Microtime Measurements in Aquifer Tests on Open-Hole Artesian Wells

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GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1545-A

Prepared in cooperation with the
Board of Commissioners, Martin County,
North Carolina

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

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By GRANVILLE G. WYRICK *and* EDWIN O. FLOYD

METHODS OF AQUIFER TESTS

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MICROTIME MEASUREMENTS IN AQUIFER TEST ON OPEN-HOLE ARTESIAN WELLS

By Granville G. Wyrick and Edwin O. Floyd

ABSTRACT

Water-level and time measurements made during the early seconds or minutes of drawdown or recovery tests on a pumped or flowing well may be used to determine the transmissibility of an artesian aquifer. This report describes a photographic method, using a motion picture camera, stopwatch, and manometer tube, of recording water-level measurements and microtime measurements (time measurements at intervals of about $\frac{1}{25}$ second) in a well penetrating a leaky artesian aquifer. The results of the test are compared with the results obtained from conventional measurements at a control well. Further tests are necessary to determine the utility of this method under different field conditions.

INTRODUCTION

There are few satisfactory methods for determining the coefficient of transmissibility of an artesian aquifer from water-level measurements made at pumped or flowing wells unless data from nearby observation wells are used. One of the problems involved in using a single well for a drawdown or recovery test is that the water level changes so rapidly in the initial part of the test that it cannot be measured accurately, and it follows that the plot of the first part of the drawdown or recovery curve is only an approximation. The inaccuracy can be an especially serious problem if leakage or barrier effects exert an effect early in the test. When a single well is used, a rapid and precise method for obtaining time and water-level measurements in the early part of drawdown or recovery tests is needed. This paper describes such a method which may supplement the conventional types of measurements, especially when observation wells are not available.

The method was developed in the course of a detailed investigation of the ground-water resources of Martin County, N.C., being made by the U.S. Geological Survey in cooperation with the Martin County Board of Commissioners.

TEST SITES

Two wells in Martin County, each fully penetrating the same aquifer, were selected for recovery tests (fig. 1). Well 69[1] is about 10 feet from the Roanoke River in an area where the piezometric map indicates considerable upward leakage from the artesian aquifer (fig. 2). Well 311 is about 4 miles from the Roanoke River in an area where the piezometric map indicates no leakage or recharge. Well 311 was selected as a control well for the tests because of the lack of indications of leakage and because the transmissibility determined at the well compares well with values determined in other tests on the same aquifer.

Both wells are finished as open holes in a porous limestone aquifer. This aquifer is about 17 feet thick in well 69 and 12 feet thick in well 311. The aquifer at both locations is overlain by clay and underlain by silty, clayey sand. The overlying clay has been thinned and possibly breached by the channel of the Roanoke River near well 69. Both wells had flowed freely for several months prior to being tested.

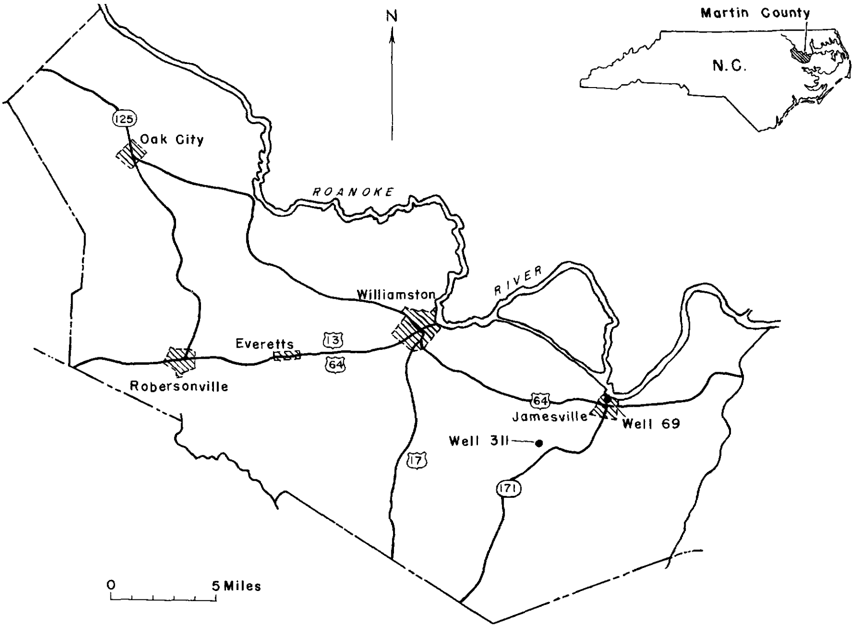

FIGURE 1.—Map of Martin County, N.C., showing location of wells used for microtime-measurement tests.

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[1] Well numbers conform to the consecutive county numbering system used by the U.S. Geological Survey in Martin County, N.C., in order that the wells used in these tests may be identified in other published reports.

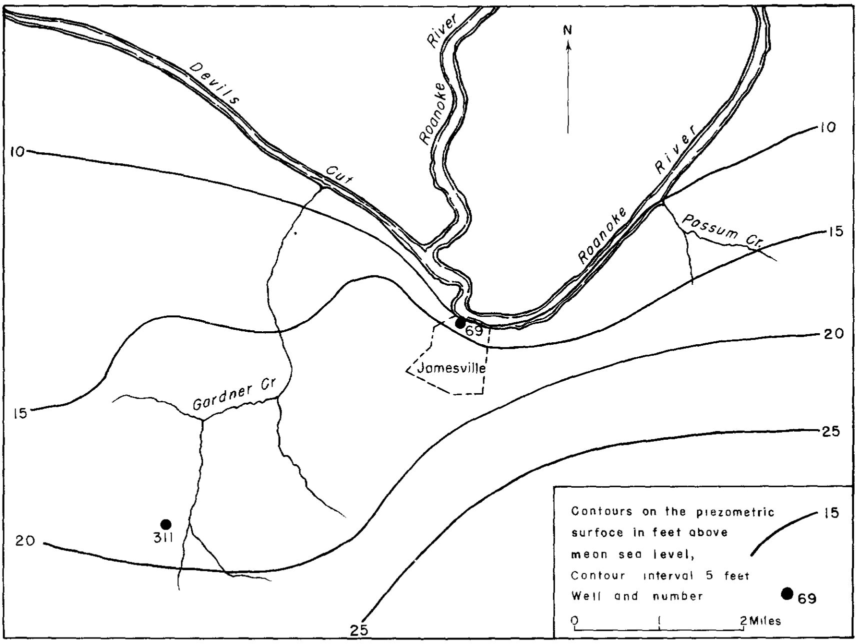

FIGURE 2.—Piezometric map of test area, November 1959.

RECOVERY TESTS

A conventional recovery test was made at each well; the measurements of head were made by measuring the rise in water level in a clear plastic hose that was connected to a tap in the well casing. Figure 3 shows a semilog plot of the data from the test at well 69. The semilog plot (Cooper and Jacob, 1946, p. 526–534) was selected for analyzing these data because the radius (*r*) was sufficiently small to permit use of this method and because a break in the curve due to leaky-aquifer conditions is more noticeable on a straight-line plot than on the Theis curve. Both wells had flowed freely for several months, so that the artesian head was declining very slowly. Therefore, it was considered unnecessary to correct the recovery measurements for the pretest water-level trend as the tests were short. The only part of the plot (fig. 3) that can be used to calculate the coefficient of transmissibility (*T*) of the aquifer occurs after about 2 minutes of recovery. From this straight-line part of the curve, *T* is calculated as 80,000 gpd (gallons per day) per foot. As this is about 7 times the value of 12,000 gpd per foot for *T* in well 311 (fig. 4) and as the value of 80,000 is inconsistent with values determined for the aquifer elsewhere, it is assumed that the part of the recovery curve used was already affected by leakage.

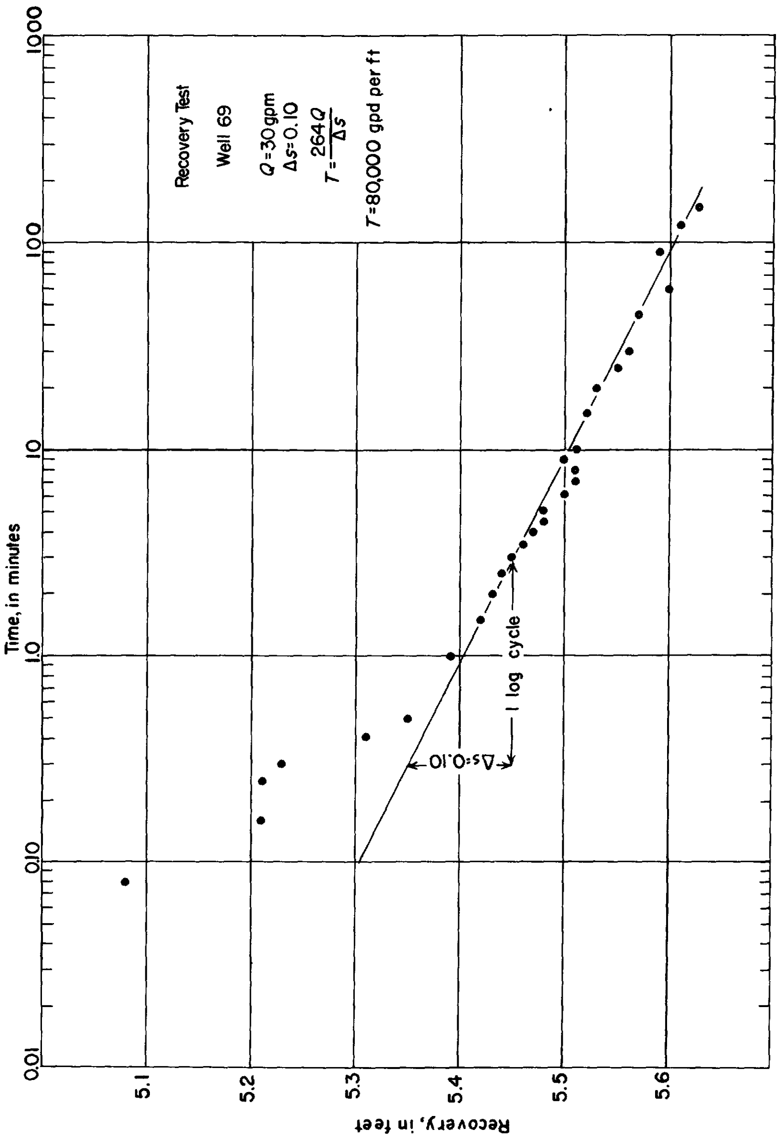

FIGURE 3.—Anlysis of data from well 69 (first test).

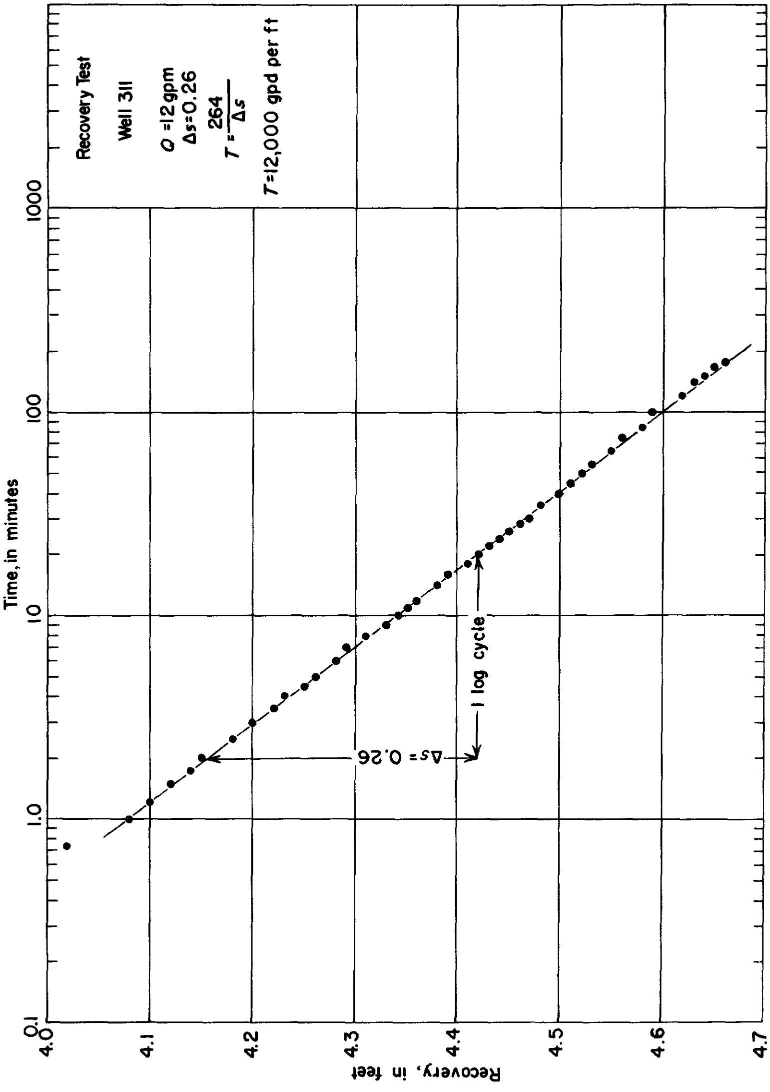

FIGURE 4.—Analysis of data from control well 311.

METHOD OF PHOTOGRAPHING RECOVERY MEASUREMENTS

A second recovery test was made on well 69 during which the water level was measured by means of a mercury manometer. The test setup and a typical frame from the film strip are shown in figure 5. The manometer tube and a stopwatch were photographed with an 8-mm. motion-picture camera that could be adjusted to nominal values of 12, 16, 24, and 32 frames per second. The camera was focused to include both the manometer tube and the stopwatch in each frame and was set at the position for 24 frames per second. However, after the film was developed it was found, by counting the number of frames for each 1-second interval on the stopwatch, that the camera had actually operated at 25 frames per second. Thus, the change in pressure in the manometer tube was recorded at intervals of $\frac{1}{25}$ second.

The camera and stopwatch were started before the valve on the discharge line of the well was closed. The valve was closed as rapidly as possible, within 3 to 4 seconds, and the manometer tube and stopwatch were photographed at intervals of $\frac{1}{25}$ second for the first minute and at intervals of 30 seconds thereafter for the next 8 minutes of the recovery period. For the first minute on the graph (fig. 6) only the measurements at about $\frac{1}{4}$-second intervals were used. The data were taken from the film by projecting the film with a still projector, so that the projected image of the manometer tube was almost 1/1.1 natural size. At this magnification a standard foot scale could be used as a vernier with the projected manometer scale. Thus, changes in the manometer tube could be measured with a precision equivalent to a few hundredths of a foot of water.

ANALYSIS OF DATA

When the test was completed and the data were taken from the photographs and plotted on a hydrograph, the first 14 seconds of the hydrograph shows fluctuations which resulted from surges due to closing the valve. These fluctuations do not appreciably affect the solution of this test since they lasted for only about 10 percent of the critical part of the curve. However, since there might be longer periods of fluctuations under different hydrologic conditions, the fluctuations were corrected, and the corrected data were used in solving this test.

The correction was made graphically by tracing the hydrograph, inverting and matching the traced hydrograph to the original hydrograph, and picking the corrected curve from the points where the

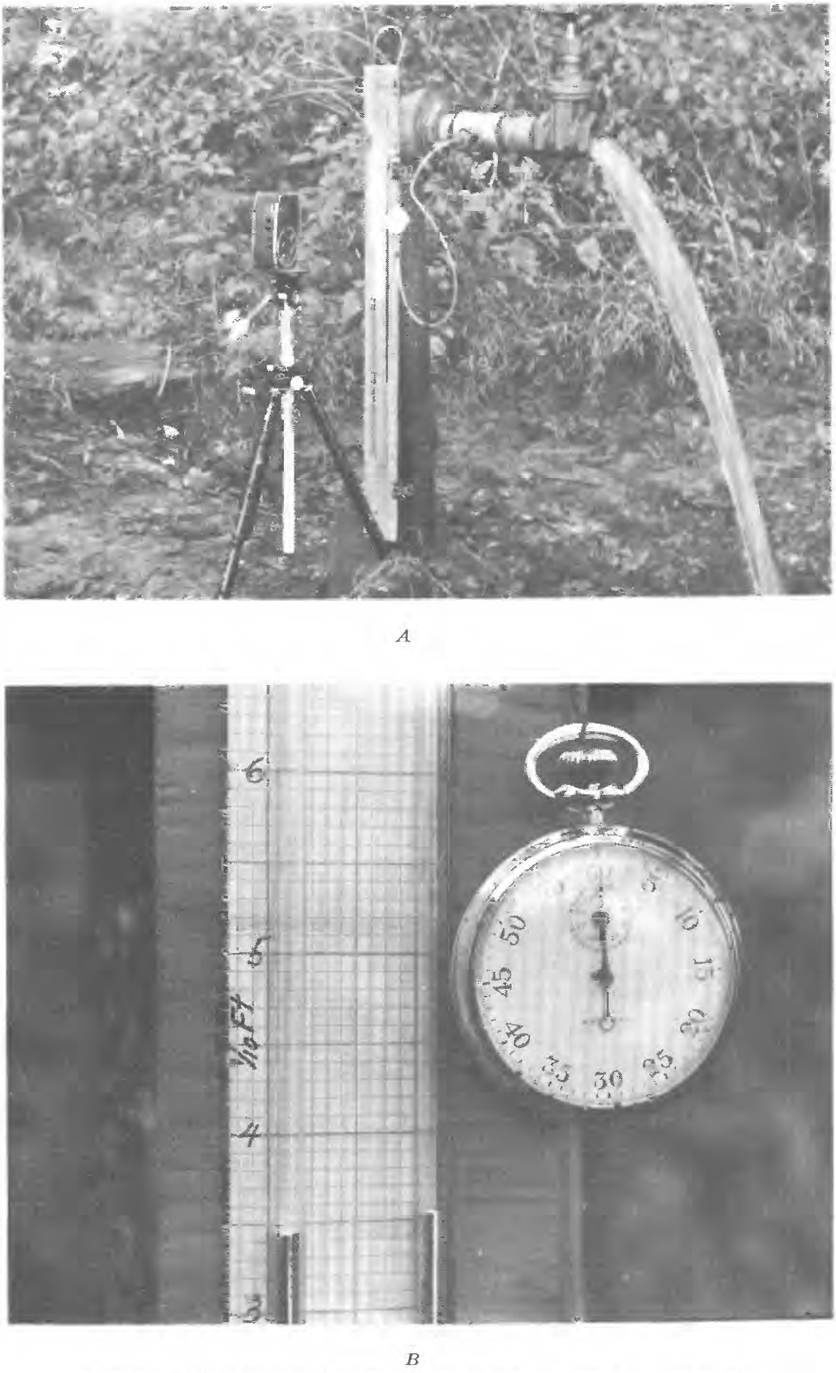

FIGURE 5.—Photographs of equipment used in microtime measurements. *A*, Typical equipment setup. *B*, Typical frame from film strip.

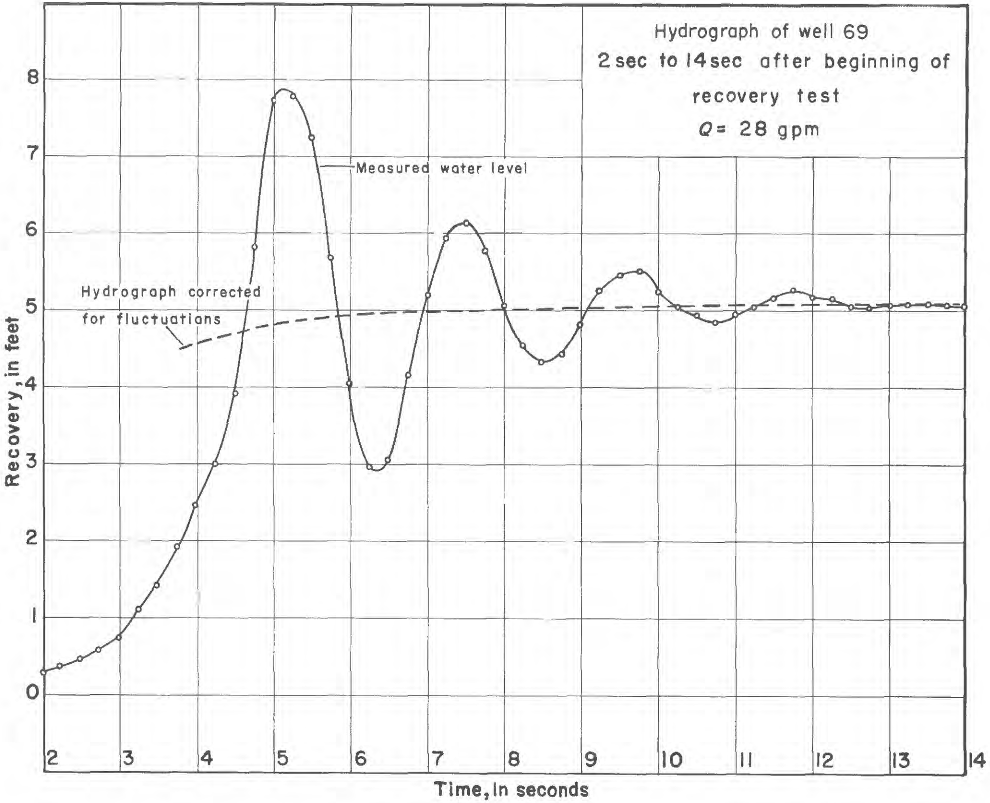

FIGURE 6.—Hydrograph and corrected curve for first part of second test at well 69.

two hydrographs intersected. Figure 6 shows the measured and corrected hydrographs from 2 seconds to 14 seconds after flow stopped.

A semilog plot of the data from the second test at well 69 is shown in figure 7. As may be seen, the plot of data, from about 6 seconds to about 2 minutes after flow stopped, falls in a straight line which when analyzed gives $T=18{,}000$ gpd per foot (solution 1). The part of the curve preceding this segment is not valid because of the 3 or 4 seconds required to close the discharge valve completely. The part of the curve following this segment reflects the apparent change in transmissibility due to the effects of leakage from the aquifer to the river (solution 2). The value for T in solution 2 compares very well with the value for T determined in the first test of this well. The second test (fig. 7) at well 69 was continued for 9 minutes, which was about 6 minutes after the first test (fig. 3) indicated that leakage had started. The semilog plots of the first and second tests at well 69 (figs. 3 and 7) may not be compared directly for two reasons. First, the time measurement in the first test may be in error as much as 15 or 20 seconds which would result in considerable error in the semilog plot between 0.1 and 1.0 minutes. This source of error has been eliminated by photographing the measurements in the second test. Also, the possible number of measurements made during the first minute has been increased from 6 or 7 questionable measurements in the first test to about 1,500 accurate measurements in the second test. The second reason that the two semilog plots may not be compared directly is that Q (yield in gallons per minute) decreased about 7 percent between the first and second test. Thus, the amount of water-level recovery for any given time during the early part of recovery would also decrease from the first to the second test.

The value of T (solution 1) was converted to the field coefficient of permeability (P_f) for comparison with P_f at the control well (fig. 4). P_f at well 69 was about 1,100 gpd per square foot, and P_f at well 311 was 1,000 gpd per square foot.

SUMMARY AND CONCLUSION

A comparison of the results of the recovery test at control well 311 and with those of the second test at well 69 indicates that the method of photographically recording the early measurements of a drawdown or recovery test gives accurate results and can aid considerably in determining the correct coefficient of transmissibility of an aquifer if certain conditions are met. The conditions are as follows: (a) The method is restricted to use in artesian aquifers, and (b) the effective radius of the well tested must be considered in the calculations. Only

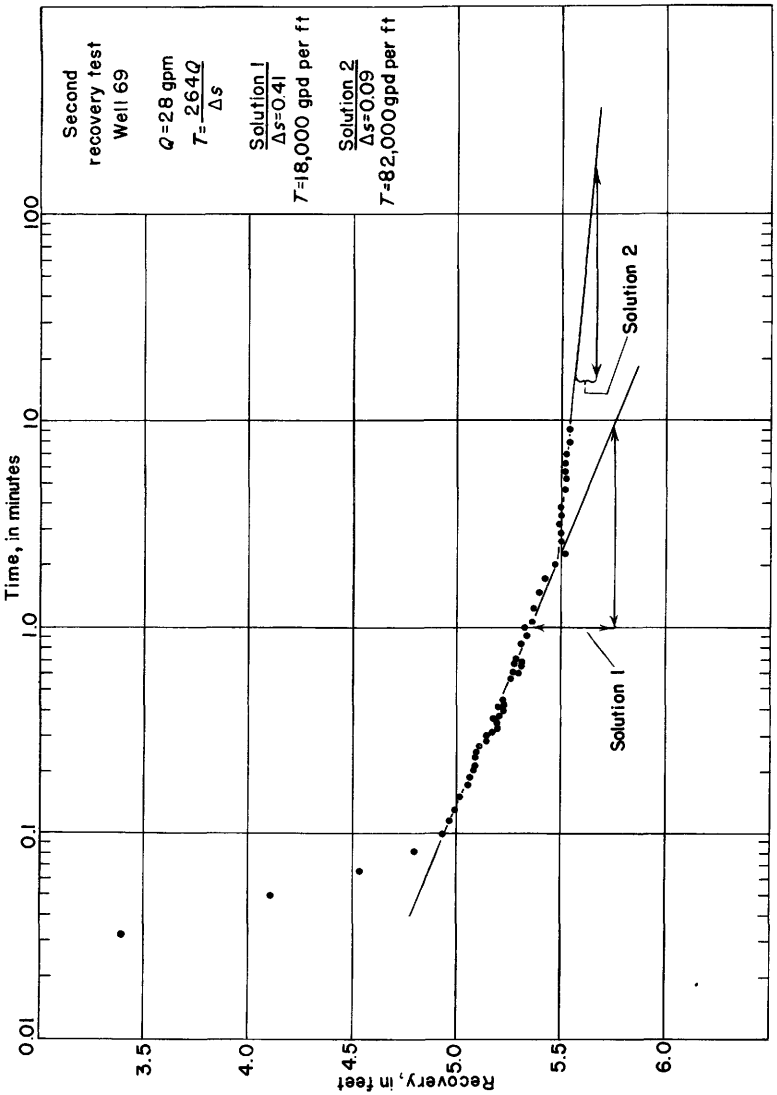

FIGURE 7.—Analysis of data from well 69 (second test).

in an open-hole (unscreened) well can it be assumed with any confidence, in the absence of correlating data from other wells, that the effective radius of the well is substantially equal to the actual radius.

This method of measuring the early part of the drawndown or recovery has not been used in tests on fully developed screened wells. It is anticipated that such tests will be made, and that a later paper will discuss more fully the advantages and limitations of this method in tests on other types of wells and aquifers.

REFERENCE

Cooper, H. H., Jr., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., v. 27, p. 526–534.

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