irrigated at this time and compete for available water, particularly on heavy soils. Where such competition occurs, wheat and alfalfa usually are irrigated before sorghum land. On sandy soils, the main competition for early season water is between cotton and sorghum. On cooperating farms, preplanting irrigation was less for sorghum than for cotton on both soil groups. When it is impossible to water the seedbed of both crops, the tendency is to irrigate cotton land first. This practice is encouraged by the fact that grain sorghums have a longer planting period than cotton, and there is an urgency for getting cotton established. The fact that cotton makes the better use of deep subsoil moisture, also encourages the preplanting irrigation of cotton before sorghum.

The difference in the amount of preplanting irrigation was more than offset by an average of 2.3 seasonal irrigations on heavy soils and 1.7 irrigations on sandy soils.

Sorghum and cotton are irrigated in the same manner. Preplanting irrigation is applied in the lister furrow to aid in carrying the crop through one or two cultvations. Seasonal irrigations are applied between the rows. The first usually follows a cultivation but this is not the case with later irrigations; the crop usually is too large to cultivate after the first seasonal irrigation.

The time and pattern of irrigation of sorghum is essentially the same as that of cotton. In addition to the preplanting irrigation done in April, seasonal irrigations are applied largely during July and August. Once the crop is established, the timing of each application of water with reference to the stage of maturity is important in determining yields. Maximum yields are obtained when moisture conditions are most favorable during the boot and dough stages of growth.

Wheat

Most of the irrigated wheat on cooperating farms was grown on heavy soils where it occupied about 23 percent of the irrigated land, as compared with only 1.5 percent on the sandy soils. On the basis of acreage irrigated, wheat ranked second to grain sorghum on heavy soils (Table 5).

About 9 percent of the water pumped during the 3-year period was used to irrigate wheat. Among the major irrigated crops on the High Plains, wheat made the lightest use of irrigation water. The average amount of water used to irri-

Table 9. Average number of irrigations, amount of irrigation water and percentage of wheat acreage watered each irrigation, 1947-49

Year	Average number of irrigations	Acre-inches pumped		Percentage of land watered each irrigation				
		Each irrigation	Per year	Preplanting	Seasonal 1st	2nd	3rd	4th
				SANDY SOILS				
1947	1.0	4.1	4.3	—	100	4	—	—
1948	1.6	5.5	8.6	8	95	30	13	7
1949	1.9	4.6	8.5	—	100	85	—	—
Av.	1.5	4.7	7.1	3	98	40	4	2
				HEAVY SOILS				
1947	1.0	4.0	4.1	—	100	2	1	—
1948	2.2	5.3	11.4	49	97	60	9	—
1949	1.3	4.8	6.3	21	89	20	2	—
Av.	1.5	4.7	7.3	23	95	27	4	—

gate an acre of wheat was 7.1 inches on sandy soils and 7.3 inches on heavy soils. As shown in Table 9, the heaviest pumping occurred in 1948, an extremely dry year, and the lightest in 1947, a year in which the amount and distribution of rainfall was very favorable for wheat production. (Note in Table 2 the heavy rainfall during the late summer of 1946 and again in May 1947.) Even though 1949 was a year of above-normal rainfall, the crop harvested that year received close to the average amount of irrigation water. Most of this irrigation occurred during the extremely dry fall of 1948.

During 2 of the 3 years of study, wheat on sandy soils received more irrigation water than that on heavy soils. The widest difference occurred during the dry year of 1948 when almost 3 inches more water were applied on heavy soils than on sandy soils. A large part of this difference may be accounted for by a greater amount of preplanting irrigation on heavy soils that year.

The 3-year average for the number of irrigations applied to wheat was 1.5 for both soil groups. Year-to-year variations on heavy soils ranged from slightly more than one irrigation in 1947 to more than two in 1948. Despite the heavier rainfall in 1949, wheat was irrigated more heavily and more frequently during that year than in 1947. As indicated above, the extra watering of the 1948 crop occurred during the dry fall of 1947 and was applied to establish the crop and maintain it through the winter. Although the fall of 1948 was dry, rainfall in August and September was sufficient to establish the 1949 crop on most farms without the aid of irrigation.

The amount of water applied each irrigation varied from year to year mainly because of differences in the amount of rainfall and its distribution. The average for the 3-year period, however, was practically the same for both soil types (Table 9). Farm-to-farm variations in the amount of water in each application were sometimes rather wide owing to a complex of factors, all of which are important. These include the timeliness and intensity of local rains, soil texture and slope, soil moisture at the time of application, thickness of stand and differences in operators.

The time of irrigation of wheat varies with seasonal conditions. When preplanting irrigation occurs, it usually comes in September or early October. During years when the growing season is not abnormally dry, most of the irrigating is done in April. On the other hand, fall irrigations are sometimes necessary to carry the crop through the winter. The 1948 crop, for example, followed the extremely dry fall of 1947, a year in which the irrigation of wheat was necessary during November and December.

The irrigation of wheat is done largely by flooding from field ditches and to some extent by border irrigation. In flooding from field ditches, the water is permitted to spread down the slope between ditches spaced at intervals that vary with the slope, type of soil and head of water. The field ditches are sometimes on the contour but more frequently are straight and uniformly spaced across the slope.

Border irrigation is similar to flooding from field ditches, except that small levees or borders confine the water to a limited area as it moves down the slope. In both methods, the water usually is released from the ditch by means of siphon tubes. Although not used extensively in irrigating wheat, border irrigation provides more uniform wetting of the soil and consequently more efficient use of irrigation water than flooding from field ditches.

In the case of close-seeded crops, furrows are not available for irrigating; therefore, the problem of spreading water uniformly over them is much greater than that of irrigating row crops. The difficulty of obtaining uniform wetting of wheat land suggests the need for greater emphasis on adequate land leveling.

Table 10. Average number of irrigations, amount of water pumped, and percentage of alfalfa acreage watered each irrigation, 1947-49

Year	Average number of irri-gations	Acre-inches pumped		Percentage of land watered each irrigation														
		Each irri-gation	Per year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								SANDY SOILS										
1947	7.2	5.5	39.3	100	98	98	93	77	55	53	49	44	29	13	13	—	—	—
1948	6.4	6.0	38.7	100	96	92	86	79	74	62	50	4	—	—	—	—	—	—
1949	4.9	5.5	26.8	100	91	91	91	69	47	3	—	—	—	—	—	—	—	—
Av.	6.2	5.7	34.9	100	95	94	90	75	59	39	33	16	10	4	4	—	—	—
								HEAVY SOILS										
1947	8.0	3.8	30.3	100	93	92	87	71	61	63	56	52	50	36	22	8	4	4
1948	8.4	4.1	34.8	100	99	98	94	91	83	76	65	48	28	23	15	8	5	4
1949	5.4	4.2	22.7	100	99	92	85	68	56	21	11	5	2	2	2	1	1	1
Av.	7.3	4.0	29.3	100	97	94	89	77	67	53	44	35	27	20	13	6	3	3

Alfalfa

All alfalfa grown on the High Plains is irrigated and production is concentrated largely on heavy soils. Alfalfa occupied nearly 7 percent (Table 5) of the irrigated cropland on heavy soils and less than 2 percent on sandy soils.

Alfalfa makes extremely heavy use of irrigation water. In spite of the relatively small acreage, alfalfa received about 13 percent of the irrigation water pumped by cooperating farmers. Among crops irrigated, it ranked third in total use of water, exceeded only by cotton and sorghum. The deep rooting characteristics of alfalfa, coupled with vigorous, rapid growth, are factors contributing to its high water requirements. The average amount of water used on alfalfa was 34.9 inches an acre on sandy soils and 29.3 acre-inches on heavy soils. The amount of water pumped for alfalfa varied from year to year with the amount of rainfall and its distribution. As shown in Table 10, the lightest pumping occurred in 1949, when rainfall was above normal and well distributed. The heaviest pumping on heavy soils occurred in 1948—an extremely dry year. On the other hand, the heaviest pumping on sandy soils occurred in 1947.

The great difference between soil groups in the average amount of water pumped for alfalfa is believed to be due to the tendency of sandy soils to absorb water more readily than heavy soils. This difference also is reflected in the amount of water used in each application.

The average amount of water pumped per acre for each irrigation was 5.7 inches on sandy soils and 4.0 inches on heavy soils. The farm-to-farm variations in many cases were much greater because of differences in slope, soils, climatic conditions and irrigation practices. The year-to-year differences in the average amount of water pumped in each irrigation were too slight to be significant.

The time of irrigation of alfalfa normally extends from April to October. Although the frequency of irrigation varies with weather conditions, it usually occurs at intervals of 2 to 3 weeks.

It is the usual practice to make three or four cuttings of alfalfa each season. The crop is irrigated once or twice between cuttings and once or twice before the first cutting and after the last cutting, as seasonal conditions require.

Table 11. Average number of irrigations, amount of water pumped and percentage of seeded permanent pasture watered each irrigation, 1947-49

Year	Average number of irrigations	Acre-inches pumped		Percentage of land watered each irrigation									
		Each irrigation	Per year	1	2	3	4	5	6	7	8	9	10
				SANDY SOILS									
1947	4.9	4.5	22.1	100	93	83	68	46	38	23	13	13	8
1948	5.2	4.6	23.7	100	89	89	81	59	32	30	19	14	—
1949	3.0	4.2	12.9	100	88	36	19	16	15	15	5	5	5
Av.	4.4	4.4	19.5	100	90	69	56	40	28	23	12	11	4
				HEAVY SOILS									
1947	4.5	3.4	15.4	100	79	65	63	47	45	18	13	9	2
1948	3.8	4.8	18.0	100	81	62	44	28	16	15	11	9	7
1949	3.6	4.6	16.8	100	69	66	50	32	28	5	3	3	3
Av.	4.0	4.3	16.7	100	76	64	52	36	30	13	9	7	4

Like wheat, alfalfa is irrigated by flooding from field ditches or border irrigation, the latter method being more extensively used. Alfalfa land is more carefully leveled than land for other crops.

Alfalfa competes with cotton and sorghum for irrigation water during the entire time the latter two crops are irrigated. Alfalfa needs irrigating at the same time a preplanting irrigation is needed by cotton and grain sorghum. Alfalfa makes a heavy demand for water during July and August when there is a peak demand for the irrigation of cotton and sorghum.

For the best use of the irrigation water available, a farmer needs to consider the alternate uses for this water. Crops that are heavy users of water must give a proportionately greater return in order to be profitable. The amount of water required to irrigate one acre of alfalfa, for instance, would irrigate an average of three or more acres of either cotton or sorghum.

Permanent Pasture

Permanent pasture, consisting of some combination of brome, perennial rye, western wheat grass, alfalfa or sweetclover, makes heavy use of irrigation water. On sandy soils, an average of 19.5 acre-inches was used, and on heavy soils 16.7 inches (Table 11). In some years, the difference between the amount of water used on the two soil groups was rather wide. With the exception of 1949, pasture was watered much more heavily on sandy soils than on heavy soils. To a large extent, this difference is probably the result of two factors: the tendency of the sandy soils to absorb water more readily than heavy soils, and the greater competition for irrigation water by other crops on heavy soils. In 1949, when rainfall was above normal and less water was needed for competing crops, the amount of water used per acre for pasture on heavy soils was greater than on sandy soils.

As in the case with most other crops, the amount of water used on seeded permanent pasture varied from year to year with the amount and distribution of rainfall. The pumpage was greatest in the extremely dry year of 1948.

The difference between the soil groups in the average amount of water used per irrigation was slight: 4.4 acre-inches on sandy soils and 4.3 acre-inches on heavy soils. On the other hand, the difference in the number of irrigations was somewhat greater and there was more variation from year to year in the number of irrigations on sandy soils. This reflects differences in the amount of rainfall and its distribution.

The season of irrigation for seeded permanent pasture is similar to that of alfalfa, as most of it is done from April to October. Some variation from this pattern occurred in that there was more irrigation of pasture than of alfalfa during March and less in October.

Like other close-seeded crops, pasture is irrigated mostly by flooding from field ditches or border irrigation. The border method, which is used more extensively, provides fairly uniform distribution of water where the width and length of the strip are properly adjusted to slope and type of soil.

Seeded permanent pasture competes for irrigation water, throughout the growing season, with cotton, sorghum and alfalfa, and in early spring there also may be competition with wheat. In considering alternate uses of water, it may be noted that the amount of water used on an acre of permanent pasture on sandy land would irrigate 2 acres of either cotton or sorghum. Similarly, 1.6 acres of either crop could be irrigated with the water used for an acre of pasture on heavy soils. More than .5 acre of alfalfa could be irrigated on either kind of soil with the water ordinarily used on an acre of permanent pasture. Approximately 2 acres of Sudan pasture could be irrigated with the water used on an acre of seeded permanent pasture.

Sudan

Sudan for pasture is a minor irrigated crop on the High Plains. It comprises only a very small portion of the cropland, an average of around 3 acres per farm.

Sudan competes with other summer-growing crops for irrigation water. As it was a minor crop on most of the farms studied, the tendency was to water it lightly. On sandy land, an average of about half of the crop was irrigated before planting. Irrigation practices on heavy soils varied from no irrigation before planting in 1947 to the irrigation of 23 percent of the crop before planting in 1948 (Table 12). After planting, the situation was reversed. On sandy soils, Sudan was given less than 1.5 irrigations, but on heavy soils the crop averaged 2.3 seasonal irrigations. During 1949, a year of above-normal rainfall and less competition in the use of water from other crops, many farmers greatly increased the use of water on Sudan pasture. When seasonal and preplanting irrigations were combined, Sudan on heavy land received an average of .6 more irrigations on sandy soil.

Table 12. Average number of irrigations, amount of water pumped and percentage of Sudan pasture acreage watered each irrigation, 1947-49

Year	Average number of irri-gations	Acre-inches pumped		Percentage of land watered each irrigation				
		Each irri-gation	Per year	Pre-planting	Seasonal			
					1st	2nd	3rd	4th
				SANDY SOILS				
1947	1.9	3.8	7.3	26	95	69	1	—
1948	1.8	4.3	8.0	59	97	28	—	—
1949	1.7	4.9	8.6	56	61	32	16	—
Av.	1.8	4.4	8.0	47	84	43	6	—
				HEAVY SOILS				
1947	3.0	3.5	10.4	—	100	77	77	43
1948	2.1	3.7	7.7	23	100	56	28	—
1949	2.3	4.0	9.4	18	100	71	22	22
Av.	2.5	3.8	9.2	14	100	68	42	22

On the other hand, more water was pumped at each irrigation on sandy soils than on heavy soils. This difference averaged .6 acre-inch each irrigation. More rapid absorption of water on sandy soils no doubt accounts largely for this difference.

From the standpoint of total water pumped for the crop, the greater number of irrigations on heavy soils more than offsets the greater amount of water applied in each irrigation on sandy soils. The 3-year average of the amount of water pumped for Sudan was 9.2 acre-inches on heavy soils, or 1.2 acre-inches more than the amount pumped for Sudan on sandy soils.

Preplanting irrigation usually is applied shortly before planting. Water is run down the lister furrow after the land has been bedded, as in the case of cotton and other row crops. The first seasonal irrigation normally is applied between the rows after one cultivation, usually in July. Later irrigation, if any, likely will be in August.

Sugar Beets

Sugar beets, a relatively new crop on the High Plains, are grown entirely under irrigation. Most growers have limited experience in the production of this crop. Only a relatively small acreage of sugar beets was grown in any one year. Production centers in Deaf Smith county where 1,316 acres were grown in 1947, 3,397 acres in 1948 and 1,216 acres in 1949, according to data supplied by the Production and Marketing Administration. A few other High Plains counties had comparatively small acreages during the same years.

Sugar beets are a major cash crop on farms where they are grown. Farmers who grew them averaged 67 acres a farm.

Information on the use of irrigation water on sugar beets was obtained for the 1949 crop. Because this was a year of above-normal rainfall, additional information was obtained concerning the usual irrigation practices.

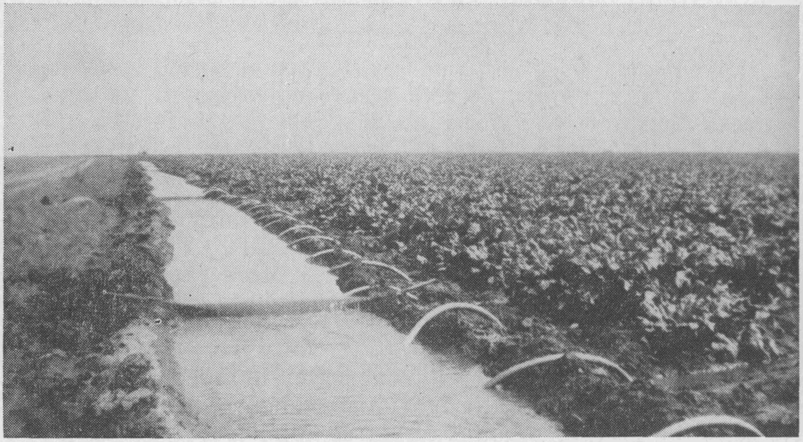

Figure 7. Irrigating sugar beets with one siphon to the row. Canvas check dams are used to raise the level of the water in the ditch.

Sugar beets use an extremely large volume of irrigation water. In 1949, the amount of water pumped on beets averaged 20.2 inches an acre. But the usual practice is to irrigate 8 to 10 times for a total of about 35 to 45 acre-inches. Although the amount of water used each irrigation varies with the soil moisture, it averaged 4.5 inches an acre in 1949.

The usual practice is to irrigate once before planting and again shortly after planting to insure a satisfactory stand of beets. Preplanting irrigation is done in the latter half of March or early April, and the first irrigation after seeding is done from early in April to May 15, depending on the planting date. Later irrigations follow at intervals of about 2 or 3 weeks, depending largely on the amount of rainfall.

Beets are planted in narrow rows (24 inches is the most common width) and water is run in a small furrow between the rows.

Much of the early irrigation of sugar beets is in competition with the preplanting irrigaton of other spring-planted crops. This crop competes for water with cotton and sorghum during July and August, and competes with alfalfa throughout the year.

Normally, sugar beets require more water than any of the other crops studied. An average of at least 4 acres of either cotton or sorghum can be irrigated with the water commonly required for a single acre of sugar beets. An acre of sugar beets requires about the same volume of water as 1.3 acres of alfalfa.

Irish Potatoes

Commercial production of Irish potatoes also is relatively new to the High Plains and has developed along with the widespread use of irrigation. Here the crop is grown only under irrigation. Although the total acreage is comparatively small, potatoes where grown are an important cash crop. Although grown to some extent over a wide area, the crop tends to be concentrated in Deaf Smith county.

Information concerning the use of irrigation water on Irish potatoes was obtained for the 1949 crop. But it was also necessary to get additional information pertaining to the usual irrigation practices for this crop because 1949 was a year of above-normal rainfall.

Irish potatoes make heavy use of irrigation water, but not to the same extent as sugar beets. In 1949, the average amount of water pumped for Irish potatoes was 15.7 inches an acre. The variation from farm to farm was 6 to 35 acre-inches. The normal practice, however, consists of 1 irrigation before planting and 8 to 10 irrigations after planting. This normally would amount to 25 to 30 inches an acre.

Irrigation before planting averaged about 5 inches an acre and in most cases was completed before March 15. Between planting and the last cultivation, the potato crop usually was watered once or twice. Following the last cultivation, the ground is kept moist continuously. This is accomplished by frequent but light irrigations. During this period, water usually was applied at intervals of 5 to 7 days. After planting, each irrigation averaged about 2.5 acre-inches. A common practice after the last cultivation was to run water down the middles between alternate rows. For the next irrigation, water was run down the middles that were missed the previous time. It was common to continue this practice of watering alternate rows throughout the remainder of the season.

Table 13. Irrigated and nonirrigated crop yields on sandy and heavy soils, 1947-49

Item	Unit	1947		1948		1949		1947-49[1]	
		Irrigated	Dry land	Irrigated	Dry land	Irrigated	Dry land	Irrigated	Dry land
SANDY SOILS									
Cotton	Lbs.	536	278	402	106	460	296	466	227
Grain sorghum	Do.	2,305	1,055	2,272	606	2,609	1,513	2,395	1,058
Forage sorghum	Do.	5,747	2,659	4,777	2,069	6,222	3,895	5,582	2,874
Wheat[2]	Bu.	26	21	18	2	17	14	20	12
Alfalfa hay[2]	Lbs.	6,386	——	8,126	——	7,717	——	7,410	——
Sudan seed[3]	Do.	1,128	323	1,100	——	1,387	1,200	1,205	762[4]
HEAVY SOILS									
Cotton	Lbs.	492	196	415	73	476	295	461	188
Grain sorghum	Do.	2,498	955	2,598	289	2,636	1,271	2,585	914
Forage sorghum	Do.	6,568	2,387	4,688	1,353	5,386	4,072	5,547	2,604
Wheat	Bu.	18	18	20	1	20	19	19	13
Alfalfa hay	Lbs.	5,725	——	7,927	——	7,533	——	7,061	——
Sudan seed[3]	Do.	900	——	1,750	250	——	——	1,325[4]	250[5]

[1]Arithmetic average.
[2]Wheat and alfalfa are minor crops on sandy soils.
[3]Yields of Sudan seed based on small sample.
[4]Two-year average.
[5]One-year average.

Although it is desirable to keep the ground moist for potatoes, standing water should be avoided. Ditch ends are kept open so that surplus water is drained off quickly.

An acre of potatoes normally uses about the same amount of water as an acre of alfalfa on heavy soils. The water required for an acre of potatoes will irrigate 2.5 to 3 acres of cotton or sorghum.

EFFECT OF IRRIGATION ON YIELDS

Supplementing rainfall with irrigation both increases and stabilizes crop yields on the High Plains. It also makes possible the production of crops having higher water requirements than can be met ordinarily by rainfall. Yields from irrigated and dry-land portions of the cooperating farms are shown in Table 13, as well as yields on sandy and heavy soils.

For the four principal crops—cotton, sorghum, wheat and alfalfa—the difference in yields of irrigated crops between the two soil types was not significant. However, there was a somewhat greater spread in yields between irrigated and dry-land crops on heavy soils than on sandy soils. This indicated that the effect of irrigation was somewhat greater on heavy soils than on sandy soils. Yields of cotton and sorghum were more than doubled by irrigation on both soil groups. Wheat yields were not increased as much as were row crop yields. On heavy soils, where most of the wheat was grown, there was no significant difference in wheat yields between dry-land and irrigated in 1947 or 1949, but there was a big difference in 1948 when most dry-land wheat failed. The 3-year average yield of wheat harvested from irrigated heavy soils was about 50 percent higher than that harvested from dry land. Because of its high water requirements, alfalfa is rarely grown without irrigation, therefore, yield comparisons on irrigated and dry land are not possible.

Yield differences do not tell all of the story. Table 13 shows that year-to-year variations are much more extreme for crops produced on dry land than on irrigated land. Furthermore, the variations are more extreme on heavy soils than on sandy soils. Here again, the data do not tell the whole story, as in years of extreme drouth, such as occurred in parts of the area in 1948, a high percentage of the acreage in crops may not be harvested. Another consideration is the difficulty of carrying out planting intentions on the High Plains under dry-land conditions. Without irrigaton, crops such as cotton, which require a long growing season, may have to give way to second or third choice crops when the spring rains come late.

Similarly, lack of fall rains may greatly affect the acreage of wheat seeded and disrupt crop production plans.

Information obtained in this study raises questions to which the answers are necessary for the improvement of irrigation practice on the High Plains. In view of the wide range from farm to farm in the number of irrigations, the time of irrigation and the total amount of water applied, emphasis in future studies should be on these questions. The importance of these problems in their relationship to crop yields and, in turn, to costs and incomes of farmers will become greater as the pressure increases on the limited supply of water through application to more and more land, or with application of greater intensity to present acreages.

SUMMARY

The data and conclusions presented in this bulletin are based on information obtained from an average of 154 farms and 203 irrigation wells during the 3-year period 1947-49, and from 35 additional farms and the accompanying wells in 1949.

A highly variable and low average rainfall has contributed to wide fluctuations in production and income on the High Plains. This problem was partly solved through the development of irrigation.

At the present time (1952), more than 2 million acres of cropland are being irrigated from 16,000 or more wells.

The available supply of water in the Ogallala formation underlying that part of the High Plains studied has been estimated by the U. S. Geological Survey and the State Board of Water Engineers to be approximately 150 million acre-feet.

The withdrawal of water from the reservoir is at present in excess of 2 million acre-feet annually and the rate is increasing.

The average amount of water used per acre of irrigated cropland during the 3-year period was about 11 acre-inches. It varied from 13 inches in 1948, a dry year, to 8.5 inches in 1949, a wet year.

Farms with low-yielding wells used less water per acre than did farms with high-yielding wells. The range was from 7.2 inches for wells yielding 500 gallons and under to 12.3 inches per acre for wells yielding more than 1,000 gallons.

The acreage irrigated per well, which averaged 138 during the 3-year period, also fluctuates from season to season, owing largely to differences in rainfall and its distribution. In 1948, a dry year, the per-well average was 155 acres and in 1949, a wet year, the average was 125 acres.

The average acreage irrigated per well during the 3-year period was 121 on sandy soils and 151 on heavy soils. The difference of 30 acres is largely the result of two factors: a higher discharge rate or yield per well on heavy soils (780 gallons per minute, as compared with 699 on sandy soils), and a more diversified cropping system on heavy soils which spreads the demand for water more uniformly over a somewhat longer season.

On sandy soils, 70 percent of the irrigated land was planted to cotton and 21 percent to sorghum. No other crop occupied as much as 2 percent of the irrigated acreage.

On heavy soils, sorghum accounted for 39 percent, and cotton and wheat were about equally planted on another 45 percent of the irrigated land. In addition, most of the alfalfa, potato and sugar beet acreage is on heavy soils.

Methods of spreading water vary with the crop and with the slope of the land and the texture of the soils. On most farms, the water is carried to the field by gravity through open earthen ditches from which there is a substantial loss of water from seepage, evaporation and transpiration through weeds. A few operators have reduced this loss through the use of underground pipe.

Water is spread over the field by running it between the rows or beds of row crops and down the slope between borders or furrows of close-seeded crops. In either case, the water is taken from the ditch by means of siphon tubes.

Differences in the yield of the well, the slope of the land and the texture of the soil may affect the practices followed in spreading irrigation water. Farmers adjust to such differences by varying the rows irrigated per set, the number of siphons per row and the length of run. For cotton and sorghum, the length of run was 125 yards longer on heavy soils than on sandy soils.

Increasing the number of siphons per row and shortening the run reduces the amount of water required for a given rate of application, but it increases the number of sets to water a given acreage and the labor required to do the irrigating. The resulting compromise usually will reflect the relative scarcity of water and labor on the farm.

Two-thirds of all water pumped on sandy soils and one-fifth on heavy soils was used for cotton production. The average amount of water used per acre of cotton was 10.8 inches on sandy soils and 9.5 inches on heavy soils. Year-to-year variations on sandy soils ranged from 8.9 inches in 1949 to 13.3 inches in 1948. On heavy soils, it was 7.3 inches in 1949 and 12.4 inches in 1948. Cotton received 2.5 irrigations on sandy soils and 2.3 irrigations on heavy soils.

Three-fourths of the cotton on sandy soils received a preplanting irrigation, while only about half of the cotton on heavy soils was so treated. The number of irrigations after planting were the same on both soil groups. Slightly more than 4 inches of water were applied with each irrigation.

Most of the preplanting irrigation is done in April and most of the seasonal irrigation in July and August.

Sorghum is the principal crop irrigated on heavy soils and is second only to cotton on sandy soils. Thirty-one percent of all water pumped was used on sorghum. Sorghum received about the same amount of irrigation water per acre, on the average, as cotton, but there was a difference between soil groups. On sandy soils, the predominant crop (cotton) received about one inch more water than did sorghum, but on heavy soils, where sorghum was the main crop, the amounts of water were reversed. Also, there was a proportionate difference in the number of irrigations of these two crops between the two soil groups.

There was less preplanting irrigation on sorghum than on cotton, but as in the case of cotton there was more preplanting and less seasonal watering on sandy soils than on heavy soils.

Nine percent of the water pumped was applied to wheat, most of which was on heavy soils. An average of slightly more than 7 inches was applied during the 3-year period. The extremes on heavy soils ranged from 4 inches in 1947 to more than 11 inches in 1948. The number of irrigations varied from 1 in 1947 to slightly more than 2 in 1948. There is more preplanting irrigation of wheat on heavy soils than on sandy soils. Almost half of the wheat on heavy soils was irrigated before planting in 1948. Most water is applied to wheat during April. Late fall watering is sometimes necessary to carry the crop through the winter, as was the case in 1948. Since wheat is irrigated mostly by flooding from field ditches, some land leveling is needed to insure an even distribution of the water.

Alfalfa, grown only with irrigation on the High Plains, is a heavy user of water. Like wheat, it is grown mainly on heavy soils. Thirteen percent of the water pumped on cooperating farms was used on alfalfa. It was applied at the average rate of about 30 inches per acre per season on heavy soils and almost 36 inches per acre per season on sandy soils. Alfalfa is watered every 2 to 3 weeks from April to October and competes with all other crops for water. The peak of its demand is reached in July and August when the demand for cotton and sorghum is the heaviest. Between 3 and 4 acres of cotton or sorghum may be irrigated with the amount of water used on 1 acre of alfalfa. More use is made of borders in controlling the movement of water on alfalfa than on wheat and the land is more carefully leveled for its irrigation.

Other crops for which information on the use of irrigation water was obtained include permanent and rotation pastures and sugar beets and potatoes. Rotation pastures, mainly Sudan, are irrigated at near the same rates and in similar manner as sorghum. Permanent seeded pastures are watered at about twice the rate as rotation pastures. Sugar beets normally receive from 35 to 45 inches of water, or about 4 times as much as cotton or sorghum. Potatoes normally receive 25 to 30 inches of water per acre, or enough to water almost 3 acres of cotton or sorghum.

Except for wheat, yields of crops commonly grown without irrigation (principally cotton and sorghum) were more than doubled when irrigated during the 3-year period. Year-to-year differences in yields were much greater on dry land than on irrigated land. Cotton and grain sorghum on sandy soils averaged 466 pounds of lint and 2,395 pounds of grain, respectively, when irrigated, as compared with 227 pounds of lint and 1,058 pounds of grain from dry-land crops. On heavy soils, the difference was greater—461 pounds of cotton lint and 2,585 pounds of grain, as compared with 188 pounds of lint and 914 pounds of grain from dry-land crops.