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MEMORANDUM

Results of Pumping Tests at Goodrich Plant Site, Miami, Oklahoma

approved by Sears 1/30/51 for release to open file from war file.

by

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U. S. Department of Interior, Geological Survey
in cooperation with
Oklahoma Geological Survey
Norman, Oklahoma,
June 1944

51-121

Mac - here is a paragraph which could be substituted for the first paragraph under "Geology" and then we could omit fig. 1. Feel free to edit it, simplify it or whatever.

Alice

The following geologic units are penetrated by the wells of the Goodrich Tire Plant: about 40 feet of unconsolidated clay and silt; Mississippian rocks including 30 feet of undifferentiated limestone and shale of Chester age, and nearly 400 feet of limestone and chert of Meramec, Osage, and Kinderhook age; Chattanooga shale of Mississippian or Devonian age; more than 1100 feet of dolomitic formati ns of Ordovician and Cambrian age including the Cotter, Swan Creek (of some authors), Jefferson Cirty, Roubidoux, Gasconade, Van Buren, Eminence, and Bonneterre formations, and granite of prob ble pre-Cambrian age.

MEMORANDUM

Results of Pumping Tests at Goodrich Plant Site,

Miami, Oklahoma

Introduction

This memorandum has been prepared to indicate the quantity of water available at the Goodrich Tire Forming Plant now being constructed at Miami, Oklahoma. It is estimated that 3,000 gallons per minute will be the peak demand for the plant, taking into account the expanded program now contemplated.

The quantitative results are based on the application of Theis' non-equilibrium formula to determine future drawdowns at certain rates of pumpage. However, substantiating evidence as to the magnitude of the resultant drawdowns is given by long-term declines in water levels are reported throughout the area.

In order to supply the Goodrich plant, the City of Miami has drilled four wells, one in each corner of the tract, and is drilling two more, Nos. 4 and 6, as shown on the accompanying map. The city will equip the wells and furnish water to the plant at a flat rate as water service. It was originally planned to obtain the water from five deep wells located on the south and east edges of the Goodrich tract and spaced at intervals of 1,000 feet; but since the first two wells, drilled 2,000 feet apart, showed interference, 1/2-mile spacing was adopted and additional wells in the southwest and northwest corners of the tract were drilled. The pumping test of No. 1 well (southwest corner) established that the Miami fault affected the drawdowns, and this was further borne out by the low production of the No. 2 well (northwest corner). It was then evident that additional wells had to be drilled further east, and Nos. 4 and 6 are being drilled as shown on the map. No. 7 is tentatively located as shown but has not been drilled.

Geology

See supplemental ¶ to replace this and also Fig 1

The columnar section shown in figure 1 has been prepared in order to avoid a lengthy description of the rocks penetrated by the wells of the Goodrich Tire Plant. The correllations are based on studies of acid-insoluble residues of drill cuttings made by J. G. Grohskopf of the Missouri Geological Survey and H. A. Ireland of the Federal Geological Survey. The section above the Eminence dolomite is that encountered in well No. 5 at the Goodrich plant, and the remainder has been generalized from deeper wells in the same area.

The most important water-bearing formation is the Roubidoux of the Ordovician system. This formation consists of sandy dolomite with two beds

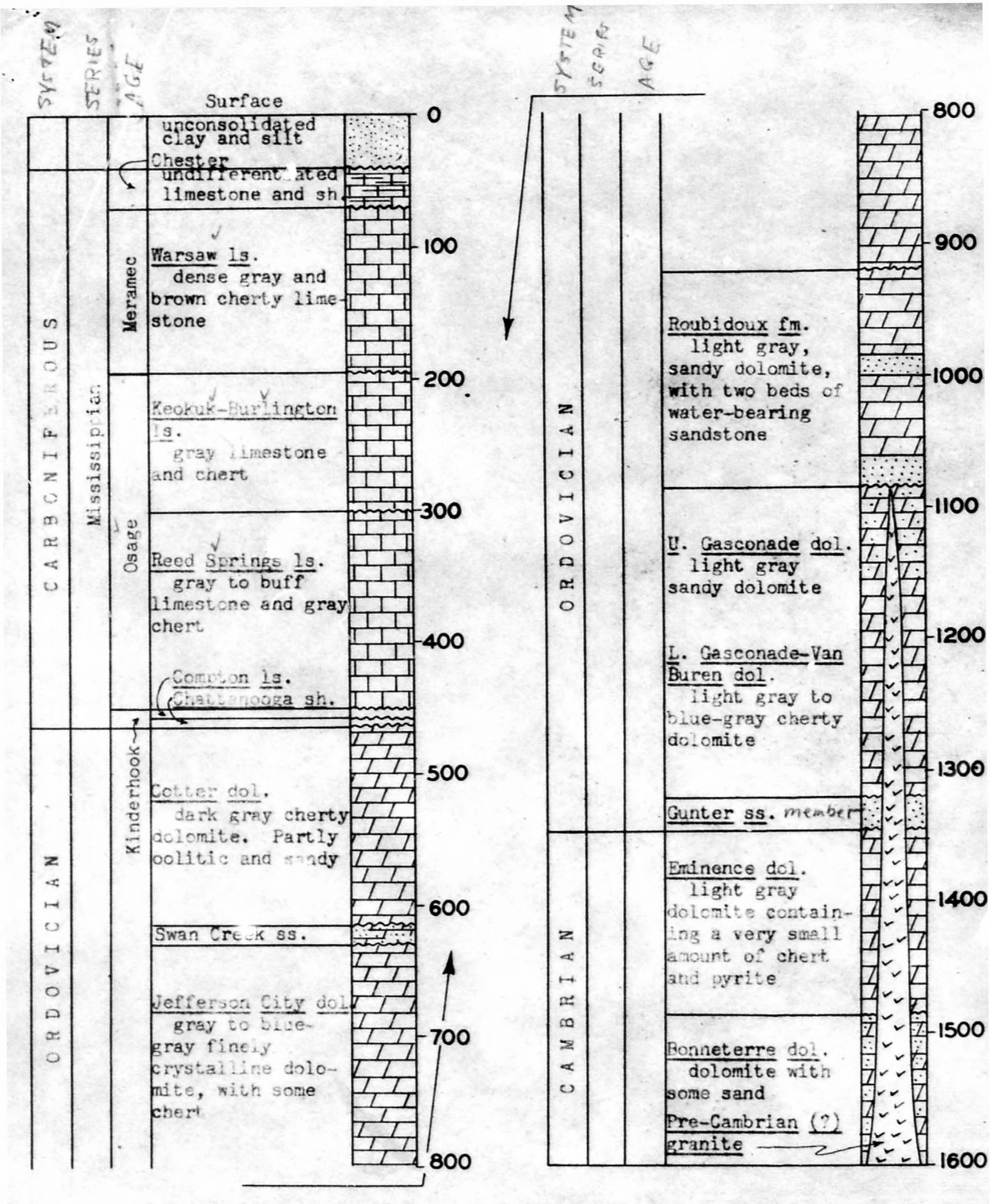


Figure 1. Generalized geologic section in the vicinity of Miami, Oklahoma.

Is this be omitted to avoid conflicts in nomenclature in this area. ASA of sandstone about 15 feet thick, one near the middle and the other at the base. The two sandstone beds are the most important source of water, though it is probable that the entire formation is water-bearing.

The Ordovician dolomites also yield water, the Cotter from the porous zone beneath the Ordovician-Mississippian disconformity, the Jefferson City from solution openings, and the Gasconade from the sandy upper portion.

The drillers of the Goodrich wells reported that nearly all the water in those wells was coming from the Roubidoux formation; but some geologists, including S. W. Lohman of the Federal Geological Survey in Kansas, believe that a large proportion of the water is coming from porous zones in the dolomite.

The Mississippian limestones yield large quantities of water, but it is of generally unsatisfactory quality, being high in sulfur content and also very hard. This water is cased off in most wells drilled to the Roubidoux.

The Ordovician rocks present in the subsurface at Miami outcrop in southern Missouri and northern Arkansas around the periphery of the Ozark uplift. The nearest outcrop of the Cotter dolomite is approximately 60 miles east of Miami, and the nearest outcrop of the Roubidoux is more than 100 miles east of Miami. These rocks dip radially away from the uplift; and in the vicinity of Miami, the dip is to the northwest at about 15 or 20 feet to the mile. 1/

The ~~Cambro-~~ Cambrian and early Ordovician rocks of the area were deposited on a very irregular pre-Cambrian granite surface, and locally there are granite peaks protruding a considerable height into the younger sedimentaries. One of these was encountered in well No. 3 at a depth of 1,055 feet, although in well No. 5, 2,000 feet to the north, no granite had been found to a depth of 1,465 feet. The granite in well No. 3 was overlain by about 10 feet of arkose, which probably is water-bearing.

There are at least two local structural features in the Miami area that are important in any ground water study. These are the Miami trough and the Seneca fault, the locations of which are shown on the accompanying map. The Miami trough is a well known feature in the Oklahoma lead and zinc mining district, and has been described by Weidman 2/ and Fowler and Lyden 3/ in studies of the district. It is an elongate synclinal fold having a number of down-faulted blocks along its length. Fowler 4/ has said that there is a maximum displacement of 350 feet in the active mining district, but that the displacement lessens to the south, and in the area directly west and south of Miami there is no actual displacement but only a synclinal fold. Still further south, in the vicinity of Afton, Weidman 5/ has described additional faulting.

The Seneca fault has been described by Siebenthal 6/ and Weidman 7/, and is shown on the Oklahoma State Geological Map. It extends from a point several miles northeast of Spurgeon, Missouri, southwestward to a point between Pryor and Choteau, Oklahoma. At its nearest point it is about 15 miles from the Goodrich plant site. The fault is double and in places multiple, letting down an elongated central block as much as 140 feet. In general, however, the throw is considerable less, being measured in tens of feet; and for part of its length it may be similar to the Miami trough, that is, have no displacement but be represented only by synclinal warping.

In addition to these two features there are, as shown on the Missouri Geological Map, several faults between the Miami area and the outcrop area. None of these completely cut off the recharge area, but they may serve to slow the movement of ground water. However, their effect cannot be evaluated with the data at present available.

Water Levels

The wells in the Miami area are usually drilled to at least the lower sandstone member of the Roubidoux. Casing is set and cemented below the Chattanooga shale, the remainder of the hole being left uncased. Thus, the wells derive their water from the Ordovician formations, and the more highly mineralized water from the overlying Mississippian rocks is cased off.

Water, as precipitation or influent seepage from streams, enters the outcrops in Missouri and Arkansas and tends to flow downdip. The water, being confined to the aquifer by the overlying shale, is under artesian pressure; and, on being tapped by a well, the water rises in the well some distance above the confining beds. Since artesian conditions prevail, the water levels in the wells are measures of the hydrostatic pressure in the aquifer and are points on the piezometric surface. There has been a continuous decline in water level throughout the area, with the greatest decline in the vicinity of Miami.

Siebenthal 8/ reports on the artesian wells in the Miami area, (1907), as follows:

> "At Miami there are three flowing wells — one at the waterworks, one piped to the ice plant from a point half a mile east of town, and the third two miles north of town. The third well has a small flow of sulphur water from a bed just below the Chattanooga shale. The well used at the ice plant is 1,680 feet in depth, and the one at the waterworks 1,000 feet. Both draw their supply from various horizons between 600 and 1,000 feet. The water is soft with a very slight sulphur odor. The temperature is $69\frac{1}{2}^{\circ}$ F. The pressure at the ice plant well is about 12 pounds and the flow is more than 100 gallons per minute ... These two wells affect each other decidedly, though half a mile apart."

The static water level in the Goodrich wells in May 1944 was about 250 feet below the surface; and, making allowances for differences in elevations, there has been a total decline of water level of about 252 feet in 27 years at Miami.

Siebenthal reports other flowing wells in northeastern Oklahoma at Afton, Vinita, Fairland, and other places where the water level is now considerably below the surface. It is apparent that most of the wells originally flowed in the Miami area at the beginning of the century.

Further evidence of a general lowering of water levels in the area was collected in 1942 by C. C. Williams of the Kansas office of the Ground Water Division. Williams reports that the pumps in the City of Picher wells have been lowered 150 feet in 10 years. The static level in the well at the Eagle-Picher Central Mill, about 3½ miles north of the Goodrich tract, dropped from 210 feet below the pump base in 1932 to 325 feet below the pump base in 1941.

That there has been a general lowering of water levels in Kansas wells tapping the Ordovician rocks is also reported by Williams. The water level at Cherokee has declined 62 feet since 1896. At Girard there was a drop of 85 feet from March 1929 to May 1944. At Frontenac, the operator reported a decline of 82 feet from 1912 to 1942. From 1918 to 1942 the water level dropped 29 feet at Arma. At Pittsburgh, Kansas, the water level in a well owned by the Kansas City Southern Railway declined 16 feet from 1928 to 1942 and 7 feet from 1942 to 1943. The Hull and Dillon Packing Company well at Pittsburgh declined 13 feet during the period from 1926 to 1942. At Altamount a decline of 8 feet from 1931 to 1940 is reported.

The declines in water levels in Kansas have not been as great as the declines in the Miami area but do indicate a general lowering of pressure throughout the entire aquifer. However, so far as known, the Kansas wells are not located between two faults as are the Miami area wells; and since the faults limit the extent of the cone of depression of the wells, it would not be unreasonable to expect larger drawdowns in this area than in the Kansas area.

Pumping Tests

Pumping tests of the Goodrich wells have been made as these wells have been completed. In April, after the completion of wells No. 3 and 5, well No. 3 was pumped for a continuous period of nine days at an average rate of 420 gpm; and after it was shut down, measurements were made of the recovery in well No. 5. After the completion of wells 1 and 2, well No. 1 was pumped for 46 hours at an average rate of 479 gpm. Measurements were made of the drawdown in wells 3 and 5; and when pumping was stopped, measurements were made of the recovery in wells 2, 3, and 5. Well No. 2 was also tested but its production was so low, only 100 to 110 gpm, that no appreciable interference effects were noticed. The results of the tests are shown on the accompanying hydrographs.

These hydrographs were analyzed by means of the Theis non-equilibrium formula 9/ in order to determine the coefficients of transmissibility and storage of the aquifer. The coefficient of transmissibility indicates the capacity of the aquifer to transmit water to wells. It is defined as the number of gallons of water a day that will move through a one-foot wide vertical strip of the height of aquifer under a hydraulic gradient of unity. The coefficient of storage is a measure of the amount of water released from storage in a formation when the artesian head is lowered. It is defined as the volume of water, measured in cubic feet, released from storage in each one foot square column of the aquifer having a height equal to the thickness of the aquifer when the artesian head is lowered one foot. Together, these two coefficients determine the amount and rate of decline of water levels caused by the pumping of wells.

The coefficients of transmissibility and storage obtained by application of the non-equilibrium formula to the results of the pumping tests are shown in the following table.

Date of test	Pumped well turned on or off	Observation well	Coefficient of Transmissibility (T) gpd/ft	Average T	Coefficient of storage (S)	Average S
Apr. 2	3 off	5	33,650	33,650	.0000560	.0000560
May 19	1 on	3	26,900)	26,325	.0000320)	.0000346
May 21	1 off	3	25,750)		.0000373)	
May 19	1 on	5	26,000)	26,890	.0000273)	.0000316
May 21	1 off	5	27,780)		.0000358)	
May 21	1 off	2	19,250	19,250	.0000810	.0000810
		Averages		26,504		.0000508
		Averages excluding #2		28,922		.0000407

Table 1. Coefficients of Transmissibility and Storage Determined from Pumping Tests on Wells of the Goodrich Plant.

The coefficients determined in wells 3 and 5 during the test of well No. 1 check each other very closely, but there is a considerable discrepancy in the other two. The higher figures found in well No. 5 when No. 3 was tested is possibly due to the presence of a water-producing arkose bed in well No. 3 that is not present in any of the other wells. The determination made in well No. 2 is a very poor one because the well is located adjacent to the Miami trough, and, hence, reflects an abnormal condition of the aquifer.

The presence of the Miami trough is apparent in all of drawdown and recovery curves obtained. When these curves were analyzed, it was found that after the first several hours the actual drawdowns and recoveries were appreciably and progressively greater than those theoretically expected from the type curve determined from the first part of the test. An anomaly such as this could be caused by either the introduction of additional pumpage or by a lateral change in the aquifer. However, the fact that it occurred in all tests, plus the knowledge that there was no pumpage nearer than the City of Miami, the time of which did not coincide with the observed anomaly, clearly indicates that it was due to a change in the aquifer.

The known presence of the Miami trough nearby seemed to provide a sufficient explanation of the anomaly, and computations were made of the effect this would have on the water levels if it constituted an impermeable boundary to the aquifer. The computed effects agreed closely with the difference between the observed and theoretical drawdowns and recoveries, and thus supported the conclusion that the aquifer was definitely limited by the Miami trough.

The coefficients of transmissibility and storage given in Table 1 were all determined from the first part of the drawndown and recovery curves.

Boundaries

Before an estimate can be made of the decline in water-level caused by the withdrawal from an aquifer of a known amount of water, its lateral boundaries as well as its hydrologic properties must be known. Recharge in the outcrop area tends ultimately to decrease the rate of decline caused by pumping of wells, while faulting or lensing out of the aquifer has the opposite effect and tends to increase the rate of decline. The effect of a lateral boundary to an aquifer decreases with the distance of the boundary from the wells.

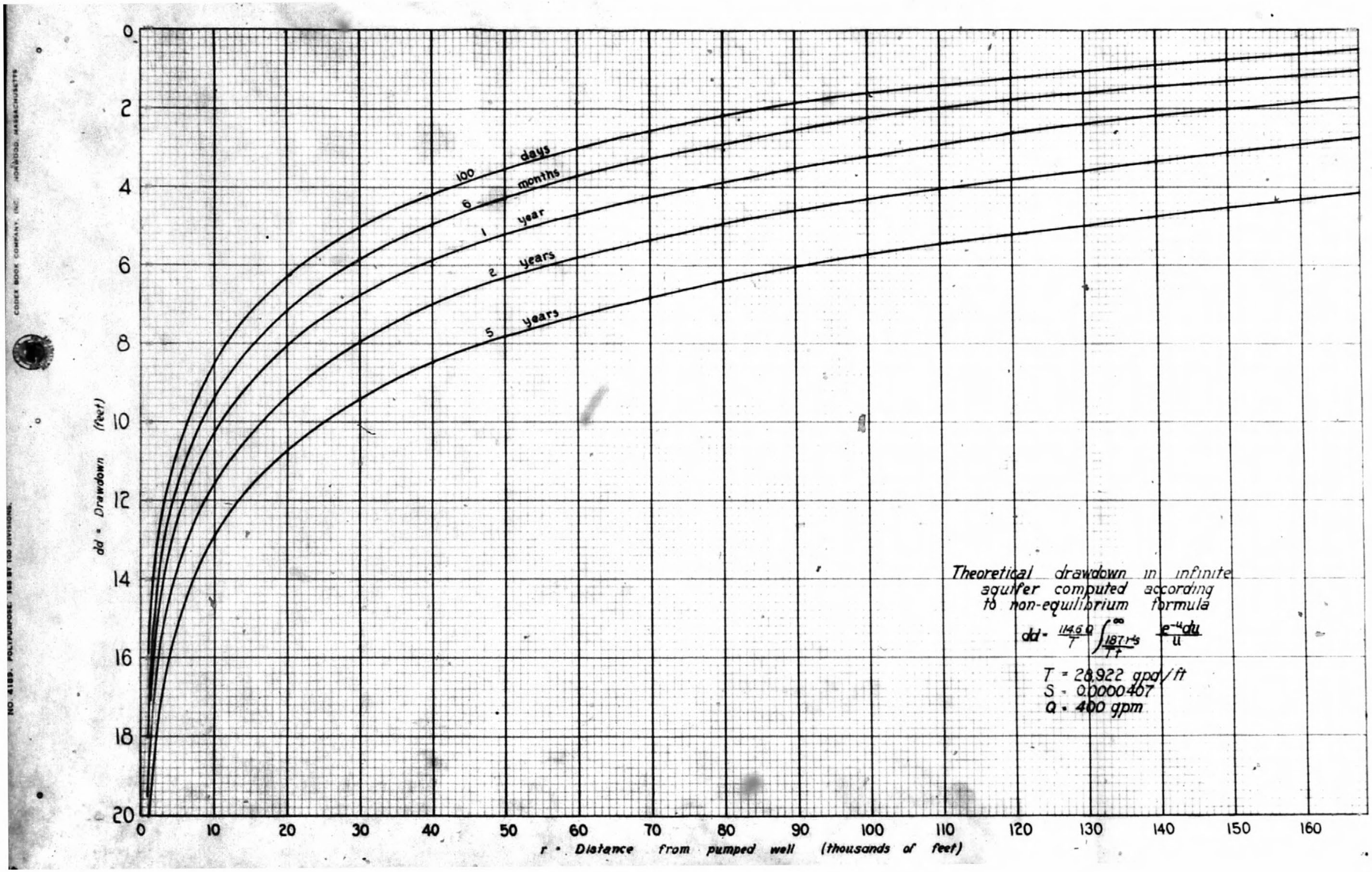
It was originally thought that since there was no displacement along that part of the Miami trough adjacent to the proposed Goodrich development, the trough would have no effect on wells there. However, as has been shown, this assumption is now known to be invalid. The pumping tests clearly indicate that, at least for short periods of pumping, the trough behaves as an impermeable boundary. It seems probable that although there is no actual displacement of beds, the compression and silicification accompanying the deformation has been sufficient to effectively seal the water-bearing beds. The tests were not of great enough duration to determine the influence of the Seneca fault; but since the deformation along it is even more pronounced than along the Miami trough, it presumably is also an impermeable barrier.

Theoretical Drawdowns

The average coefficients of transmissibility and storage determined from the pumping tests were used to compute by the non-equilibrium formula the curves in figure 2, which show the drawdown at the end of different periods of pumping produced at various distances from a well pumped at the rate of 400 gpm. An aquifer of infinite extent was assumed in computing these curves.

For the purpose of estimating drawdowns of water levels at the Goodrich plant, a continuous rate of pumping of 400 gpm from each of wells 1, 3, 4, 5, 6, and 7, and 200 gpm from well No. 2 was assumed.

The estimated drawdown of water level in well No. 5 below the original level as a result of the assumed pumpage is given in Table 2. The

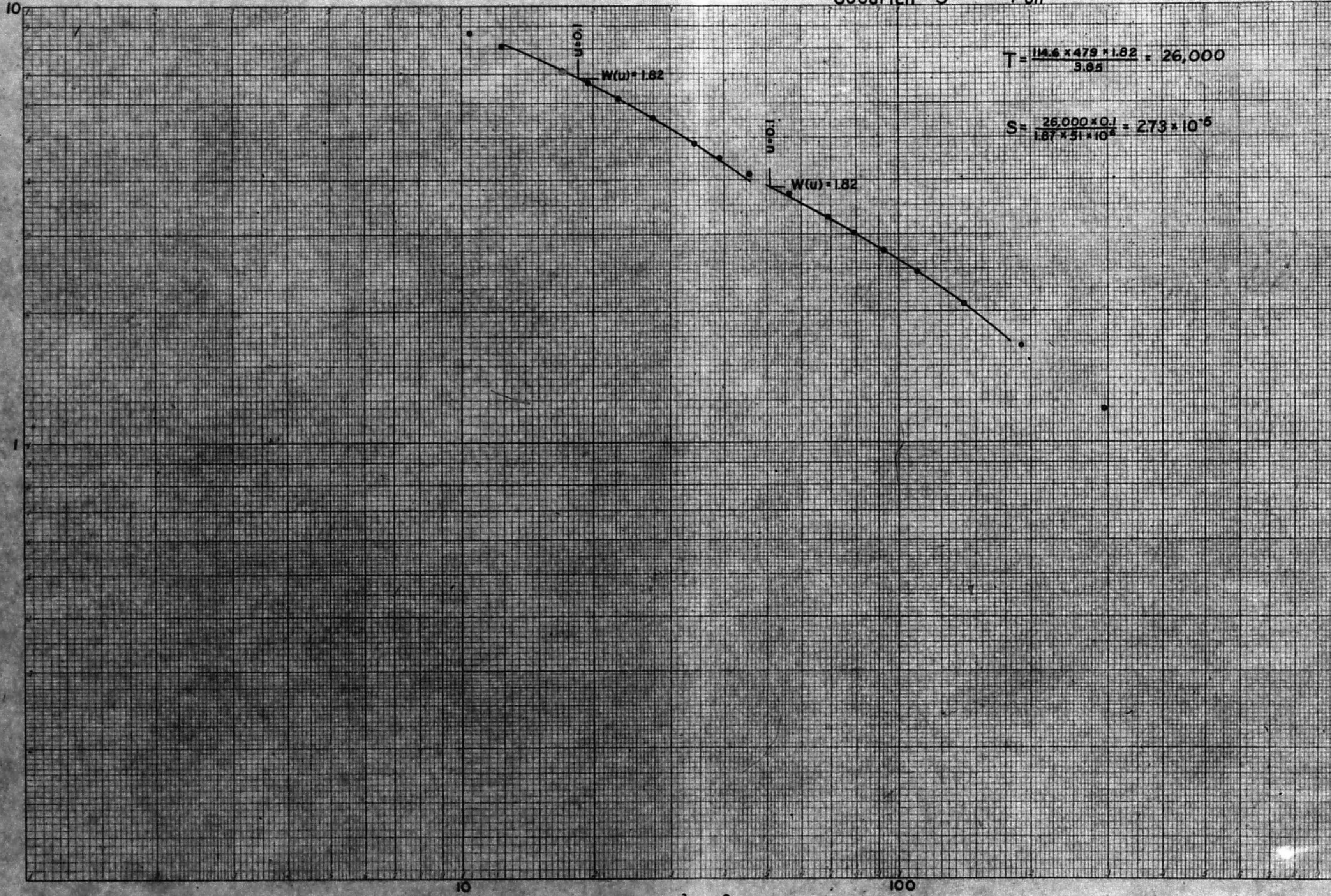

100 days
6 months
1 year
2 years
5 years
dd = Drawdown (feet)
r = Distance from pumped well (thousands of feet)
Theoretical drawdown in infinite aquifer computed according to non-equilibrium formula
$dd = \frac{114.6\,Q}{T}\int_{\frac{1.87 r^2 S}{Tt}}^{\infty}\frac{e^{-u}\,du}{u}$
T = 28,922 gpd/ft
S = 0.0000407
Q = 400 gpm

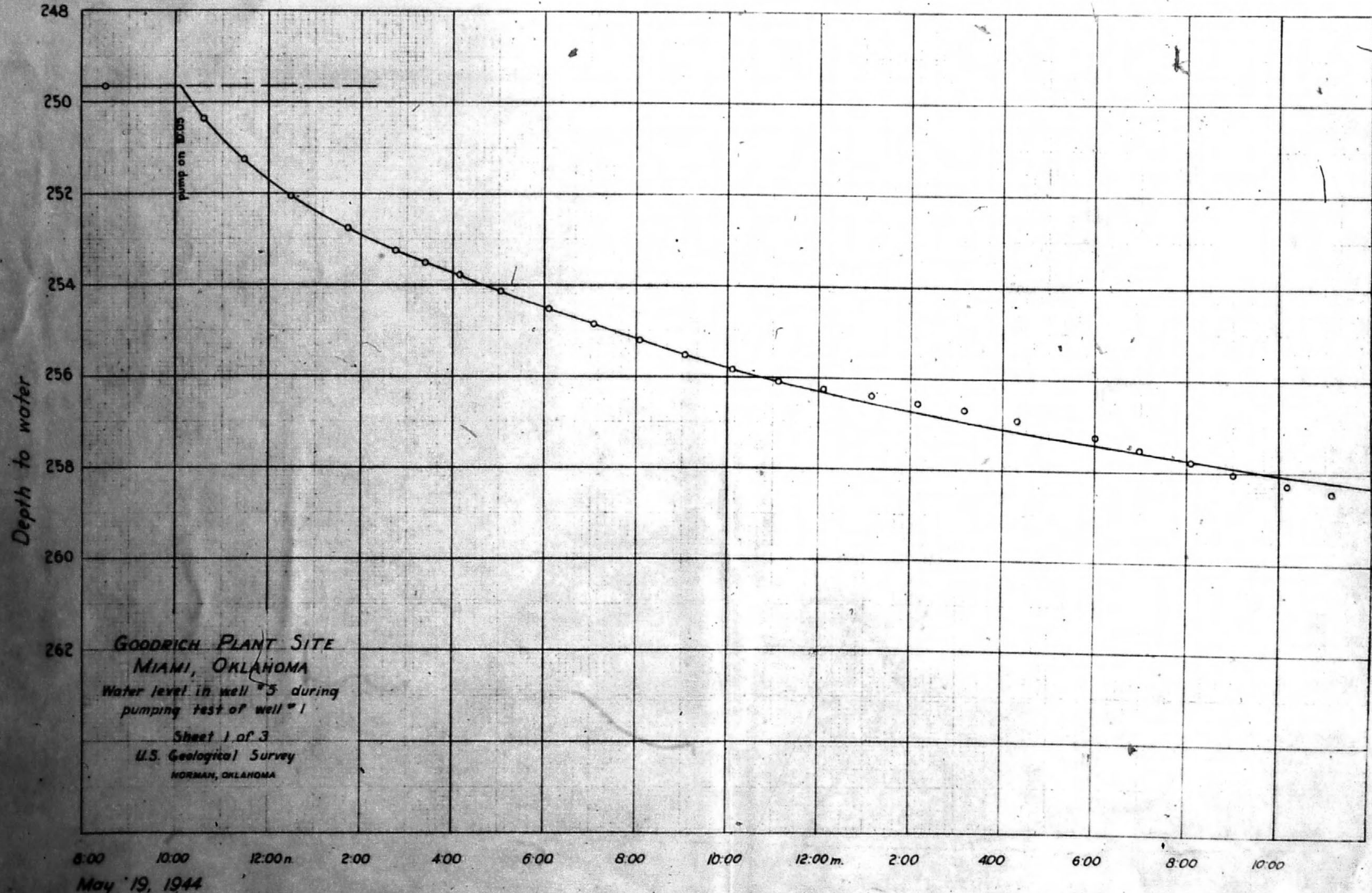
drawdown caused in a well from its own pumping was determined from the specific capacity of the well; the interference caused by the other wells was determined from the non-equilibrium formula, and the effect of the two faults was evaluated by means of the Theis' image well theory 10/. The principal of the image well theory is that the effect of a single boundary can be evaluated by assuming another well pumping the same amount of water as the actual well placed on a line drawn through the actual well perpendicular to the boundary, at an equal distance from it and on the opposite side. The total drawdown at any point in the aquifer is equal to the sum of the drawdowns (based on an infinite aquifer) at that point caused by both the actual and image wells. When more than one well is pumping in the area, each pumping well must have an image well and the resultant drawdown at a point is equal to the sum of the drawdowns due to all the wells and all the image wells. A second boundary complicates matters, since both actual and image wells must be "reflected" perpendicular to the second boundary and this second group of "reflected" wells must in turn, be reflected perpendicular to the first boundary. Thus the system of reflected wells becomes infinite, reflection of reflection, ad infinitum. However, the effect of the reflected wells will become less as the distance increases and only the first few reflections need be calculated. In this report, calculations have been further simplified by grouping the wells together and assuming the total pumpage of all the wells in the group is coming from one well at the average distance from No. 5 well. The appended sketch shows the location and distances of the image wells used in calculating table 2. The system of image wells was not carried farther since the distances are such that their effect will be small, and the effect of the outcrop will probably cancel them out.

	Drawdown at end of period of continuous pumping				
	100 days	6 months	1 year	2 years	5 years
Drawdown produced by well 5 alone pumping 400 gpm	213	215	217	218	219
Interference of other six wells (total pumpage 2200 gpm	67	71	76	83	91
Reflection of all 7 wells on Miami trough (2600 gpm)	56	61	67	76	84
Effect of first set of 4 image wells (two reflections on each barrier, total pumpage 10,400 gpm)	16	32	54	79	114
Effect of 2nd set of 4 image wells (10,400 gpm)	1	6	17	34	65
Effect of 3rd set of 4 image wells (10,400 gpm)	0	1	6	17	42
Total drawdown well 5	353	386	437	507	615

Table 2. Theoretical Drawdown of Water Level in Well No. 5 below Original Water Level.

Goodrich #5 #1 on




248
250
252
254
256
258
260
262
Depth to water
pump on 10:05
GOODRICH PLANT SITE
MIAMI, OKLAHOMA
Water level in well #5 during
pumping test of well #1
Sheet 1 of 3
U.S. Geological Survey
NORMAN, OKLAHOMA
8:00
10:00
12:00 n.
2:00
4:00
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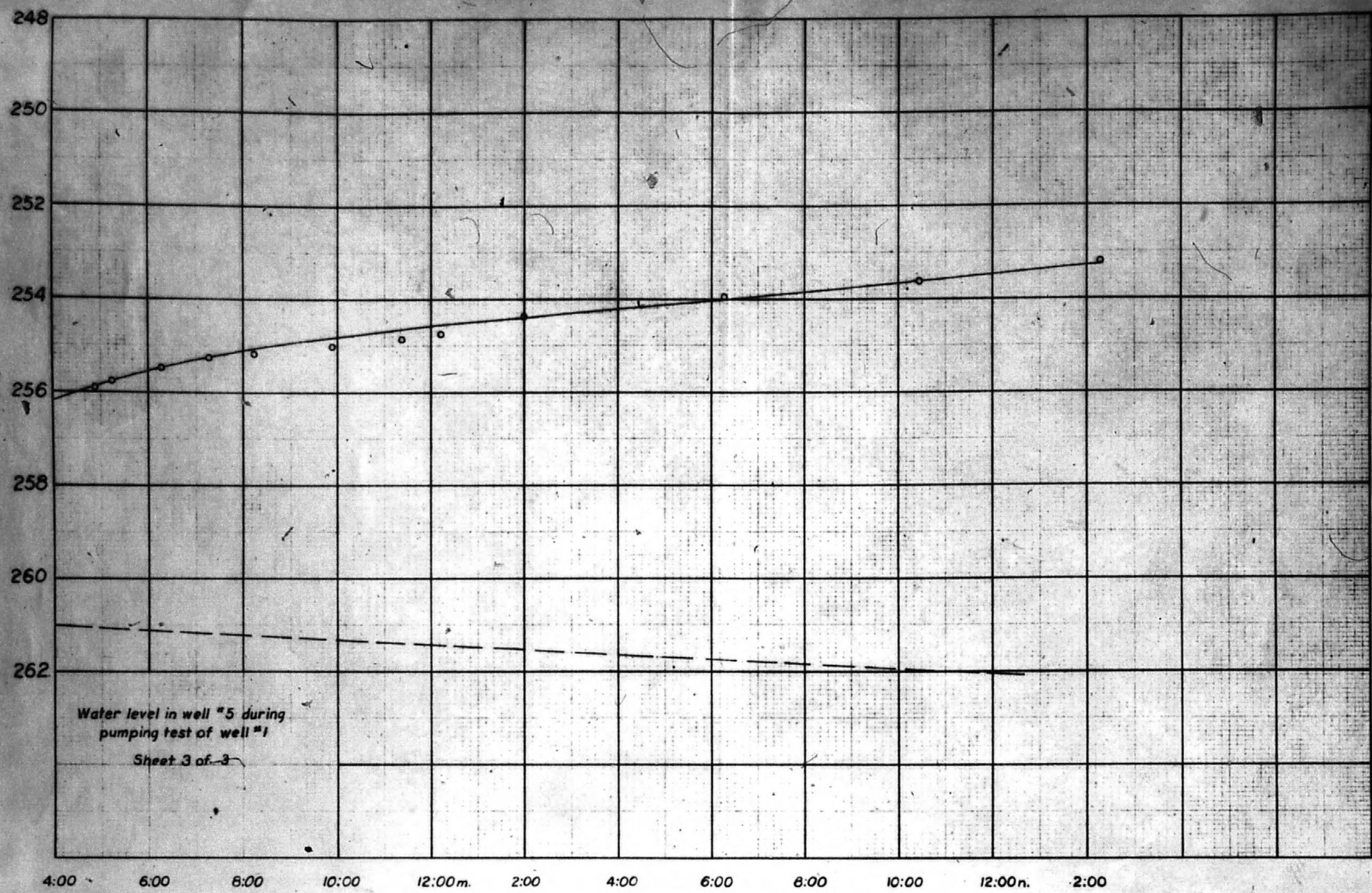
May 19, 1944


248
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Water level in well #5 during
pumping test of well #1
Sheet 3 of 3
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12:00m.
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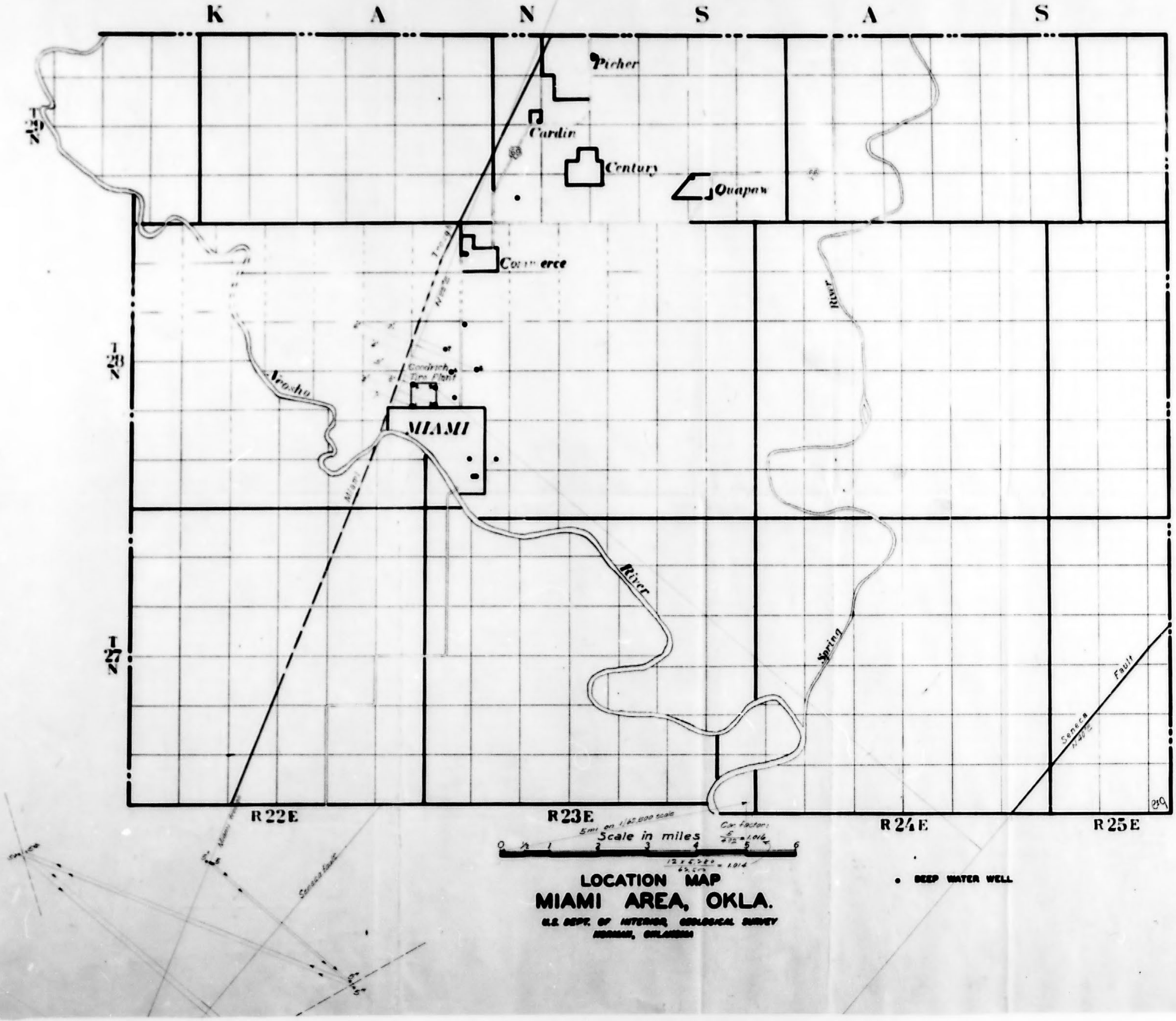
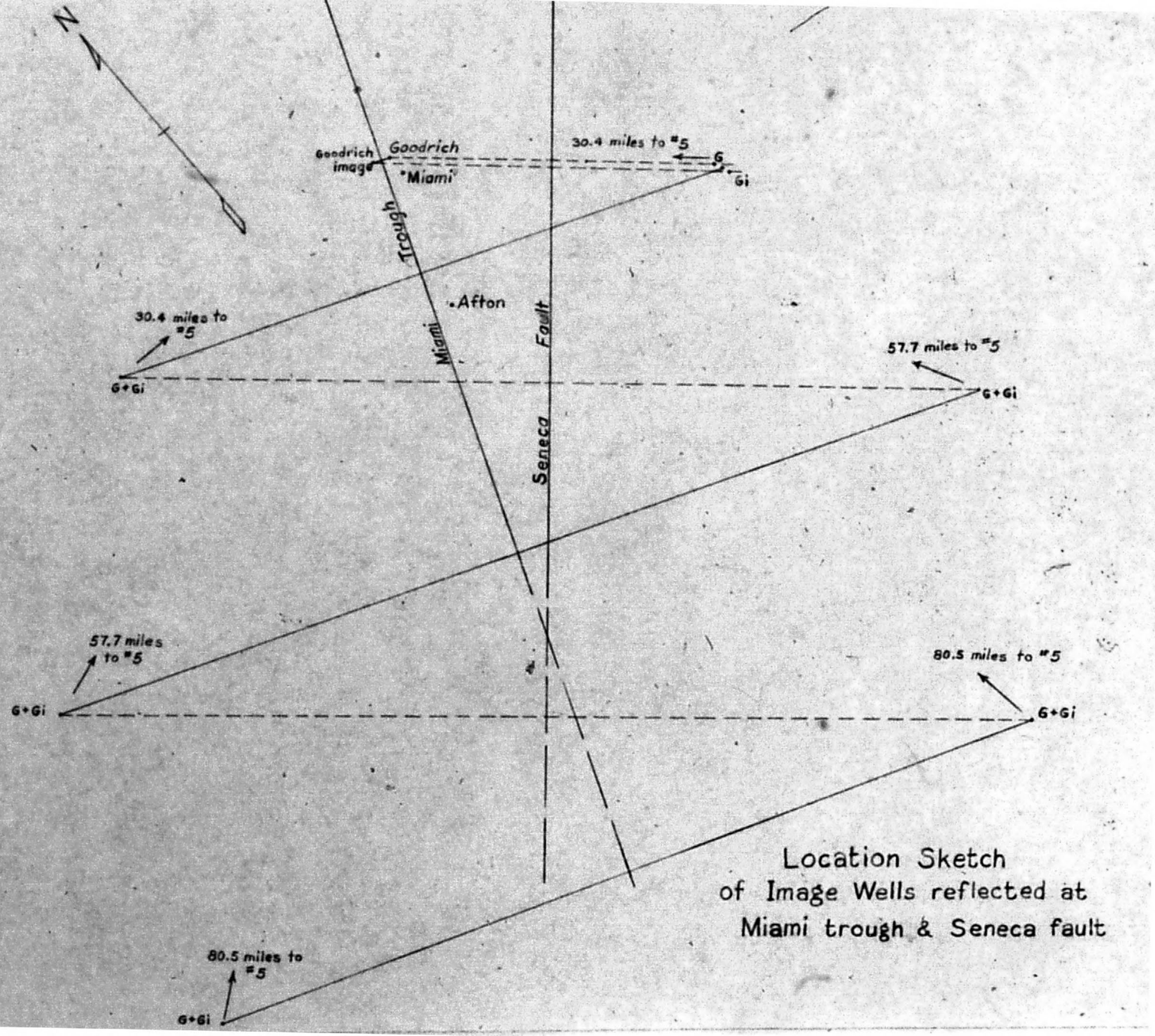


LOCATION MAP
MIAMI AREA, OKLA.
U.S. DEPT. OF INTERIOR, GEOLOGICAL SURVEY
NORMAN, OKLAHOMA



Location Sketch
of Image Wells reflected at
Miami trough & Seneca fault

Effect on outlying wells -- The effects on the wells at Miami and Afton have been computed for a total pumpage of 2600 gpm, and are given in the following table:

Table 5. Effect of pumpage of 2600 gpm. from Goodrich Wells on wells at Afton.

Well	Distance from Goodrich plant	Drawdown caused by pumping 2,600 gpm at Goodrich Plant for period of			
		6 mos.	1 year	2 years	5 years
City of Miami	1.9 mi.	149	201	269	381
City of Commerce	2.6 mi.	139	185	253	359
City of Quapah	5.3 mi.	98	139	206	316
City of Picher	7.4 mi.	94	133	200	304
City of Afton	14.7 mi.	85	142	216	330

The drawdown is proportional to the rate of pumping, and hence, to calculate the drawdown caused by any other rate of pumping it is only necessary to multiply the above figures by the proper fraction. For instance, to compute the drawdown caused by pumping each well 300 gallons per minute the drawdown indicated on the graph or in the table should be multiplied by 0.75.

Accuracy of results.--Several sources of error are encountered in analyzing the behavior of an aquifer by means of the Theis non-equilibrium formula. The formula assumes that the coefficients of transmissibility and storage do not differ from place to place and do not change with time, but the pumping tests give variable results. Compensation for differences in the coefficients from place to place has been made by averaging the results, as shown in Table 1. In regard to changes with time, the transmissibility probably will not change significantly unless the aquifer becomes partly unwatered. In view of the fact that all or nearly all the water is derived from depths greater than the practicable pumping lift, it is believed that appreciable unwatering of the aquifer will not occur. The coefficient of storage will probably increase slowly with time, owing to the fact that the water is not released from storage instantaneously, as assumed in the computations, but instead is released gradually. This means that more water will be derived from storage than assumed in the computations, and the drawdowns will be less than assumed. However, even if the coefficient of storage at the end of five years is several times as large as that shown by the relatively brief pumping tests made by the Geological Survey, the drawdowns will not be much less than computed.

The fact that the Miami trough definitely bounds the aquifer is brought out by the continuation of the type curve in the appended graphs, the low discharge of well 8, and the larger drawdowns reported for wells in the Miami area during past years as compared to the drawdowns in Kansas. However, the Miami trough may not continue as an impermeable barrier south of the Goodrich tract, and the Seneca fault may not be entirely impermeable throughout its length; thus some water may move across these barriers, whereas the computations assume that they are impermeable. Nevertheless, the reductions in drawdown that would result from differences from the assumed conditions would be small, and would not appreciably change the conclusions given beyond.

During the pumping tests, measurements of discharge were made by means of a Sparling meter and a standard orifice. The orifice measurements indicated discharges approximately 10 percent greater than those given by the Sparling meter. The lower figures were used in making the computations.

The computations, based on the lower discharge figures, the average transmissibility as determined by the tests, the assumption of no change in the coefficient of storage, and the assumption that both the Miami trough and the Seneca fault act as impermeable boundaries to the cone of depression, give the maximum probable values for drawdown at the assumed rate of pumpage. Thus, a program of pumpage based on these results would have a factor of safety, and, at the assumed rate of pumpage, declines of water level greater than those shown should not occur. At different rate of pumpage the drawdowns will be proportional to those shown for the assumed rate, as indicated previously.

Conclusions

It is apparent that pumping 2,600 gallons per minute from the Goodrich tract will cause excessive drawdowns at the Goodrich plant itself and in wells in the surrounding area. However, if the need for water is sufficiently urgent, it would be possible to pump about 1,800 gallons per minute at the Goodrich site. Under the conditions assumed in the computations, the water levels would be about 600 feet below the surface at the Goodrich site at the end of two years of pumping; if the conditions with respect to the impermeability of the boundaries of the aquifer are less unfavorable than assumed, it might be possible to pump at the rate of 1,800 gallons per minute for a few additional years before the water levels are 600 feet below the surface. The effect of the pumpage will be such that the pump bowls of most of the wells in the surrounding area will have to be lowered. At least in the Miami public-supply wells, this will require reaming out the lower parts of the wells to permit lowering the pump bowls.

It would be inadvisable to continue any program of heavy pumpage for more than a few years. Other sources of water supply to be used to supplement the ground-water supply should be developed for such permanent industries as the Goodrich plant.

Neosho (Grand) River to the west and Spring River to the east of the Goodrich tract are possible sources of supplies. A plan to recharge the aquifer supplying the wells by pumping cold filtered river water into the wells during the winter months might prove to be feasible. The use of recharge wells for returning ground water to the aquifer after it has been used for cooling purposes may be considered, although this would eventually lead to warming of the aquifer and a corresponding reduction in the efficiency of equipment cooled by means of the ground water.

The only additional source of moderate or large supplies of ground water is the Mississippian rocks above the Ordovician. The water from the Mississippian rocks is not suitable for most uses, but with suitable equipment might be satisfactory for cooling purposes. The alluvium of the stream valleys does not yield large supplies of water to wells.

In conclusion, it appears that, although sufficient water can be obtained from the Ordovician rocks to meet the present needs of the Goodrich plant for a few years, the overall effects of such pumpage would be detrimental to the areas as a whole, and supplementary water supplies should be developed.

REFERENCES

1. Weidman, S., The Miami-Picher zinc-lead district, Oklahoma: Oklahoma Geol. Survey Bull. 56, p. 29, 1932.

2. Idem.: pp. 31-35, 1932.

3. Fowler, G. M. and Lyden, J. P., Structural deformation in the Tri-State district: Min. and Met., vol. 15, no. 334, pp. 415-418, Oct., 1934.

4. Fowler, G. M., oral communication.

5. Weidman, S., op. cit.: p. 37, 1932.

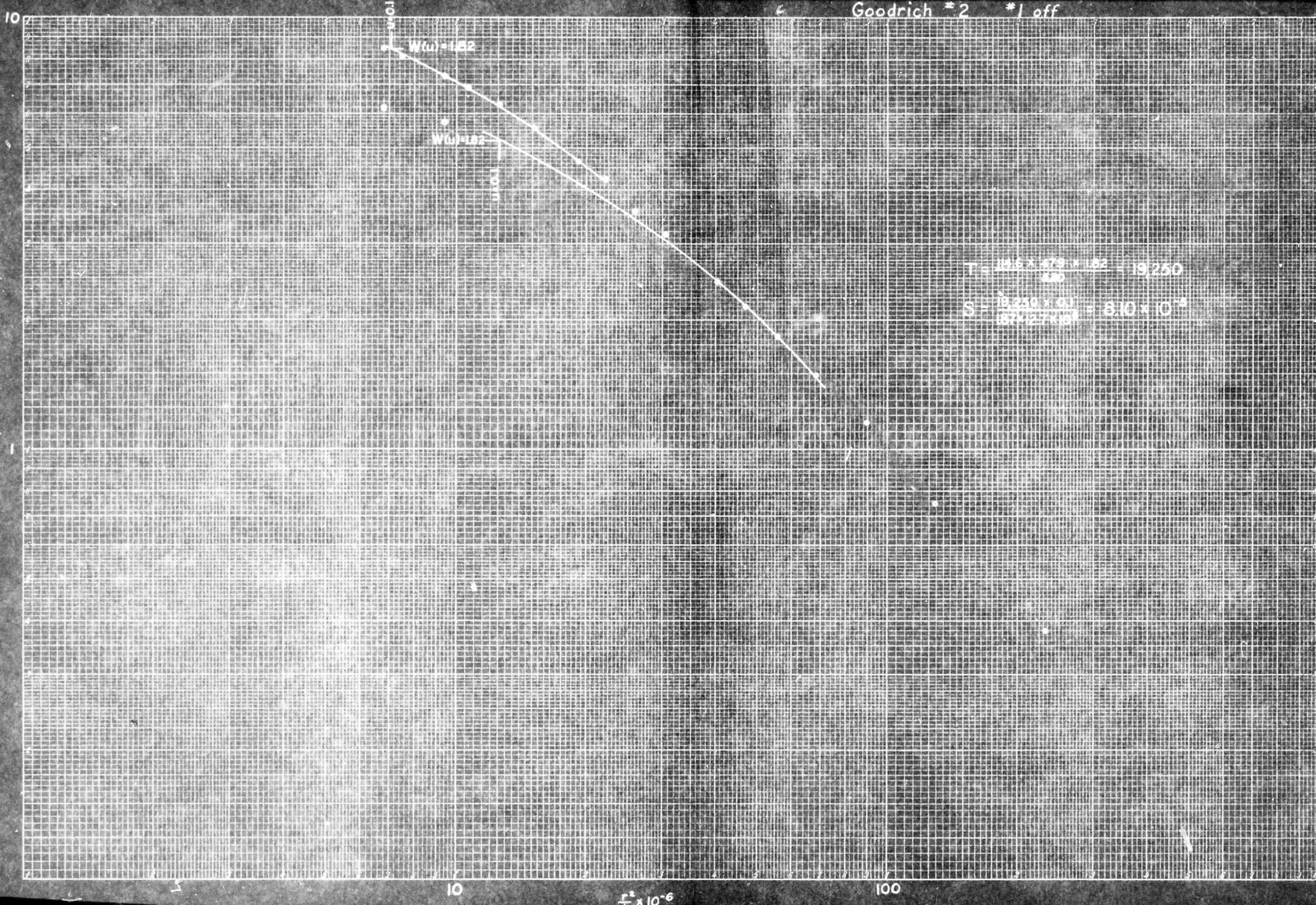
6. Siebenthal, C. E., Mineral resources of northeastern Oklahoma: U. S. Geol. Survey Bull. 340-C, pp. 197, 198, 1908.

7. Weidman, S., op. cit.: pp. 35-37, 1932.

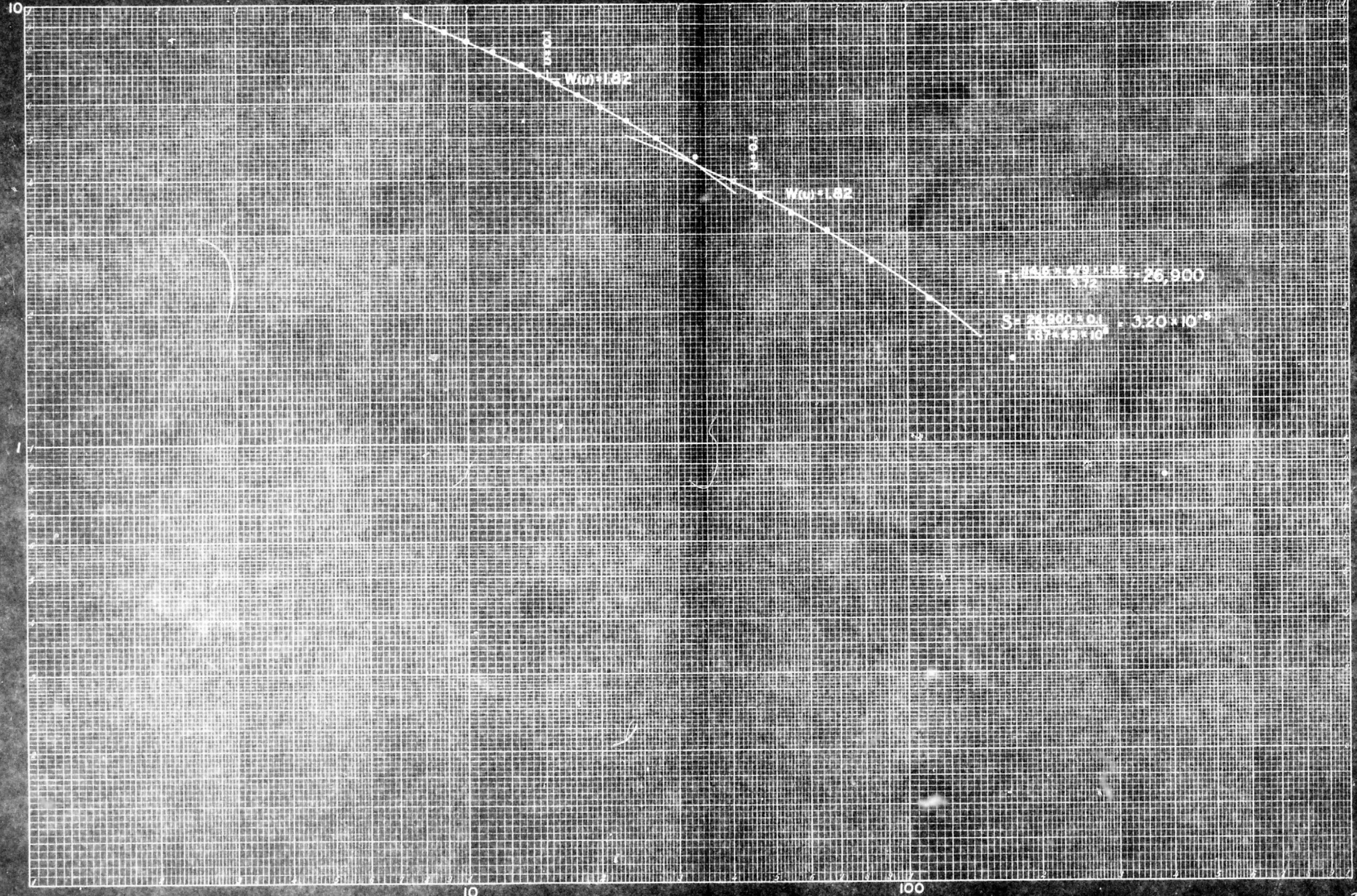
8. Siebenthal, C. E., op. cit.: pp. 225-228, 1908.

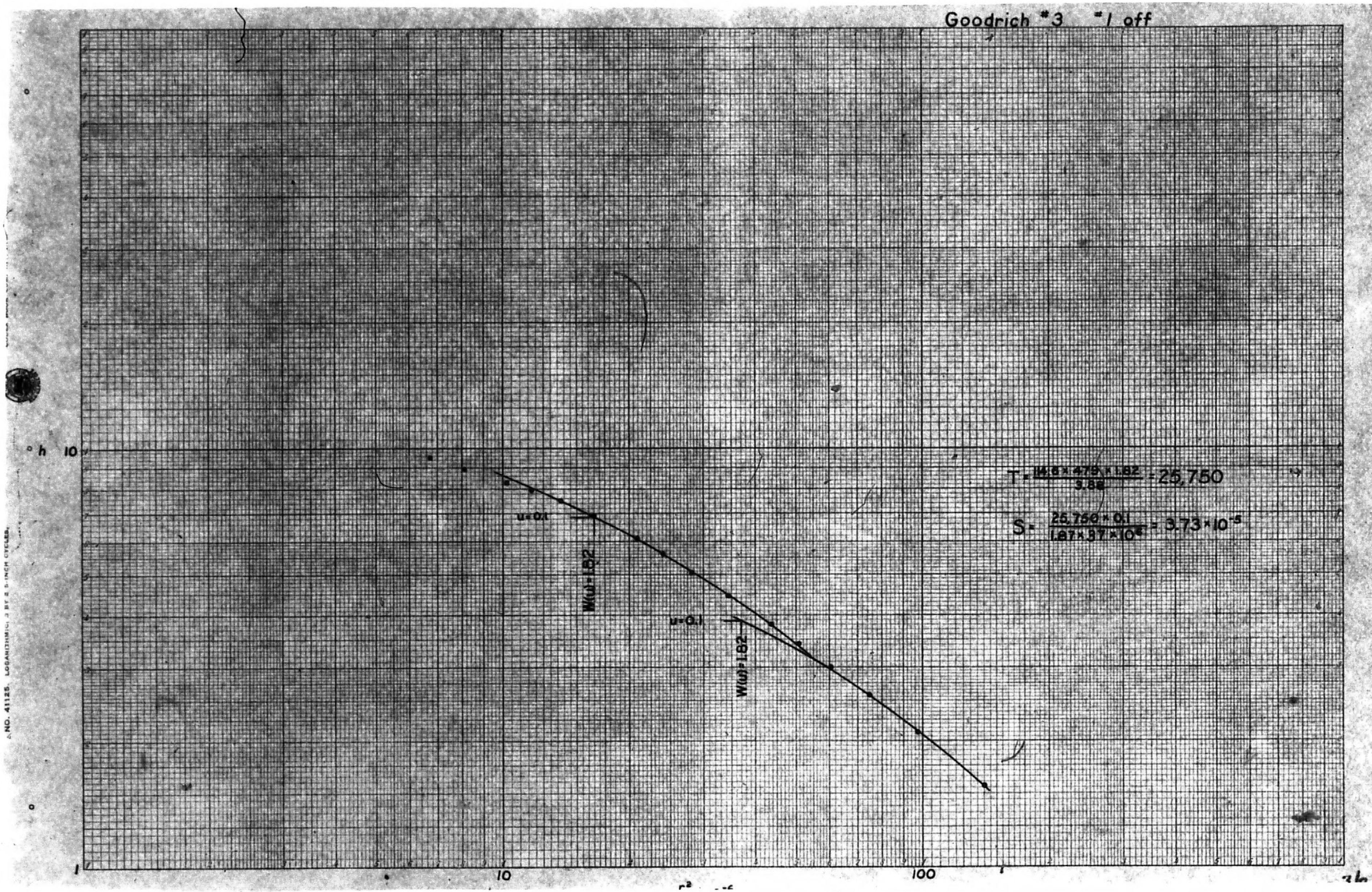
9. Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., 1935, pp. 519-524.

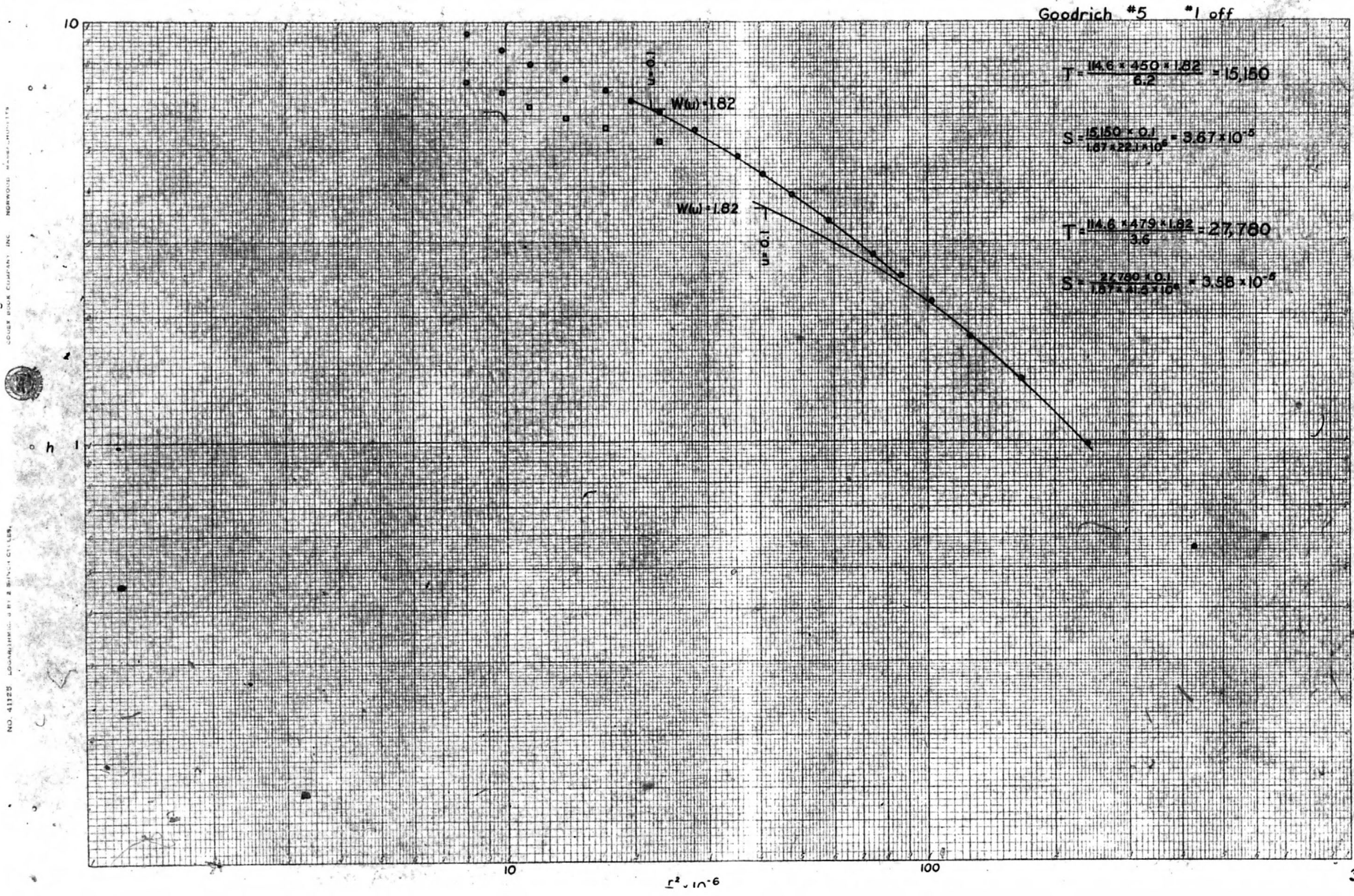
10. Theis, C. V., Chart for computation of drawdown in wells in vicinity of a discharging well: U. S. Geol. Survey, Ground Water Division circ., 1939.

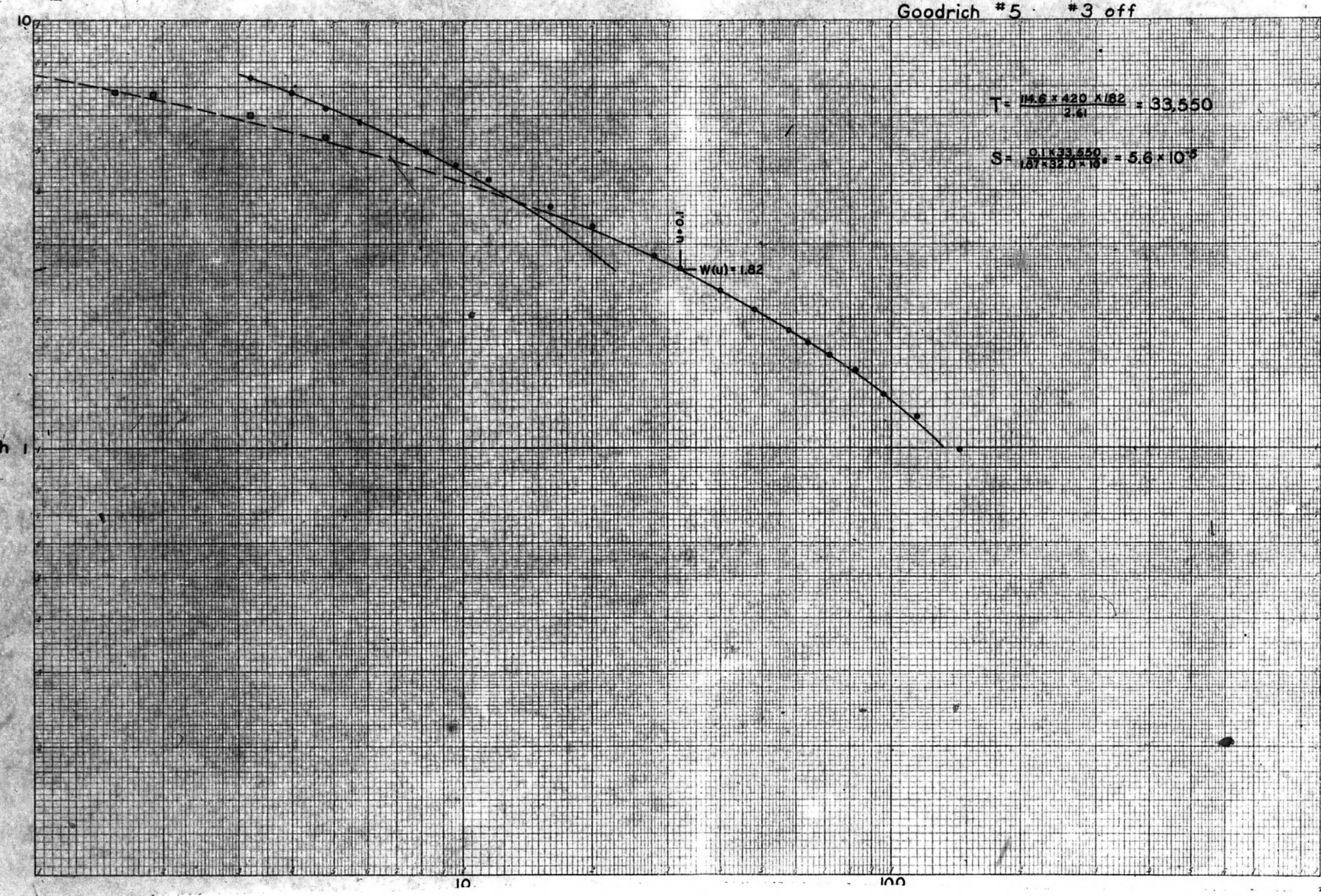

Goodrich #2 #1 off
u=0.1
W(u)=1.82
W(u)=1.82
1.0=u
10
1
10
100
r²/t × 10⁻⁶
T = 14.6 × 479 × 1.82 / 660 = 19,250
S = 19,250 × 0.1 / 187 × 12.7 × 10⁶ = 8.10 × 10⁻⁵

Goodrich #3 #1 on

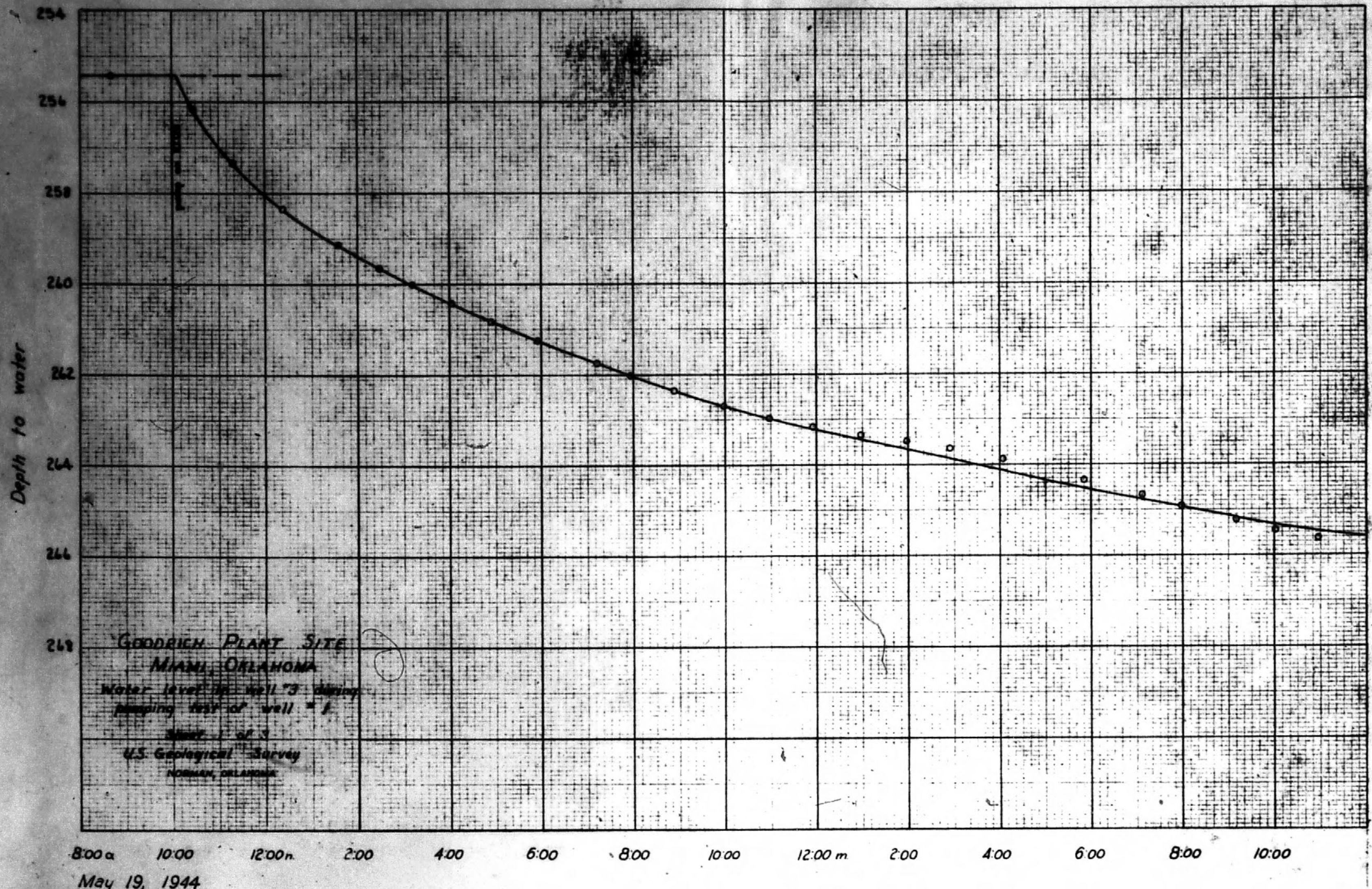


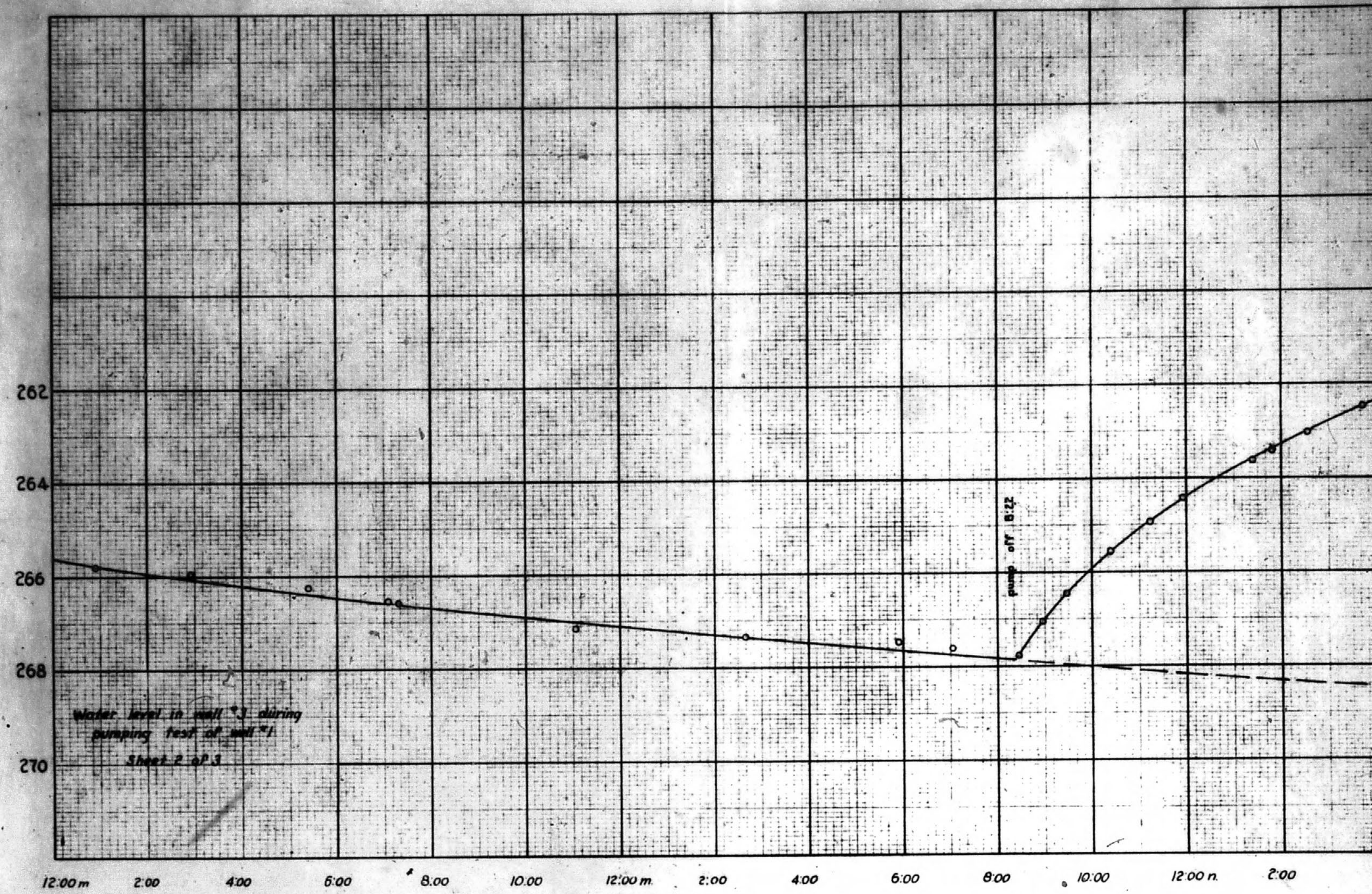

Goodrich #3 #1 off
h
10
u=0.1
W(u)=1.82
u=0.1
W(u)=1.82
T = 14.6 × 479 × 1.82 / 3.88 = 25,750
S = 25,750 × 0.1 / 1.87 × 37 × 10^6 = 3.73 × 10^-5
1
10
100
NO. 41125. LOGARITHMIC 3 BY 2 5-INCH CYCLES

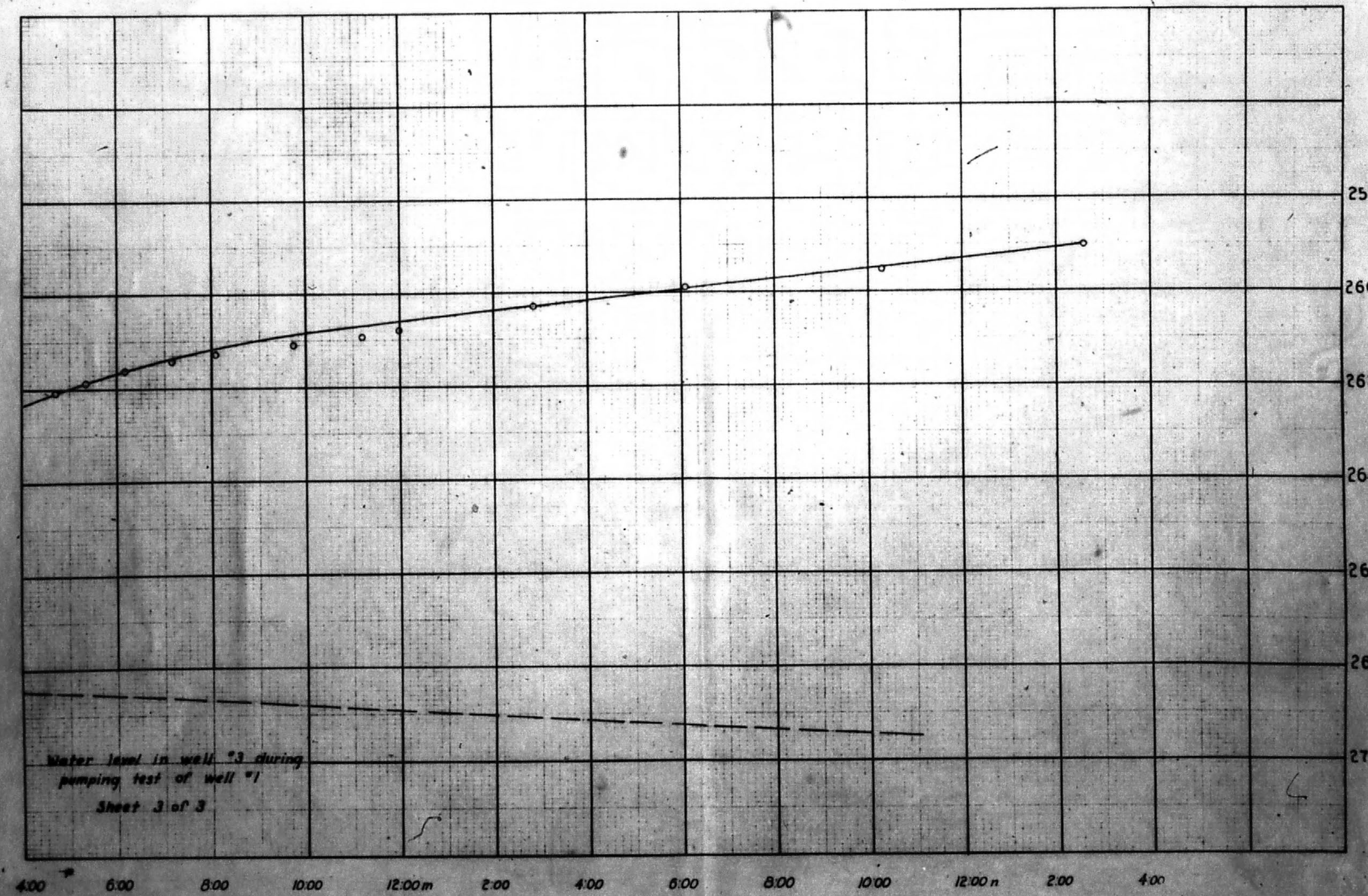

Goodrich #5 #1 off
$T = \frac{114.6 \times 450 \times 1.82}{6.2} = 15,150$
$S = \frac{15,150 \times 0.1}{1.87 \times 22.1 \times 10^6} = 3.67 \times 10^{-5}$
$T = \frac{114.6 \times 479 \times 1.82}{3.6} = 27,780$
$S = \frac{27,780 \times 0.1}{1.87 \times 41.5 \times 10^6} = 3.58 \times 10^{-5}$
u = 0.1
W(u) = 1.82
W(u) = 1.82
u = 0.1
10
1
h
10
100
$r^2 \times 10^{-6}$
NO. 41125 LOGARITHMIC 3 BY 2 INCH CYCLES
CODEX BOOK COMPANY INC. NORWOOD MASSACHUSETTS



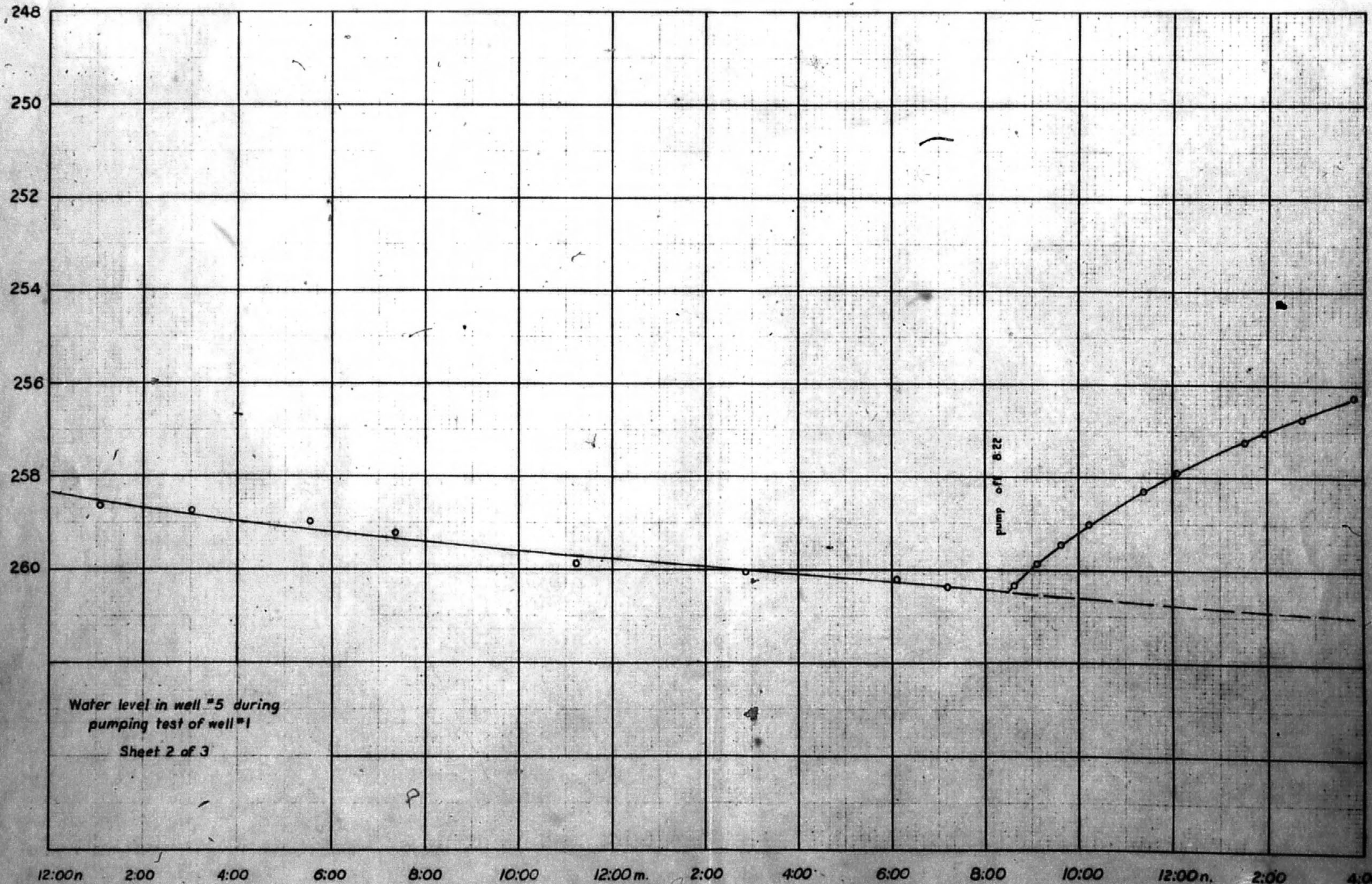
Goodrich #5 #3 off
T = 114.6 × 420 × 1.82 / 2.61 = 33,550
S = 0.1 × 33,550 / 1.87 × 32.0 × 10⁶ = 5.6 × 10⁻⁵
u = 0.1
W(u) = 1.82
h
10
1
10
100

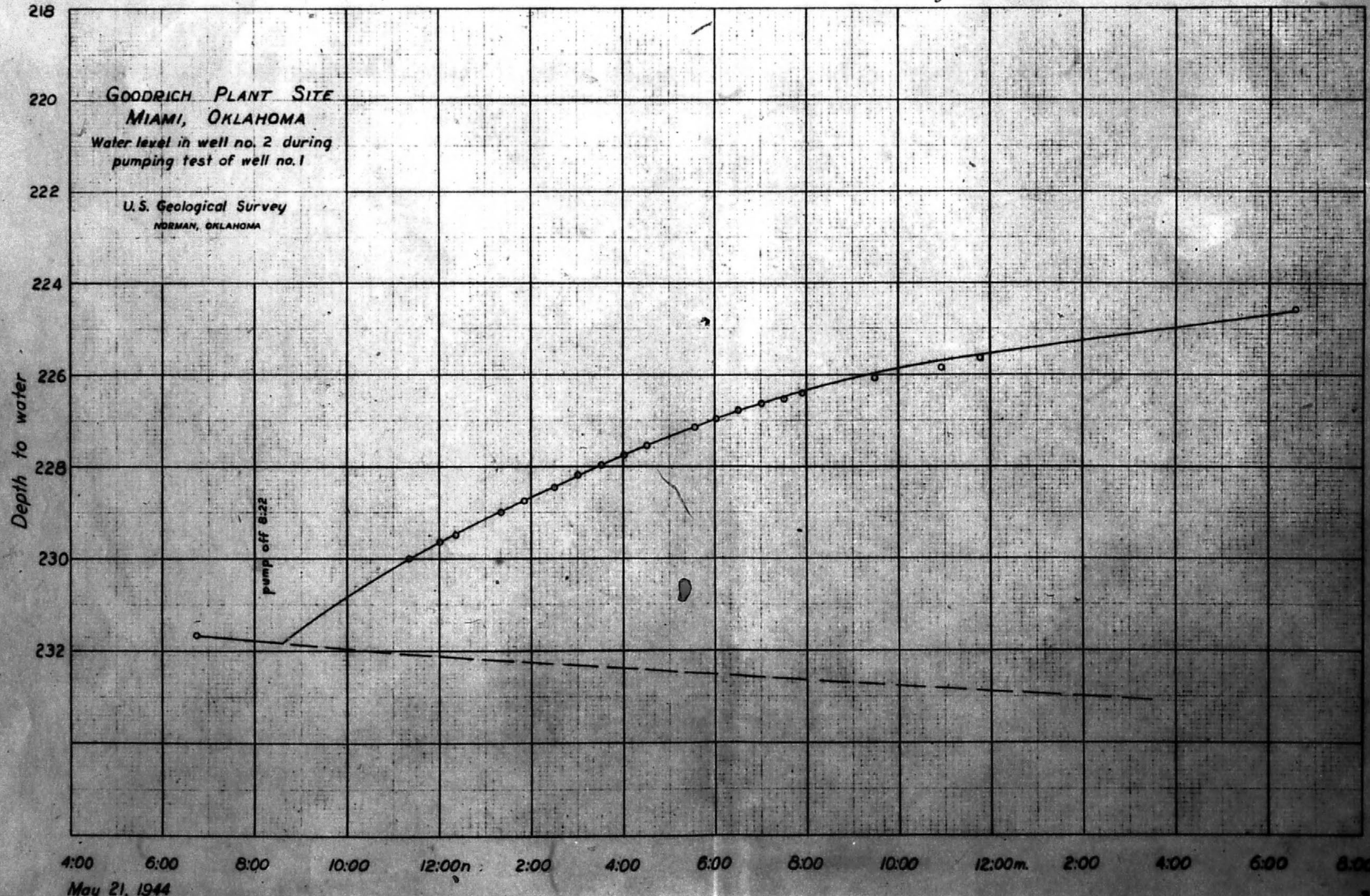

GOODRICH PLANT SITE
MIAMI, OKLAHOMA
Water level in well "3 during
pumping test of well "1
Sheet 1 of 3
U.S. Geological Survey
NORMAN, OKLAHOMA
Depth to water
254
256
258
260
262
264
266
268
8:00 a
10:00
12:00 n.
2:00
4:00
6:00
8:00
10:00
12:00 m
2:00
4:00
6:00
8:00
10:00
May 19, 1944


262
264
266
268
270
12:00 m
2:00
4:00
6:00
8:00
10:00
12:00 m.
2:00
4:00
6:00
8:00
10:00
12:00 n.
2:00
pump off 8:22
Water level in well #3 during
pumping test of well #1
Sheet 2 of 3



258
260
262
264
266
268
270
Water level in well #3 during pumping test of well #1
Sheet 3 of 3
4:00
6:00
8:00
10:00
12:00 m
2:00
4:00
6:00
8:00
10:00
12:00 n
2:00
4:00


248
250
252
254
256
258
260
pump off 8:22
Water level in well #5 during
pumping test of well #1
Sheet 2 of 3
12:00 n
2:00
4:00
6:00
8:00
10:00
12:00 m.
2:00
4:00
6:00
8:00
10:00
12:00 n.
2:00
4:00



GOODRICH PLANT SITE
MIAMI, OKLAHOMA
Water level in well no. 2 during pumping test of well no. 1
U.S. Geological Survey
NORMAN, OKLAHOMA
Depth to water
218
220
222
224
226
228
230
232
pump off 8:22
4:00
6:00
8:00
10:00
12:00n
2:00
4:00
6:00
8:00
10:00
12:00m.
2:00
4:00
6:00
8:00
May 21, 1944