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Use of Groundwater for Irrigation in Clay County, Nebraska, 1970

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Prepared in cooperation with U. S. Geological Survey and Clay County Ground Water Conservation District

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Fred Stahnke, *Chairman*

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USE OF GROUNDWATER FOR IRRIGATION IN CLAY COUNTY, NEBRASKA, 1970

By Eugene K. Steele, Jr.

ABSTRACT

About 126,400 acres, or 35 percent of the land in Clay County, is irrigated with water pumped from wells. The downward trend of water levels shown by depth-to-water measurements made by the Clay County Ground Water Conservation District in selected wells since 1958 indicates that the groundwater supply is being depleted progressively in most of the county. Comparison of water levels in the spring of 1970 with estimated water levels prior to irrigation development indicates a net decrease of about 519,000 acre-feet in the stored supply. Pumpage during the 1970 irrigation season, about 208,000 acre-feet, reduced groundwater storage an additional 131,000 acre-feet, increasing total depletion of the stored supply to about 650,000 acre-feet since irrigation development began. If seasonal water-level declines are proportional to seasonal pumpage, hydrographs of water-level changes since 1958 in five wells indicate that the net decline in 1970 was more than in 1967, 1968, or 1969 but not as great as in 1966.

INTRODUCTION

Clay County, in southeastern Nebraska (fig. 1), has an area of 571 square miles, or 365,440 acres. It is on an upland plain

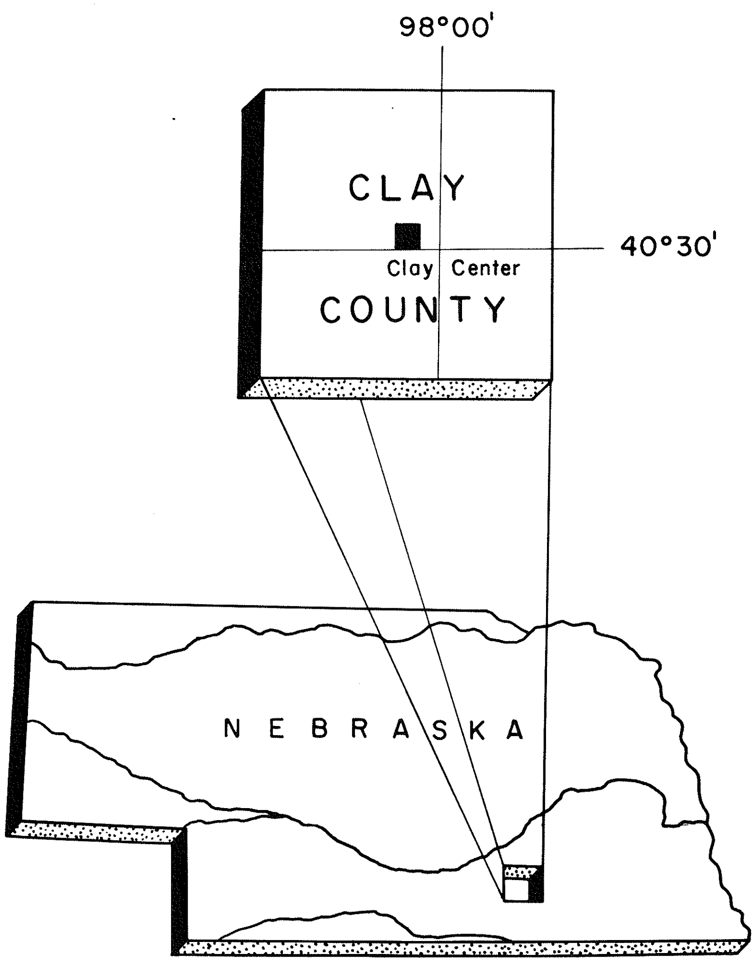


Figure 1.--Index map showing location of Clay County.

that slopes southeastward and is entirely within the area drained by the Big Blue River. The West Fork of the Big Blue River and its tributary School Creek drain the northern part of the county; the Little Blue River and its tributary Big Sandy Creek drain the southern part; and Turkey Creek drains a small area in the east-central part. A considerable part of the upland drains to shallow depressions and thus does not contribute directly to streamflow.

Most soils developed in loess, locally called "yellow clay." The soils on nearly level or gentle slopes have a claypan subsoil that ranges in depth below land surface from about 6 to 28 inches and in thickness from 8 to 20 inches. The claypan subsoil slows downward percolation of both precipitation and applied irrigation water and reduces the amount of water passing through the soil.

At Clay Center, located near the center of the county, the average annual precipitation during 1930-70 was 24.21 inches; of this an average of 13.94 inches, or 57.6 percent, fell during May through August. (See fig. 2.) Because the growing-season precipitation generally is poorly distributed both areally and with respect to time, supplemental water is needed virtually every year for full crop development.

A small amount of lowland along the Little Blue River is irrigated with water pumped from the stream. Much additional irrigation development close to the river is not likely because most of the remaining valley land is rough and thus is difficult and expensive to irrigate. Other streams in the county flow

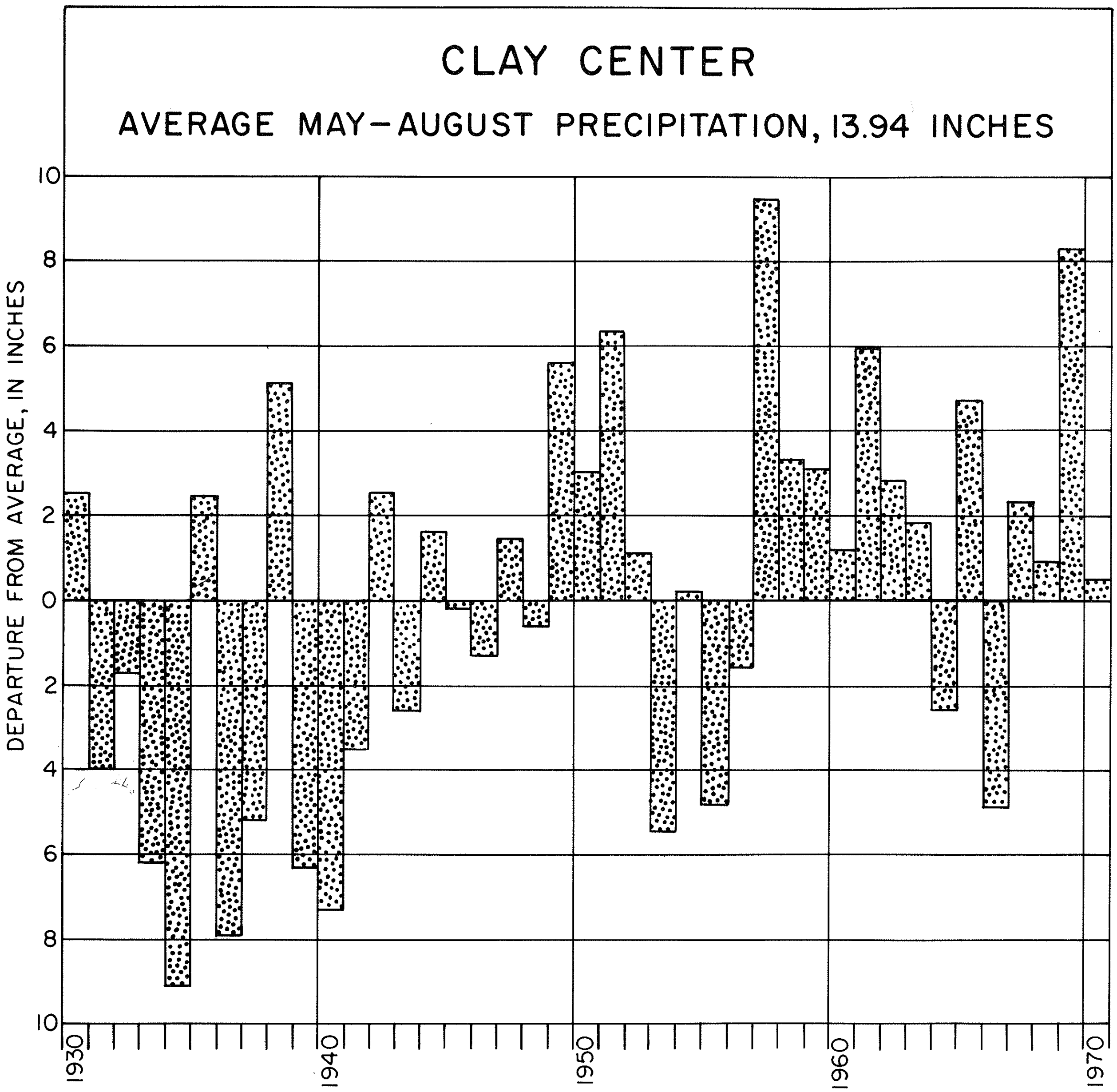


Figure 2a.--Yearly departures from average growing-season precipitation at Clay Center, 1930-70.

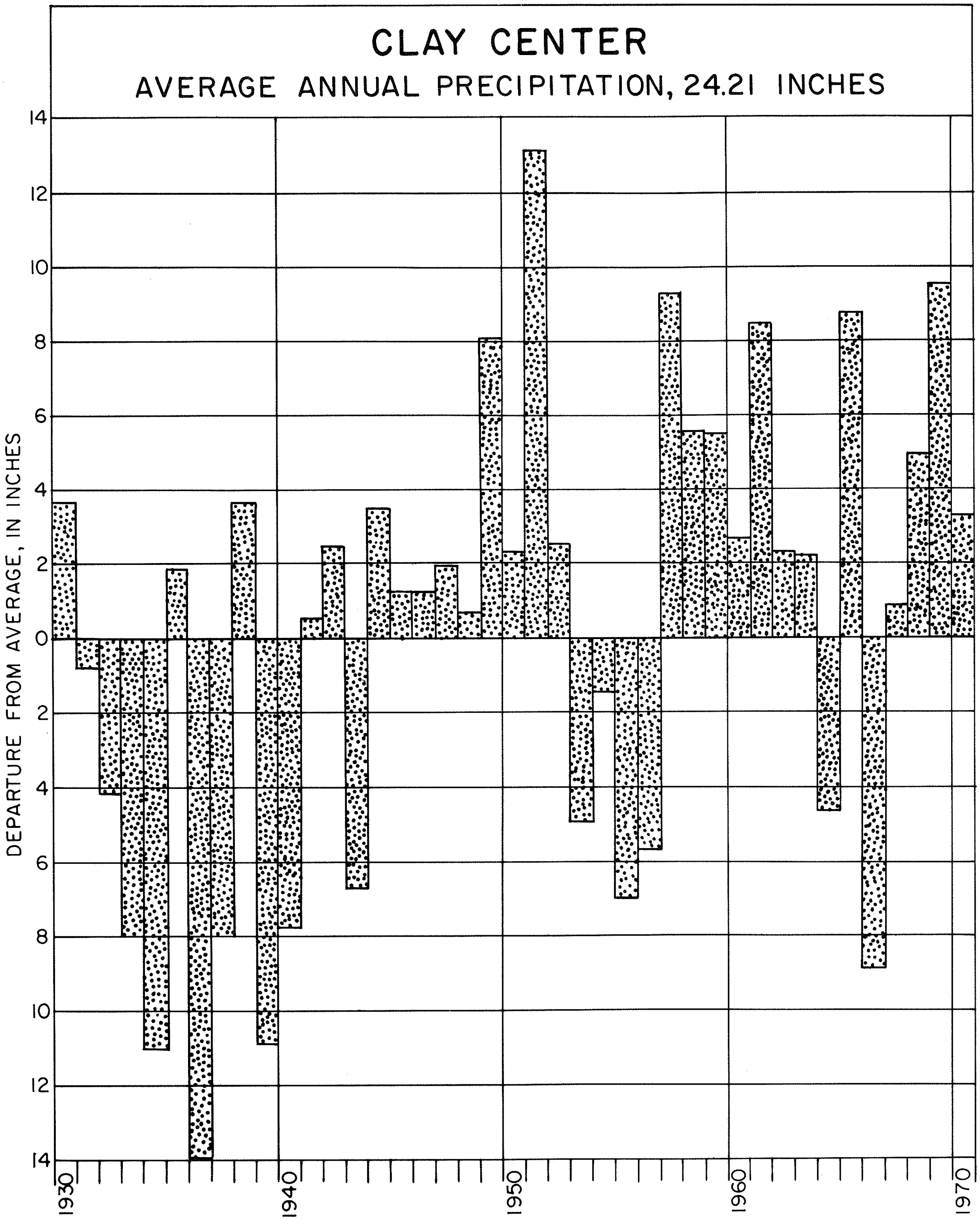


Figure 2b.--Yearly departures from average annual precipitation at Clay Center, 1930-70.

intermittently, for the most part, and generally are dry during the periods of heavy irrigation demands. The principal source of water to meet irrigation demands is water withdrawn from the groundwater reservoir by irrigation wells.

The need to supplement water received from precipitation during the growing season was realized during the drought of the 1930's, but owing to economic conditions only a few irrigation wells were drilled during this period. Beginning in the early 1940's, when economic conditions started to improve, some farmers installed wells as insurance during years of below-normal precipitation, and by 1950 there were about 100 irrigation wells in the county. During 1953-56, which was a period of sub-normal precipitation and increased crop prices, drilling activity accelerated. This higher rate of well installation continued through 1957 as farmers, with the drought of 1953-56 firmly implanted in their minds, were anxious to prevent a recurrence of the crop failures that had been so disastrous. During this 5-year period, 1953-57, 582 wells were added, more than four times the total for all previous years. Because pump operators were learning from experience that application of irrigation water also increased crop yields in years of normal and above-normal precipitation, drilling of irrigation wells continued, though at a reduced rate.

Depending upon rainfall amounts and economic conditions, the number of new installations ranged from 8 to 89 per year, and by December 31, 1970, 1,241 irrigation wells had been registered in the county (State-Federal Division of Agricultural

Statistics, 1970). Annual well installations during 1945-70 and the cumulative number of wells by year during the same period are shown in figure 3 by a bar graph and a line graph, respectively. The areal distribution of these wells is shown in figure 4. Comparison of the well-installation rate with graphs of yearly departures from both average growing-season and average annual precipitation at Clay Center (fig. 2) shows that well-drilling activity since about 1950 has been spurred by deficiencies in precipitation.

The amount of water pumped for irrigation has increased faster than the increase in the number of wells. During the early stages of irrigation development, water was applied only when necessary to prevent crops from deteriorating, but now more water is applied because irrigation practices are geared to soil-moisture conditions and stage of crop growth. Furthermore, efforts to obtain maximum yields by applying more fertilizer and by planting new crop varieties have tended to increase the total water requirement. Although timely precipitation during the irrigation season is generally welcome, most farmers no longer depend on summer rains for their moisture supply and regard some summer storms as detrimental to their irrigation operations.

Of the 126,400 acres developed for irrigation, 108,000 acres were irrigated in 1970. About 86 percent of the irrigated acreage was planted to corn, 10 percent to grain sorghum, and most of the remainder to alfalfa and soybeans (State-Federal Division of Agricultural Statistics, 1971). During 1954-70, the

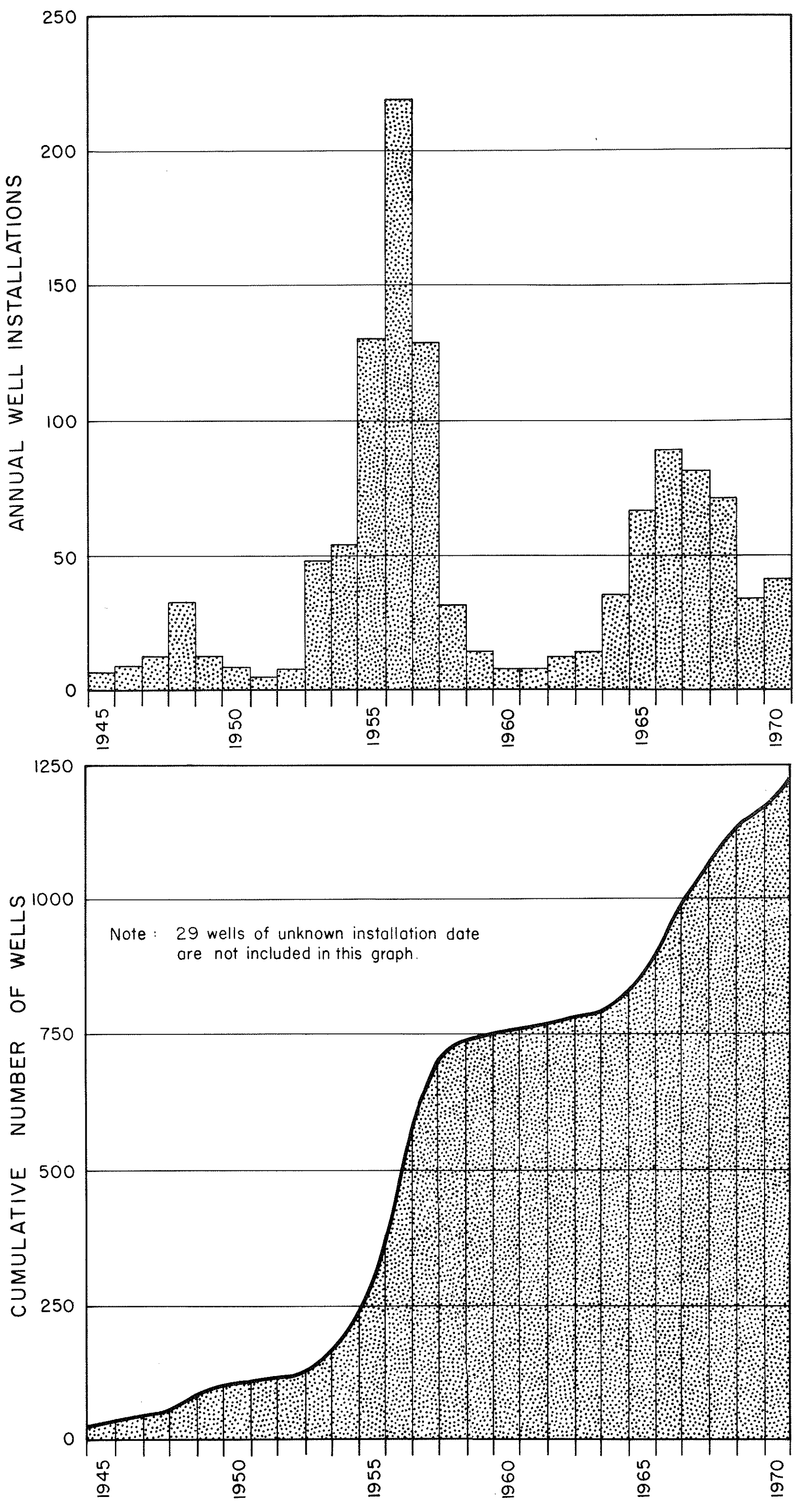


Figure 3.--Annual irrigation-well installations and cumulative total number of irrigation wells, 1945-70.

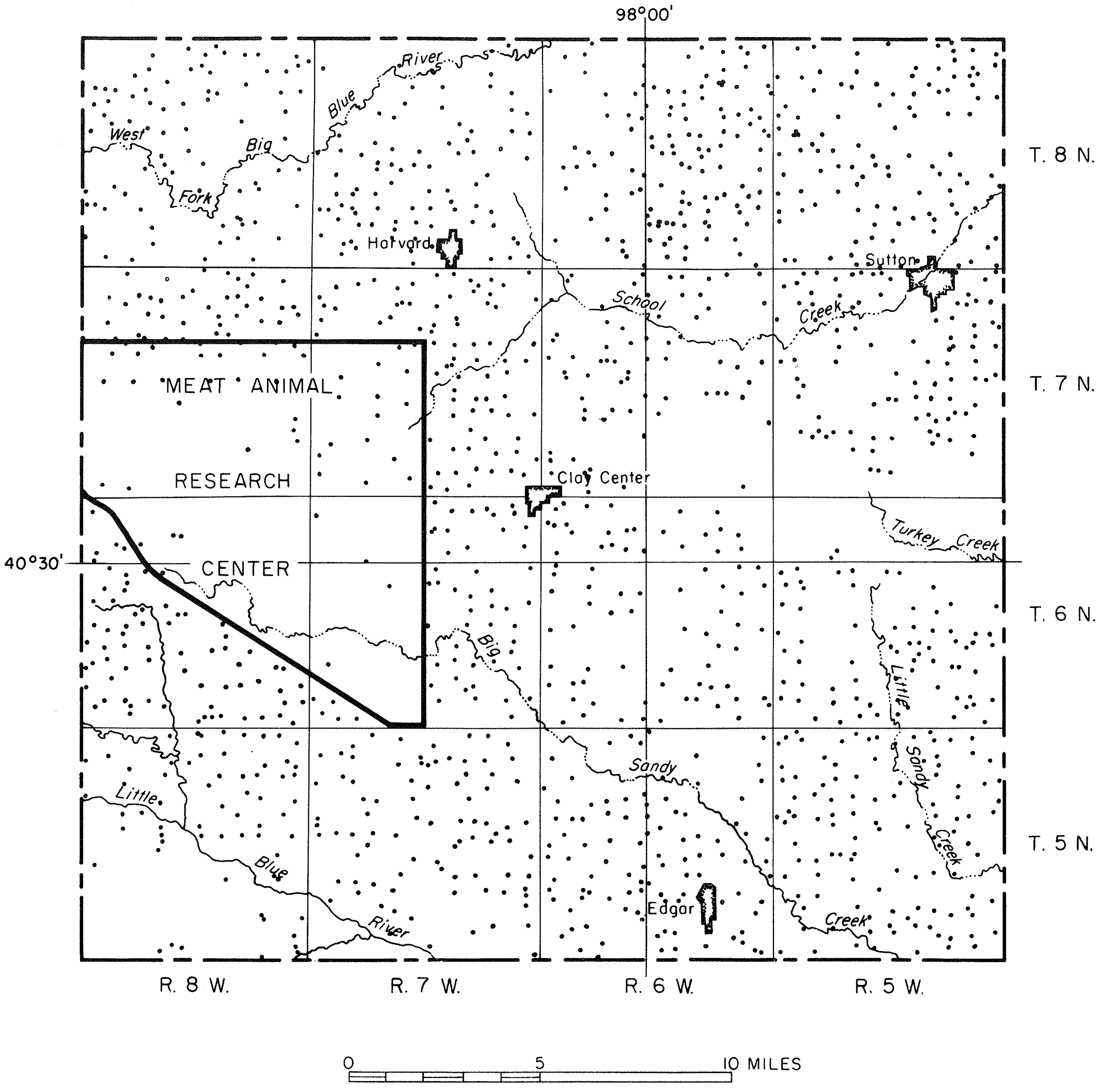


Figure 4.--Locations of irrigation wells in Clay County.

average yield per acre of irrigated corn generally ranged from 1.7 to 4.0 times that of nonirrigated, but in the drought years of 1955 and 1956 was, respectively, about 10 and 12 times greater. The average yield per acre of irrigated grain sorghum during 1956-70 generally ranged from 1.2 to 2.9 times greater than non-irrigated, but in 1956 was about 8 times greater. Even in 1969, when climatic conditions were especially advantageous to dryland crop production, the average yield per acre of irrigated corn was 1.7 times, or 51 bushels, greater than that of nonirrigated corn. In the same year the average yield per acre of irrigated grain sorghum was 1.3 times, or 22 bushels, greater than that of nonirrigated grain sorghum.

Average yields for irrigated and nonirrigated corn and grain sorghum, as compiled from annual reports of Nebraska agricultural statistics, are shown in table 1.

Comparison of the yields of nonirrigated corn and grain sorghum with the departures from average annual precipitation and average growing-season precipitation reveals that yields have little relation to precipitation amounts. Even when seasonal rainfall is considerably more than average, crop damage due to drought may occur before precipitation is received or rain may fall at rates greater than can be absorbed by the soil and thus may be lost to overland runoff. Conversely, crop yields during some years of below-normal rainfall may be larger than in years of above-normal precipitation. For example, crop yields in 1966, when precipitation was scanty, were far better than in 1965, when rainfall was considerably more than normal.

Table 1.--Average yields of irrigated and nonirrigated corn, 1954-70, and grain sorghum, 1956-70 /State-Federal Division of Agricultural Statistics, 1954-70/

Year	Bushels per acre			
	Corn		Grain sorghum	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated
1954	62	17	...	...
1955	63	6	...	...
1956	75	6	65	8
1957	79	34	72	38
1958	80	39	74	46
1959	79	41	72	50
1960	82	42	82	52
1961	79	39	83	56
1962	90	45	97	79
1963	87	39	82	58
1964	80	27	82	28
1965	101	25	82	35
1966	116	55	96	64
1967	115	38	93	55
1968	104	41	87	45
1969	121	70	104	82
1970	115	50	96	54

As of the end of 1970, 1,241 irrigation wells in Clay County had been registered with the Nebraska Department of Water Resources (State-Federal Division of Agricultural Statistics, 1970). Additional wells are likely to be installed in future years, especially as development of the center-pivot system has made irrigation of the more rolling marginal lands feasible, and it is reasonable to assume that the irrigated acreage will continue to increase. The rate of expansion will depend upon the availability of water supply, suitability of land, and other factors, including economic considerations.

Although irrigation of the present magnitude eliminates much of the drought hazard for farmers, it places a heavy demand on the available groundwater supply. Continued heavy withdrawals are certain to result in a significant lowering of the water levels in wells, in interference between wells being pumped, in decreased yields from wells, and in abandonment of wells where the aquifer is relatively thin and is no longer capable of supplying enough water for irrigation use. However, as the quantity of water still in storage is tremendous, the groundwater supply will not soon be exhausted where the aquifer is thick.

In a concerted effort to appraise and better manage the groundwater supply, a majority of the irrigators in the county voted, in the late 1960's, to organize the Clay County Ground Water Conservation District, as authorized by the 1959 Nebraska State Ground Water Conservation Act. In general, the District was formed to do the following (Axthelm and Hecht, 1967):

1. Work with and seek assistance from all local, state, and federal agencies having expertise in appraisal, development, and protection of groundwater resources.
2. Develop a program for eliminating waste of water.
3. Investigate methods and encourage research on more effective use of rainfall.
4. Investigate and develop potential groundwater and surface-water resources for recharge and irrigation.
5. Determine costs of water for various crops and pumping conditions.
6. Begin a program of water-level measurement throughout

the District and coordinate the program with those of state and federal agencies.

7. Investigate the possibility of income-tax benefits in compensation for depletion of groundwater reserves.
8. Provide a pumping-plant testing program.
9. Institute measures, if and when necessary, to correct wasteful practices relating to groundwater use.
10. Perform, as the need arises, additional functions related to groundwater conservation.

In 1970, the District contracted with the U. S. Geological Survey to evaluate their groundwater resource, to determine the effect of groundwater pumpage upon the available supply, and to obtain data needed by the District to manage their water resources. This report, which presents the results of the study through the spring of 1971, is a step towards obtaining facts needed for a detailed appraisal of adequacy and longevity of the water supply. Considerable additional data will be needed before projects that would increase the supply by importing water can be undertaken.

Pertinent information from earlier publications that describe the geology and water resources of Clay County has been used in making this appraisal. Those publications are included among the selected references listed at the end of this report.

ACKNOWLEDGMENTS

Many persons aided in this study by contributing time and

information. George Woolsey, Clay County Extension Agent, provided information on well locations and records of depth to water in wells. In addition to providing financial support, the District Board of the Clay County Ground Water Conservation District publicized the study locally and encouraged pump operators to cooperate by keeping records of hours pumped and permitting water-level and water-yield measurements to be made. District Chairman Fred Stahnke provided information and data obtained by the District prior to the study and rendered valuable assistance while the study was in progress.

WELL-NUMBERING SYSTEM

Wells are numbered in this report according to their location within the system of land subdivision of the U. S. Bureau of Land Management. The numeral preceding the N (north) indicates the township, the numeral preceding the W (west) indicates the range, and the numeral preceding the terminal letters indicates the section in which the well is located. The terminal letters A, B, C, and D indicate location within the section; the first letter denotes the quarter section, or 160-acre tract, and the second the quarter-quarter, or 40-acre tract. The letters are assigned in a counter-clockwise direction, beginning in the northeast corner of each tract. The well-numbering system is illustrated in figure 5.

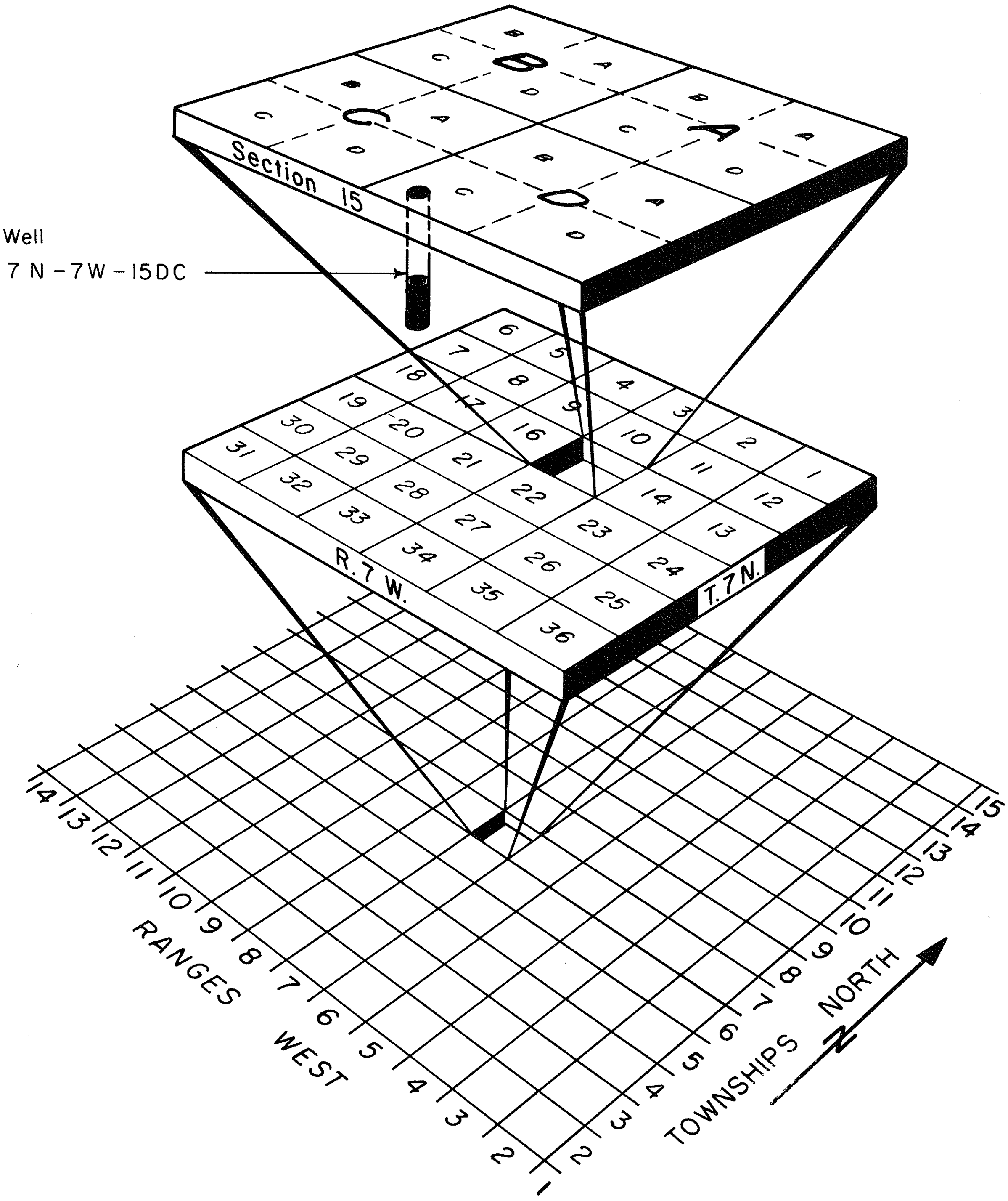


Figure 5.--Well-numbering system.

METHODS USED AND SUMMARY OF DATA COLLECTED

The principal goal of the investigation during 1970 was to establish a program of observation, similar to that already underway in Hamilton and York Counties, whereby annual pumpage for irrigation could be related to annual changes in water levels and the corresponding changes in groundwater storage. Because pumpage and water-level change records were not kept by all irrigators, such information was obtained for a representative sample of the wells so that the average values for the sample then could be applied to the entire county. The 50 wells selected for the sample are referred to in this report as "project wells"; their locations are shown in figure 6.

Long-term records of water-level changes were available for 15 water-level observation wells which have been measured by the District (12 of these wells were selected as project wells) and another 15 wells that are included in the statewide network of water-level observation wells which are measured semiannually or annually as part of the State-Federal cooperative program of water-resources investigations. The locations of the wells for which long-term water-level records are available are shown on figure 7. Measurements made in these wells and in the project wells were used in determining changes in water levels and depletions in storage.

Each operator of a project well was given a calendar on which he was asked to record hours of operation. Of those given out, 42 calendars were returned by the operators. Fuel-consumption (electric and natural gas) records were available for 28 of

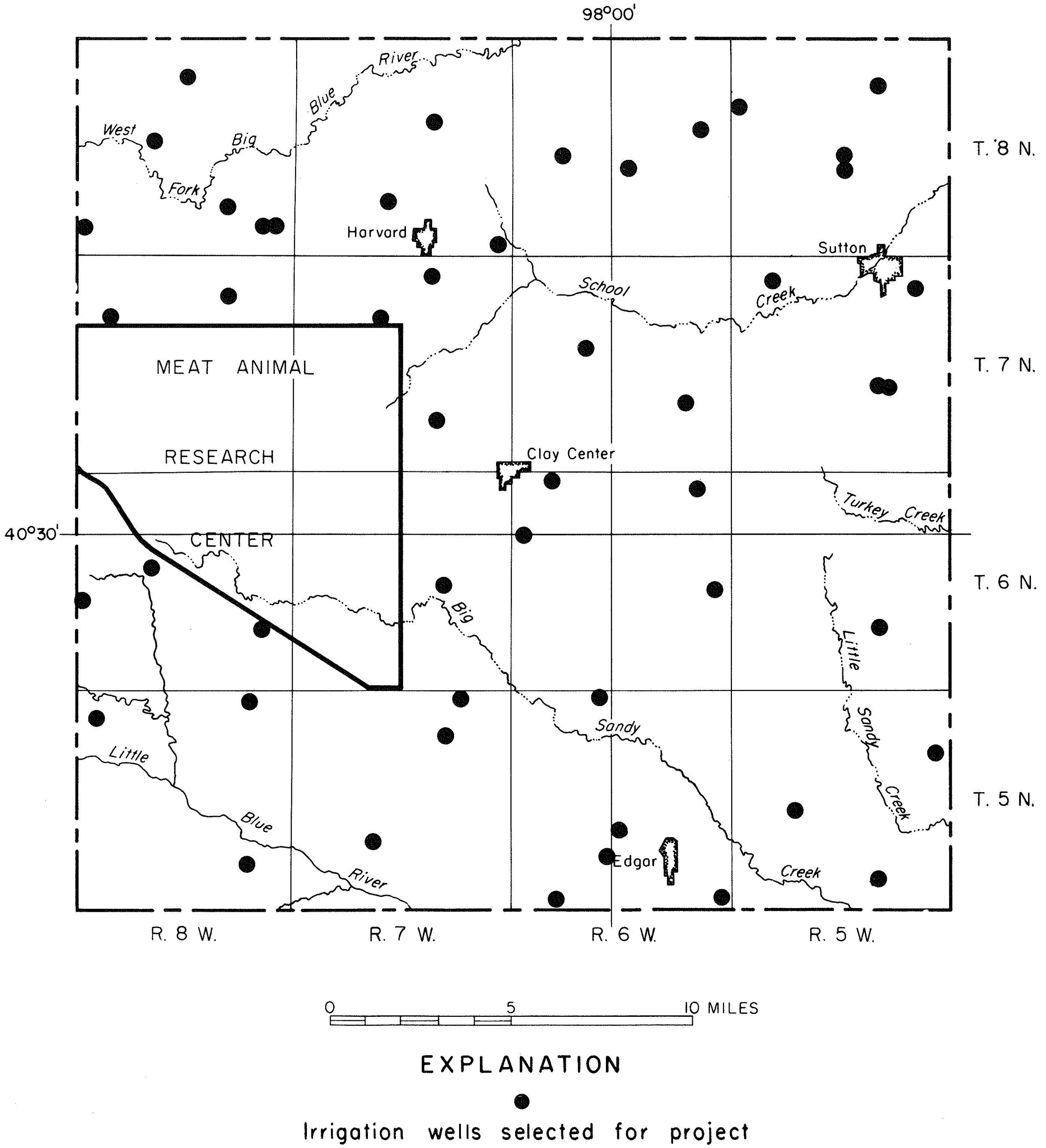
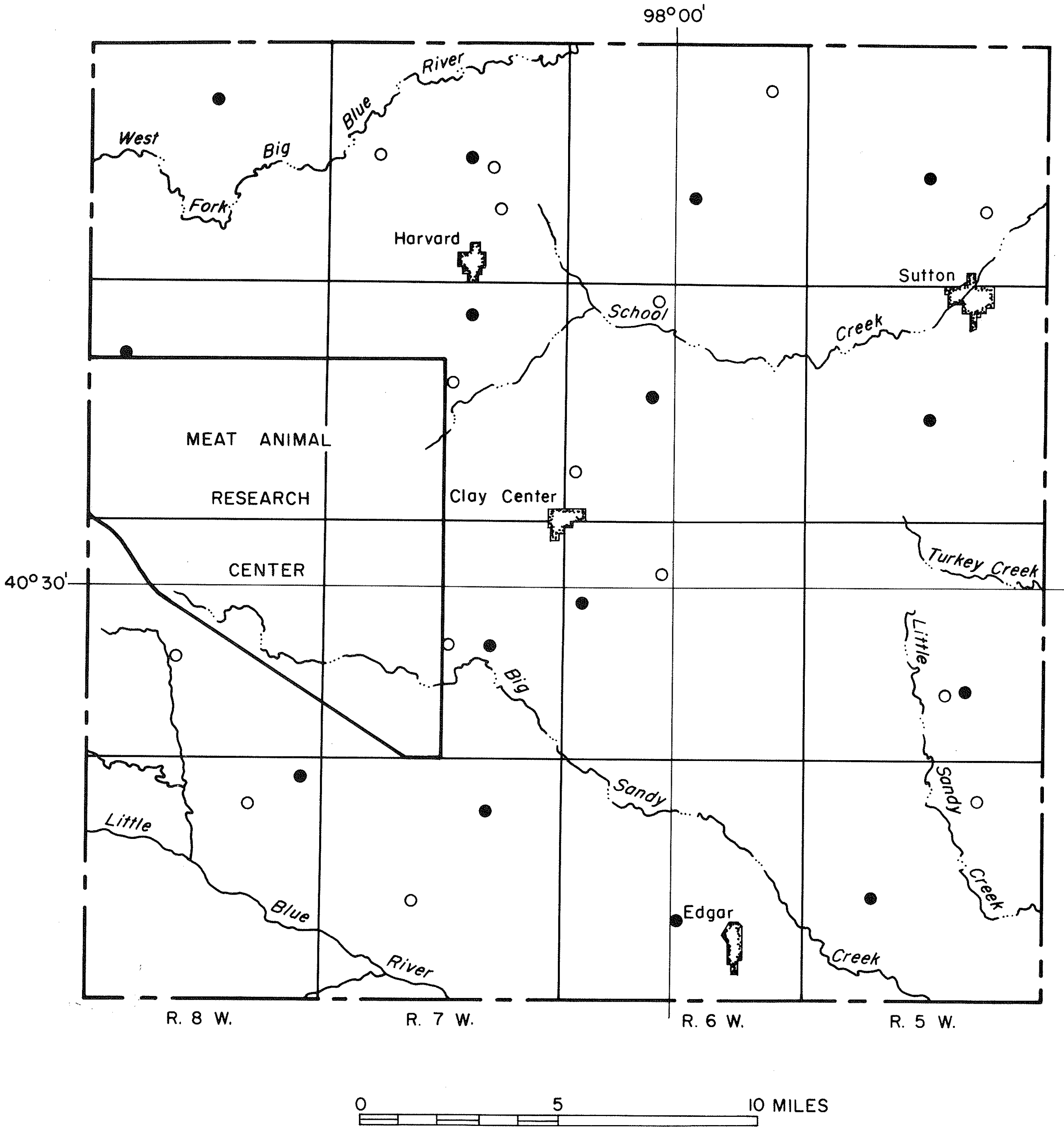


Figure 6.--Locations of project wells in Clay County.



EXPLANATION

● Water – level measurements made by Clay County Irrigation Association

○ Water – level measurements made as a part of the Federal-State Cooperative Program

Figure 7.--Locations of long-term observation wells in Clay County.

the project wells; these were used to obtain a value for hours of operation for three wells where hours had not been recorded.

Either a current meter or a pitot tube was used to measure the rate of discharge from 46 of the project wells; the rate of discharge from the remaining four wells was not determined. Other data collected consisted of drawdown, type of power, time pumped during the 1970 irrigation season, and number of acres irrigated. The collected information is summarized in table 2.

A predevelopment water level was estimated for each project well (table 3) so that water-level and water-storage changes since irrigation began would be computed. In making the estimates, use was made of water-level measurements and water-table contour maps in earlier reports.[1/] As part of the field work for this report, measurements of the depth to water in all project wells were made in the spring and fall of 1970 and again in the spring of 1971.

As the wells in which water-level measurements were made are irregularly distributed in the county, computation of the average net water-level change for a given period requires that the measured water-level change in each well of the network be weighted according to the size of the area represented by that well. Such an area for any well in a network is a polygon in which all points are closer to that well than to any other. A U. S. Geological Survey computer program that not only determines

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1/ Average water levels during 1948-54 were assumed to represent predevelopment conditions. By this time water levels had recovered from the effects of drought in the 1930's and had not yet been affected significantly by withdrawals for irrigation.

Table 2.--Summary of data for project and selected other irrigation wells in Clay County

[All averages are arithmetic (nonweighted) unless indicated otherwise]

Number of wells	1/68
Depth to water (60 wells), spring 1970:	
Maximum....feet..	117.95
Minimum....do....	60.23
Average....do....	87.22
Depth to water (68 wells), fall 1970:	
Maximum....feet..	126.87
Minimum....do....	63.74
Average....do....	91.52
Water-level decline (59 wells), spring 1970 to fall 1970:	
Maximum....feet..	18.93
Minimum....do....	.00
Weighted average decline....do....	3.40
Depth to water (63 wells), spring 1971:	
Maximum....feet..	119.22
Minimum....do....	62.16
Average....do....	89.10
Water-level difference (58 wells), spring 1970 to spring 1971:	
Maximum decline....feet..	5.19
Minimum decline....do....	.30
Weighted average decline....do....	1.77
Wells for which discharge was rated	46
Rate of discharge:	
Maximum....gallons per minute..	2,060
Minimum....do....	340
Average....do....	953
Wells for which time pumped in 1970 was recorded by operator....	44
Time pumped in 1970 (47 wells):	
Maximum....hours..	1,635
Minimum....do....	233
Average....do....	948
Total....do....	44,568
Pumpage in 1970 (44 wells):	
Maximum....acre-feet..	443
Minimum....do....	43
Average2/....do....	168
Area irrigated in 1970 (46 wells):	
Maximum....acres..	196
Minimum....do....	10
Average....do....	84
Total....do....	3,845
Depth of water applied to crop in 1970:	
Maximum....feet..	5.77
Minimum....do....	1.05
Average3/....do....	1.97

Table 2.--Summary of data for project wells in Clay County--Continued

Wells having pumps run by natural gas............................	23
Wells for which gas consumption records were obtained.............	21
Wells having pumps run by electricity............................	10
Wells for which electricity consumption records were obtained......	7
Wells having pumps run by propane, tractor fuel, or diesel fuel....	17

1/Complete information not furnished for all wells. Maximums, minimums, averages, and totals computed from all available data.

2/Total pumpage, in acre-feet, divided by number of wells.

3/Total pumpage, in acre-feet, divided by irrigated acreage.

polygon areas but also uses them in calculating average net water-level changes was utilized for making computations from the water-level data collected during this investigation. The weighted water-level declines given in table 2 were calculated by using that computer program.

To determine the change in storage indicated by the measured net lowering of water levels for a given period, the weighted water-level decline was multiplied by the county area and the resulting product was multiplied by 0.20, which is considered to be a reasonable value for the specific yield1/ of the water-bearing sandy gravel that underlies Clay County. As the change in water level is expressed in feet and the county area in acres, the change in storage is in acre-feet.

Total pumping time during 1970 and rate of discharge were obtained for 44 of the 50 project wells. The method used to obtain a value for total pumpage in the county was as follows:

1/Specific yield is the ratio of (1) the volume of water that a water-saturated material will yield by gravity drainage to (2) the volume of that material.

Table 3.--Records of project and selected other irrigation wells in Clay County, Nebraska

[Well number: See text for explanation of well-numbering system. Type of power: D, diesel; E, electric; NG, natural gas; P, propane; TF, tractor fuel]

Well number	Owner or operator	Water level (feet below measuring point) Predevelopment	Spring 1970	Fall 1970	Spring 1971	Water-level difference, Spring 1970 to Spring 1971 (feet)	Drawdown (feet)	Type of power	Rate of discharge (gpm)	Hours pumped in 1970	Acres irrigated in 1970
5N-5W-11BA	Dale Friedline	77.00	......	87.32	......	....	......	.....	....	......	....
5N-5W-12DA	Harold Roush	82.00	87.99	89.50	89.09	-1.10	9	P	1,100	233	45
5N-5W-20AA	Aubrey Wilson	72.00	75.15	77.23	76.39	-1.24	21	NG	1,000	1,018	80
5N-5W-35BB	Jerry White	72.00	81.38	83.89	84.72	-3.34	22	NG	1,470	396	80
5N-6W- 4BA	Raymond Wolf	80.00	85.63	86.12	87.05	-1.42	18	TF	990	694	60
5N-6W-21DD	Leland Hawley	77.00	83.62	86.24	85.11	-1.49	16	E	790	836	50
5N-6W-28DB	Robert Koontz	77.00	84.82	87.16	86.27	-1.45	17	E	1,080	986	65
5N-6W-32CC	Ron Brennfoerder	75.00	81.69	83.57	82.93	-1.24	17	D	840	807	62
5N-6W-36DD	Wendell Lee	76.00	83.95	86.10	85.03	-1.08	......	P	1,170	1,635	61
5N-7W- 2AB	Fred Stahnke	79.00	86.87	88.74	87.99	-1.12	13	NG	1,370	813	150
5N-7W-11BB	Robert Matticks	75.00	80.34	82.45	81.36	-1.02	12	NG	1,000	879	100
5N-7W-21CA	Joseph R. Skalka	79.00	82.27	85.27	84.32	-2.05	......	.....	....	......	....
5N-7W-28BB	A. J. Skalka & Sons	86.00	90.10	91.41	90.72	-.62	......	E	....	1,352	....
5N-8W- 1AC	Lloyd Dana	86.00	89.84	92.62	......	....	......	.....	....	......	....
5N-8W- 2AA	Ward Fitzke	94.00	97.67	100.40	99.10	-1.43	17	P	740	872	95
5N-8W- 6DB	Duane Schliep	95.00	98.03	99.54	98.74	-.71	28	P	1,060	564	67
5N-8W-11BB	Harm Lindemann	90.00	93.95	96.10	95.10	....	......	.....	....	......	....
5N-8W-26DD	Alex Bednar	92.00	92.22	92.72	92.52	-.30	23	E	340	752	10
6N-5W-26BC	Gayle McLaughlin	94.00	103.42	105.51	104.61	-1.19	20	E	1,020	940	94
6N-5W-27AC	Herschel Gowan	92.00	......	102.67	101.89	....	......	.....	....	......	....
6N-6W- 1CB	Raymond Anderson	80.00	86.49	87.20	88.22	-1.73	22	NG	680	1,088	76
6N-6W- 5BB	Dale Livgren	64.00	70.60	75.37	72.58	-1.98	25	NG	800	1,203	110
6N-6W- 7CD	Howard Dahlstren	72.00	78.84	81.09	80.10	-1.26	......	P	....	......	....
6N-6W- 9BD	T. R. Nelson	81.00	87.83	91.67	89.67	-1.84	......	.....	....	......	....
6N-6W-24AC	M. J. Dedrickson	90.00	95.04	96.89	96.13	-1.09	7	NG	760	1,135	92
6N-7W-22BB	Warren Wilson	83.00	......	99.46	89.54	....	......	.....	....	......	....
6N-7W-23BB	Donald Wolf	88.00	93.13	94.70	93.73	-.60	16	NG	1,030	1,278	143
6N-8W-16CB	Harold Hinrichs	90.00	94.31	96.67	98.50	-1.49	18	P	710	1,310	102
6N-8W-19CB	Don Ernst	97.00	101.13	103.97	102.62	-1.49	23	P	1,680	854	116
6N-8W-21DD	Mrs. Carrie Stahnke	93.00	96.08	98.85	97.36	....	......	.....	....	......	....
6N-8W-25BC	Dale Hinrichs	92.00	95.91	98.02	97.34	-1.43	14	P	760	595	58
7N-5W- 1CC	Warren Krause	78.00	90.18	99.97	93.46	-3.28	45	NG	640	594	65
7N-5W- 5CB	Clarence J. Carlson	52.00	64.50	69.76	66.42	-1.92	34	E	720	1,038	90
7N-5W-22BC	Gerald McLaughlin	95.50	108.28	117.07	......	....	......	.....	....	......	....
7N-5W-23CBA	Floyd Schmer	97.50	110.36	126.25	114.55	-4.19	42	NG	740	894	65

7N-5W-23CBB	.....do.................	95.00	107.94	126.87	111.88	-3.94	46	NG	500	730	42
7N-6W- 4BD	Ivan L. Johnson.........	60.00	67.97	73.52	71.06	-3.09	......	.....	....	......	....
7N-6W-16CB	Russell Hultine.........	68.00	75.76	79.33	77.54	-1.78	38	NG	1,060	907	70
7N-6W-23AA	Leo Leininger...........	54.00	60.87	63.74	62.16	-1.29	41	NG	1,010	1,160	115
7N-6W-30CC	Robert E. Kinyoun.......	77.00	......	87.73	......	....	......	.....	....	......	....
7N-7W- 3DA	Walter Yost.............	69.00	76.89	80.99	79.57	-2.68	20	NG	930	1,216	85
7N-7W- 9DC	Dale Yost...............	70.00	82.03	84.79	83.46	-1.43	24	NG	1,100	974	70
7N-7W-15CA	Arthur Anderson.........	69.00	79.05	80.74	79.05	.00	......	.....	....	......	....
7N-7W-27DA	Steven Yost.............	75.00	81.39	84.91	82.75	-1.36	43	P	700	979	95
7N-8W- 7DD	Kenneth Drew............	101.00	108.65	110.59	109.95	-1.30	9	E	1,040	1,436	85
7N-8W-11BB	Charles Roback..........	85.00	88.32	90.54	91.42	-3.10	37	D	2,060	616	113
8N-5W- 7CC	Harold R. Griess........	68.00	80.59	87.46	85.78	-5.19	28	NG	640	984	89
8N-5W-11BB	Tom Griess..............	82.00	94.65	97.62	95.28	-.63	22	NG	680	1,368	100
8N-5W-22BB	Edmond R. Griess........	74.00	86.24	88.50	87.78	-1.54	33	NG	350	996	26
8N-5W-22BC	.....do.................	68.00	......	83.28	81.93	....	16	NG	1,110	1,306	85
8N-5W-26AB	John Sheridan...........	69.00	81.97	87.52	85.59	-3.38	......	.....	....	......	....
8N-6W-12BB	Paul Helzer.............	77.00	......	90.07	86.29	....	......	.....	....	......	....
8N-6W-13BC	Wayne Moore.............	65.00	72.90	81.22	77.69	-4.79	49	NG	1,020	871	....
8N-6W-20BA	Donald Stilley..........	63.00	71.48	79.45	75.82	-4.34	......	P	....	333	25
8N-6W-22CB	Donald Nelson...........	53.00	60.23	68.99	65.26	-5.03	35	P	890	933	121
8N-7W-15AA	Raymond Keller..........	83.00	89.94	96.74	93.03	-3.09	25	E	....	526	68
8N-7W-15DB	.....do.................	86.00	92.89	99.43	......	....	......	.....	....	......	....
8N-7W-17CD	Daniel H. Schultz.......	83.00	90.18	95.30	93.23	-2.15	......	.....	....	......	....
8N-7W-23BB	University of Nebraska..	79.00	87.61	94.40	91.02	-3.41	......	.....	....	......	....
8N-7W-26BA	Everett England.........	74.00	80.97	86.02	84.59	-3.62	......	.....	....	......	....
8N-7W-28AC	John Brenneman..........	81.00	88.02	94.16	91.57	-3.55	22	E	850	1,003	85
8N-7W-36DB	Elmer Plettner, Jr......	67.50	76.62	82.18	80.03	-3.41	19	NG	1,090	1,054	100
8N-8W-10BB	Dean Mankin.............	90.00	98.58	103.69	101.43	-2.85	32	NG	1,000	......	....
8N-8W-16CC	Harry Wilson............	99.00	106.72	109.64	108.43	-1.71	20	NG	1,070	1,160	97
8N-8W-26CB2	Richard Glantz..........	105.00	......	114.41	113.47	....	18	D	1,520	1,583	196
8N-8W-31BB	Winston Olson...........	110.00	117.95	122.90	119.22	-1.27	9	P	740	967	62
8N-8W-36BA	Art Haack...............	67.00	......	76.34	75.66	....	18	E	1,020	......	110
8N-8W-36BB	.....do.................	69.00	75.32	78.54	77.89	-2.57	20	D	950	700	70

1. Total pumping time for each of the 44 wells was expressed in minutes and then was multiplied by that well's rate of discharge;

2. The resulting products were averaged, and the value obtained was converted to acre-feet;

3. Average pumpage for the 44 project wells was multiplied by the total number of wells in the county.

CHANGES IN WATER LEVELS AND GROUNDWATER STORAGE

Before water was pumped for irrigation in Clay County, the quantity of groundwater in storage and the position of the water table beneath the county remained nearly the same. Additions (recharge) to the supply resulting from precipitation that infiltrated to the water table and from subsurface inflow beneath the west boundary of Clay County were balanced, over the long term, by losses (discharge) resulting from subsurface outflow into Hamilton, Fillmore, and Nuckolls Counties and from spring discharge, evapotranspiration, and seepage into the channel of the Little Blue River in the southwestern part of the county. Only minor changes in storage and water-table position resulted from the ever-changing ratio of natural recharge to natural discharge, and imbalances never lasted for long. However, now that so much water is being pumped from irrigation wells, recharge and discharge are no longer in balance, and because discharge exceeds recharge, both the quantity of groundwater and water levels in wells are trending downward, as shown by the hydrographs in figure 8.

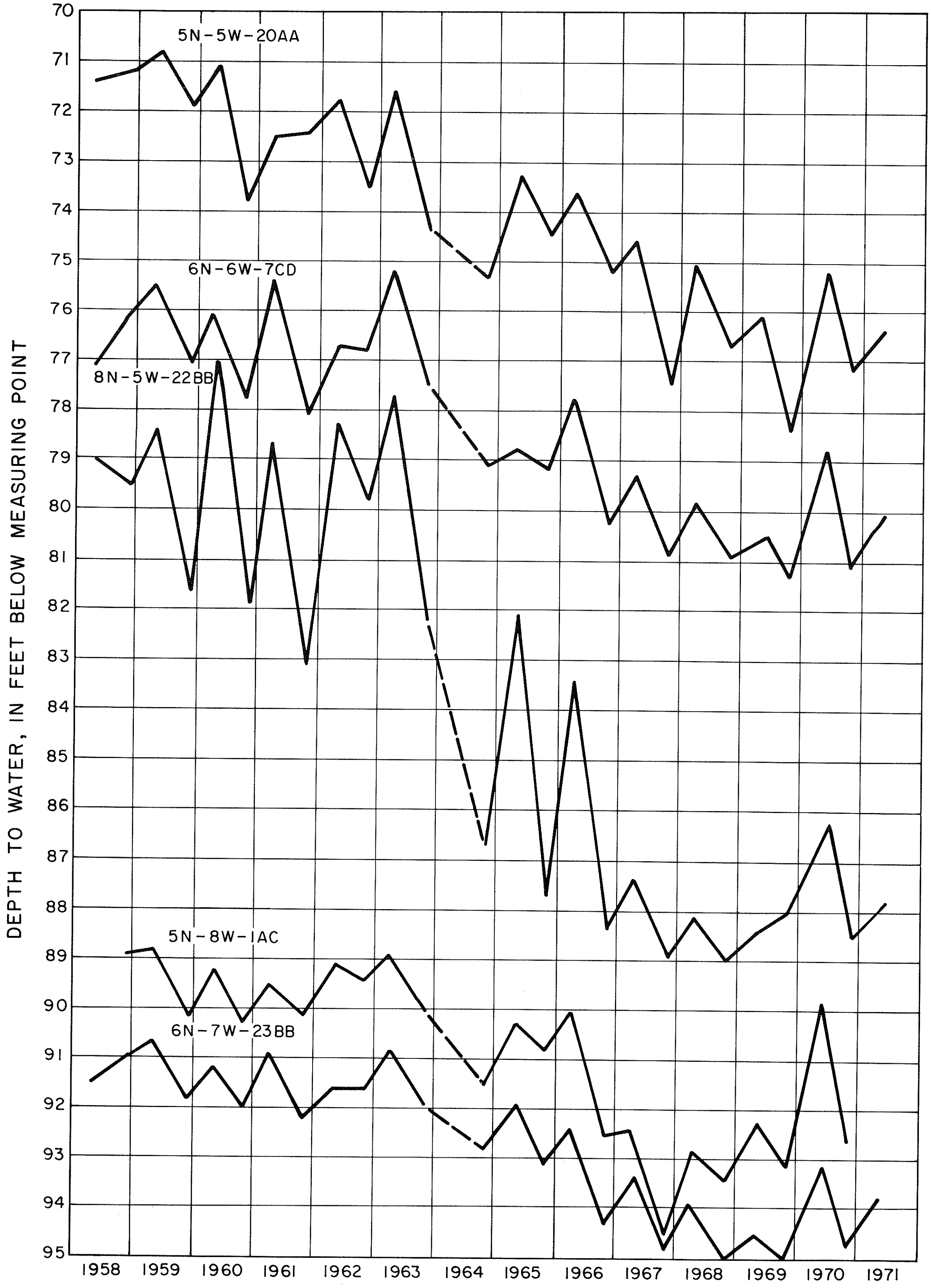


Figure 8.--Hydrographs for five wells in Clay County, 1958-71.

The water-level measurements, which were used in plotting the hydrographs, generally were made twice each year--in the spring before pumping for irrigation began and in the fall after pumping ended. As may be seen, the water-level declines between spring and fall measurements differ considerably in magnitude from year to year and the amount of water-level recovery between fall and spring measurements ranges from a very small fraction of the preceding seasonal decline to as much or more than that decline. It is because the sum of the annual declines is more than the sum of the annual recoveries that the long-term water-level trend is downward. If water-level measurements had been made more frequently during the nonpumping season and hydrographs plotted from them, the differences between the seasonal high and low water-level positions probably would be greater in most years than that shown by the hydrographs in figure 8. Even so, the long-term trend would be similar.

Of special interest to this study is the fact that the spring 1970 water-level measurements, as shown by the hydrographs for wells 6N-6W-7CD, 6N-7W-23BB, and 8N-5W-22BB, indicate higher water levels than those for spring 1968. In fact, the downward trend that characterized the years preceding 1968 is shown to have been either arrested or reversed during 1968-70. However, a long-term downward trend of water levels has been established and will undoubtedly continue. The rate of decline in the future will depend upon climatic conditions, amount of groundwater withdrawn, and irrigation and water-conservation practices.

The amount of water-level decline that has occurred in the county since irrigation began is not the same everywhere. As shown by figure 9, a decline of more than 10 feet characterizes two areas. The larger area, in the northeastern part of the county, is about 50 square miles, and the smaller, in the northwestern part of T. 7 N., R. 7 W., is about 7 square miles. The largest of the three areas where the water levels have declined less than 5 feet is in the southwestern part of the county and is about 120 square miles in extent. The smaller areas, totaling about 45 square miles, are in the southeastern and east-central parts of the county. Comparison of the predevelopment water levels with those of spring 1970 indicates a weighted-average water-level decline of 7.0 feet in the county and a reduction of storage amounting to about 519,000 acre-feet.

The distribution of net declines during the 1-year period spring 1970 to spring 1971 is shown by figure 10. In about two-thirds of the county the net decline was less than 2 feet, but in the remaining third--mostly in the northeastern and north-central parts--it ranged from 2 to 5 feet. The weighted-average water-level change for this period was a decline of 1.77 feet, and resulted in a net depletion from the groundwater reservoir of 131,000 acre-feet for the season.

Comparison of the spring 1970 and fall 1970 water levels in project wells (fig. 11) indicates the greatest water-level declines occurred in the east-central and northeastern parts of T. 7 N., R. 5 W., and in the central part of T. 8 N., R. 6 W.

Contrary to the belief that the amount of groundwater withdrawn for irrigation use is related inversely to the amount

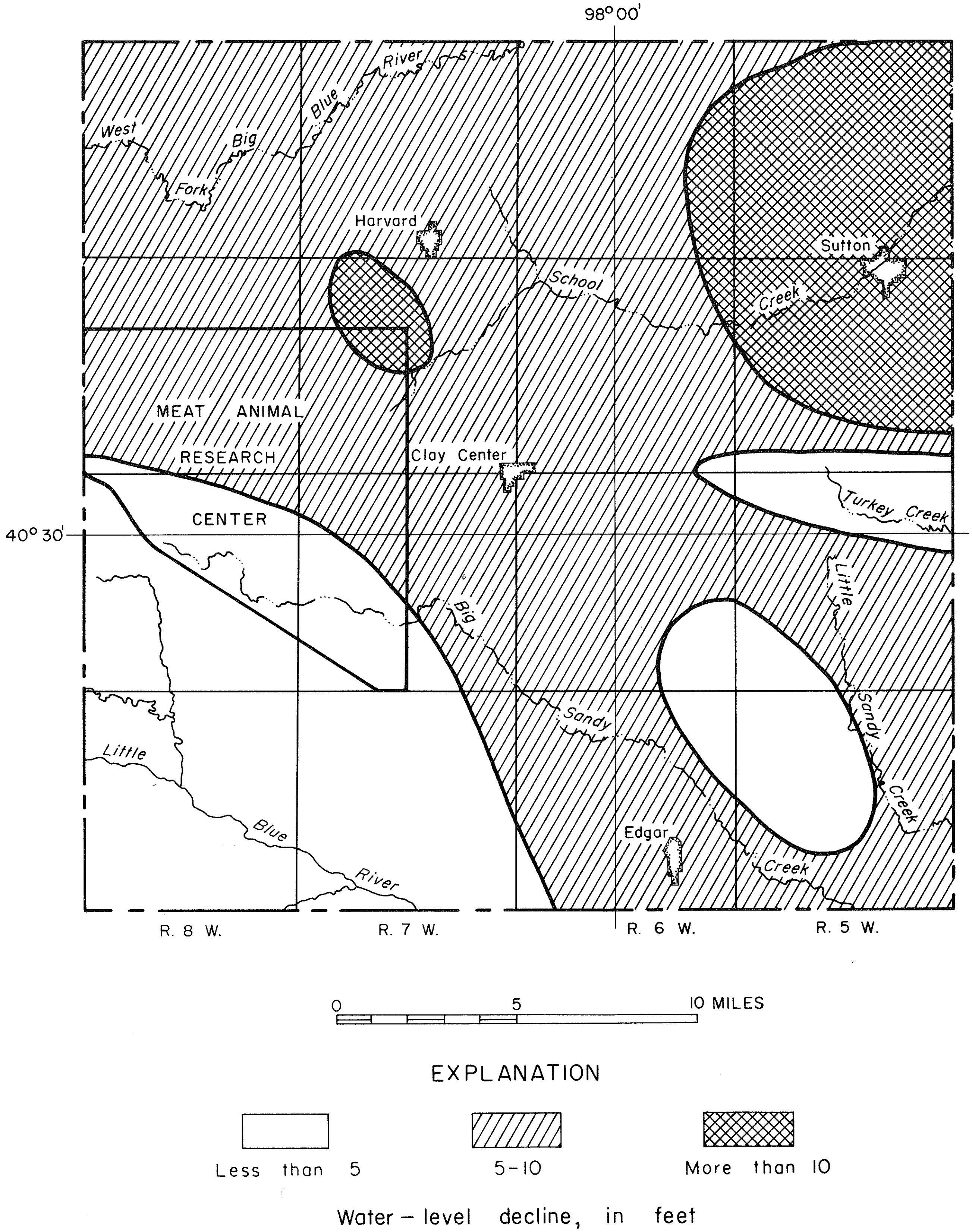


Figure 9.--Difference between estimated predevelopment water levels and spring 1970 water levels.

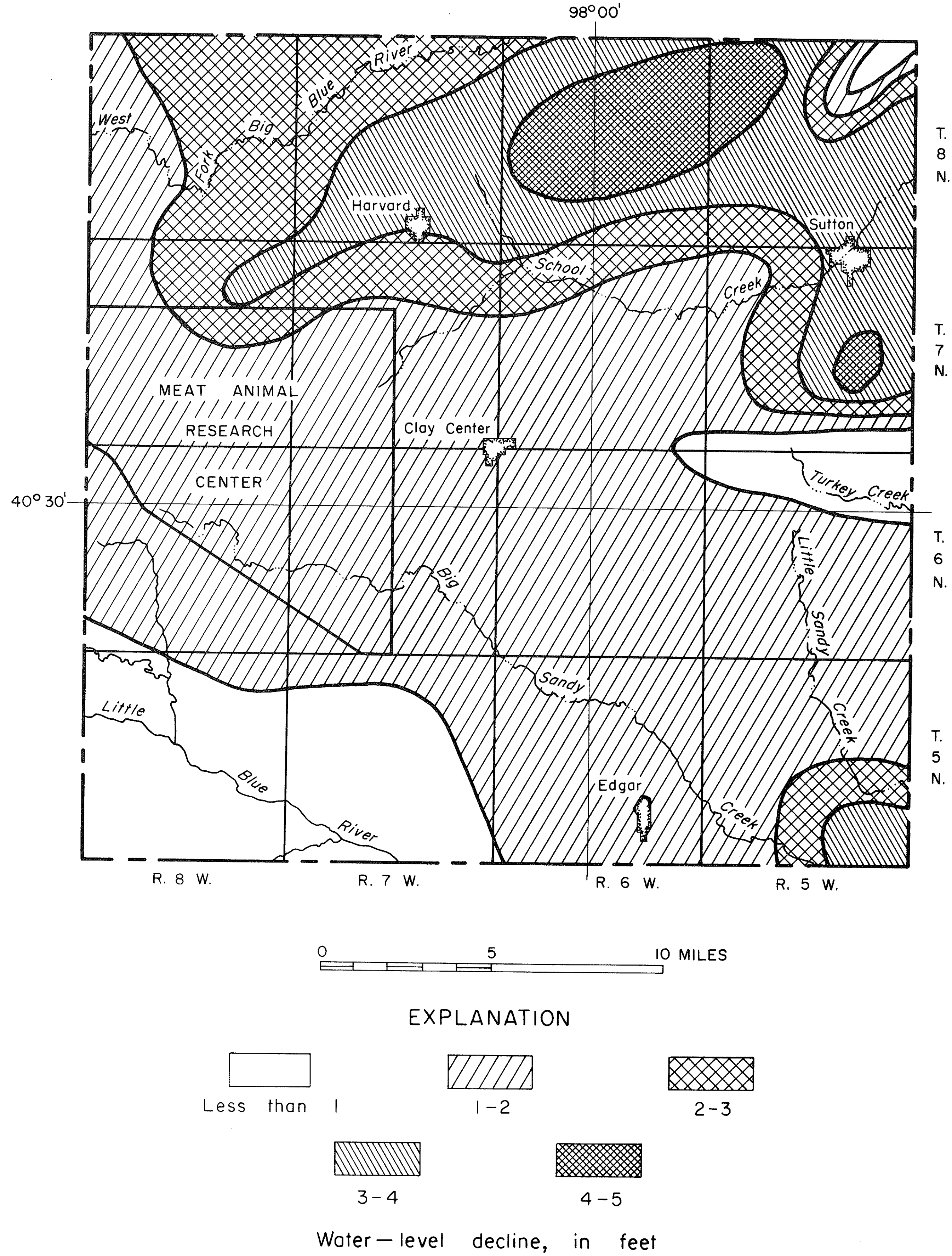


Figure 10.--Difference between spring 1970 and spring 1971 water levels.

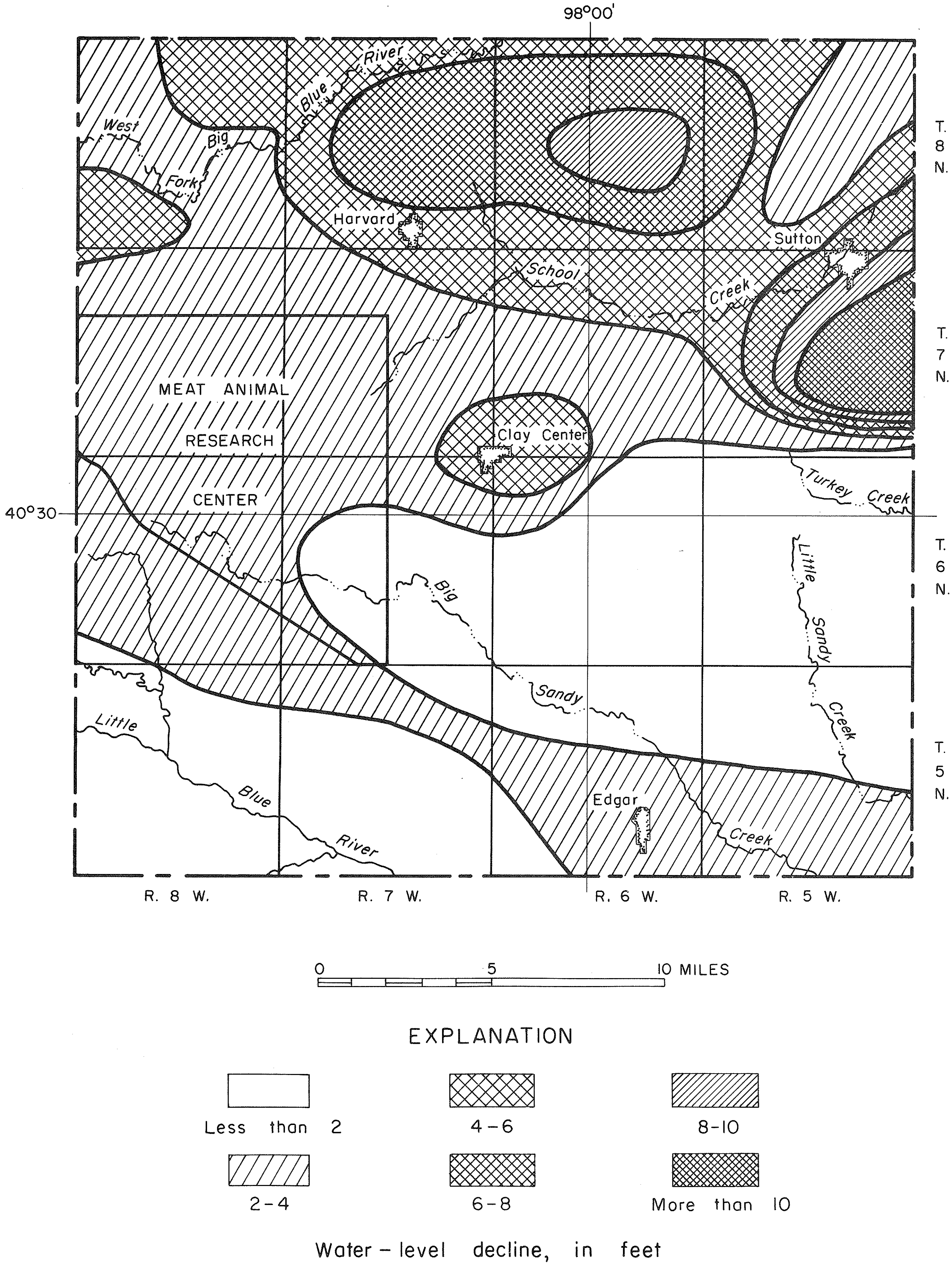


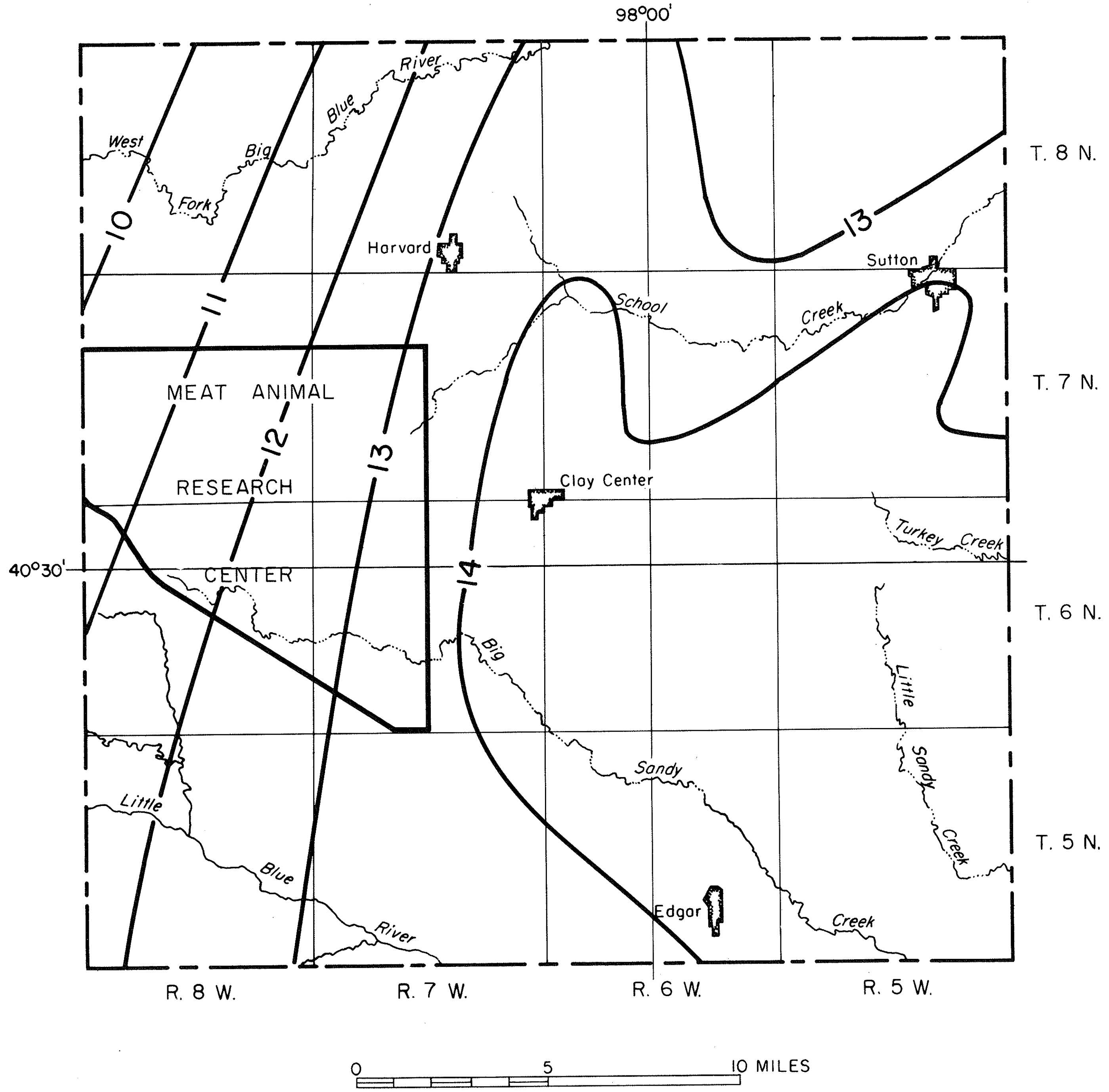
Figure 11.--Difference between spring 1970 and fall 1970 water levels.

of precipitation during the growing season, the area in which the water-level decline was greatest during the 1970 irrigation season was in the part of the county where precipitation during the growing season was more than the average for the entire county (fig. 12). Evidence indicates that the distribution of precipitation with respect to time during the growing season is a more important factor than the actual amount of precipitation. For example, three of the hydrographs in figure 8 indicate that seasonal declines (here assumed to be roughly proportional to seasonal withdrawals) in 1967 were nearly as great as or greater than those in 1966 even though precipitation during the May-August period in 1967 was almost twice that of the same period in 1966.

Several other factors may affect the amount of water withdrawn. One factor is the relative density of wells. For example, the Meat Animal Research Center, an area of about 68 square miles in Clay County, contains only 44 irrigation wells whereas several townships contain between 100 and 120 irrigation wells. Although withdrawals per township may not be proportional to number of wells, it is almost certain that the combined withdrawals of a large number of wells would far exceed the combined withdrawals of a small number of wells. Also, both the yield rate of wells and the number of hours pumped differ considerably from well to well, as shown by data in table 3.

PUMPAGE IN 1970

The amount of water pumped in 1970 was determined by



EXPLANATION

—— 12 ——

Line of equal accumulated rainfall, May–August 1970.
Interval 1 inch

Figure 12.--Precipitation in Clay County, May through August 1970.

multiplying the number of registered irrigation wells in the county by the average pumpage from project wells, as follows:

Total number of registered irrigation wells		Average pumpage from project wells (acre-feet)		Total pumpage (acre-feet)
1,241	x	168	=	208,488

It is deduced from the hydrographs in figure 8 that the amount pumped in 1970 probably was greater than the amount pumped in any of the preceding 3 years. However, pumpage in 1970 was almost as great as in 1966, when the growing-season precipitation was about 5 inches less than in 1970. If not for the net gain in storage indicated by the difference between the spring 1969 and spring 1970 water-level measurements, pumping for irrigation in 1970 probably would have caused water levels to reach all-time lows by fall 1970.

Data for the 1970 irrigation season are presented in table 4.

Table 4.--Irrigation season data, 1970

Date pumping started:	
Earliest	June 13
Latest	July 6
Average	June 23
Date pumping ended:	
Earliest	August 2
Latest	September 12
Average	August 19
Number of days between first and last day of pumping:	
Maximum	76
Minimum	39
Average	58
Number of days water actually pumped:	
Maximum	64
Minimum	14
Average	44

RUNOFF FROM IRRIGATION

Irrigation applications in excess of the soil's capacity to absorb water result in runoff from fields to nearby drains. At five locations where the flow in a stream or a roadside ditch obviously consisted wholly of irrigation runoff, a measurement of discharge was made during the period July 7 to 10 (fig. 13 and table 5). Measurement sites 1 and 2 were, respectively, on Little Sandy and Big Sandy Creeks where they flow out of the county, and at both sites the creeks had been dry on May 26 and were again dry on October 28. The other three sites were on drainage ditches that, except during periods of irrigation runoff, carry water only after rain and at times of snowmelt. Flow at site 3 drains into Big Sandy Creek and leaves the county as overland runoff; flow at sites 4 and 5 empties into a closed depression and is mostly lost to the atmosphere by evaporation. Irrigation for the season was well underway when the discharge measurements were made.

It is not known how many wells contributed to the measured losses, nor is it known how large a fraction of the total losses was represented by those that were measured. The data are significant, however, because they indicate a need for improved water-management practices.

As runoff from irrigated fields constitutes a nonbeneficial reduction of groundwater storage, it should be minimized as much as is practicable. Where runoff from irrigated fields cannot be prevented, an effort should be made to use the water for irrigation of additional land or other worthwhile purposes.

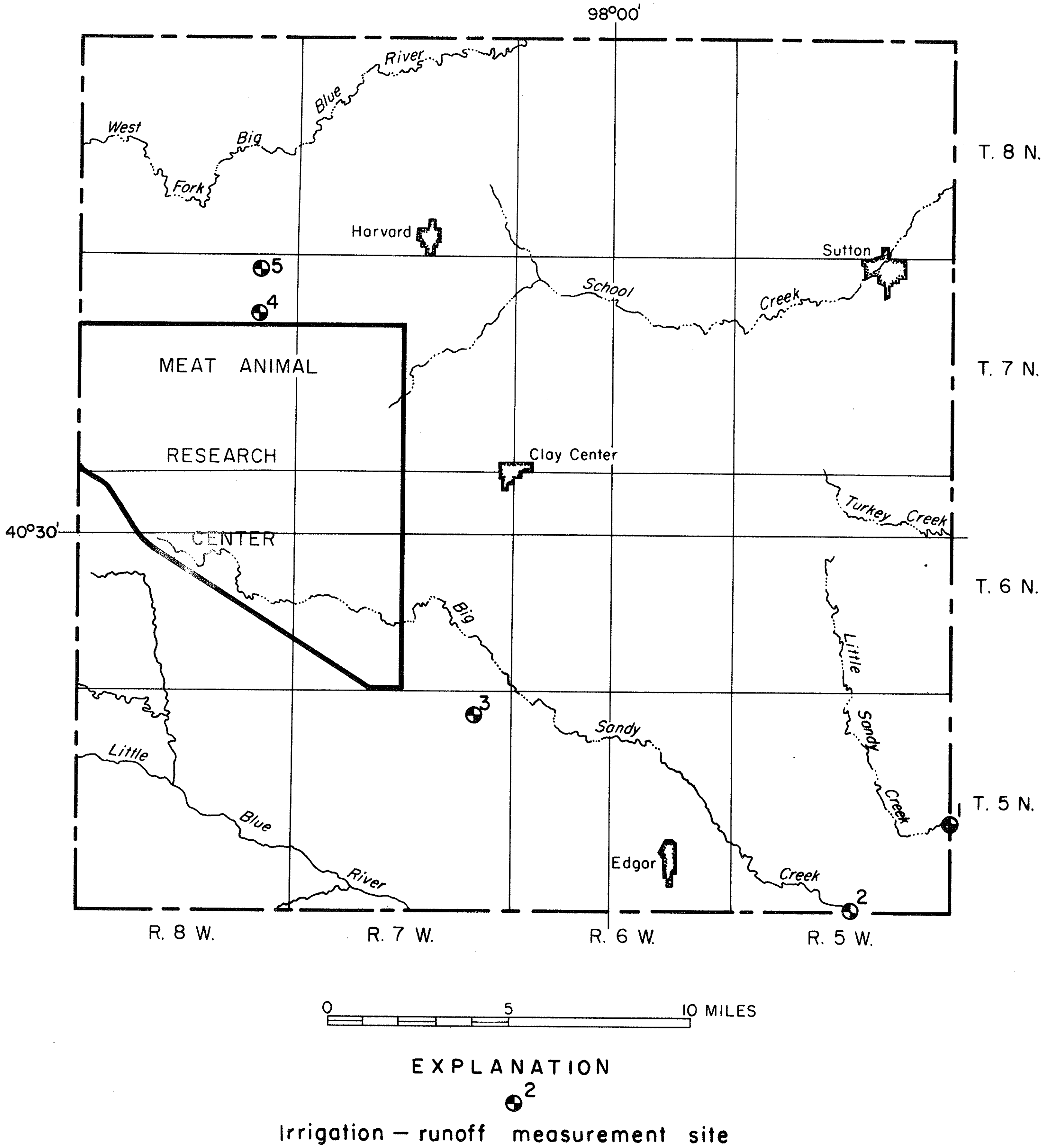


Figure 13. Sites of measured irrigation runoff in Clay County, 1970.

Table 5.--Measurements of runoff from irrigation

Site No.	Location	Date	Discharge	
			Cubic feet per second	Gallons per minute
1	Little Sandy Creek at east county line (SE¼SE¼ sec. 24, T. 5 N., R. 5 W.)	7- 7-70	8.3	3,725
2	Big Sandy Creek at south county line (SW¼SW¼ sec. 34, T. 5 N., R. 5 W.)	7- 7-70	2.2	987
3	Culvert under county road near Fairfield (NE¼SE¼ sec. 2, T. 5 N., R. 7 W.)	7- 9-70	1.1	493
4	Culvert under county road east of Inland (NE¼SE¼ sec. 11, T. 7 N., R. 8 W.)	7-10-70	.69	310
5	County road ditch east of Inland (SE¼NE¼ sec. 2, T. 7 N., R. 8 W.)	7-10-70	.94	422

SUMMARY AND RECOMMENDATIONS

Comparison of depth-to-water measurements made in 60 wells in the spring of 1970 with estimated values of depth to water at the same sites prior to development of pump irrigation in Clay County indicates that groundwater withdrawals before 1970 had reduced the supply in storage by about 519,000 acre-feet. A similar comparison of spring 1971 water levels with spring 1970 water levels indicates that groundwater withdrawals during the 1970 irrigation season resulted in a net additional reduction in storage amounting to 131,000 acre-feet, bringing the total depletion of the stored supply to 650,000 acre-feet. From hydrographs of water-level fluctuations in five wells having long records it is concluded that pumpage during the 1970 irrigation season was greater than in either of the 2 preceding years and that the net change in storage due to pumping in 1970 was the greatest since 1966. In view of the prospect for additional depletion of the supply, methods for extending the life of the resource should be explored and those that are feasible should be implemented.

It is recommended that measurement of water levels and hours of operation be continued in project wells and that the computer program be used for computation of annual changes in groundwater storage and of annual volumes of water pumped. To satisfy the need for better information on factors affecting pumpage, it also is recommended that a network of rain gages be installed and that measurements of soil moisture be made regularly at selected sites. An inventory of reuse pits and of the acreage irrigated with water from them would provide a sounder basis for computation of depth of water applied to crops.

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