Steele, Eugene K. Jr.

USE OF GROUND WATER FOR IRRIGATION IN SEWARD COUNTY, NEBRASKA IN 1971. 1973.


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USE OF GROUND WATER FOR IRRIGATION IN SEWARD COUNTY, NEBRASKA IN 1971

by

Eugene K. Steele, Jr.

Open-file Report 7308

Prepared by the
United States Geological Survey
in cooperation with the
Seward County Ground Water Conservation District and
Conservation and Survey Division, University of Nebraska

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By

Eugene K. Steele, Jr.

Abstract

Use of ground water for irrigation in Seward County west of the Big Blue River increased tremendously from 1945 to 1971. During that period, the number of irrigation wells increased from 5 to 614. Ground-water withdrawals prior to 1971 are estimated to have reduced ground-water storage by about 270,000 acre-feet, and withdrawals during 1971 continued to reduce storage. The values for changes in storage were computed from weighted-average net differences in ground-water levels.

In 1971, average pumpage from the 32 wells for which well yield and hours of pumping were recorded indicates that pumpage from all wells totaled about 83,000 acre-feet.

Introduction

Seward County is an almost square area of 572 square miles in southeastern Nebraska (fig. 1). A large acreage west of the Big Blue River is irrigated with water pumped from wells. The decline of the water table has caused concern about the long-term adequacy of the ground-water supply in that part of the county. In 1970, a majority of the irrigators voted to organize the Seward County Ground Water Conservation District, as authorized by the 1959 Nebraska State Ground Water Conservation Act. In general, the District was organized 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 ground-water 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 ground-water and surface-water resources for recharge and irrigation.

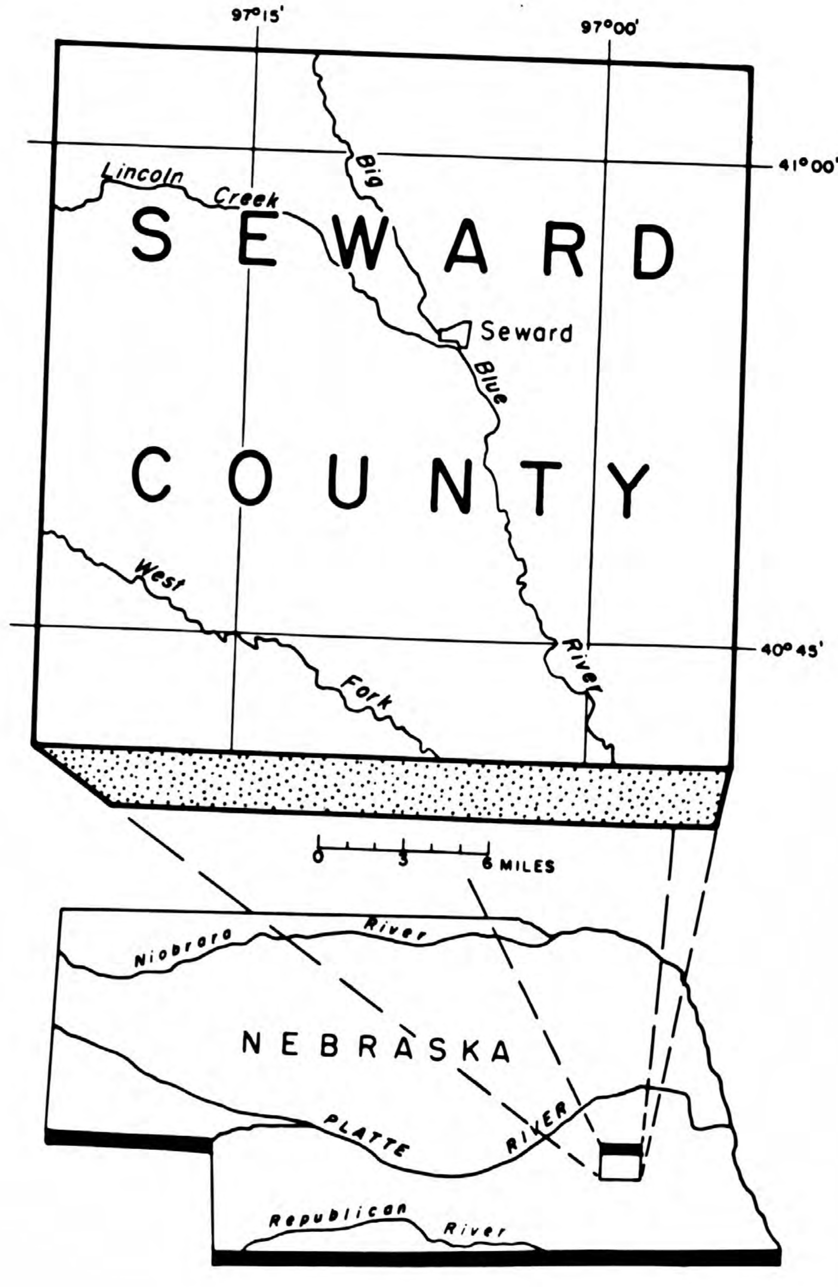


Figure 1.—Location of Seward County

5. Determine costs of water for various crops and pumping conditions.

6. Begin a program of water-level measurements 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 ground-water resources.

8. Provide a pumping-plant testing program.

9. Institute measures, if and when necessary, to correct wasteful practices relating to ground-water use.

10. Perform, as the need arises, additional functions related to ground-water conservation.

The year following its organization, the Seward County Ground Water Conservation District arranged with the U.S. Geological Survey to cooperatively finance an evaluation of the ground-water resources of the county, to determine the effect of ground-water pumpage on the available supply, and to obtain data needed by the District to monitor and manage its water resources. This report, which presents the results of the study through the spring of 1972, is a step towards obtaining facts needed for a detailed appraisal of the adequacy and longevity of the ground-water supply.

Many persons aided in the study by contributing time and information. Dennis Bejot, Seward 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 Seward County Ground Water Conservation District publicized the study locally and urged pump operators to keep records of hours pumped and to permit water-level and water-yield measurements to be made. District Chairman Ray Gard provided information and data obtained by the District prior to the study and rendered valuable assistance while the study was in progress.

For identification purposes, wells for which data are presented in this report have been given numbers that represent their location within the U.S. Bureau of Land Management's system of land subdivision. Each number consists of an alternating sequence of numerals and letters. 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, the second the quarter-quarter section, or 40-acre tract. These letters are assigned in a counterclockwise direction, beginning with A in the northeast quarter of each tract. The well-numbering system is illustrated in figure 2.

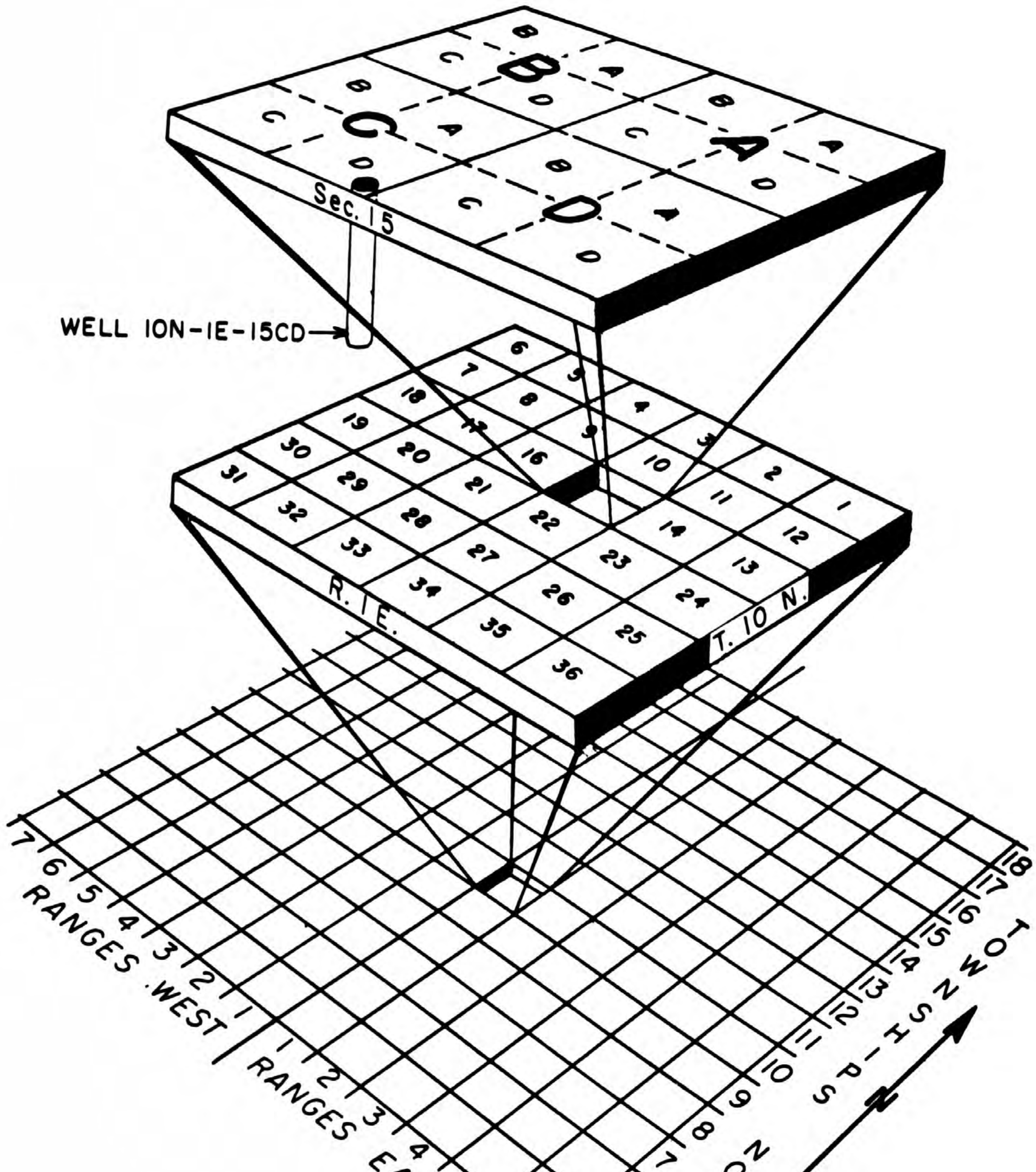


Figure 2.—Well-numbering system.

Drainage, topography, and soils

The Big Blue River flows south-southeasterly across Seward County from a point 9 miles east of the northwest corner to a point 4 miles west of the southeast corner. Its valley is as much as 1.5 miles wide. All of the area west of the river (60 percent of the county) and about half of the area east of it are drained by the Big Blue. The rest of the eastern part of the county is drained by Salt Creek, a tributary of the Platte River.

The uplands west of the Big Blue are part of an extensive plain that has a southeastward slope of about 5 feet per mile in Seward County. Lincoln Creek and West Fork, tributaries of the Big Blue, have incised their valleys to depths of as much as 190 feet below the plain. In their lower reaches, these valleys are about 1 mile wide.

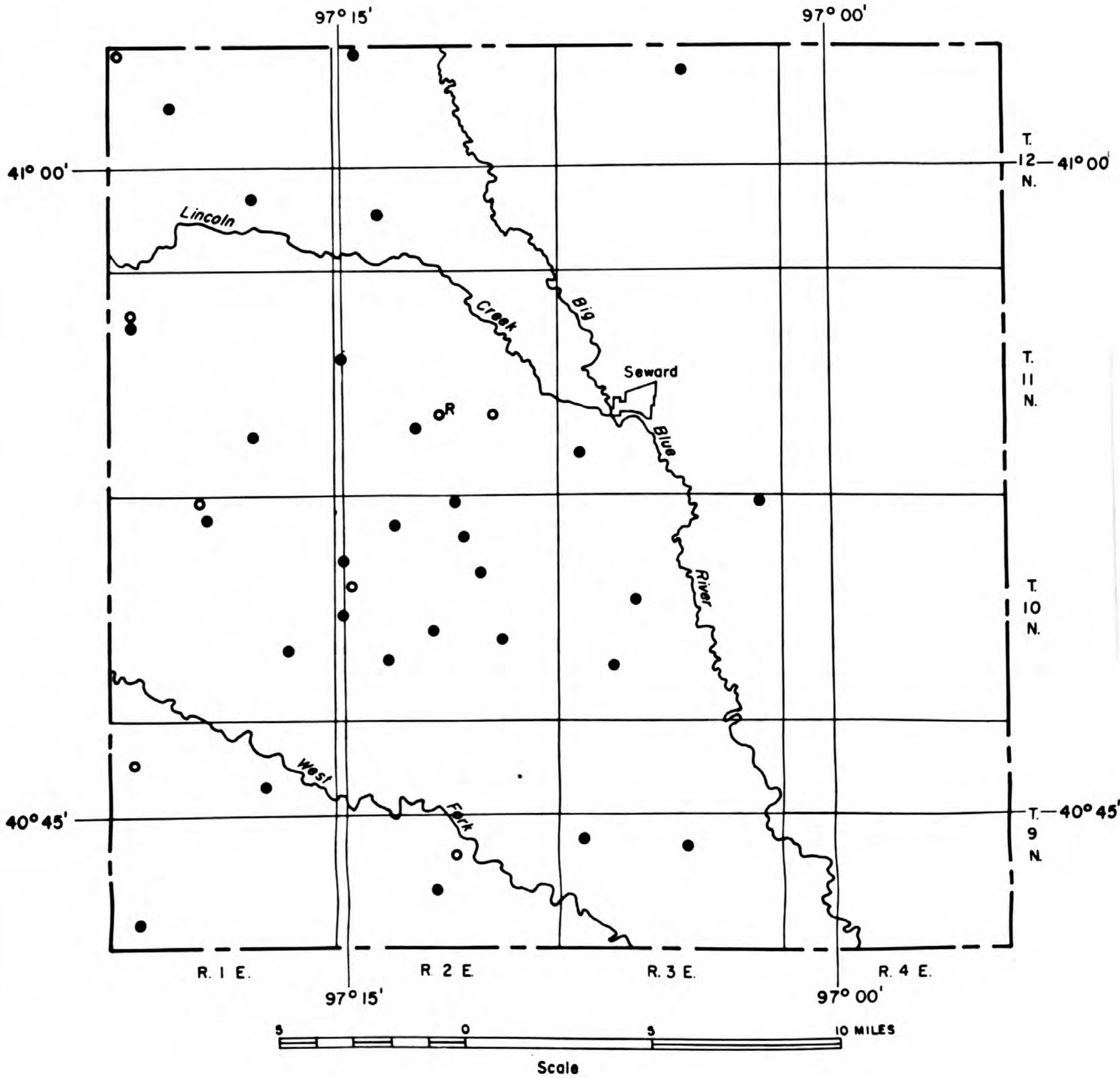
The topography of the area east of the Big Blue is rolling. The crests of the hills along the divide between the Big Blue River and Salt Creek drainage basins are about 50 feet higher than the general level of the uplands just west of the Big Blue.

Upland soils west of the Big Blue River formed in loess (wind-deposited silt) and the valley soils formed in colluvium and alluvium derived mainly from the loess. These soils are mostly silt loam and are ideally suited for agriculture. Unconsolidated sand and gravel of Quaternary age underlies the entire area west of the Big Blue. These deposits are capable of yielding ample water for irrigation in much of that area.

Most soils east of the Big Blue River also formed in loess or in colluvium and alluvium derived mainly from loess. However, the loess in this area is almost everywhere underlain by till and other nearly impervious materials that will not yield sufficient water for irrigation. Deposits of sand and gravel capable of yielding enough water for irrigation are present in very few places in the area.

Ground-water data collected prior to this study

As part of a statewide program of ground-water investigations being made cooperatively by the Conservation and Survey Division of the University of Nebraska and the U.S. Geological Survey, water levels were measured in seven wells in Seward County for about 20 years (fig. 3). In six of the wells, measurements of depth to water were made at fairly regular intervals, generally in the spring and fall, by the wetted-tape method. The remaining well is equipped with a water-level recorder that has provided a nearly continuous record of water-level fluctuations since 1958. Figure 4, which is a hydrograph of that record, shows that seasonal withdrawals in the vicinity



EXPLANATION

●
Water-level observation well measured by Seward County Irrigation Association

o oR
Water-level observation well measured by Conservation and Survey Division of University of Nebraska or U.S. Geological Survey as part of State-Federal cooperative program of water-resources investigations

R, well equipped with automatic recording gage

Figure 3.—Locations of water-level observation wells having long-term records.

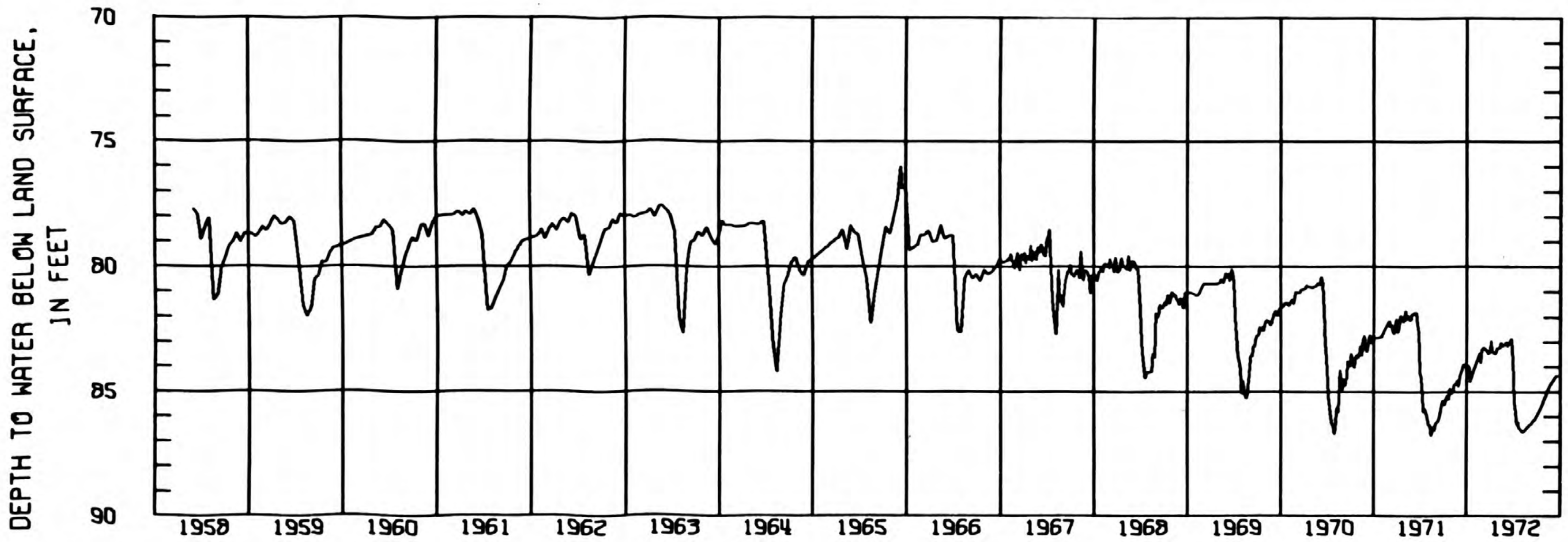


Figure 4.—Water-level fluctuations in well 11N-2E-21DD, 1958-72.

of the well have caused marked fluctuations of the water level almost every year. In 1960 and 1962, when fluctuations were of smaller amplitude than in other years, precipitation was better distributed with respect to time than usual and less water was pumped. Beginning in 1966, a downward trend in water levels has been observed with a net decline of about 5 feet at the well site. Water levels have also trended downward since 1966 in the six wells measured seasonally.

In 1957 the Agricultural Extension Agent in Seward County began a program of water-level measurements in selected wells, 27 of which are west of the Big Blue River (fig. 3). The program was taken over and continued first by the Seward County Irrigation Association and then by the Seward County Ground Water Conservation District. Hydrographs for five of these wells are shown in figure 5. Two of these indicate a declining water-level trend beginning in 1962, and the other three indicate a declining trend beginning in 1964.

Also as part of the State-Federal cooperative program, test holes have been drilled at 24 locations in Seward County (Johnson and Keech, 1959, pls. 1 and 2). Of these, 17 are west of the Big Blue River. The drilling provided information on differences in thickness and composition of the water-bearing materials and provided a basis for estimating the quantity of ground water in storage.

In 1968, Jess (1970) made a study of ground-water use for irrigation in Seward County. Average pumpage from 31 wells was determined to be 76.8 acre-feet that year, and total pumpage from the 540 irrigation wells then in existence was estimated at 42,000 acre-feet. Considerably less water was pumped in 1968 than in 1971 because abundant rainfall in late July 1968 brought an early end to the irrigation season for most farmers.

As State law requires that all irrigation wells be registered with the Nebraska Department of Water Resources, wells in Seward County were located as registered without a field inventory. As shown by figure 6, all but 12 of the 626 irrigation wells that had been registered before the end of 1971 are in the part of the county west of the Big Blue River.

Ground-water data collected during this study

The principal goal of the study during 1971 was to establish a program for collecting information needed to evaluate the effect of irrigation pumpage on ground-water levels and ground-water storage. The study was designed to collect data for selected representative irrigation wells scattered throughout the part of Seward County west of the Big Blue River and to use those data in computing weighted-average water-level changes, net differences in ground-water storage for selected periods of time, and both average

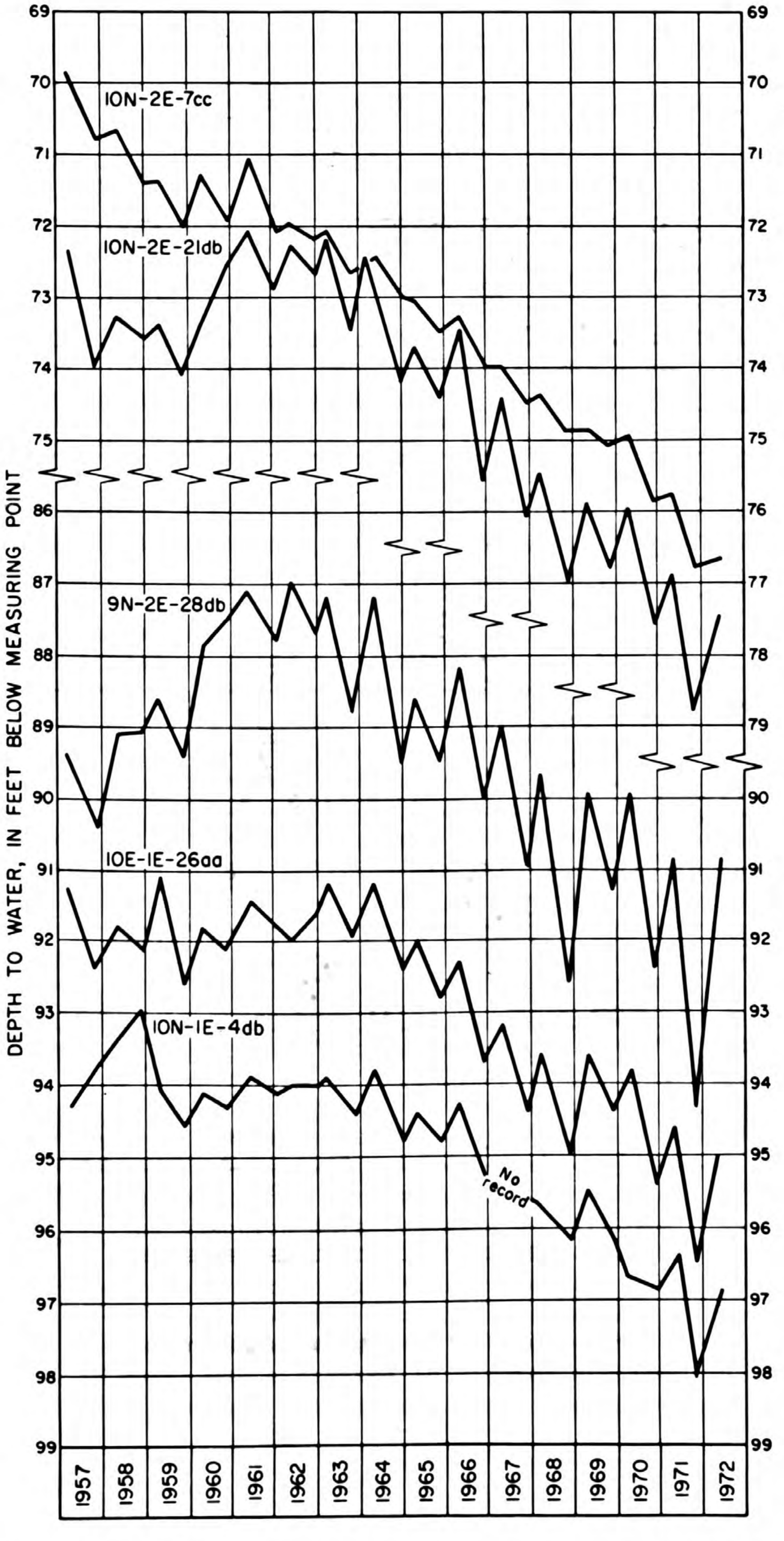


Figure 5.—Seasonal fluctuations of water levels in five wells, 1957-72.

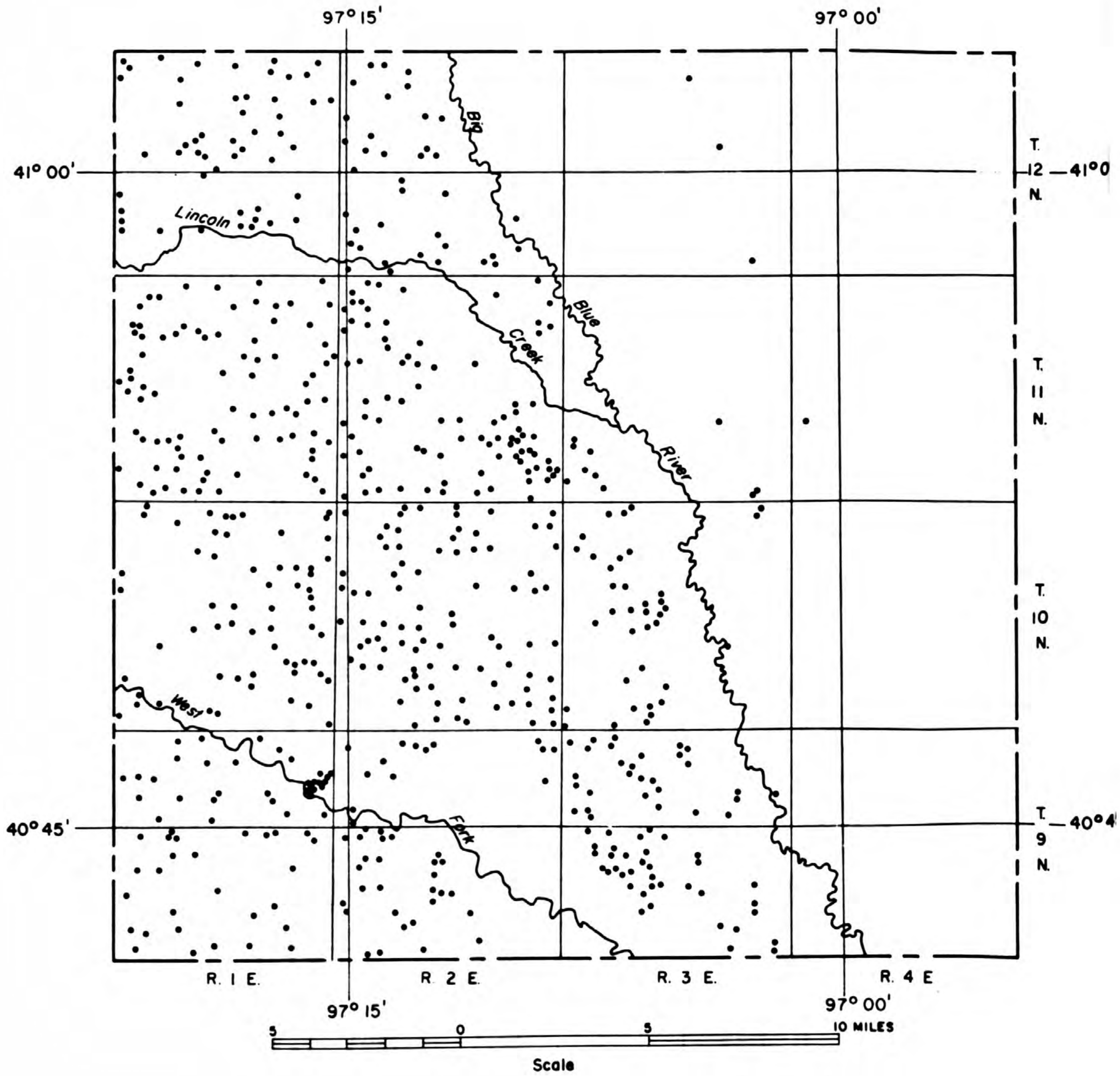


Figure 6.—Locations of registered irrigation wells.

and total pumpage values for the 1971 irrigation season. Similar studies were initiated in 1969 in Hamilton and York Counties (Steele 1971a, 1971b) and in 1970 in Clay County (Steele, 1972).

Important criteria used in choosing representative wells were location of the well and willingness of the operator to record the needed data. Forty-nine wells were selected and the operators of these wells were supplied calendars suitable for recording the number of hours the well was pumped. Figure 7 shows locations of these wells, which hereafter are referred to as project wells. Of the 49 calendars given out, 35 were completed and returned by the operators.

Average water levels during 1948-52 were used in estimating a predevelopment water level for each project well. Water levels during that period had recovered from the drought of the 1930's and had not yet been lowered significantly by pumping for irrigation. Comparison of the predevelopment water levels with water levels measured in all project wells in the spring and fall of 1971 and in the spring of 1972 provided the basic information needed for computation of water-level and water-storage changes that resulted from ground-water withdrawals prior to the period of study.

Because the wells in which water-level measurements were made are distributed irregularly in the county, the measured water-level change in each well of the network was weighted in accordance with the size of the area represented by that well. Such an area for any well in a network is a polygon enclosing all points closer to that well than to any other. Both the shape and size of the polygons for project wells in Seward County were determined by means of a U.S. Geological Survey computer program, which then used the size values in computing the weighted-average net water-level changes from the water-level data collected during the study.

The rate of discharge from 44 of the project wells was measured by either a current meter or a pitot tube. Water-level drawdown under pumping conditions in 40 of these wells was also measured. Other information obtained consisted of type of power (all project wells), total hours of operation (35 wells), and acreage irrigated (31 wells). The relation of electricity and natural-gas consumption to hours of operation for 12 project wells was used to determine hours of operation for two project wells for which only fuel-consumption data could be obtained.

Values for total hours of operation and rate of discharge were obtained for 32 of the 49 project wells. To obtain a value for total pumpage in the study area, these values were used as follows: (1) Total pumping time for each of the 32 wells was expressed in minutes and then 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 32 project wells was multiplied by the total number of wells in the study area.

The data collected during the study from the 49 project wells and the 10 selected other wells are given in table 1. Also included in the table

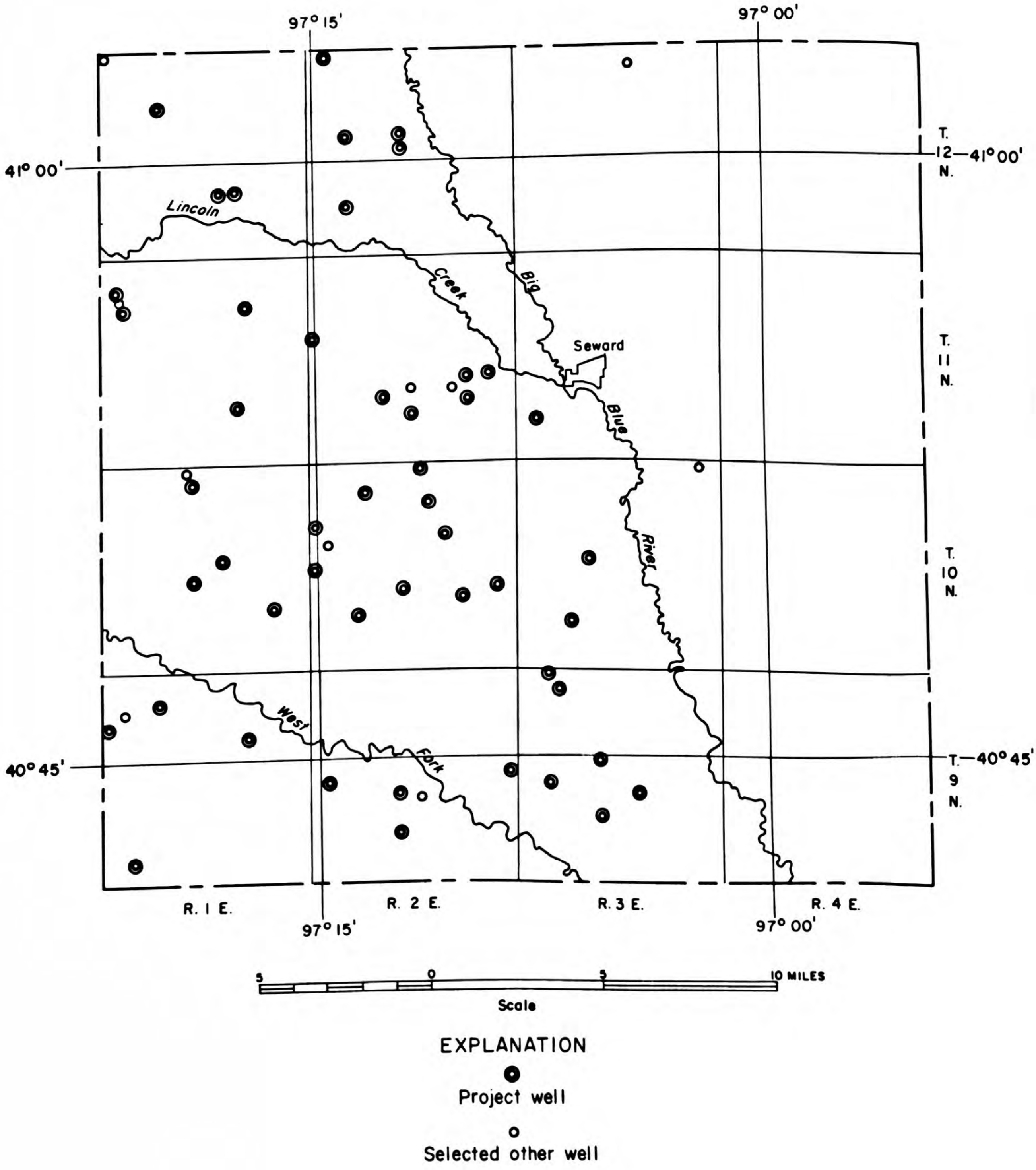


Figure 7.—Locations of project wells and other selected wells.

Table 1.--Records of project wells and other selected wells in Seward County

[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, in feet below measuring point					Net water-level change, in feet (+, rise; -, decline)				Type of power	Rate of dis-charge, in gallons per minute	Water-level draw-down, in feet	Hours pumped in 1971	Acres irri-gated in 1971
		Prede-velop-ment	Fall 1970	Spring 1971	Fall 1971	Spring 1972	Prede-velop-ment to spring 1971	Spring 1971 to spring 1972	Spring 1971 to fall 1971	Fall 1970 to fall 1971					
9N-1E- 5DC.....	Ray Gard................	14.00	.....	16.00	18.58	16.53	-2.00	-0.53	-2.58	.....	P....	....	......	598	90
9N-1E- 7AB.....	Arlin Wellman...........	40.00	43.05	42.24	43.22	42.80	-2.24	-.56	-.98	-0.17	.....	....	......	......	.....
9N-1E- 7BC.....	.....do.................	44.00	.....	48.34	49.24	48.86	-4.34	-.52	-.90	.....	E....	850	24	919	100
9N-1E-11CC.....	Kenneth Weber...........	23.00	26.47	25.13	27.95	25.42	-2.13	-.29	-2.82	-1.48	P....	750	......	......	.....
9N-1E-31AD.....	David Jurgensen.........	80.00	93.12	92.91	94.24	93.85	-12.91	-.94	-1.33	-1.12	E....	670	22	1,175	90
9N-2E-13DD.....	Lyle Beckler............	......	.....	......	......	......	......	......	......	.....	D....	980	......	......	.....
9N-2E-19AB.....	Walter Miller...........	4.00	.....	7.98	12.03	9.08	-3.98	-1.10	-4.05	.....	P....	380	13	744	.....
9N-2E-21AC.....	.....do.................	13.00	.....	17.34	23.29	18.49	-4.34	-1.15	-5.95	.....	P....	....	......	398	.....
9N-2E-22CB.....	H. E. Harvey............	10.00	17.90	14.95	18.94	15.53	-4.95	-.58	-3.99	-1.04	.....	....	......	......	.....
9N-2E-28DB.....	Arnold Burkey...........	80.00	92.46	90.87	94.33	90.90	-10.87	-.03	-3.46	-1.87	P....	670	36	698	75
9N-3E- 5CB.....	Burdette Burkey.........	82.00	.....	87.28	89.84	88.29	-5.28	-1.01	-2.56	.....	P....	870	......	865	75
9N-3E- 6AA.....	.....do.................	69.00	.....	73.29	75.68	74.14	-4.29	-.85	-2.39	.....	P....	....	......	865	75
9N-3E-16CA.....	Ezra Ehresman...........	71.00	.....	73.62	75.92	74.10	-2.62	-.48	-2.30	.....	P....	1,040	30	853	100
9N-3E-19AA.....	Walter Ackerman.........	68.00	75.51	74.46	77.68	75.47	-6.46	-1.01	-3.22	-2.17	P....	710	24	......	.....
9N-3E-22AC.....	Lavern Kremer...........	76.00	81.05	80.16	83.15	80.26	-4.16	-.10	-2.99	-2.10	P....	460	31	......	.....
9N-3E-28BA.....	Delmar Roth.............	75.00	.....	77.94	81.83	78.49	-2.94	-.55	-3.89	.....	P....	460	20	......	.....
10N-1E- 4BA.....	Harlan Liggett..........	76.00	90.10	90.46	91.96	91.03	-14.46	-.57	-1.50	-1.86	.....	....	......	......	.....
10N-1E- 4DB.....	Charles Geiger..........	81.00	96.88	96.43	98.13	96.78	-15.43	-.35	-1.70	-1.25	D....	990	23	1,226	127
10N-1E-15CD.....	Richard Heser...........	85.00	.....	94.93	97.33	95.83	-9.93	-.90	-2.40	.....	D....	910	20	......	.....
10N-1E-21AC.....	.....do.................	90.00	.....	96.74	98.76	97.60	-6.74	-.86	-2.02	.....	E....	670	18	655	.....
10N-1E-26AA.....	Richard Pariset.........	85.00	95.36	94.60	96.49	94.97	-9.60	-.37	-1.89	-1.13	P....	1,030	29	1,131	105
10N-2E- 3BB.....	Walter Meinberg.........	52.00	65.89	65.66	68.98	66.73	-13.66	-1.07	-3.32	-3.09	P....	1,020	29	925	102
10N-2E- 5DC.....	Kenneth Haas............	66.00	79.55	78.50	80.44	79.23	-12.50	-.73	-1.94	-.89	D....	900	26	780	63
10N-2E- 7CC.....	Dave Thonen.............	64.00	75.86	75.80	76.79	76.70	-11.80	-.90	-.99	-.93	Tf...	240	20	1,050	60
10N-2E-10BA.....	Walter Hentzen..........	63.00	75.33	74.38	76.88	75.27	-11.38	-.89	-2.50	-1.55	E....	870	16	908	.....
10N-2E-15AA.....	Lorain Hackbart.........	50.00	63.37	62.99	64.27	63.82	-12.99	-.83	-1.28	-.90	P....	1,120	37	......	.....
10N-2E-18BD.....	Katie Bell Olston.......	70.00	81.87	81.90	82.85	82.80	-11.90	-.90	-.95	-.98	.....	....	......	......	.....
10N-2E-19BB.....	Lloyd Schulz............	69.00	79.73	79.32	80.87	79.91	-10.32	-.59	-1.55	-1.14	E....	780	......	1,728	.....
10N-2E-21DB.....	Willard Schroeder.......	69.00	77.65	76.91	78.76	77.52	-7.91	-.61	-1.85	-1.11	E....	740	31	1,196	79
10N-2E-23CD.....	Orlin Stauffer..........	69.00	74.11	73.50	74.80	74.40	-4.50	-.90	-1.30	-.69	E....	830	18	999	106
10N-2E-24CA.....	George Eberspacher......	62.00	.....	67.20	68.92	68.37	-5.20	-1.17	-1.72	.....	E....	1,190	33	641	.....
10N-2E-29BD.....	Dean Loofe..............	73.00	81.29	80.73	82.58	80.62	-7.73	+.11	-1.85	-1.29	E....	940	61	590	70
*10N-3E- 1BA.....	Lloyd Baumbach..........	......	58.51	56.95	59.72	58.49	......	-1.54	-2.77	-1.21	.....	.....	......	......	.....
10N-3E-16CC.....	John Brinkmeyer.........	55.00	58.95	58.10	59.16	58.53	-3.10	-.43	-1.06	-.21	Tf...	.....	8	1,350	50
10N-3E-29DB.....	Bernard Ahlshwede.......	60.00	65.37	64.79	65.66	65.70	-4.79	-.91	-.87	-.29	P....	510	31	1,123	57
11N-1E- 6CD.....	Delmar Borchers.........	90.00	.....	91.84	95.78	93.42	-1.84	-1.58	-3.94	.....	Ng...	1,230	37	708	106
11N-1E- 7AB.....	John Peters.............	94.00	98.90	96.20	99.98	97.22	-2.20	-1.02	-3.78	-1.08	.....	....	......	......	.....
11N-1E- 7AC.....	Darrell Gierhan.........	90.00	93.15	92.00	95.03	93.15	-2.00	-1.15	-3.03	-1.88	Ng...	710	43	1,439	100
11N-1E-11BC.....	Delmar Borchers.........	92.00	.....	96.05	97.62	96.68	-4.05	-.63	-1.57	.....	Ng...	1,120	38	924	90
11N-1E-27AD.....	Bill Lehr...............	86.00	96.00	94.63	95.99	95.52	-8.63	-.89	-1.36	+.01	P....	650	62	......	.....
11N-2E-18BC.....	Martin Hartman..........	76.00	84.67	83.66	86.54	84.46	-7.66	-.80	-2.88	-1.87	Ng...	860	22	1,134	95
11N-2E-21DD.....	U.S. Geological Survey..	74.00	83.75	82.15	84.98	83.19	-8.15	-1.04	-2.83	-1.23	.....	....	......	......	.....
11N-2E-23CC.....	August Rolfsmeier.......	78.00	86.64	85.56	88.33	86.74	-7.56	-1.18	-2.77	-1.69	.....	....	......	......	.....
11N-2E-23DB.....	Dale Rocker.............	32.00	.....	40.04	42.74	41.37	-8.04	-1.33	-2.70	.....	P....	410	32	1,614	88
11N-2E-24BC.....	Max Propst..............	26.00	.....	28.89	31.63	30.26	-2.89	-1.37	-2.74	.....	Tf...	260	30	1,635	80
11N-2E-26AB.....	.....do.................	76.00	.....	.....	88.22	86.39	......	......	......	.....	P....	....	......	1,127	75
11N-2E-28BB.....	.....do.................	73.00	.....	83.02	86.27	84.30	-10.02	-1.28	-3.25	.....	P....	720	12	565	67
11N-2E-28DA.....	Lee Cain................	67.00	79.75	78.53	82.54	79.82	-11.53	-1.29	-4.01	-2.79	P....	980	25	......	.....
11N-3E-30DC.....	Walter Meinberg.........	15.00	22.60	21.43	23.95	21.97	-6.43	-.54	-2.52	-1.35	E....	550	32	880	80
12N-1E- 6BB.....	Carl Richert............	88.00	.....	101.04	104.68	102.06	-13.04	-1.02	-3.64	.....	.....	....	......	......	.....
12N-1E- 8DB.....	Walter Richert..........	75.00	82.56	81.30	84.74	81.73	-6.30	-.43	-3.44	-2.18	D....	800	30	1,438	140
12N-1E-27AA.....	Dale Sampson............	10.00	13.24	12.62	14.22	12.50	-2.62	+.12	-1.60	-.98	Tf...	240	26	1,067	35
12N-1E-27BA.....	Cleon Nagel.............	12.00	.....	......	14.51	12.92	......	......	......	.....	P....	970	44	......	.....
12N-2E- 6AB.....	Florian Geiger..........	80.00	93.55	91.71	96.46	93.02	-11.71	-1.31	-4.75	-2.91	P....	770	41	953	90
12N-2E-16AC.....	Ed Duer.................	75.00	.....	83.39	85.25	84.08	-8.39	-.69	-1.86	.....	E....	480	19	1,252	90
12N-2E-16DC.....	.....do.................	72.00	.....	80.47	82.18	81.18	-8.47	-.71	-1.71	.....	E....	350	25	1,287	75
12N-2E-17CB.....	Victor Baack............	71.00	.....	80.25	82.73	81.87	-9.25	-1.62	-2.48	.....	P....	600	85	......	.....
12N-2E-29CB.....	Ronald Suhr.............	66.00	72.21	71.34	72.54	71.82	-5.34	-.48	-1.20	-.33	P....	530	31	......	.....
*12N-3E- 3CA.....	Raphael Hotovy..........	4.00	.....	7.67	9.99	8.57	-3.67	-.90	-2.32	.....	.....	....	......	......	.....

*Well is east of Blue River; data not used in computations of average water-level declines and corresponding changes in storage are 35 water-level measurements made by the Seward County Irrigation Association in the fall of 1970.

Precipitation and development of irrigation

Although the total amounts of annual precipitation and of growing-season rainfall are important factors in successful agriculture, timeliness and intensity of precipitation also are important. During 1930-71 annual precipitation at Seward, which is near the center of the county, ranged from 15.62 inches in 1934 to 39.25 inches in 1951 and averaged 27.06 inches (fig. 8). Precipitation during the growing season (May through August) ranged from 5.06 inches in 1934 to 24.72 inches in 1951 and averaged 15.20 inches (fig. 9). Rarely, if ever, is the natural supply of moisture both ample and timely enough for yields of nonirrigated crops to be optimum.

The need to supplement precipitation with irrigation became especially apparent during the drought of the 1930's. However, the existence of ground-water supplies sufficient for irrigation was not generally recognized at that time. A few wells were drilled during the 1940's and early 1950's; however, by the end of 1952 the total number of wells was still less than 15. The first big increase in well installations began in 1953. By the end of 1958, the number of wells had grown twentyfold--to a few more than 300. Below-average precipitation, especially in 1953, 1955, and 1956, and increasing prices for crops were the principal causes of so large an increase within such a short period. Only 31 new wells were drilled in the next 5 years. In 1964 the second big increase in the rate of new installations began, and by the end of 1971 the total number of registered wells in the county totaled 626 (State-Federal Div. Agr. Statistics, 1972, p. 93). Figure 10 shows the number of wells installed and the cumulative number of wells for each year from 1945 through 1971. All but 12 of the wells are west of the Big Blue River.

During the early stages of irrigation development, wells were installed as insurance against disaster from drought; water was applied primarily when necessary to prevent crops from deteriorating. Well operators now strive to obtain maximum crop yields by applying water in accordance with soil-moisture conditions and stage of crop growth. This practice, together with planting of new high-yielding crop varieties and greater use of fertilizer, has tended to increase the amount of water applied.

Of the 64,200 acres developed for irrigation, 51,400 acres were irrigated in 1971. About 87 percent (44,700 acres) of the irrigated acreage was planted to corn, about 8 percent (4,100 acres) to grain sorghum, and most of the remainder to soybeans and alfalfa (State-Federal Div. Agr. Statistics, 1971). About 7,600 acres of bottom land that is irrigated with water from streams is included in the acreage irrigated in 1971. Because streamflow during periods of heavy irrigation demand is not sufficient for

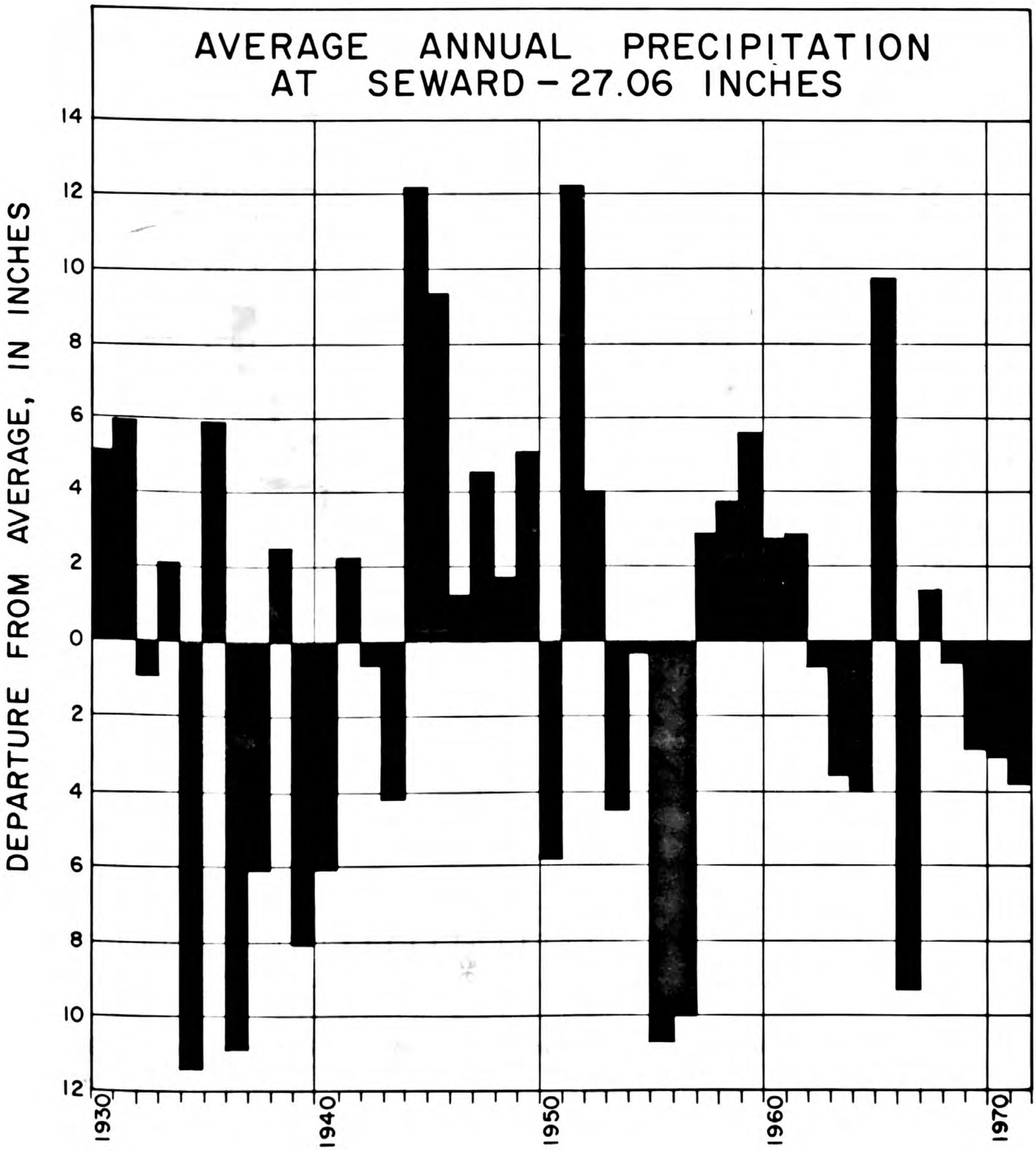


Figure 8.—Departures from average annual precipitation at Seward, 1930-71.

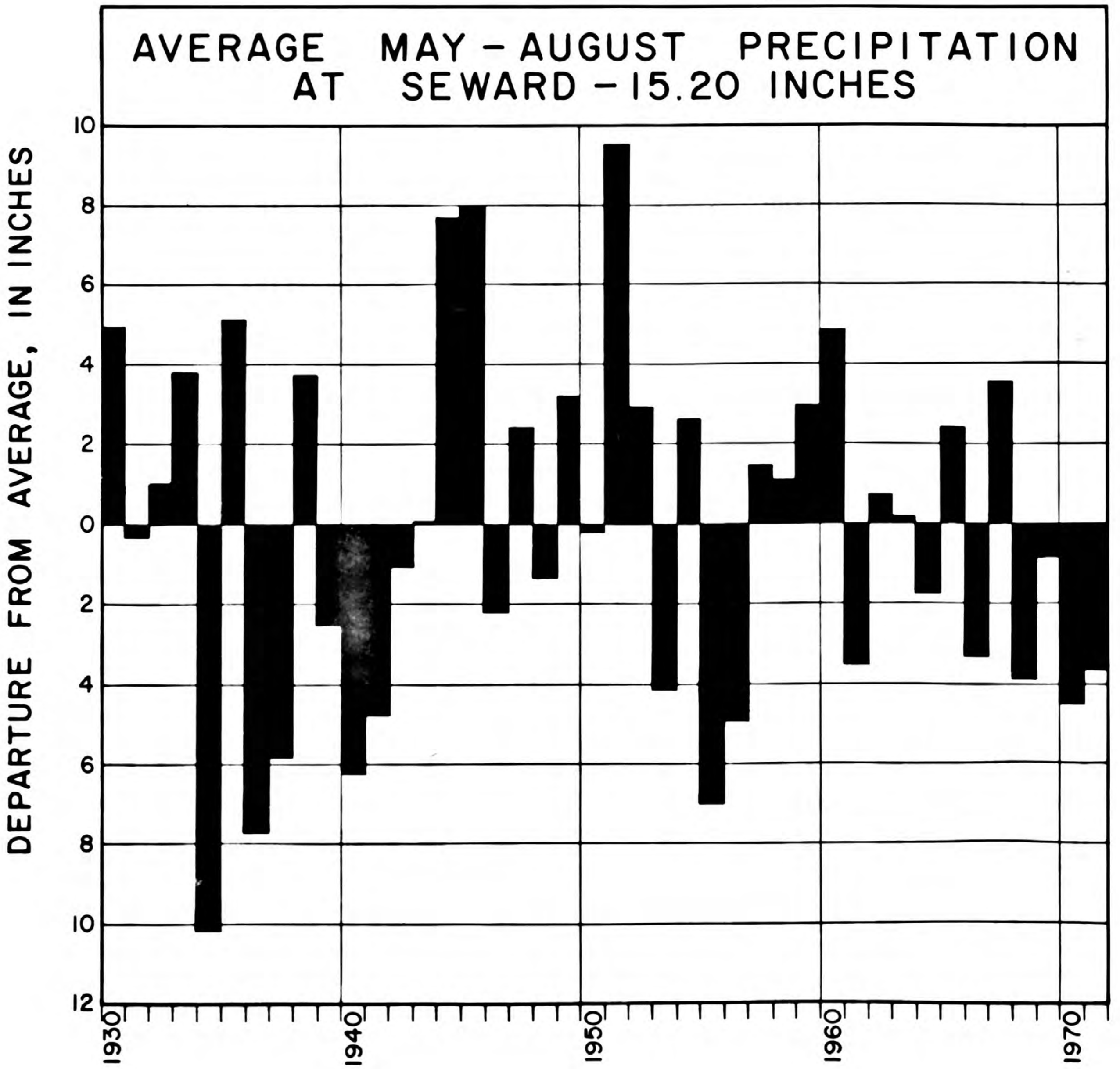


Figure 9.—Departures from average growing-season precipitation at Seward, 1930-71.

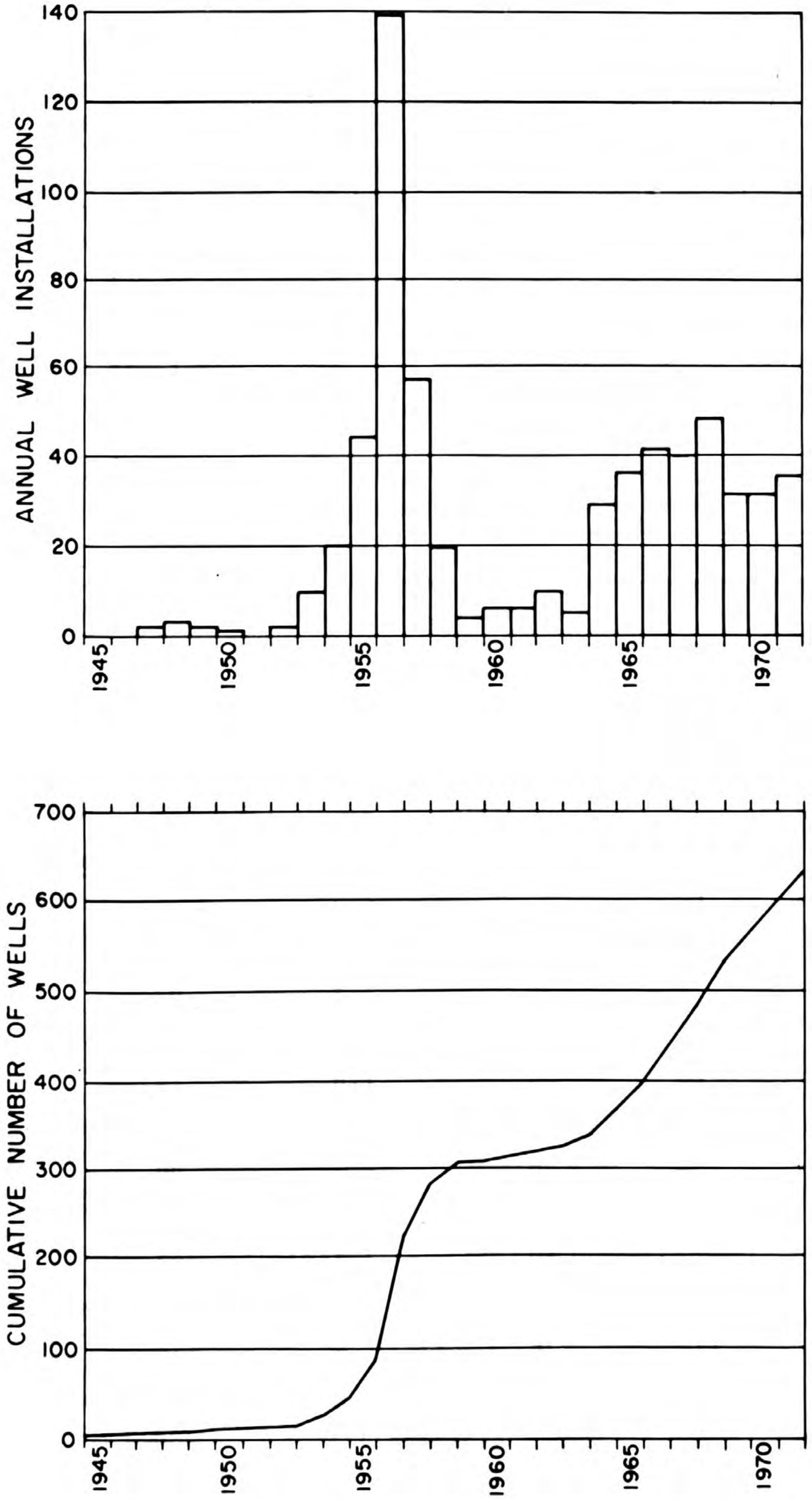


Figure 10.—Annual irrigation-well installations and cumulative number of irrigation wells, 1945-71.

the entire acreage now developed for irrigation with surface water, future increases in irrigated acreage may result in the drilling of new irrigation wells.

Data on yields of the principal nonirrigated and irrigated grains grown in the county demonstrate the increase in yield per acre obtained by supplementing precipitation with applied water. During the period 1954-71, yields per acre of irrigated corn ranged from 1.6 to 12.5 times the yields per acre of dryland corn, and during the period 1956-71, the yields per acre of irrigated grain sorghum ranged from 1.0 to 7.8 times the yields per acre of dryland sorghum. (See table 2.)

Table 2.--Average yields per acre of irrigated and nonirrigated corn and grain sorghum

[Data from State-Federal Division of Agricultural Statistics, 1954-71]

Year	Corn			Grain sorghum		
	Irrigated	Nonirrigated	Ratio of irrigated to nonirrigated	Irrigated	Nonirrigated	Ratio of irrigated to nonirrigated
	Bushels per acre	Bushels per acre		Bushels per acre	Bushels per acre	
1954	63	25	2.5	....	....	....
1955	59	8	7.4	....	....	....
1956	75	6	12.5	62	8	7.8
1957	70	36	1.9	65	38	1.7
1958	85	47	1.8	70	53	1.3
1959	85	43	2.0	73	51	1.4
1960	88	50	1.8	74	70	1.0
1961	86	45	1.9	82	63	1.3
1962	96	58	1.7	105	82	1.3
1963	94	46	2.0	88	67	1.3
1964	70	19	3.7	94	44	2.1
1965	100	51	2.0	92	59	1.6
1966	117	60	2.0	97	77	1.3
1967	106	60	1.8	93	64	1.5
1968	115	60	1.9	95	64	1.5
1969	124	76	1.6	125	82	1.5
1970	106	28	3.8	89	52	1.7
1971	108	54	2.0	102	58	1.8

Pumping for irrigation in 1971

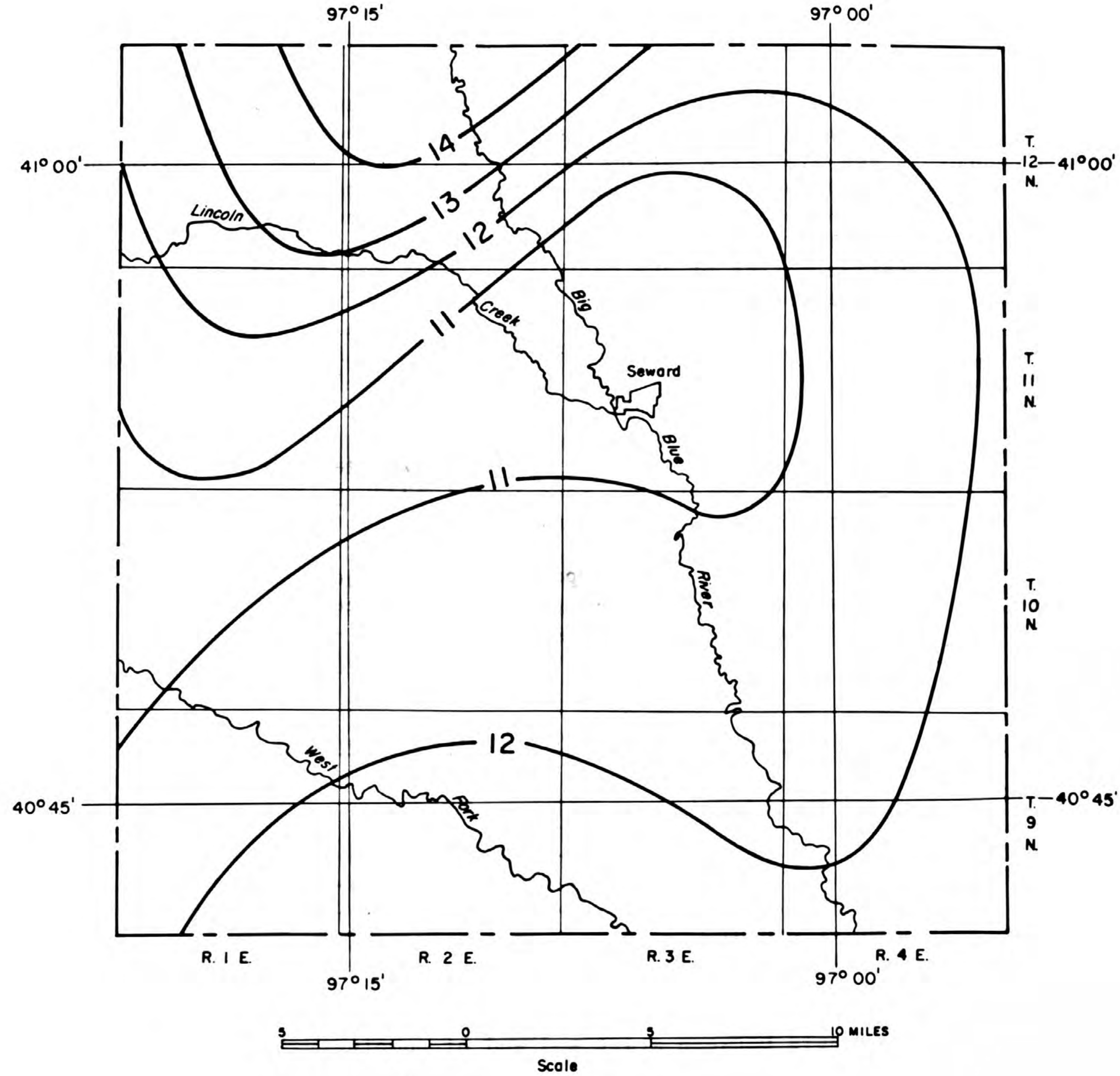
May, the first month of the growing season, was wet and cool. However, rainfall in June was only half the normal amount and the average temperature was 5.3° F. above normal. As a result, topsoils became quite dry and more than half the irrigation pumps were operating before the end of the month. Although cooler than normal, July and August were dry; at Seward, rainfall during August was less than one-fourth normal. During the 3 successive months of dry weather, irrigators applied nearly twice as much water per acre as they did in 1968, the only year for which comparable information is available. If individual values for depth of water applied to crops by project wells are superimposed on the map showing growing-season precipitation (fig. 11), total amounts of water received by irrigated crops are found to have ranged from about 20 to 37 inches.

About half the wells for which data were available supplied more than the 28 inches of water that Reed (Jess, 1970, p. 9) estimated as the maximum amount needed by crops ordinarily grown in this region.

As shown below, water was pumped from the project irrigation wells an average of 52 days out of the average 64 days between the first and last day of pumping during the 1971 irrigation season.

Data pertaining to 1971 irrigation season

Date pumping started:	
Earliest	June 19
Latest	July 17
Average	June 26
Date pumping ended:	
Earliest	August 14
Latest	September 11
Average	August 28
Number of days between start and end of pumping:	
Maximum	79
Minimum	33
Average	64
Number of days pumps were operated:	
Maximum	76
Minimum	23
Average	52



EXPLANATION

——12——

Line of equal rainfall, May through August, 1971
Interval 1 inch

Figure 11.—Amount of precipitation during 1971 growing season.

Changes in water levels and ground-water storage

Before ground water was pumped for irrigation in the western part of Seward County, the quantity of ground water in storage and the shape of and depth to the water table remained essentially unchanged. Additions (recharge) to the ground-water supply resulting from precipitation that infiltrated to the water table and from subsurface inflow from the west were balanced, over the long term, by losses (discharge) resulting from subsurface outflow into Saline County, spring discharge, evapotranspiration in places where the water table is within the reach of plant roots, and seepage into stream channels that have been incised below the water table. Only minor changes in ground-water storage and position of the water table resulted from the ever-changing ratio of natural recharge to natural discharge, and imbalances never lasted for long. Now, however, recharge and discharge are no longer in balance. The quantity of ground water in storage and the water levels in wells are trending downward as the result of irrigation withdrawals exceeding recharge.

Use of ground water for irrigation has resulted in a large demand on the available ground-water supply. The large withdrawals that will occur in drought years will result in a significant lowering of water levels in wells. However, reduction of the available ground-water supply is not likely to become a pressing problem for many years because the volume of ground water still in storage is large compared to the decrease in storage that has occurred to date.

The depth-to-water measurements used in plotting the hydrographs shown in figure 5 generally were made twice each year--in the spring before pumping began and in the fall after pumping ended. As shown, 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 small fraction of the preceding seasonal decline to as much or more than that decline. The long-term trend is downward because the sum of the annual declines is greater than the sum of the annual recoveries.

Because the dates on which the spring and fall water-level measurements were made probably did not coincide with the dates of the highest and lowest water levels, the actual differences between water-level extremes were somewhat larger than those measured. The differences between the seasonal high and low water levels can be determined precisely only from a continuous record.

The amount of water-level decline that has occurred since withdrawal of ground water for irrigation began is of considerable concern to farmers. Comparison of spring 1971 water levels with estimated predevelopment water levels (table 1) gives approximate values ranging from 2 feet to nearly 15.5 feet. Figure 12, which is based on the approximate net water-level decline in 54 wells, shows the approximate areal distribution of declines

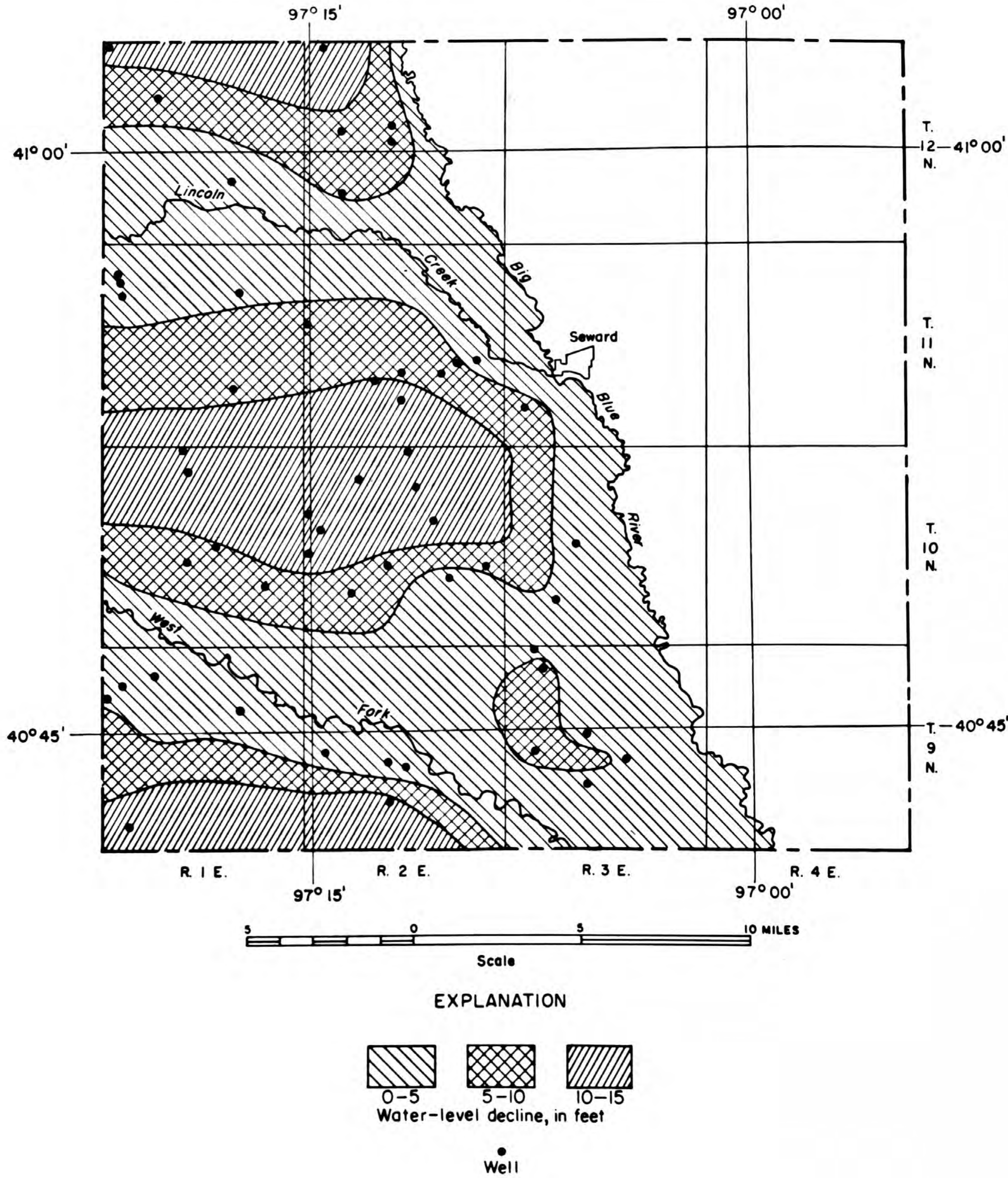


Figure 12—Difference between estimated predevelopment water levels and spring 1971 water levels.

less than 5 feet, between 5 and 10 feet, and more than 10 feet. Declines greater than 10 feet are indicated in three areas. The largest area, in the west-central part of the county between Lincoln Creek and West Fork, is about 50 square miles in extent. The other two, one in the northwestern part of the county and one in the southwestern part, are about 12 and 22 square miles in extent, respectively. Both of these smaller areas should be regarded as more speculative than the area in the west-central part of the county because their delineation was based on only two widely spaced control points in each.

In a part of western Seward County, ground water is confined under artesian pressure. The extent of the area of confinement has not been determined, but artesian conditions are known to exist in the West Fork valley in the vicinity of Beaver Crossing (sec. 2, T. 9 N., R. 1 E.). If the zone containing confined water extends beneath the adjacent uplands, it probably lies beneath a zone containing unconfined water. Thus is some upland locations a well may be constructed so that it taps only the confined water, only the unconfined water, or both. Possibly, then, the water-level declines in a few localities are due to decrease in artesian pressure or to a combination of decrease in pressure and dewatering of aquifer material. If so, those declines are of little value in computing the reduction in storage that occurred prior to spring 1971. However, for the purposes of this report, all the water-level declines were assumed correlatable with reduction in storage and were used in computing the weighted-average water-level decline of 6.15 feet.

A value of 20 percent is considered reasonable for the specific yield[1/] of the dewatered aquifer material. That value, used in combination with the weighted-average water-level decline value of 6.15 feet indicates that the net reduction of ground-water storage before 1971 amounted to about 270,000 acre-feet in the part of Seward County west of the Big Blue River.

Comparison of the spring 1971 and spring 1972 water levels in 54 project wells and other selected wells west of the Big Blue River indicates that pumping in 1971 resulted in a general lowering of water levels and an additional reduction of storage throughout nearly all the upland area. In two of the wells the water-level rise after the pumping season slightly exceeded the decline caused by pumping, but in all other wells the rise was less than the seasonal decline. Table 1 shows that the net decline of the water level in nine wells was less than 0.5 foot, in 25 wells between 0.5 and 1 foot, and in 18 wells more than 1 foot. The maximum recorded net difference was a decline of 1.62 feet.

The amount and approximate extent of water-level declines due to withdrawals for irrigation in 1971 are shown in figure 13. Comparison of this

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

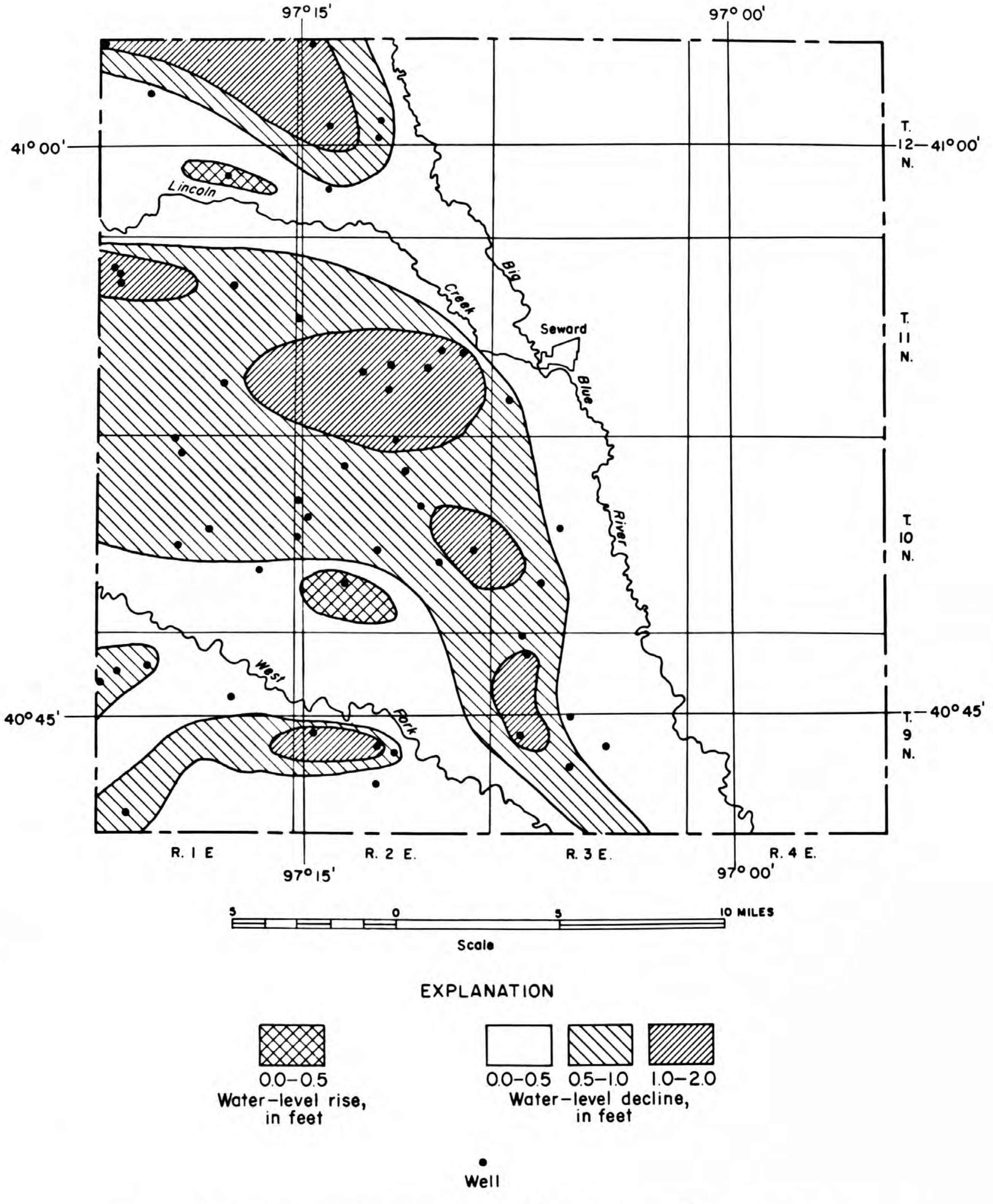


Figure 13.—Difference between spring 1971 and spring 1972 water levels.

figure with figure 12 shows that the two largest areas in which the decline during 1971 exceeded 1 foot are within the areas of greatest decline prior to 1971. The weighted-average net water-level decline during 1971 was 0.70 foot.

Average pumpage from the 32 project wells for which rate of discharge was measured and total hours of pump operation were reported was computed to be 135 acre-feet. This value, multiplied by the total number of registered irrigation wells west of the Big Blue River, gives nearly 83,000 acre-feet for total irrigation pumpage in 1971. A second method of computing total pumpage in 1971 consists of dividing pumpage from each project well by the number of acres irrigated by that well to obtain depth-of-water application to crops, averaging these depth-of-application values, and multiplying the average (1.53 ft) by the total irrigated acreage. A slightly smaller value--nearly 80,000 acre-feet--is obtained by this method. If seasonal water-level declines are proportional to seasonal withdrawals, the hydrographs in figure 5 indicate that withdrawals for irrigation in 1971 were greater than in any previous year. The average of the two computed amounts for 1971 is nearly twice the amount computed by Jess (1970, p. 7-10) for the 1968 irrigation season.

Declines between the spring 1971 and fall 1971 water-level measurements ranged from 0.87 to 5.95 feet and averaged 2.45 feet. One might expect that a change-in-storage value computed from the average water-level difference would be approximately equal to pumpage between the spring and fall water-level measurements. Such is not the case, however, as the value for change in storage thus computed is about one-third greater than the larger of the two values obtained for pumpage. Any computation of storage change based on a water-level difference involving fall measurements is considered probably in error.

The maximum water-level difference between fall 1970 and fall 1971 was a decline of 2.91 feet, the minimum was a rise of 0.01 foot, and the average difference was a decline of 1.34 feet. As water levels at the time measurements are made in the fall generally still are recovering from pumping during the irrigation season, conclusions based on a comparison of successive fall measurements may be faulty in regard to water-level trends. Trends determined from frequent or continuous monitoring of water levels over a period of several years generally are better. Although the hydrograph shown in figure 4 is valuable for this purpose, it should be regarded as representative of water-level fluctuations in only the general vicinity of the well.

The data on which the preceding discussion of changes in water levels and ground-water storage is based are summarized below:

Summary of data for project and other wells west of the Big Blue River

/All averages are arithmetic (nonweighted) unless otherwise indicated/

Number of wells		57
Estimated depth to water prior to irrigation development (56 wells):		
Maximum	feet..	94.00
Minimum	do....	4.00
Average	do....	62.61
Depth to water, fall 1970 (34 wells):		
Maximum	feet..	98.90
Minimum	do....	13.24
Average	do....	73.04
Depth to water, spring 1971 (54 wells):		
Maximum	feet..	101.04
Minimum	do....	7.98
Average	do....	70.34
Depth to water, fall 1971 (56 wells):		
Maximum	feet..	104.68
Minimum	do....	12.03
Average	do....	72.26
Depth to water, spring 1972 (56 wells):		
Maximum	feet..	102.06
Minimum	do....	9.08
Average	do....	70.58
Net difference between predevelopment and spring 1971 water levels (54 wells):		
Maximum	feet..	-15.43
Minimum	do....	-2.00
Weighted average	do....	-6.15
Net difference between spring 1971 and spring 1972 water levels (54 wells):		
Maximum	feet..	-1.62
Minimum	do....	+.12
Weighted average	do....	-.70
Net difference between spring 1971 and fall 1971 water levels (54 wells):		
Maximum	feet..	-5.95
Minimum	do....	-.87
Average	do....	-2.45
Net difference between fall 1970 and fall 1971 water levels (34 wells):		
Maximum	feet..	-2.91
Minimum	do....	+.01
Average	do....	-1.34

Rate of discharge from wells (44 wells):		
Maximum	gallons per minute	1,230
Minimum	do	240
Average	do	746
Total time wells were pumped (37 wells):		
Maximum	hours	1,635
Minimum	do	398
Average	do	1,012
Amount of water pumped (32 wells):		
Maximum	acre-feet	248
Minimum	do	46
Average	do	135
Depth of water applied (27 wells):		
Maximum	feet	2.11
Minimum	do	.77
Average	do	1.53

Summary

Comparison of depth-to-water measurements made in the spring of 1971 with estimated valued of depth to water at the same sites prior to development of irrigation in Seward County indicates that ground-water withdrawals before 1971 may have reduced the supply in storage by about 270,000 acre-feet.

From hydrographs of water-level fluctuations in five wells during the period 1957-72 it is concluded that net depletion during the 1971 irrigation season was the greatest for the period of record. As additional depletion of the ground-water supply is a likely prospect, it would be beneficial to apply no more water than is needed by crops, make maximum use of runoff from irrigated fields, and explore methods for extending the life of the ground-water resource.

Continuation of the following procedures will aid in determining the amount of ground water available for use: Measurement of water levels; recording of hours of pump operation; computation of annual changes in ground-water storage; and computation of annual volumes of water pumped. A network of rain gages and measurements of soil moisture made periodically at selected sites would assist in determining the effects of pumping. An inventory of reuse pits and of the acreage irrigated with the water that collects in them would provide information needed to refine the computation of depth of water applied to crops.

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