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HYDROLOGIC COEFFICIENTS FOR THE OGALLALA AQUIFER IN THE VICINITY OF ROY, HARDING COUNTY, NEW MEXICO

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Abstract—An aquifer test on the Village of Roy Municipal Well No. 1 was run as part of a general study of the ground-water resources available to the village. Observations of water-level changes resulting from pumping well No. 1 were made in other city wells and nearby stock wells. Analyses of the data collected indicate the coefficient of storage ranges from 0.0018 to 0.03, and the transmissivity from about 5,000 to about 16,000 gpd/ft. The best data seem to be those yielding an "S" of 0.03 and a "T" of 15,000 gpd/ft.

GENERAL HYDROLOGY

The aquifer supplying water to wells in the Village of Roy municipal well-field about 6.5 mi southeast of town (Trauger et al., 1986; Trauger and Churan, 1987) is the Ogallala Formation of Tertiary age. The wells tap the Ogallala where it is about 150 to 200 ft thick and apparently fills an old drainage channel developed in the Romeroville (Dakota) Sandstone of Cretaceous age. The Ogallala thins laterally from the area of the well-field. Stock wells one mi or so to either side produce little water from the Ogallala, and some wells only obtain water from the underlying Romeroville.

In the area of the well-field, the Ogallala consists of interbedded clay, silt, sand and minor amounts of gravel. Caliche development is apparent in the upper part of the formation as seen in nearby "gravel" and road-metal quarries. The Ogallala in the old channel-fill seems to contain little or no caliche according to oral reports, but no logs of city wells could be found in city records to confirm this.

BASIC ASSUMPTIONS

The analysis of the data collected during the aquifer test on village well No. 1 (19.27.5.341) is based on the assumption that the water is unconfined in sand and gravel of the Ogallala Formation, and that the Theis (1935) non-equilibrium theory and the Jacob (1946) modification of the theory is applicable. The pumping test made of well No. 1 in the Roy well-field (Fig. 1) gave varying results because the Ogallala is an example of an aquifer that is not homogeneous or isotropic, nor of uniform thickness or infinite in extent, as required by the basic assumptions of the theory. The beds of clay, sand and gravel that make up this aquifer vary horizontally and vertically within short distances. The strata, in general, have greater continuity horizontally than vertically; thus, water may be assumed to move more easily parallel to the bedding than across bedding planes. This characteristic may explain some of the anomalous results noted in the analysis of the data.

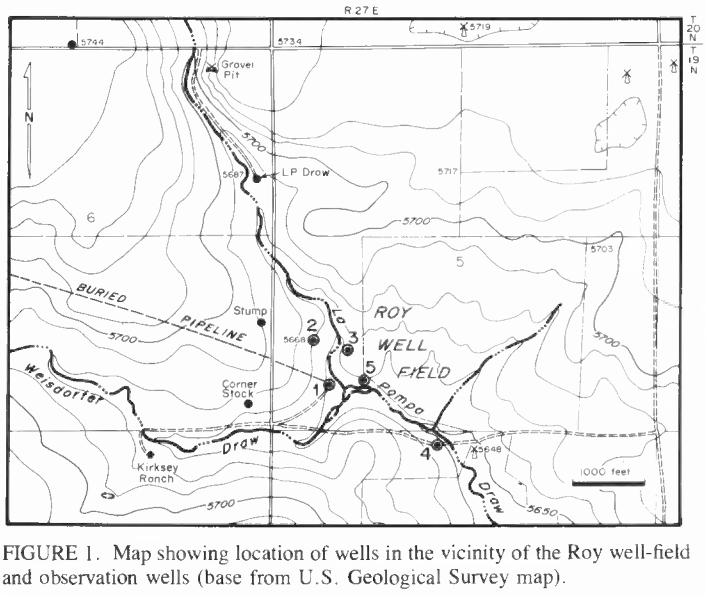


FIGURE 1. Map showing location of wells in the vicinity of the Roy well-field and observation wells (base from U.S. Geological Survey map).

AQUIFER EVALUATION

Pre-testing conditions

The mayor of Roy reported that municipal well No. 1 (19.27.5.3341) would deliver 60 gpm to the system with a total drawdown of about six ft. On the basis of this pre-test information, it was decided that well No. 1 would be tested at a continuous pumping rate of 60 gpm for three days (72 hours). The water level in well No. 1 at the start of the test was 53.21 ft below the measuring point (MP). A steel tape was fastened to an electric sounding probe and "zeroed" at the MP so that all readings measured drawdown directly.

In order to minimize pre-testing effects of prior pumping in the well-field, all of the city wells were shut down five days prior to start of the test. Also, a micro-barograph was installed in the pump house at well No. 1 twenty-four hours prior to starting the test. Atmospheric pressure change was recorded throughout the test period.

Water levels in seven non-pumping wells were measured during the test. These included municipal well Nos. 2, 3, 4 and 5, plus the LP Draw, Stump and Corner Stock wells (Fig. 1). The distances from the production well to the observation wells ranged from 405 ft to 3,000 ft. It was not anticipated that large pumping effects would be seen in any of the observation wells. However, because the hydrologic conditions and coefficients in the vicinity of the well-field were not known, it was considered best to make observations to confirm the supposition. None of the Kirksey wells west of the well-field had been pumped for more than a month, and water levels in the wells had reached non-pumping static level. Measurements were made in all wells for several days prior to start-up of the test.

Aquifer testing and analysis

The pump in No. 1 well was started at 10:00 a.m., 20 November 1985. Trouble was experienced getting the probe to run down the hole for the first seven minutes, hence no measurements were made during that time. At about 8 minutes after start of pumping, the discharge was steady at about 60 gpm on the flow meter. The drawdown was 4.18 ft below the pre-pumping static level.

Pumping continued at a rate of about 60 gpm for 33 hours, and the drawdown was 5.9 ft at that time. Discharge went to the city line and water tanks. At 7:17 p.m., 21 November, it was necessary to divert the flow into the adjacent stream channel because the city tanks were overflowing. Adjustments in the gate valve had to be made to compensate for change in head, and the resulting pumping rate then became a bit erratic for a short time. At about 8:20 a.m. the next morning, discharge was again sent to the storage tanks and was temporarily erratic. During the test a total of 439,000 gallons of water were pumped; approximately half of the total went into the municipal system and half to waste.

At about 48 hours after pumping began, the discharge rate was still 60 gpm, and the drawdown was 5.9 ft. The original plan had been to pump for three days (72 hours), then observe recovery for three days. However, no effects attributable to pumping had yet been noted in any of the observation wells after 48 hours, and it was decided to continue pumping for at least another 24 hours. At noon on 24 November, the drawdown was 6.37 ft, and possible effects were noted in water levels in city well Nos. 2, 3 and 5. Pumping was continued, and the drawdown was 6.40 ft by 6:30 p.m. of 24 November. No further declines occurred, and it was believed that recirculation had begun between the water discharged to the nearby channel and the pumping well (Fig. 2A). Pumping was stopped at 9:33 a.m., 25 November, 7,173 minutes, or approximately five days, after start-up.

The initial recovery of the water level (Fig. 2B) was rapid, and within four minutes the residual drawdown was about 2.5 ft; thereafter recovery was slower. After ten minutes, residual drawdown was 2.34 ft, and after 30 minutes it was 2.19 ft. At 9:00 a.m. the next day the residual drawdown was still 1.06 ft. The last recovery measurement was made at 11:00 a.m., 27 November 1985, and the residual drawdown at that time was 0.65 ft (Fig. 2B).

City well Nos. 2, 3 and 5 had not been in use for more than a month, and fluctuations of water levels in these wells were presumed to be due to the effects of pumping well Nos. 1 and 4. In the two days prior to start of pumping on 20 November 1985, measurements made in city well Nos. 2, 3 and 5 indicated that water levels were declining until about noon of 19 November at which time they started to rise, presumably the result of curtailed pumping that began on 13 November.

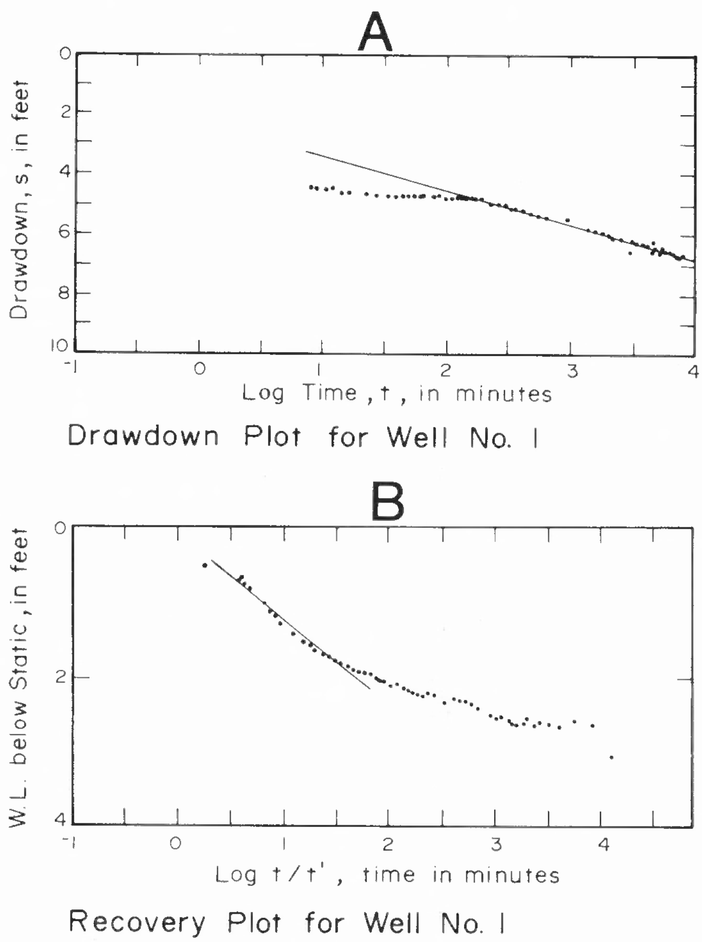


FIGURE 2. Drawdown and recovery plots for Roy well No. 1 during aquifer test, Harding County, 5

TABLE 1. Summary of aquifer parameters as determined during test of production well No. 1. Locations are shown in Figure 1.

Well Name	Distance, in feet	Transmissivity, in gpd/ft	Storativity
Production (No. 1)			
drawdown	0	15,900	-
recovery	0	13,900	
City Well No. 2	663	14,822	0.03
City Well No. 3	530	7,900	0.0018
City Well No. 4	1,700	no response	-
City Well No. 5	486	5,200	0.073
LP Draw	3,000	no response	-
Stump	1,250	no response	-
Corner Stock	1,175	no response	-

The transmissivity was determined by computer analysis and by analytical methods of data collected from the production well (No. 1). The computer method uses the technique described by Walton (1970, pp. 129–133). In general, a best-fit line is calculated for the points selected by the hydrologist as the most representative of the aquifer characteristics. The drawdown per log cycle is then used in the equation:

$$T = \frac{264\ Q}{\Delta s}$$

where "Δs" is the drawdown per log cycle. The units are given in gpd/ft (gallons per minute per foot of aquifer saturation). The transmissivity (T) determined for the production well was 14,000 gpd/ft or 1,870 ft^2/day (Table 1). The specific capacity was determined to be 9.33 gpm/ft (gallons per minute per foot of drawdown). After five days of recovery the water level returned to about 0.5 ft of the pre-test static water level.

The data collected during both drawdown and recovery in each observation well were plotted on log-log paper. A type curve was then matched to the plot, and values of "W(u)" and "u" were determined which correspond to specific values of drawdown(s) and r^2/t (units are feet-squared per day). These values were then used in the equations given by Lohman (1972, pp. 15–27). The value for the transmissivity was then determined from these equations. The storativity or coefficient of storage was also determined from the observation well data.

City well No. 2 is located north and slightly west of the production well at a distance of 663 ft. The plot of data collected shows a scatter of points (Fig. 3). However, a transmissivity value of 14,822 ft^2/day was determined using the best fit; the value of storativity was determined to be 0.03.

City well No. 3 was located 530 ft northwest of the pumping well (Fig. 1). The plot of data from this well shows little effect from the pumping well. However, one fit of the curve indicates a transmissivity of 7,900 ft^2/day and storativity of 0.0018 (Fig. 4), suggestive of semi-confined conditions in the aquifer.

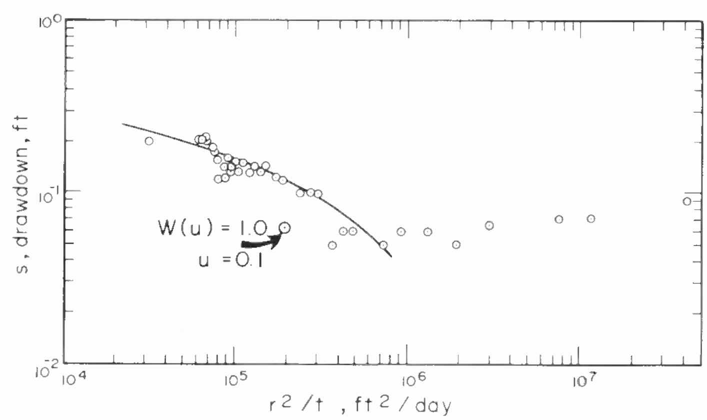


FIGURE 3. Log-log plot of drawdown measurement in city well No. 2 during pumping of well No. 1, Roy well-field, Harding County, New Mexico.

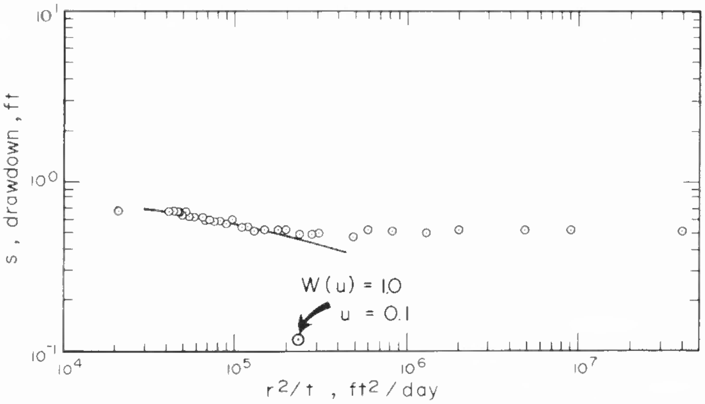


FIGURE 4. Log-log plot of drawdown measurement in city well No. 3 during pumping of well No. 1, Roy well-field, Harding County, New Mexico.

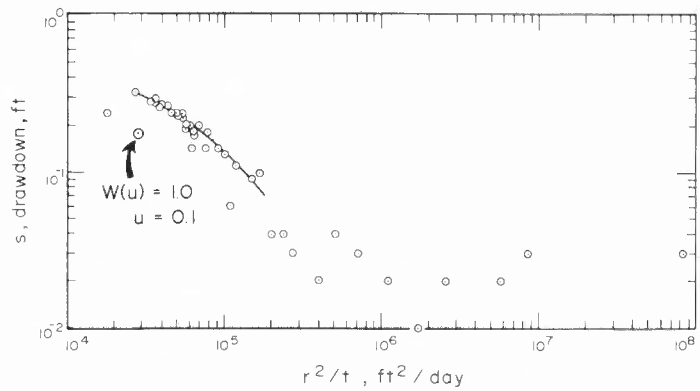


FIGURE 5. Log-log plot of drawdown measurement in city well No. 5 during pumping of well No. 1, Roy well-field, Harding County, New Mexico.

City well No. 4 was located 1,700 ft southeast from the production well. This distance was too great to identify any response during the aquifer test. During the test, the water level in this well continued to rise, which probably was in response to recovery after the last pumping cycle prior to the test. Also, at the beginning of the test the well turned on automatically and pumped for about half an hour before it was shut down. Therefore, no valid conclusions can be drawn about observation well No. 4.

City well No. 5 was located 486 ft east-northeast of the production well. It is the closest observation well to the pumping well and shows some response to pumping. Although there is some scatter to the data, the transmissivity was calculated to be 5,200 ft^2/day and storativity is 0.073 (Fig. 5).

The more distant observation wells appeared to respond only to changes in barometric pressure. The barometric pressure at the end of the test was only inches of mercury lower than at the start. Thus, the differences in water levels in the city wells at the start and end of the test can be attributed to effects of pumping. The level in city well No. 5 (closest to pumping well) shows the greatest decline of about 0.29 ft (Fig. 6). The decline was about 0.20 ft in well No. 3, and 0.15 ft

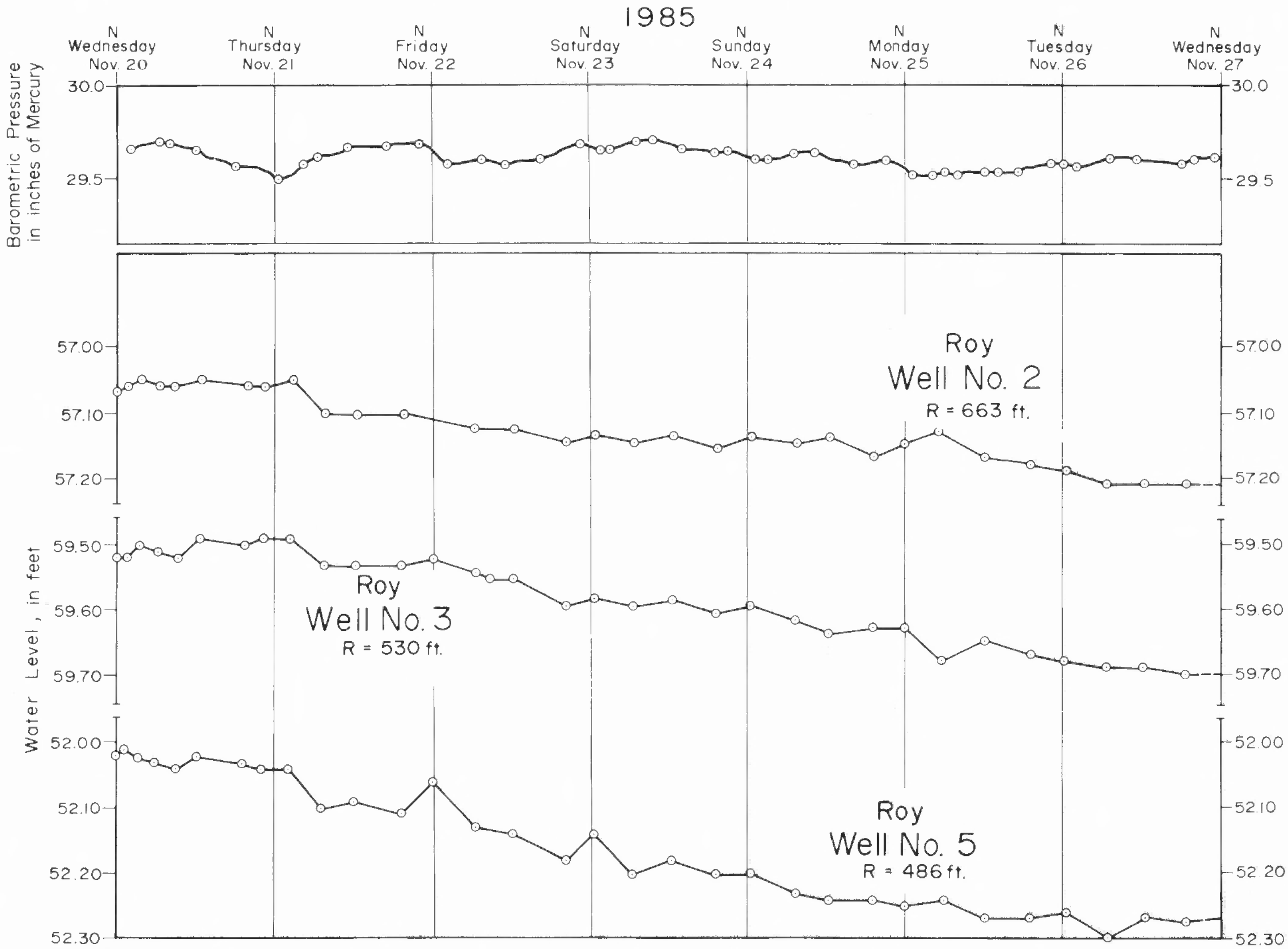


FIGURE 6. Water levels in well Nos. 2, 3 and 5 during aquifer test of well No. 1, Roy well-field, Harding County, New Mexico.

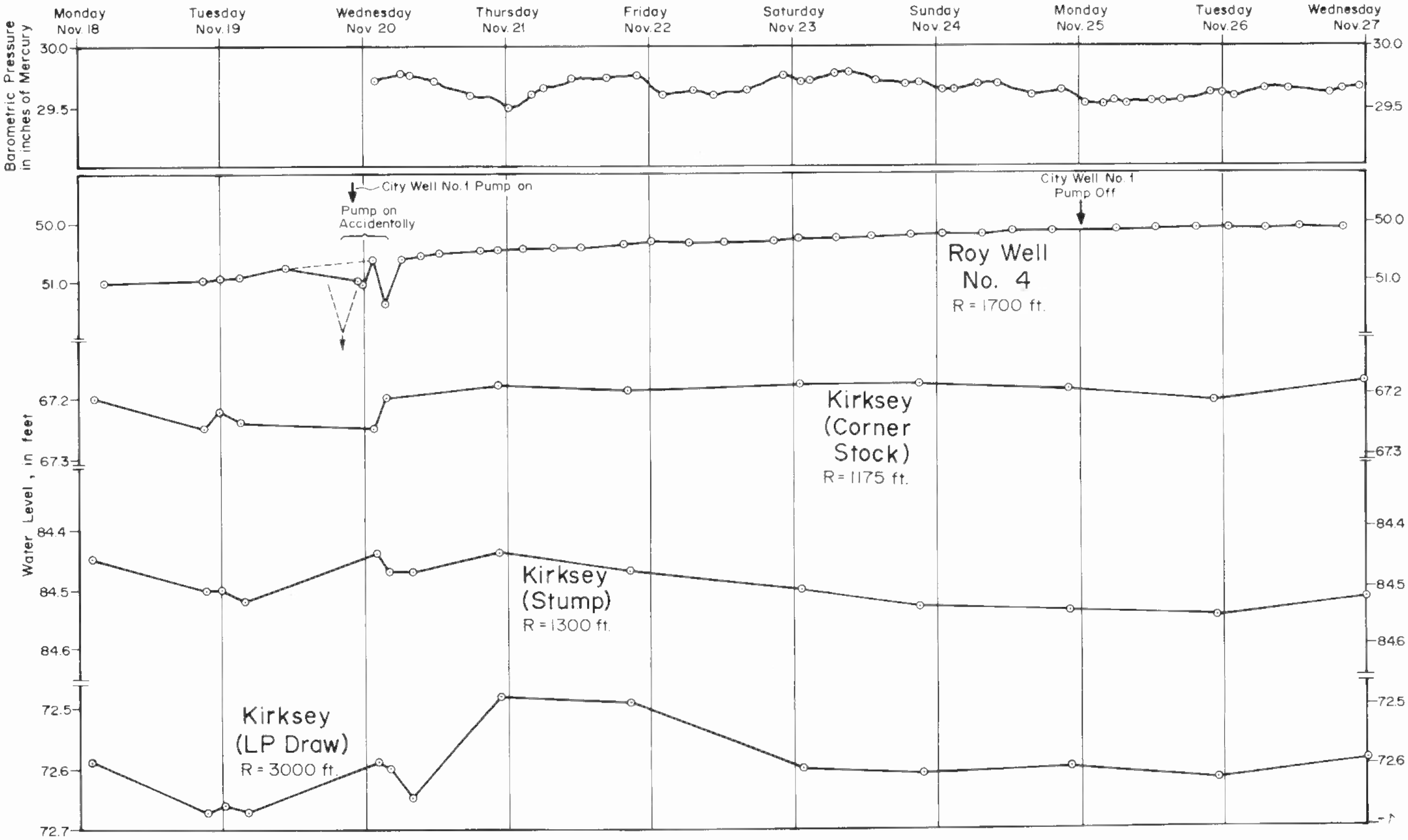


FIGURE 7. Water levels in Kirksey Observation Wells and city well No. 4 during aquifer test of well No. 1, Roy well-field, Harding County, New Mexico.

in well No. 2 (Fig. 7). The level in well No. 4 rose continuously during pumping. It had been in steady use prior to curtailment. At a distance of about 1,700 ft from No. 1 well, it was too far for the effects of pumping of No. 1 to reach the well and reverse recovery from heavy prior pumping.

No effects due to pumping No. 1 well could be detected with certainty in two of the three Kirksey wells west of the well-field. The nearest of these, well 19.27.6.44 ("Corner Stock") is 1,175 ft from the pumped well (Fig. 1). It showed fluctuations of a few hundredths of a ft, some of which appeared to be related to barometric pressure fluctuations, others possibly to pumping effects (Fig. 7). No definite changes due to pumping could be detected.

Larger fluctuations were noted in the Stump well (19.27.6.424) and the L.P. Draw stock well (19.27.6.242). At distances of 1,300 and 3,000 ft, respectively, from the pumped well, they should have shown no response to pumping in the length of time observed under strictly water-table conditions. What appear in Figure 7 to be effects of pumping seen on the hydrographs of L.P. Draw and Stump are believed to be residual effects of a period of heavy rain accompanied by some surface runoff in La Pompa Draw that occurred a week or so prior to the pump test (B. Kirksey, oral commun., 1986). The effects noted could result if the runoff caused a recharge surge followed by slow leveling off in the aquifer. The same small effects would occur in the city wells but would be obscured by the much greater effects of city pumping schedules.

The plot of water-level measurements (Fig. 7) shows maximum fluctuations of about one-tenth ft in Stump to two-tenths ft in L.P. Draw. The fluctuations of the water level in Stump correlate roughly with the barometric pressure fluctuations but in such manner that, had pressure changes not occurred, the water levels would have been even lower. It is believed, therefore, that some of the water-level fluctuations noted in Stump could reflect effects of pumping of well No. 1, damped, perhaps, by semi-artesian conditions absent between the No. 1 well and Corner Stock. The effects noted were considered not reliable enough to warrant use in determining hydraulic coefficients.

The fluctuations of water levels in L.P. Draw, at 3,000 ft the most distant of the observation wells, are also the greatest but with some sharp fluctuations that do not correlate well as either pumping or barometric effects. A possible effect due to pumping may be detected but it is, at best, obscure, and the fluctuations in this well are more likely the result of recharge after the runoff mentioned above.

All of the observation wells except well No. 4 show water-level fluctuations that reflect some barometric pressure effects and residual drawdown and recovery effects resulting from the curtailment of pumping prior to the start of the pump test at 10:00 a.m. on 20 November 1985 (Fig. 6). It is clear that all the wells tap the same aquifer, and that pumping any one of the wells must eventually have an effect on water levels in the others, to a degree proportional to the volume of water pumped.

The data obtained during the test indicate that the transmissivity values for the aquifer range from about 5,000 gpd/ft to more than 15,900 gpd/ft (Table 1). This is compatible with other transmissivity values reported for the Ogallala; however, the values for the Roy wells are near the lower end of the range. Values for storativity ranged from 0.0018 to 0.03. These values indicate that semi-confined conditions exist in the Roy well-field, whereas water-table conditions predominate in the Union-Baca County area. The local distribution of aquifer coefficients in the Roy well-field indicates that well Nos. 1 and 2 are appreciably more productive than Nos. 3 and 5. All future wells therefore should be located north and west of well No. 1 in order to maximize production.

REFERENCES

Jacob, C. E., 1946, Radial flow in a leaky artesian aquifer: Transactions of the American Geophysical Union, v. 27.

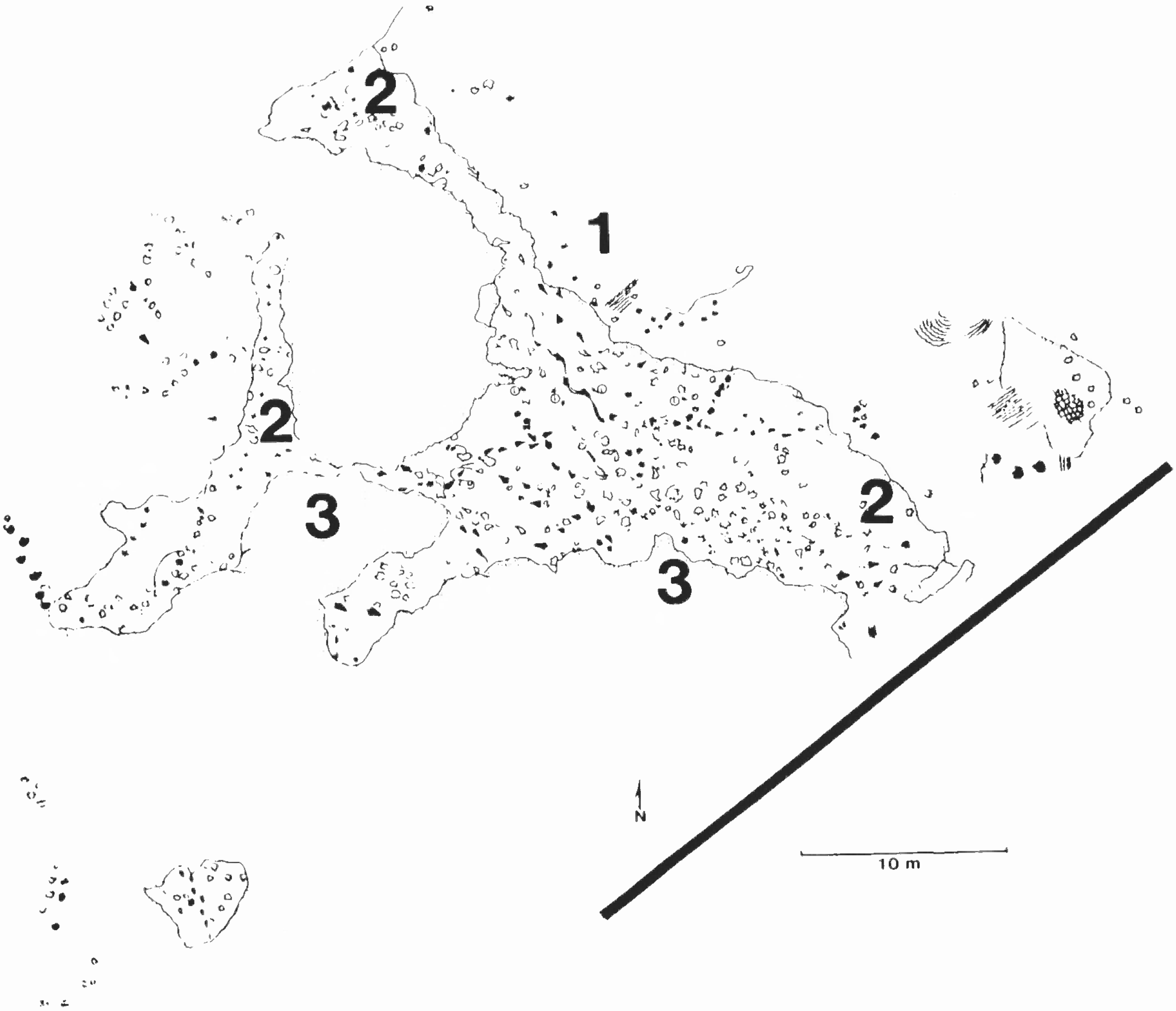
Lohman, S. H., 1972, Ground-water hydraulics: U.S. Geological Survey, Professional Paper 708, 70 pp.

Theis, C. V., 1935, The relation between the lowering of piezometric surface and the rate and duration of discharge of a well using ground-water storage: Transactions of the American Geophysical Union 16th Annual Meeting, Part 2.

Trauger, F. D. and Churan, K. R., 1987, Geohydrology of the Roy-Solano area, Harding County, New Mexico: New Mexico Geological Society, Guidebook 38.

Trauger, F. D., Churan, K. R. and Kelly, H. T., 1986, Quantitative analysis of the Roy municipal well field, Harding County, New Mexico: Geohydrology Associates, Inc., Consultant Report to the Village of Roy, 97 pp.

Walton, W. C., 1980, Use of analog computer in groundwater hydrology; *in* The progress of hydrology: Urbana, Illinois University Department of Civil Engineering, pp. 265–289.



Map of dinosaur footprints exposed in the Mesa Rica Sandstone and Pajarito Formation at Clayton Lake State Park, Union County, New Mexico. From article by Gillette and Thomas in the 1985 New Mexico Geological Society Guidebook.