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Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System

P. D. Thorne
D. R. Newcomer

November 1992

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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SUMMARY

Improving the hydrologic characterization of the Hanford Site unconfined aquifer system is one of the objectives of the Hanford Site Ground-Water Surveillance Project. To help meet this objective, hydraulic property data available for the aquifer have been compiled, mainly from reports published over the past 40 years. Most of the available hydraulic property estimates are based on constant-rate pumping tests of wells. Slug tests have also been conducted at some wells and analyzed to determine hydraulic properties. Other methods that have been used to estimate hydraulic properties of the unconfined aquifer are observations of water-level changes in response to river stage, analysis of ground-water mound formation, tracer tests, and inverse ground-water flow models.

To assess the reliability of published hydraulic property estimates determined from constant-rate pumping tests, selected tests were reanalyzed using updated techniques. Analysis methods for constant-rate pumping tests are based on assumptions about the aquifer and well configurations that are not completely met for most tests. Therefore, it is important to apply the analysis method to a range of test data for which the assumptions apply and where the results are not significantly affected by less than ideal test conditions. Recently developed diagnostic techniques utilizing log-log plots of the derivative of the test data are helpful in identifying the range of data where semilog straight-line analysis methods apply and where nonideal well or aquifer effects are significant.

Available hydraulic property estimates indicate that the transmissivity of tested permeable intervals within the unconfined aquifer ranges from less than 10 to more than 500,000 ft^2/d. Corresponding values of equivalent hydraulic conductivity were calculated by dividing the transmissivity values by the estimated thickness of the permeable zone. The resulting hydraulic conductivity ranged from less than 1 to more than 5000 ft/d. Storativity and specific yield values could only be determined from a few multiple-well tests. These results ranged from 7×10^{-5} to 0.45.

CONVERSION TABLE

Most of the information in this report was originally reported in English units. Therefore, English units are used as the primary convention in the text, figures, and tables. For converting English units to metric, the following conversion table is provided:

Multiply	By	To Obtain
inches	2.540	centimeters
feet	0.3408	meters
miles	1.6093	kilometers
gallons	3.7854	liters
$feet^2$/day	0.0929	$meters^2$/day
pounds/$inches^2$	6.8948	kilo-Pascals

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1.0 INTRODUCTION

Ground-water movement beneath the Hanford Site provides a pathway for the transport of radioactive and hazardous wastes that have been discharged in various locations on the site since 1944. The Hanford Ground-Water Surveillance Project, operated by Pacific Northwest Laboratory (PNL),[a] is responsible for predicting the rate of movement of contaminants in ground water and determining the discharge of contaminants to the Columbia River. To meet these objectives, detailed characterization of the ground-water flow system is needed. Ground-water flow in the uppermost aquifer is of primary importance because most wastes have been discharged at or near the ground surface.

The spatial distributions of hydraulic properties for the uppermost aquifer are part of the data needed for understanding ground-water flow and contaminant transport. The uppermost, generally unconfined, aquifer system at the Hanford Site is located in unconsolidated to semiconsolidated sediments overlying the basalt bedrock. Parts of the aquifer are locally confined or semiconfined. However, because the entire suprabasalt aquifer system is interconnected on a site-wide scale, it has commonly been referred to as the Hanford "unconfined" aquifer, while aquifers located within the Columbia River Basalts have been included in the confined aquifer system. This nomenclature is used in this report.

The primary aquifer properties affecting ground-water flow are hydraulic conductivity, specific storage, and aquifer thickness. Transmissivity is the product of hydraulic conductivity and aquifer thickness, and storativity is the product of specific storage and aquifer thickness. For unconfined aquifers, both the storativity associated with elastic aquifer response and the specific yield from dewatering of the aquifer are important components of total aquifer storativity. In addition, effective porosity is an important parameter in determining ground-water velocity and rates of contaminant transport. When combined with information on boundary conditions and

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(a) PNL is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

2.0 HYDROGEOLOGIC SETTING

The Hanford Site (Figure 1) lies adjacent to the Columbia River in the Pasco Basin, a structural depression defined by surrounding basalt anticlines. Within the Pasco Basin, late Miocene- to Pleistocene-aged fluvial, lacustrian, and glaciofluvial sediments overlie a thick sequence of basalt flows of the Columbia River Basalt Group. During the late-Miocene to mid-Pliocene, a sequence of intercalated fluvial and lacustrian deposits of the Ringold Formation partially filled the subsiding Pasco Basin. Pleistocene-aged glaciofluvial sediments, informally named the Hanford formation, were deposited over the Ringold Formation by both catastrophic and normal flood events. More detailed descriptions of the Hanford Site geology are provided in Myers and Price (1979) and DOE (1988).

Except at basalt outcrops, the uppermost aquifer at Hanford lies mainly within the Ringold and Hanford formations. The Hanford formation consists of unconsolidated beds and lenses of silt, sand, and gravel, while the underlying Ringold Formation consists of unconsolidated to weakly cemented beds and lenses of clay, silt, sand, and gravel. The Ringold sediments are generally more consolidated, contain more silt, and are about 10 to 100 times less permeable than the sediments of the overlying Hanford formation. However, sand and gravel layers with relatively high permeability are also present within the Ringold Formation and permeable strata of the aquifer sometimes cross the division between these two main stratigraphic units. In an effort to provide more detailed characterization of the aquifer, recent attempts have been made to define individual strata, or lithofacies, that possess similar hydrogeologic characteristics (Poeter and Gaylord 1990; Lindsey 1991). This methodology holds promise for improving the accuracy of ground-water flow models, particularly three-dimensional flow models, of the unconfined aquifer.

Ground water in the unconfined aquifer at Hanford generally flows from recharge areas in the west toward the Columbia River on the eastern and northern boundaries of the site (DOE 1988). Prior to waste-water disposal operations at the Hanford Site, the uppermost aquifer was almost entirely within the Ringold Formation and the water table only extended into the Hanford formation at a few locations (Newcomb et al. 1972). However,

waste-water discharges have increased the water-table elevation and created ground-water mounds under the two main waste-water disposal areas near the 200-East and 200-West areas. The water table has risen about 90 ft under a disposal area in the 200-West Area, and about 30 ft under disposal ponds near the 200-East Area. The volume of water that has been discharged to the ground at the 200-West Area is actually less than that discharged at the 200-East Area (Zimmerman et al. 1986). However, the lower permeability of the aquifer in the vicinity of the 200-West Area has inhibited ground-water movement in this area and resulted in a higher ground-water mound. Because of the increased ground-water elevation, the water table is now in the Hanford formation over much of the eastern portion of the Hanford Site.

3.0 HYDROLOGIC TEST AND ANALYSIS METHODS

Several types of hydrologic tests have been conducted to determine hydraulic properties of the unconfined aquifer at Hanford. Pumping tests have been conducted at many wells using either a single-well configuration, where aquifer drawdown and recovery is measured in the pumped well, or a multiple-well configuration, where aquifer response is measured at one or more observation wells. Single-well pumping tests have been conducted more frequently because of the expense of installing multiple wells. Many single-well slug tests have also been conducted, especially during the past decade. These tests are generally performed more quickly and with less elaborate equipment than pumping tests. They also have an advantage in areas of ground-water contamination because it is not necessary to remove large volumes of ground water. However, single-well slug tests can only be analyzed over a relatively narrow range of transmissivity and the results apply to only a small area surrounding the well. A multiple-well slug test method that avoids these problems to some extent has been used by Spane (1992a).

In addition to these standard hydraulic test methods, a few estimates of hydraulic properties have been obtained from analysis of

- tracer test results
- water-level responses to changes in Columbia River elevation
- formation of ground-water mounds under waste-water disposal areas.

Descriptions of the test and analysis methods used for determining hydraulic properties of the unconfined aquifer at Hanford are provided in this section.

3.1 CONSTANT-RATE DISCHARGE TESTS

Constant-rate discharge (or pumping) tests have probably been the most commonly employed method of determining hydraulic properties at Hanford. For this method, water is removed from a well at a constant rate and the associated drawdown and recovery water levels over time are measured at the pumping well and/or in one or more nearby observation wells.

(1963) and some have applied corrections for partial penetration of the pumping well and for aquifer dewatering at the pumped well. Fortunately, as discussed by Theis (1935), not meeting some assumptions of the Theis solution often has only a minor influence on the results of hydraulic property determination. It is important, however, to recognize when nonideal well or aquifer effects are significant. These effects may be discerned by preparing a diagnostic plot of the test data and comparing it to characteristic curves associated with various nonideal conditions. Log-log plots of water level versus time have traditionally been used for diagnostic purposes and recently the derivative of the water-level or pressure change has also been used as a diagnostic tool (Bourdet et al. 1984).

Type-curve matching methods are generally applicable only to data from observation wells. Constant-rate tests should ideally have the benefit of at least one observation well completed in the same aquifer and located near enough to the pumped well that responses can be measured. Most tests at Hanford, however, have had to rely on measurements of aquifer drawdown and recovery solely at the pumped well. Errors may have been introduced in some cases by applying type-curve matching methods for analysis of pumping well data. Friction loss at the pumping well may cause an additional component of drawdown independent of the aquifer response. This causes the data to be shifted vertically on the log-log plot employed in type-curve matching and introduces error in the calculated transmissivity and storativity values. Attempts have been made to determine the friction loss component through step-drawdown tests and then correct the drawdown measurements prior to type-curve matching (Kipp and Mudd 1973). However, the semilog straight-line method is considered a more reliable technique for analyzing data from a pumping well.

As indicated by Cooper and Jacob (1946), semilog straight-line methods are only valid for data corresponding to small values of the parameter u. It is generally accepted that the method is valid when $u < 0.01$. However, in some cases the error introduced by using data corresponding to somewhat larger values of u in straight-line analysis is minor (Chapuis 1992). The semilog methods may be applied to drawdown or recovery data. The most likely source of error in this technique is to attempt to fit a straight line to data collected before the straight-line approximation applies (large u), or to data

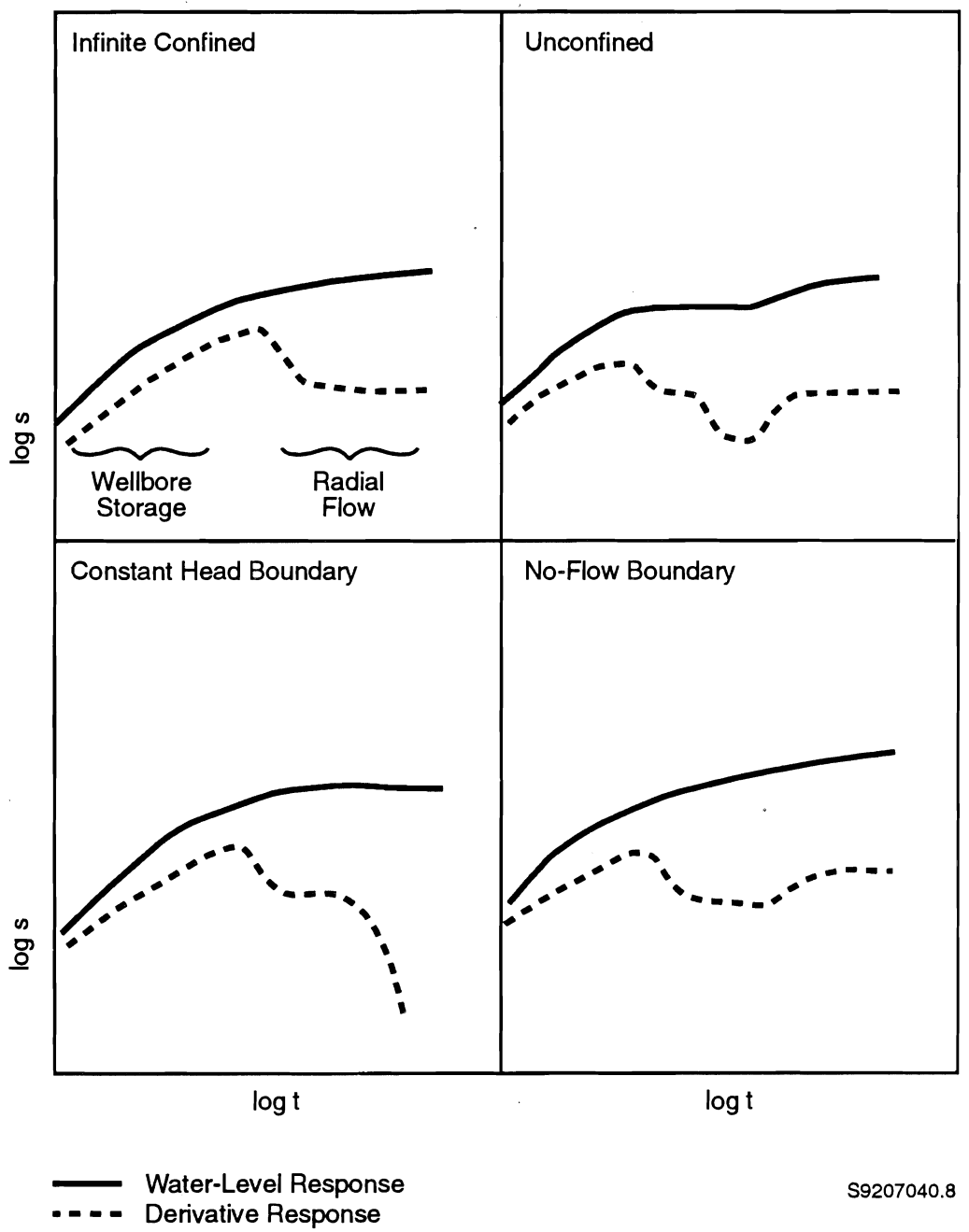


FIGURE 2. Characteristic Log-Log Plots of Water-Level and Semilog Derivative Response for Various Flow Systems

a downward trend in the derivative, which may be preceded by a stable derivative if radial flow conditions occur before the boundary effect becomes dominant.

where r_c = radius of the casing [L]

r_w = radius of the well [L]

L_e = length of the open well section [L]

R_e = effective radius of influence [L]

t = time since the test began [T]

y_t = water level - static water level [L]

y_o = induced water-level change at beginning of test [L].

For the Hvorslev method, the effective radius (R_e) is assumed to be equal to the length of the open interval. Bouwer and Rice (1976) provide empirical formulas for determining $\ln(R_e/r_w)$, based on the results of electrical analog studies of different flow system geometries.

For both analysis methods, water-level data are plotted on a logarithmic scale versus time on an arithmetic scale. Based on the above equation, the result should be a straight line, at least over a section of the plot corresponding to early time. The quantity [ln(yo/yt)]/t can be determined graphically from the straight-line portion and used to calculate K. In practice, near borehole effects, such as a gravel pack or other altered permeability zone near the well, sometimes cause a deviation from the predicted single straight line (Bouwer 1989).

A slug test analysis method based on non-steady radial flow of a compressible fluid in a confined aquifer was presented by Cooper et al. (1967). They present type curves of dimensionless head response, H_D, versus a dimensionless time parameter, β, for various values of a dimensionless wellbore storage parameter, α. These parameters are defined by

$$H_D = H/H_o \qquad \text{[dimensionless]}$$

$$\beta = Tt/r_c^2 \qquad \text{[dimensionless]}$$

$$\alpha = r_w^2 S/r_c^2 \qquad \text{[dimensionless]}$$

where H = observed head - pretest static head [L]

H_o = instantaneous head change at start of test [L]

t = time since start of test [T]

r_c = radius of well casing where water level change occurs [L]

r_w = effective radius of well [L].

4.0 REVIEW OF UNCONFINED AQUIFER TESTING AT HANFORD

Ground water in sediments underlying the Hanford Site was studied before the start of nuclear production activities because of the importance of ground water to the area's early settlers. Since the 1940s, studies of ground water at Hanford have mainly been concerned with the potential for offsite transport of radionuclides and other hazardous materials discharged to the ground or stored at the Hanford Site. In both types of study, the determination of aquifer hydraulic properties is important. Hydraulic properties control the amount of water that can be obtained from a well and they also control the rate of transport of hazardous constituents through the ground water. Some previous Hanford ground-water investigations were designed to characterize a limited area around a particular waste site while others were to define ground-water flow over the entire site. This section summarizes reports containing hydraulic property data and gives information about some hydrologic characterization activities that have not been previously presented in formal reports. Results of the hydrologic tests are summarized in Section 5.0.

4.1 INVESTIGATIONS BEFORE 1950

An early study of ground water in the vicinity of the communities of White Bluffs and Hanford was made by Jenkins (1922). The objective was to determine if the ground-water supply of the area was adequate to support sustained irrigation of tracts of land designated for the Soldier Land Settlement Project. This study preceded the discovery of many of the basic principles of ground-water hydraulics, such as the relationship described by Theis (1935) between the rate of drawdown in a well and the hydraulic properties of the aquifer. Therefore, no estimates of hydraulic parameters are provided in the report. Data were collected on local wells and showed that only small drawdowns were observed when most wells were pumped. One example well was pumped at about 1100 gal/min and reached an apparently steady drawdown of about 2 ft. From observations of well logs, water levels, and local geology, Jenkins (1922) concluded that the alluvial gravels (now informally referred to as the Hanford formation) were recharged by water from the Columbia River. Recharge of the aquifer occurred principally during the period that the river

boundary or delayed yield response. The storativity was determined to be 0.0002. The North Richland well was identified as 3000F and was completed in the Hanford formation. A transmissivity of 144,400 ft^2/d was calculated.

Newcomb and Strand (1953) estimated the porosity and transmissivity of the Ringold aquifer in the vicinity of the 200-West Area from the characteristics of the ground-water mound that formed as a result of waste-water disposal. Porosity was determined by dividing the volume of water discharged over a 4.5 yr period (1948-1953), corrected for evaporation, by the total volume change of the ground-water mound over the same period. An average porosity of 11% resulted. A porosity of 11% was also determined from a similar analysis of the 200-East Area ground-water mound.

Transmissivity was determined for the Ringold aquifer near the 200-West Area by applying a form of Darcy's Law (Wenzel 1942) to the flow across a closed water-level contour encircling the mound. The flow rate across the contour was assumed to be equal to the discharge rate to waste-disposal facilities, corrected for evaporation. The hydraulic gradient was averaged around the closed contour. An average transmissivity of 3330 ft^2/d was found by applying this procedure to two contours around the 200-West Area mound. A calculation of transmissivity was not attempted for the 200-East Area aquifer because the ground-water mound had risen into the much more permeable Hanford formation and because reduced rates of discharge had caused a lowering of the mound.

Newcomb and Strand (1953) also applied the method described by Ferris (1952) to calculate hydraulic properties from the response of wells to river fluctuations. The responses of three wells in the 300 Area were analyzed. This method gives a result for aquifer diffusivity (T/S). Therefore, storativity values had to be assumed to calculate the transmissivity. The estimated transmissivity ranged from 115,000 to 230,000 ft^2/d for assumed storativities from 0.1 to 0.2, respectively.

Bierschenk (1957) described the analysis and results of three pumping tests. One of these was the earlier test in the Ringold Formation at the 100-K Area reported by Newcomb and Strand (1953). The other two tests were in highly permeable parts of the Hanford formation at wells 699-62-43, north of

maximum observed concentration of tracer. The higher conductivity value, based on the time to first detection, was interpreted as the hydraulic conductivity of the most permeable beds in the tested formation and the hydraulic conductivity based on arrival of the peak concentration was interpreted as the average for the formation. The principles of hydrodynamic dispersion are better understood today and reveal that, even in a homogeneous aquifer, some tracer will move faster than the average ground-water velocity because of different microscopic flow paths in the porous media. Therefore, the time of peak concentration at the observation well should be used in calculating hydraulic conductivity. One test was between wells 50 ft apart at 699-62-43, just north of Gable Mountain. A hydraulic conductivity of 3880 ft/d was determined from peak breakthrough for this test. The other two tests were conducted in the area south of the 200-East Area. One of these tests used well 699-28-41 as the tracer injection well and 699-19-43 as the observation well. The other test used well 699-24-33 for tracer injection and wells 699-14-27 and 699-20-20 for observation of tracer breakthrough. Hydraulic conductivity calculated from breakthrough of the peak tracer concentration ranged from 8400 to 14,000 ft/d in this area.

Biershenk (1959) also analyzed the water-level responses at 10 wells to annual changes in the level of the Columbia River. Aquifer transmissivity values were estimated using the method of Ferris (1952). This method results in calculation of aquifer diffusivity (T/S). Therefore, a storativity value had to be assumed to calculate transmissivity. A storativity of 0.10 was assumed for seven wells and a value of 0.06 was assumed for the other three wells based on results of a nearby pumping test. The estimated transmissivities ranged from 2000 to 300,000 ft^2/d and corresponding values of hydraulic conductivity ranged from 20 to 7600 ft/d. These results were regarded as "tentative." They were, however, of the same order of magnitude as results obtained from pumping tests.

From the results of all the available test results, Biershenk (1959) concluded that the hydraulic conductivity of the Hanford sediments ranges from about 1300 to more than 8000 ft/d and that the hydraulic conductivity of the Ringold Formation ranges from about 10 to 80 ft/d.

transmissive as the next-finer-grained category. The relationship between transmissivity and the calculated number was determined by plotting the transmissivity values from pumping tests at 34 of the wells against the numbers calculated from logs of those wells. A straight line was then fit to the data and the relationship was used to estimate transmissivity for the remaining 119 wells. The results have not been reproduced for this report because of the large uncertainty in assigning hydraulic properties based on the well logs.

Kipp et al. (1976) provided an updated report on application of the Variable Thickness Transport (VTT) ground-water flow model to the unconfined aquifer at the Hanford Site. This model required distributions of hydraulic properties, which were calculated using the Transmissivity Iterative Routine (TIR) developed by Cearlock et al. (1975). The TIR is described in more detail in Section 4.8.

Lindberg and Bond (1979) report pumping tests of three wells in the 300 Area. These tests were conducted to support an application of the VTT ground-water model in this area. Transmissivity values were determined from straight-line analysis of both the drawdown and recovery data. Neither the raw data, nor details of the analyses, are provided in their report. The results of the pumping tests have been included in the tables in Section 5.0.

4.4 HYDROLOGIC TESTS REPORTED DURING 1980 TO 1990

Graham et al. (1981) provided a comprehensive analysis of hydrogeology in the "separations area," an 82-mi^2 area including and surrounding the 200-East and 200-West areas. Results of 11 constant discharge and recovery tests conducted on 10 wells in the separations area prior to 1976 were compiled. All but one of these tests was previously reported in Kipp and Mudd (1973) or Deju (1974). In addition, five pumping tests conducted at four different wells in the separations area between 1976 and 1980 were analyzed in the report. The results of those tests are listed in the tables in Section 5.0.

Eddy et al. (1983) report that 27 tests were conducted at 25 wells during the period 1973 to 1981. A map (Figure 3) was provided showing the test well locations. Some of these wells had been previously tested. The results were reportedly used to update the "Hanford transmissivity matrix" and

provide input for the Hanford VTT ground-water flow model. However, test results are not provided in Eddy et al. (1983).

Graham et al. (1984) give the results of pumping tests performed on six wells in the unconfined aquifer in 1982. These tests were part of an assessment of intercommunication between the unconfined and upper confined aquifers in the area of B Pond and Gable Mountain Pond. Several other wells completed in the upper-confined aquifers were also tested. Constant discharge pumping tests were performed without the benefit of observation wells and only the drawdown data were analyzed for the unconfined wells. Recovery data were also analyzed for some of the confined aquifer tests and slug tests were performed on several other confined aquifer wells. Results of those tests are listed in the tables in Section 5.0.

Weekes et al. (1987) conducted three aquifer tests at wells 699-25-33A and 699-26-35C to help characterize the Nonradioactive Dangerous Waste Landfill located in the central part of the Hanford Site. Tests were conducted over two separated depth intervals at well 699-26-35C. Some observation well data were available in the tested zone and in adjacent formations. Vertical hydraulic conductivity was also estimated from the results.

Pumping tests of 13 newly drilled wells in the 300 Area were reported by Schalla and Wallace (1988). Seven of the tests were severely affected by the nearby Columbia River acting as a recharge boundary and/or by changes in river stage that affected the water level in the well during the test. Therefore, only the six test results considered reliable are included in the listings of data in Section 5.0.

Liikala and Aaberg (1988) reported the results of aquifer tests performed on 17 wells near the 183-H Solar Evaporation Basins in the 100-H Area. Six constant-rate tests were conducted. However, one of these test results was not considered reliable because of the apparent dewatering of a high-permeability zone within the test interval. Transmissivity and hydraulic conductivity values determined from the other tests appear in Section 5.0. Both Theis (1935) type-curve matching and straight-line data analysis techniques were applied, and, in some cases, the result from curve matching was taken as the better value. However, as discussed in Section 2.0, the Theis

were conducted as part of the RCRA monitoring program for single-shell waste tanks located on the Hanford Site. Pumping tests were not performed because of the difficulties in disposing of contaminated ground water that would be produced during pumping. The slug tests were performed using a slugging rod and the total change in water level was low (less than 2 ft) for most of the tests. The authors state that the results of some tests may have been affected by turbulent flow conditions caused by the very fast early recovery of the water level. The Bouwer and Rice (1976) analysis method was applied.

Westinghouse Hanford Company (WHC) (1990) reports the results of constant-rate discharge tests of three wells and slug tests of seven wells near B Pond. The constant rate tests were analyzed by the semilog straight-line method. A slugging rod was used to produce the initial water-level change for the slug tests. The level of stress was small for the slug tests, ranging between 1 and 7 ft. Four of the tested intervals were considered locally confined and the data were therefore analyzed using the Cooper et al. (1967) method. The other three slug tests were analyzed using the Bouwer and Rice (1976) method.

Newcomer et al. (1992) and Trent (1992) provided compilations of hydrologic data available for the 200-West Area. Trent (1992) also provided analysis details for slug tests of five wells at the 216-S-10 facility.

Gilmore et al. (1992) calculated the volumetric discharge of ground water through a section of the unconfined aquifer near the 100-N Area. Hydraulic property data were needed as input. Because of the wide range of reported hydraulic conductivity values from two wells in this area, a reanalysis of the existing test data was undertaken. This resulted in revised estimates of transmissivity and hydraulic conductivity for wells 699-77-54 and 699-87-55. The data table in Section 5.0 reflects the revised values for those two wells.

Spane (1992a) conducted a field test evaluation of the slug-interference test method. This method may be useful for characterizing highly permeable aquifers that are not amenable to single-well slug tests and where the presence of contamination makes it undesirable to remove large volumes of ground water. A slug withdrawal test was conducted at a stress well while two

- partial penetration of the aquifer by both the pumped and observation wells
- possible flow boundaries caused by the channel-deposit nature of the formation in this area.

Because of these complications, quantitative analysis was performed only for recovery following the step-drawdown test. Antecedent head changes affecting this test could be extrapolated from pre-test measurements and a correction applied to the test data. The antecedent effects on the other two tests were more complex and could not be removed. Hydraulic properties determined from the analysis of the step-drawdown recovery were used in a simulation of the entire test sequence to determine their validity.

Recovery from the step-drawdown test was analyzed by the straight line method (Cooper and Jacob 1946) after first making a diagnostic log-log plot of the recovery data and derivative. Figure 4 shows the diagnostic plot of the data from well 699-53-55A and a superimposed curve calculated from the Theis (1935) equation assuming a transmissivity of 68,000 ft^2/d and a storativity of 0.46. The derivative plot indicated radial flow conditions between recovery times of about 40 and 120 min. The data after 120 min indicate a possible no-flow boundary response. Figure 5 shows the straight-line analysis of the step-drawdown recovery data from observation well 699-53-55A. The line was fit to the data between 40 and 120 min. Resulting transmissivity was 66,300 ft^2/d and storativity was 0.46. Analysis of data from observation well 699-53-55B and from the pumping well gave similar results for transmissivity. However, the straight-line analyses did not provide realistic results for storativity.

4.7 RECENT TESTS AT THE 300-FF5 OPERABLE UNIT

Multiple-well constant-discharge tests, a constant-head discharge test, and slug tests were conducted at two cluster sites in the 300 Area. Cluster site 4 was tested during April 1992 and cluster site 7 tests were conducted during June 1992. The results of these tests will be documented in a subsequent WHC report.

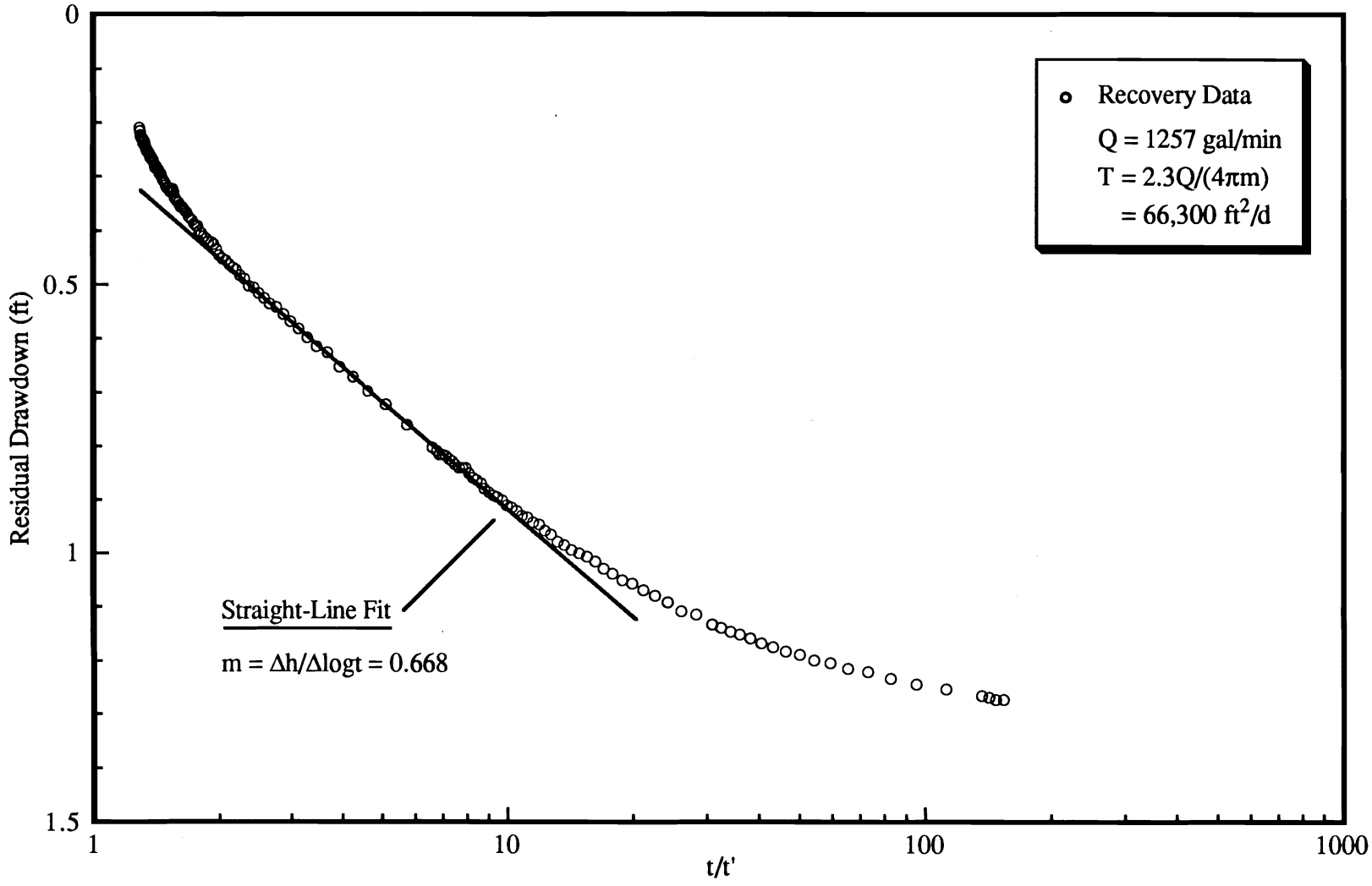
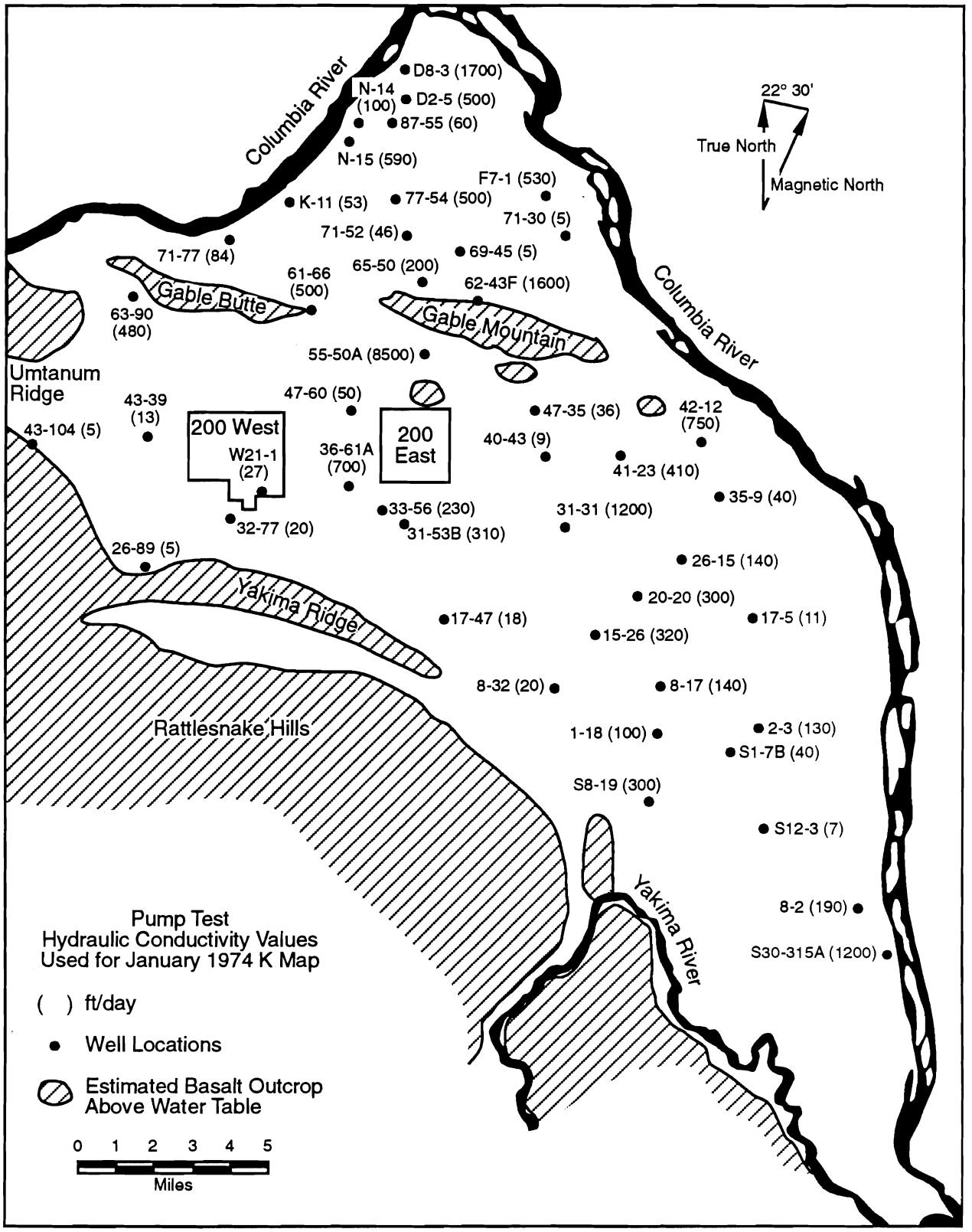
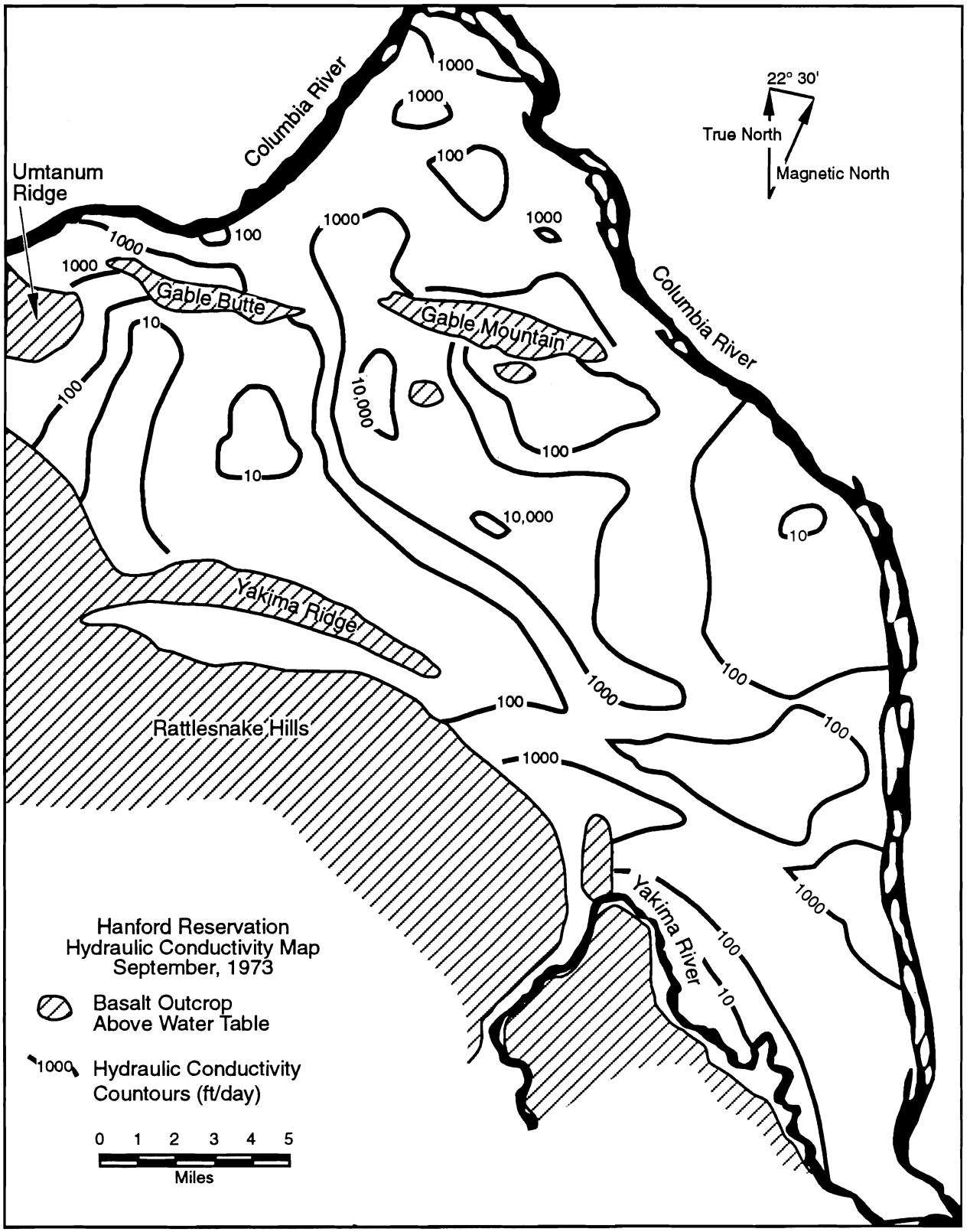


FIGURE 5. Semilog Straight-Line Analysis of Recovery Data Following the Step-Drawdown Test for Well 699-53-55A



S9207040.3

FIGURE 6. Measured Hydraulic Conductivities Used in the Variable Thickness Transport (VTT) Model (Kipp et al. 1976)



S9207040.5

FIGURE 8. Hydraulic Conductivity Distribution Calculated from the Transmissivity Iterative Routine (Cearlock et al. 1975)

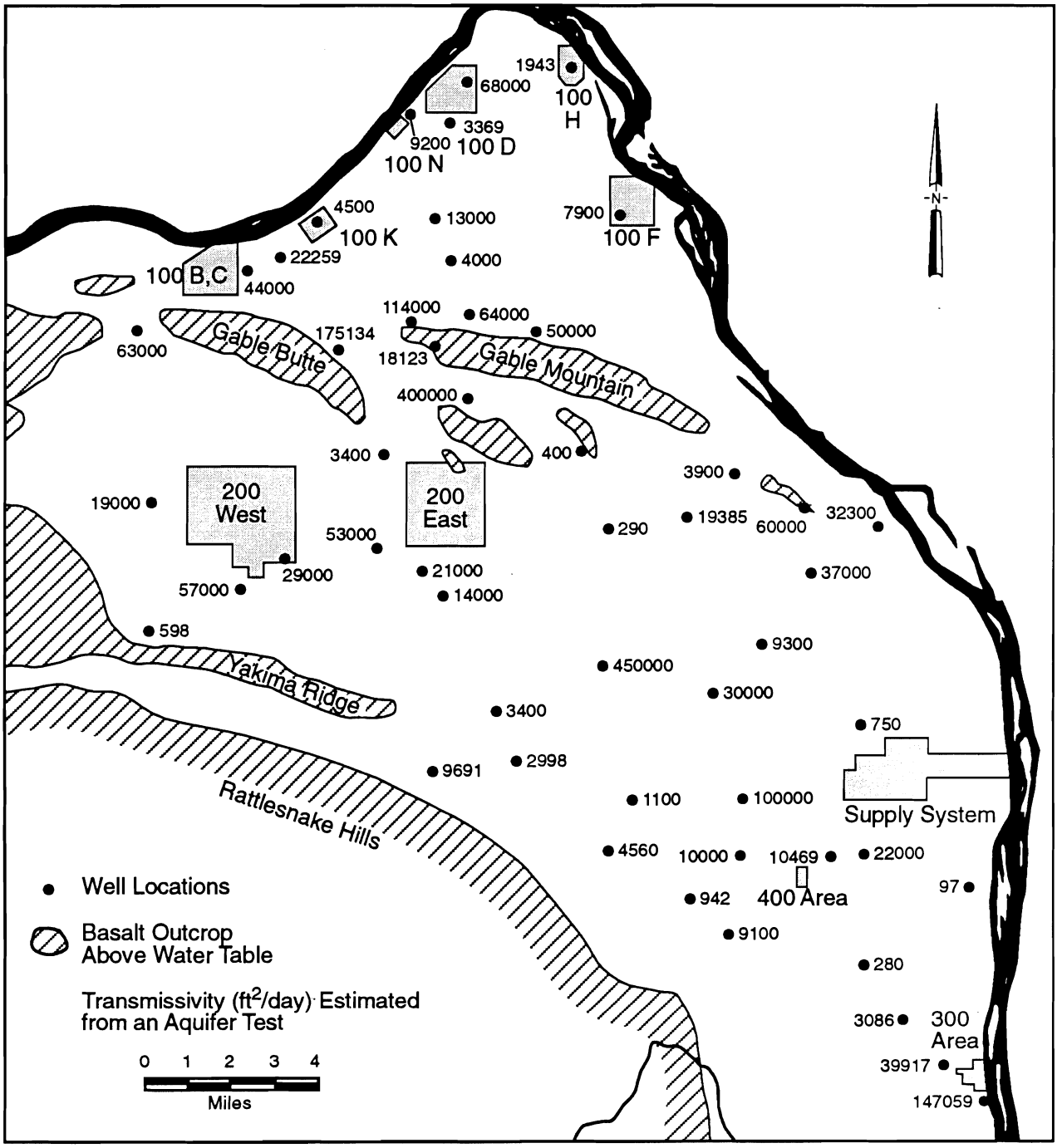


FIGURE 9. Measured Transmissivity Values Compiled for the Inverse Modeling Effort (Jacobson and Freshley 1990)

5.0 SUMMARY OF TEST RESULTS FOR THE UNCONFINED AQUIFER

Hydrologic tests have been carried out under many different programs and projects at Hanford. The resulting data are not readily available from a single source. They are contained in project files and various published and unpublished test reports. The quality of the data also varies over a wide range. This section represents an attempt to compile the available hydraulic property data determined from aquifer pumping tests, slug-tests, and other methods. Some test results were not included because the original analysts did not consider the results valid or a large uncertainty in the results was noted. There are, without a doubt, some valid test data that have not been included because of oversight. Also, test activities are ongoing at the site and results of some tests conducted before this report were not available in time for inclusion.

Table 1 lists the results of constant-rate pumping tests. Some wells have been tested more than once and the data from some tests have been reanalyzed one or more times. In cases where more than one analysis result was available, the result believed to be most accurate was listed. For pumping tests reanalyzed in the following section, results of the reanalysis are presented. Table 2 lists results from slug tests of wells in the unconfined aquifer.

Analysis of the well tests in Tables 1 and 2 resulted in determination of transmissivity and, in the few multiple-well cases, storativity and/or specific yield. An equivalent hydraulic conductivity was calculated from the transmissivity by dividing by the effective aquifer thickness. However, this is not a simple conversion for most Hanford Site wells, which may be open to a variety of saturated sedimentary facies with varying hydraulic properties. In most cases, the aquifer thicknesses listed in the tables were taken from the original test reference. They were generally determined by summing the thicknesses of the sediments that are hydraulically connected with the well and appear to be relatively permeable based on geologic logs. This total permeable thickness was then used in calculating an average hydraulic conductivity. However, the actual hydraulic conductivity of individual zones within the tested section may be higher or lower.

TABLE 1. (contd)

WELL	TEST DATE	ANALYSIS METHODS	OPEN INTERVAL (ft)	TRANSMISSIVITY (ft^2/d)	AQUIFER THICKNESS (ft)	HYDRAULIC CONDUCTIVITY (ft/d)	STORATIVITY	REFERENCE
299-W15-18	07/21/87	SLR	232-242	14,000	243	58	-	La,89
299-W18-21	07/14/87	SLR	215.5-225.5	51,000	250	200	-	La,89
299-W18-22	08/26/87	SLR	437.5-447.5	420	248	1.7	-	La,89
299-W18-23	06/22/87	SL,SLR	241-251	25,000	246	102	-	La,89
299-W18-24	07/17/87	TC	230-240	17,000	243	70	0.001	La,89
299-W21-1	/69 ?	TC	220-290	5,400	200	27	-	K&M,73
399-1-4	?	SLR	23-70 ?	70,000	?		-	L&B,79
399-8-1	?	SLR	35-83 ?	350,000	?		-	L&B,79
399-8-2	?	SLR	43-106 ?	40,000	?		-	L&B,79
499-S0-7	08/12/78	TC	221-396	10,500	400 ?	26 ?	-	Undocumented
499-S1-7A	01/05/70	TC/SL	165-200 ?	19,000	400 ?	47 ?	-	Undocumented
499-S1-7B	06/05/82	SLR	230-380 ?	6,700	400 ?	17 ?	-	Undocumented
699-S12-3	09/29/58	SLR	68-88	350	40	9	-	D,74
699-S8-19	?	?	104-132 ?	11,000	50	270	-	Bi,59
699-S3-25	06/01/79	SL,SLR	114-172 ?	930	44	21	-	Undocumented
699-1-18	/58 ?	SLR	109-265 ?	10,000	165	60	-	Bi,59
699-2-3	/69 ?	TC	-	25,000	60	420	-	K&M,73
699-2-33A	05/24/79	SLR	130-180	4,600	44	105	-	Undocumented
699-8-17	06/10/58	SLR	106-166	35,000	55	640	-	D,74
699-8-32	10/13/69	TC,TCR	150-184	1,000	50	20	-	K&M,73
699-10-54A	02/01/77	SLR	103-146	9,700	28	346	-	Undocumented
699-15-26	/58 ?	SLR ?	?	71,000	220	320	-	Bi,59
699-17-5	09/19/58	SLR	45-72 ?	1,100	45	25	-	Bi,59
699-17-47	06/23/69	SLR	175-340	5,100	105	49	-	Reanalysis

TABLE 1. (contd)

WELL	TEST DATE	ANALYSIS METHODS	OPEN INTERVAL (ft)	TRANSMISSIVITY (ft^2/d)	AQUIFER THICKNESS (ft)	HYDRAULIC CONDUCTIVITY (ft/d)	STORATIVITY	REFERENCE
699-47-35C	06/14/79	BC	67-100 ?	530	44	12	0.002, sy = 0.15	G,81
699-47-60	09/03/69	SLR	250-277	3,300	41	80	-	D,74
699-53-55A	01/16/88	SLR	197-221	66,300	98	660	0.45	Undocumented
699-55-50B	10/01/56	TC	40-100	400,000	65	6,150	0.2	Reanalysis
699-56-53	11/11/82	SL	190-270 ?	270			-	GLF,84
699-60-57	08/16/78	SL	142-155	9,800	70	140	-	G,81
699-61-66	02/22/77	SLR	116-220	>40,000	104	>400	-	D,74
699-62-43B	04/06/54	CM/CMR	33-63	50,800	30	1,700	0.06	Bi,57
699-63-90	07/16/69	TC	115-147	40,000-63,000	140	290-450	-	K&M,73
699-65-50	05/08/57	SLR	55-125	64,000	35	1,800	-	Bi,59
699-71-52	/58 ?	SLR ?	120-160	4,000	50	80	-	Bi,59
699-71-77	09/17/69	TC	60-288	16,000-44,000	367	84-120	-	K&M,73
699-77-54	07/23/57	SL	70-120 ?	3,460	72	48	-	Gi,92
699-87-55	07/02/69	SL	59-92	1,950	35	55	-	Gi,92

Key to References:

Bi,57 Bierschenk 1957
Bi,59 Bierschenk 1959
D,74 Deju 1974
F,89 Fruland et al. 1989
G,81 Graham et al. 1981
Gi,92 Gilmore et al. 1992
GLF,84 Graham et al. 1984
K&M,73 Kipp and Mudd 1973
La,89 Last et al. 1989
Li,88 Liikala and Aaberg 1988
Lu,92 Luttrell et al. 1992
L&B,79 Lindberg and Bond 1979
W,87 Weekes et al. 1987
WHC,90 WHC 1990

Analysis Methods:

TC Theis (1935) curve matching of drawdown data
TCR Theis (1935) curve matching of recovery data
BC Boulton (1963) curve matching
SL Cooper and Jacob (1946) semilog straight line
SLR Theis (1935) semilog straight line for recovery data

6.0 REANALYSIS OF SELECTED PUMPING TESTS

Eight aquifer pumping tests were selected for reanalysis using the techniques described in Section 3.0. Diagnostic plots showing the derivative of the water-level change were used to help identify valid data for semilog straight-line analysis. The objective of the reanalysis effort was to determine the reliability of past hydraulic property estimates.

Tests were selected for reanalysis mainly on the basis of their location in the area south of Gable Mountain and between the 200-East Area and the Columbia River. Most of the waste water and transportable contaminants discharged to the ground in the 200-East Area are expected to move through this area with the ground water and eventually discharge to the Columbia River. Locations of the wells selected for reanalysis are shown in Figure 11.

Well 699-17-47

Well 699-17-47 was one of 25 wells tested by PNL in 1969 using the constant discharge method (Kipp and Mudd 1973). The test interval in this well extended from the water table, at a depth of 175 ft, to a depth of 340 ft near the top of basalt. The test interval contains a clay unit between 220 ft and 280 ft. The duration of pumping was 7 h at a flow rate of 90 gal/min. Recovery measurements were made for 16.7 h following the end of pumping.

Kipp and Mudd (1973) reported a transmissivity range of 1800 to 3400 ft^2/d based on type-curve analyses of both drawdown and recovery data. The thickness of the permeable part of the test interval was assumed to be 75 ft. Based on this aquifer thickness, an average hydraulic conductivity range of 24 to 45 ft/d was calculated for the permeable section.

Deju (1974) applied the straight-line solution to the first 200 min of drawdown data to estimate a transmissivity value of 5300 ft^2/d. This result was divided by the test interval minus the thickness of the clay unit, or 105 ft, to calculate a value of 50 ft/d for average hydraulic conductivity.

Because of influences from pumping-rate variation, the drawdown data were not reanalyzed. A log-log diagnostic plot of the recovery water-level data is shown in Figure 12. The derivative of the water-level recovery is also shown. The derivative was calculated using the Agarwal equivalent time

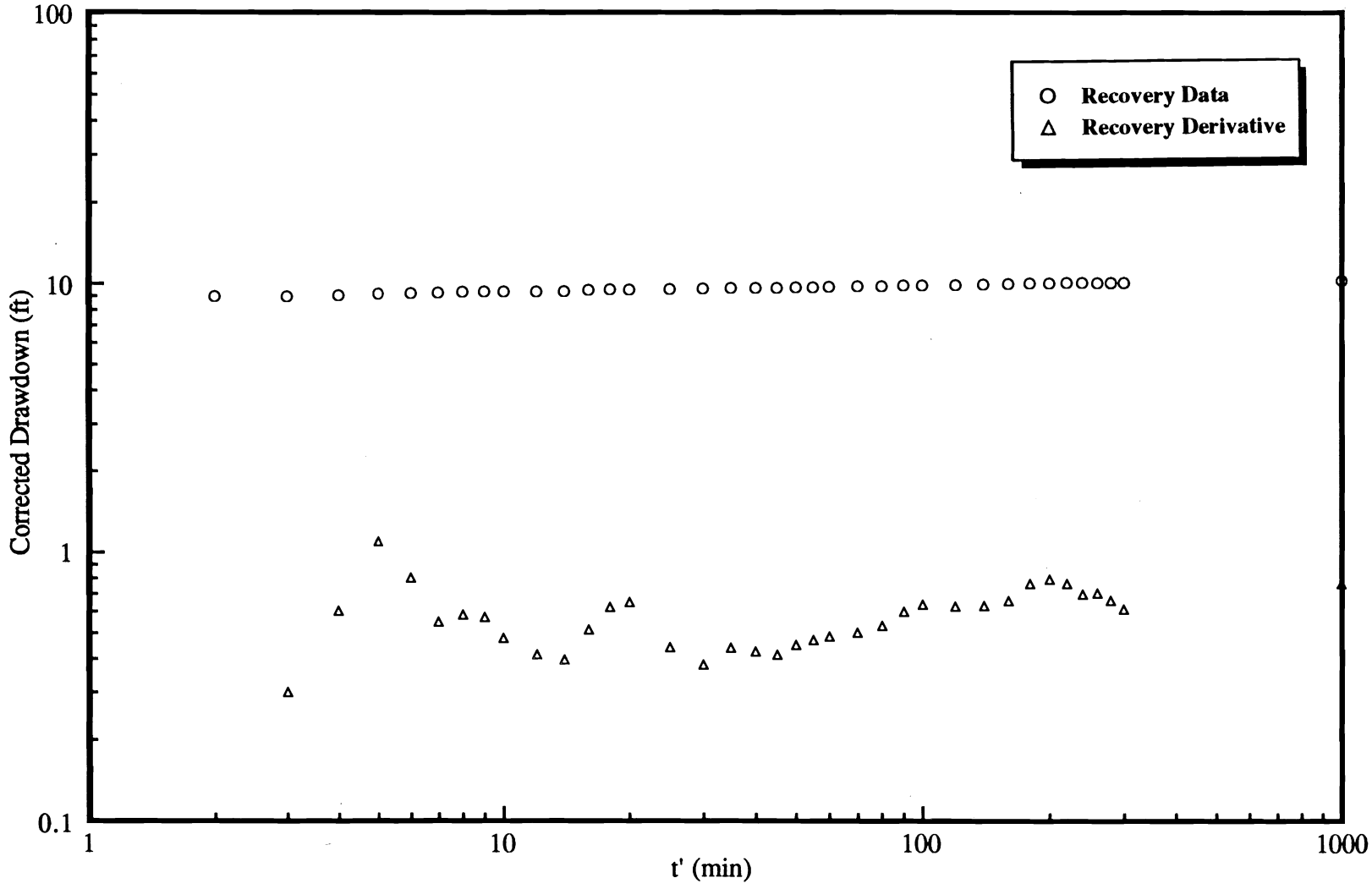


FIGURE 12. Log-Log Diagnostic Plot of the Recovery Data and Derivative for Well 699-17-47

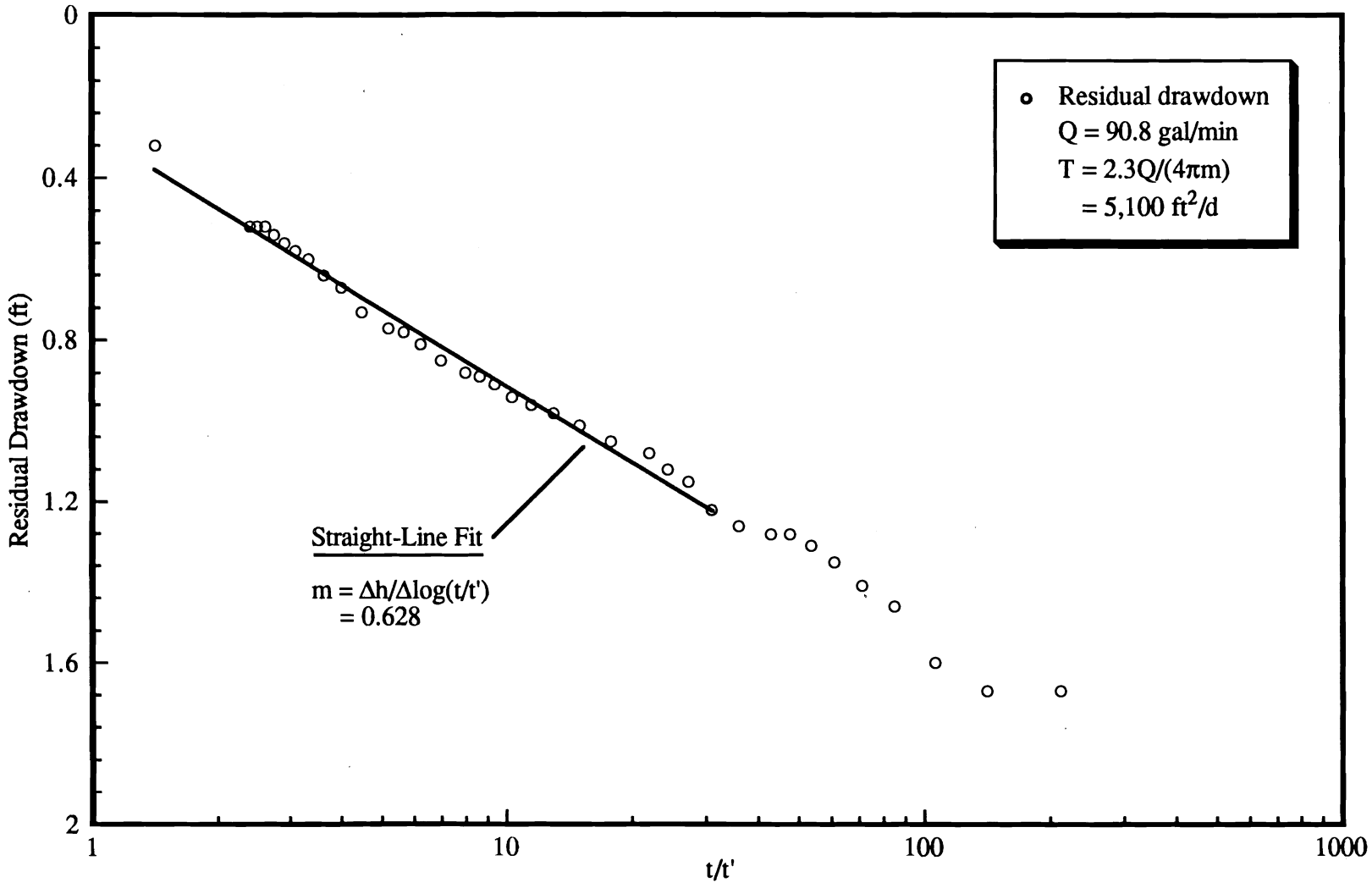


FIGURE 13. Semilog Straight-Line Analysis of Recovery Data for Well 699-17-47

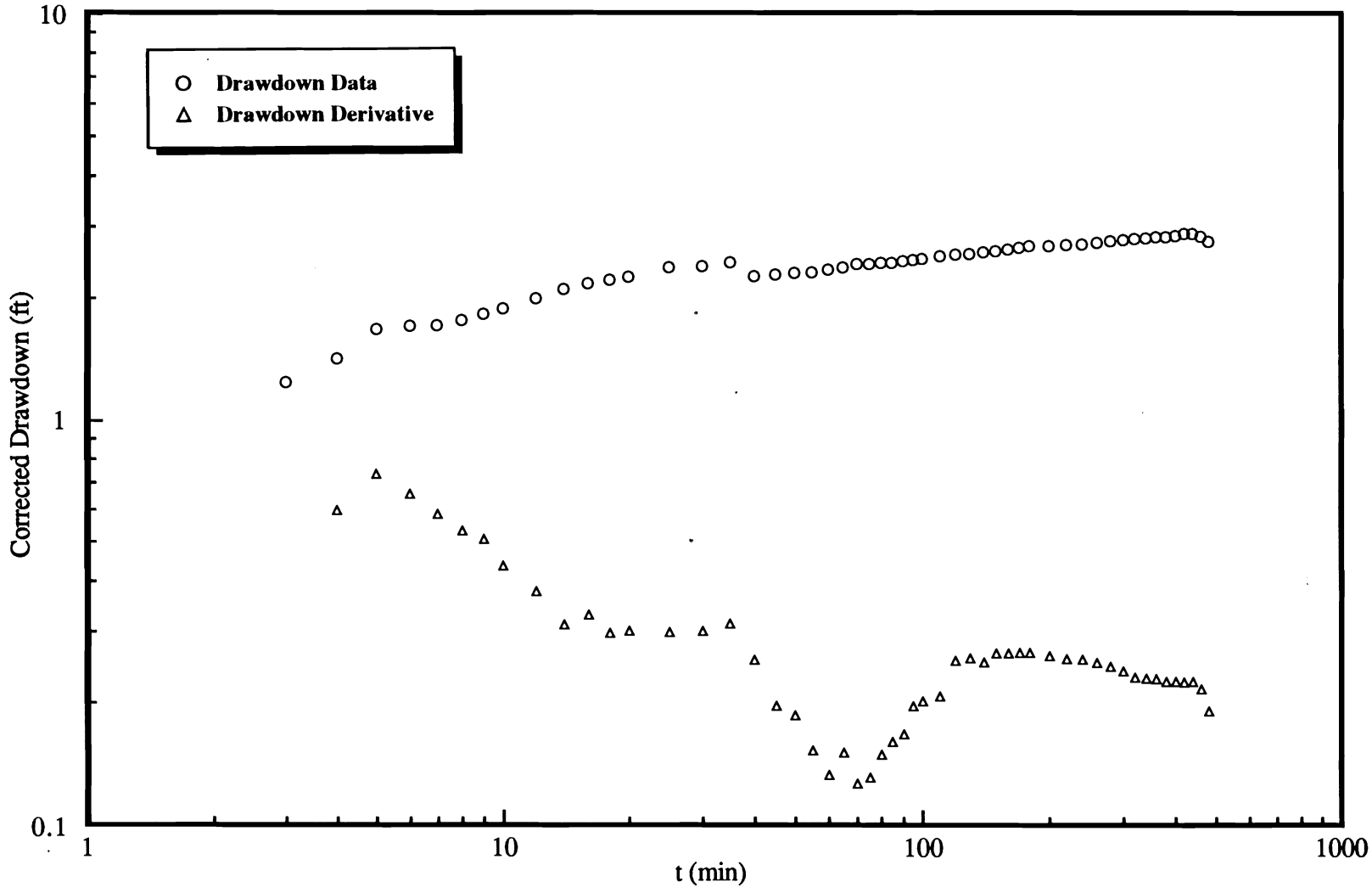


FIGURE 14. Log-Log Diagnostic Plot of the Drawdown Data and Derivative for Well 699-26-15

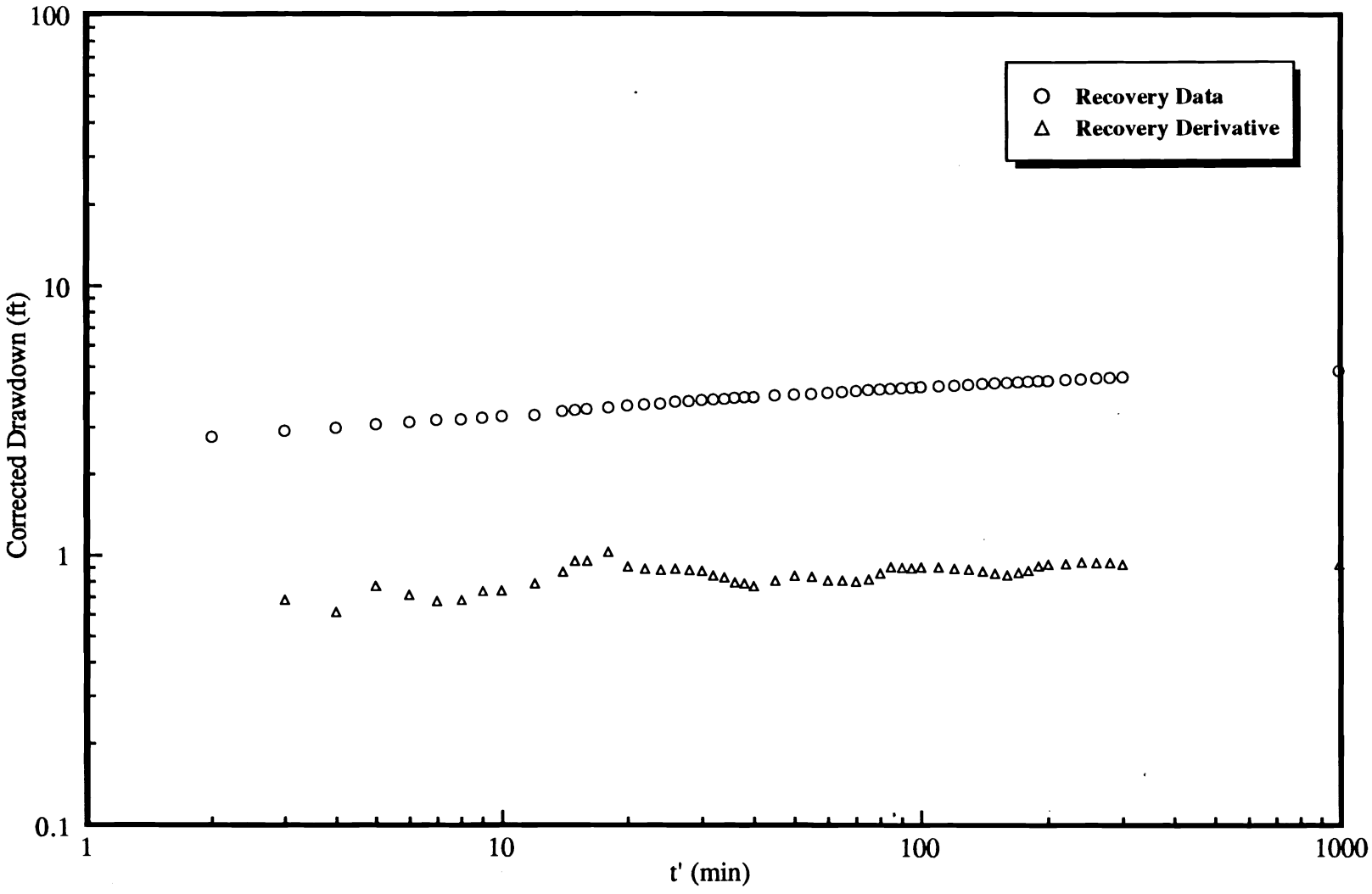


FIGURE 16. Log-Log Diagnostic Plot of the Recovery Data and Derivative for Well 699-26-15

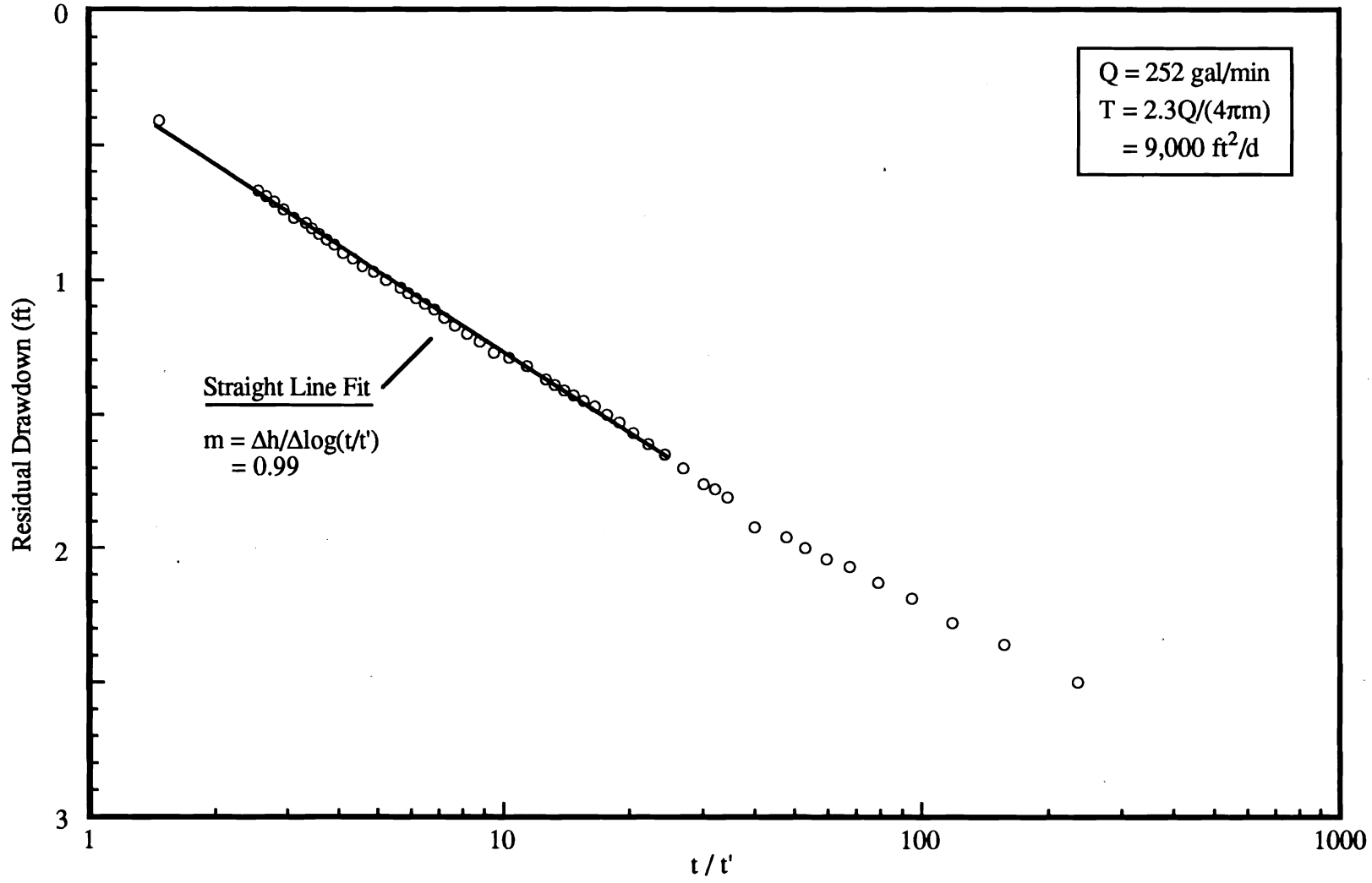


FIGURE 17. Semilog Straight-Line Analysis of Recovery Data for Well 699-26-15

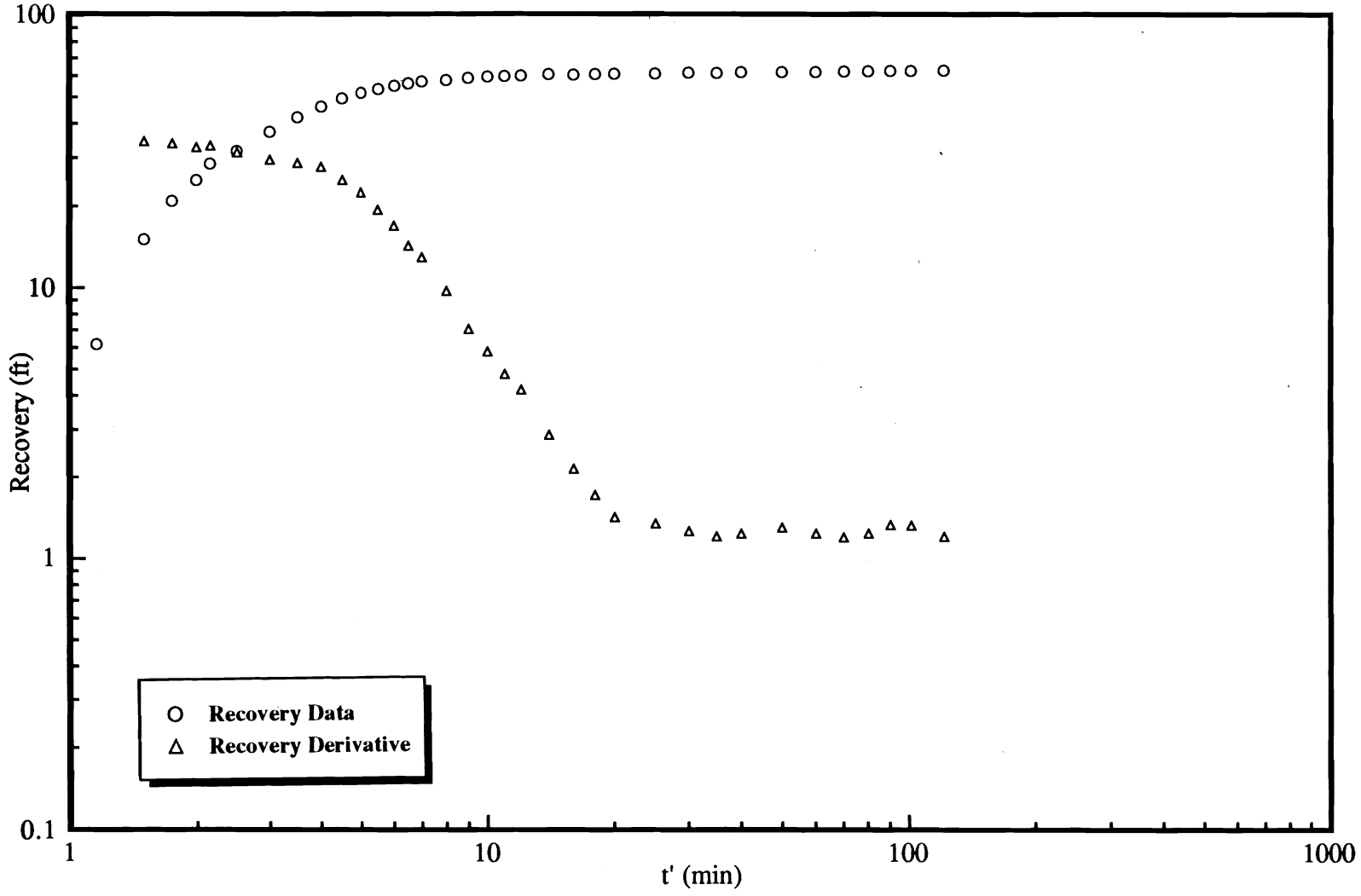


FIGURE 18. Log-Log Diagnostic Plot of the Recovery Data and Derivative for Well 699-28-40

for coefficient of storage. Graham et al. (1981) do not state which data set was used for the analysis and do not show plots and analyses.

Figure 19 shows a composite diagnostic plot of the drawdown data in both pumping well B and observation well A. An apparent well loss of 3.8 ft was subtracted from the pumping well drawdown data. Corrections for aquifer dewatering had no significant effect because the aquifer thickness is much greater than the drawdown. The derivative response for the observation well shows some stabilization for the last eight data points. However, it is still trending upward, indicating a changing slope on the semilog plot. This change may be caused by the transition from elastic response to delayed yield expected for an unconfined aquifer. Radial flow conditions are apparently not reached for the elastic response part of the curve prior to influence of the transition to delayed yield. If a transmissivity of 12,000 ft^2/d and a storativity of 0.1, corresponding to the delayed-yield portion of the response, are assumed, then t/r^2 must be greater than 0.3 for the criterion $u < 0.01$ to be met. As shown in Figure 19, pumping was terminated before this point was reached. Neither the drawdown nor the recovery data from the observation well data are, therefore, considered valid for straight-line analysis.

A match of the observation well drawdown data with the Theis curve was attempted. The curve match shown in Figure 20 results in a transmissivity of 10,000 ft^2/d and storativity of 0.2. The match is poor and the results are considered a qualitative estimate of the minimum value for transmissivity because the data fall below the type curve. A better match to the data could be achieved, but would result in an unrealistically high value of storativity. The data appear to be approaching the match curve at late time.

The early drawdown data at the pumped well (before about 50 min) appear to be affected by flow-rate variation (Figure 19). The water level in the pumped well increased for a period during the early part of the test. The late-time data show a decreasing derivative that could indicate a constant-head boundary, vertical leakage, or a decrease in flow rate. Because of these complications, only the intermediate-time drawdown data from the pumping well, collected after the flow-rate variation and before the apparent boundary effect, were considered suitable for straight-line analysis. This includes the data from 50 to 110 min after pumping began. The semilog straight-line

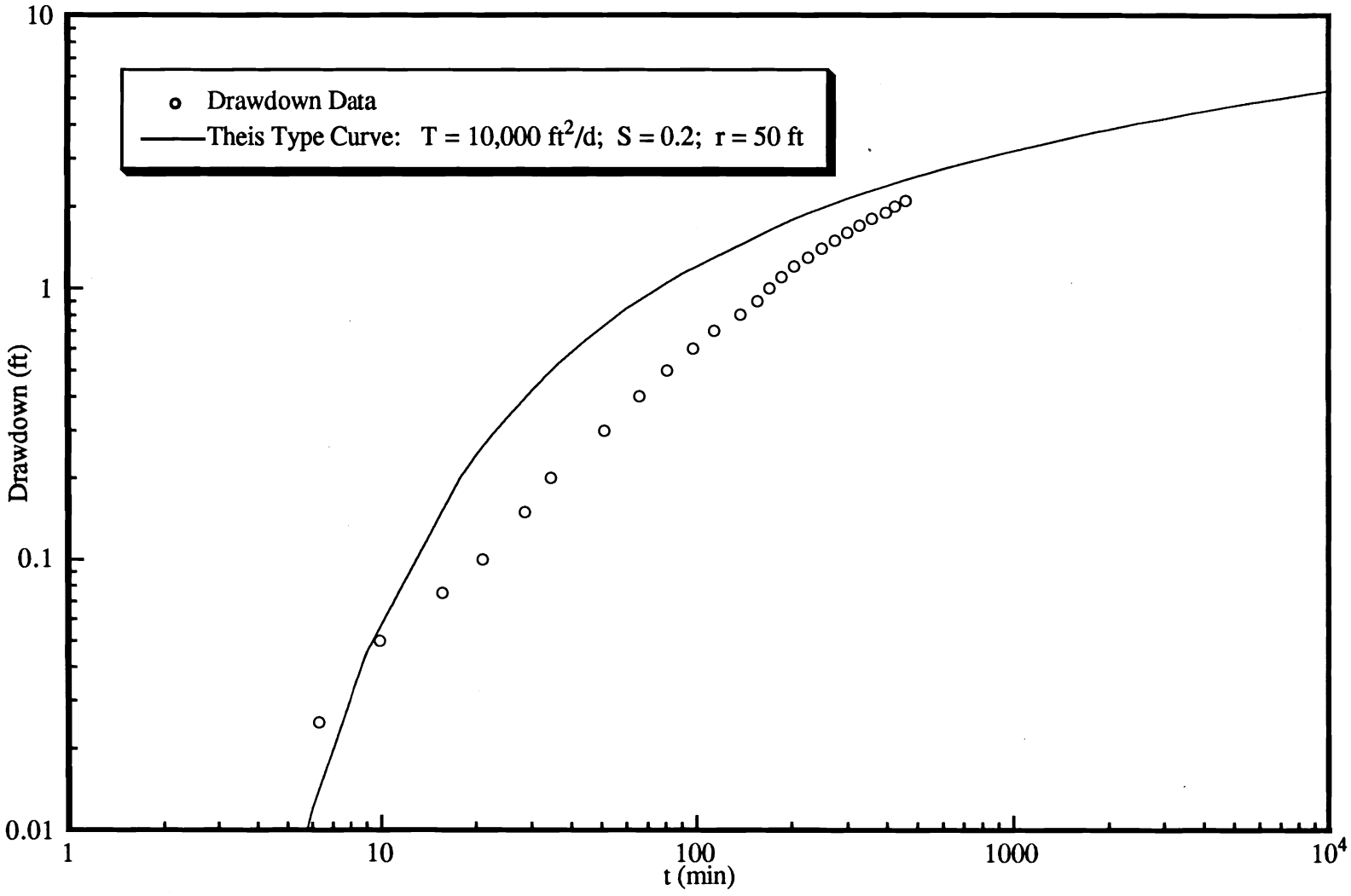


FIGURE 20. Theis Curve Match with Drawdown Data for Observation Well 699-31-53A

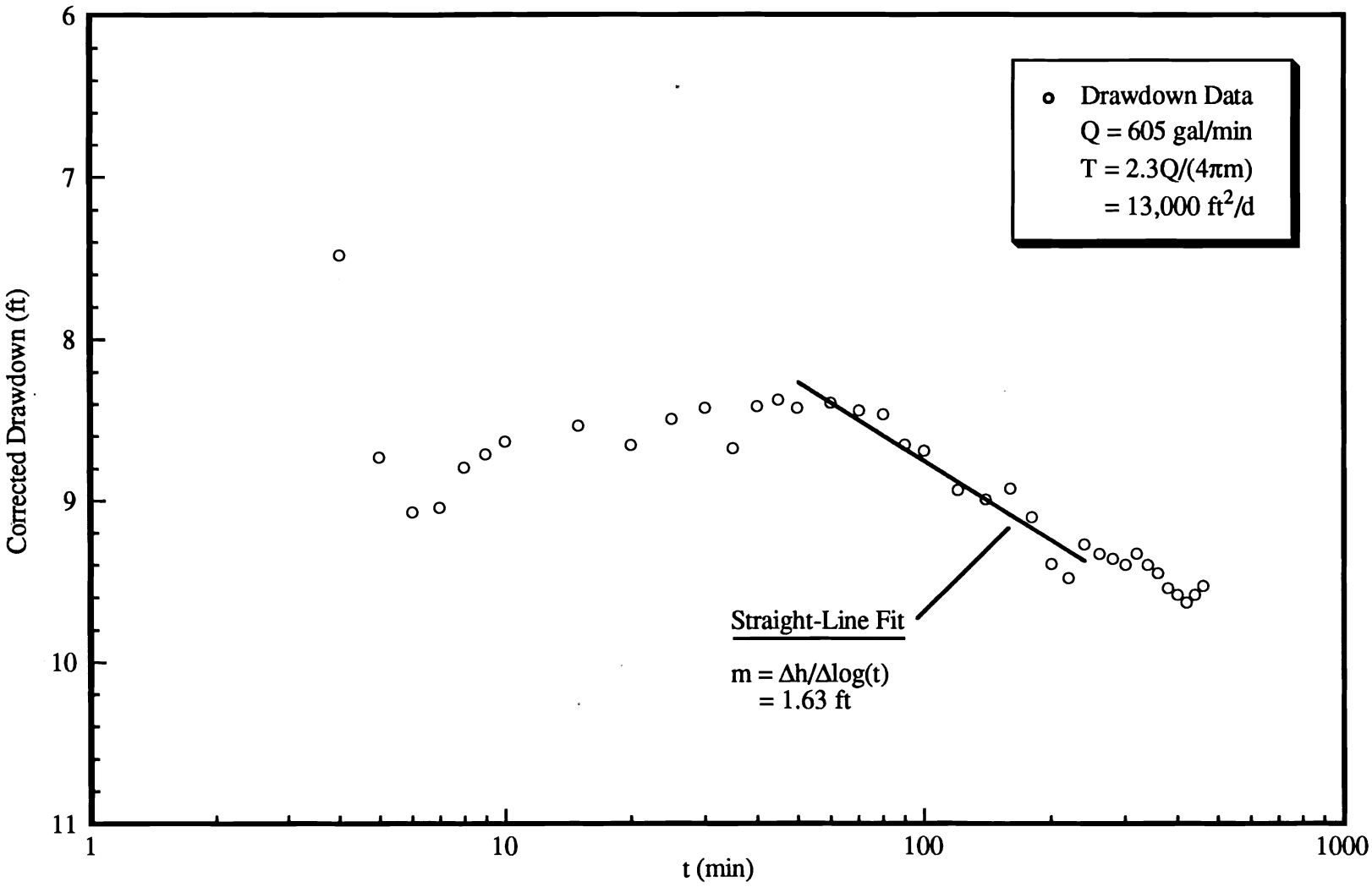


FIGURE 21. Semilog Straight-Line Analysis of Drawdown Data for the Pumping Well 699-31-53B

20,700 ft^2/d from this test. Deju (1974) disregarded the drawdown data and used only the recovery data to estimate a transmissivity value of 22,000 ft^2/d. Deju (1974) calculated a value for hydraulic conductivity of 250 ft/d for the upper 88 ft of the test interval. Graham et al. (1981) also used the recovery data and applied the Theis (1935) and Cooper and Jacob (1946) techniques to estimate values for transmissivity and hydraulic conductivity of 21,000 ft^2/d and 230 ft/d, respectively.

A log-log diagnostic plot of the drawdown data and derivative (Figure 23) shows a possible delayed yield response, indicated by a valley in the derivative beginning at about 20 min. Early-time data (before 20 min) is affected by the transition to the delayed-yield portion of the curve and is not suitable for straight-line analysis. The diagnostic plot also shows that radial flow conditions are not achieved before pumping is terminated. Therefore, the late-time drawdown data may not be analyzed by the semilog straight-line technique. The recovery data (not shown) appear to be affected by backflow from the pump column. The water level in the well increases during the first 3 min of recovery to within 0.14 ft of the pre-test level. It then decreases over the next 5 min to 0.61 ft below the pre-test level and then begins a slow increase. Because of this perturbation, no attempt was made to reanalyze the recovery data.

Because none of the data from this test were appropriate for straight-line analysis and the recovery data appear to be affected by injection of water from the pump column, the only estimate of transmissivity is a limiting value based on type-curve matching of the drawdown data. Two type-curves are shown in Figure 23. Values for storativity of 0.0001 and 0.1 were assumed in generating these curves and correspond to reasonable values for the elastic response and the delayed yield response of the aquifer, respectively. These assumed values may be incorrect. However, because this portion of the type curve is relatively flat, assuming an elastic storativity an order of magnitude higher or lower than 0.0001, or assuming a specific yield value between 0.01 and 0.2, would not change the transmissivity value determined from the curve match by more than a factor of 2. The drawdown and derivative are characteristic of transition from elastic response to delayed yield response

of an unconfined aquifer. The data were therefore fit between the two type curves. The resulting transmissivity value was 5000 ft^2/d.

The type-curve method is not as reliable as semilog straight-line methods for the pumping well because assumptions that the well is a line sink with no storage and that head losses at the well are negligible are not met. The transmissivity result of type-curve matching for this test is considered a minimum value because well loss may have caused additional drawdown at the well during the test. The transmissivity estimate of 5000 ft^2/d is, therefore, considered a minimum value. The corresponding minimum value of equivalent hydraulic conductivity is 57 ft/d based on an aquifer thickness of 88 ft. From the results of this test, it appears that a pumping duration of 3 to 6 days and a comparable recovery period is needed to accurately determine the transmissivity at this well. Care should be taken to ensure a steady pumping rate and that the recovery data are not affected by backflow from the pump column.

Well 699-35-9

Well 699-35-9 is perforated between the depths of 110 ft and 135 ft. The water-table depth was 113 ft in 1990 (Newcomer et al. 1991) and the aquifer extends to the top of a clay unit at 164 ft. Therefore, the current total aquifer thickness is about 51 ft and the well penetrates the upper 22 ft of the aquifer.

Records of four constant-rate pumping tests of this well are available. These tests were conducted in 1958, 1969, 1977, and 1983. Results of the 1958 test are reported in Bierschenk (1959). A transmissivity of 11,000 ft^2/d was calculated from the recovery data. The 1969 test was analyzed by Kipp and Mudd (1973) and Deju (1974). For this test, pumping was conducted for 4 h at a discharge rate averaging 64 gal/min. A change of slope occurred on the semilog plot of drawdown data from this test. Deju (1974) used straight-line analysis of the earlier-time data to calculate a transmissivity of 2250 ft^2/d and hydraulic conductivity of 45 ft/d. He suggested that the change in slope possibly represented a recharge boundary. Using type-curve fitting analysis, Kipp and Mudd (1973) reported transmissivity values ranging from 1500 ft^2/d to 37,000 ft^2/d. They also reported a storativity range, though this estimate

A diagnostic log-log plot of the drawdown data from the 1977 test is shown in Figure 24. This shows that the drawdown was relatively constant after about 20 min of pumping and even decreased after about 30 min. This behavior may have been caused by a decrease in the discharge rate. A significant well-loss component is likely in the total drawdown and the increase in water level may also have resulted from development of the well and a reduction in the well-loss component. Because of these complications, no analysis of the drawdown data was attempted.

Recovery data are not affected as greatly by well losses or fluctuations in discharge rate during the pumping period. Therefore, the recovery data were relied upon for test analysis. Figure 25 shows a log-log diagnostic plot of the recovery data. The derivative was calculated based on Agarwal's (1980) equivalent time function for recovery data. The derivative shows a steady decline for about the first 140 min of recovery and then begins to increase. The derivative after 140 min may reflect either a stabilization caused by radial flow conditions, or the increasing derivative expected at the beginning of the delayed-yield response. The test was not conducted for a long enough period to determine the correct interpretation. A straight-line analysis of the recovery data after 140 min was conducted as shown in Figure 26. This resulted in a calculated transmissivity of 12,400 ft^2/d and this value is considered the best estimate possible from this test. The corresponding equivalent hydraulic conductivity, based on an aquifer thickness of 50 ft is 248 ft/d. These estimates may be high if the analyzed portion of the recovery curve corresponds to the transition of the delayed-yield response. The total observed drawdown during pumping also indicates that a lower transmissivity is possible. However, the well head-loss component of drawdown is unknown. The calculated transmissivity of 12,400 ft^2/d is, therefore, regarded as a maximum limit value.

Well 699-42-40C

A multi-well test was conducted at this well site, located near B Pond, on January 18, 1982. Well C was the pumping well and water-level data are also available for observation wells A and B located 24 and 25 ft, respectively, from the pumped well. The pretest depth to water was approximately 123 ft. Well A was completed at a depth of 139 ft to 171 ft and well B was

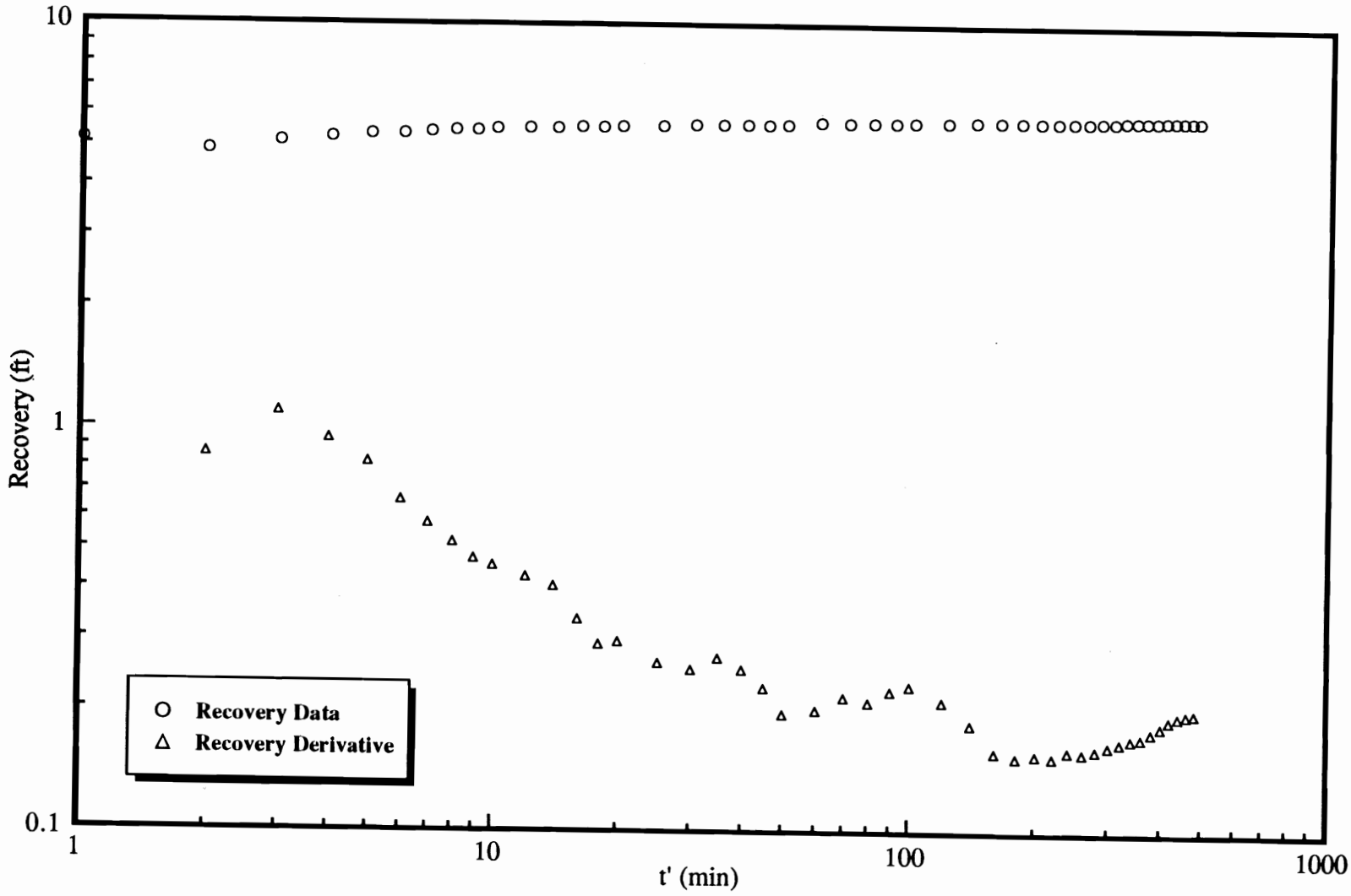


FIGURE 25. Log-Log Diagnostic Plot of the Recovery Data and Derivative for Well 699-35-9

completed at a depth of 130 ft to 150 ft. Well C was open to an adjacent interval at the time of the test. However, the well was later deepened into the basalt aquifer and no record was found of the exact depth interval penetrated by the pumping well. For the reanalysis it was assumed that the pumping well completely penetrated the aquifer. Pumping was conducted for just under 6 h at a flow rate of approximately 21 gal/min.

The Cooper and Jacob (1946) straight-line solution was applied to the drawdown data for both observation wells by Graham et al. (1984). Transmissivity values of 310 ft^2/d and 360 ft^2/d were calculated for data from wells A and B, respectively. Calculated values of storativity were 0.017 and 0.009.

A composite log-log plot of the drawdown data from both observation wells is shown in Figure 27. The derivatives are also plotted and show that straight-line semilog analysis is not valid for this data. Only the last two data points show a possible stabilized derivative. Based on the average transmissivity and storativity calculated by Graham et al. (1984), it may be calculated that the time corresponding to $u < 0.01$ is $t > 800$ min for well A and $t > 870$ min for well B. The observation well data do not meet this criteria for straight-line analysis. For reanalysis of the test data, the composite log-log plot was fit to the Theis (1935) type curve as shown in Figure 27. The resulting value of transmissivity was 300 ft^2/d and the storativity was 0.02. The data fit was relatively poor and the greatest emphasis was placed on fitting the late-time data to the expected drawdown curve. The greater drawdown at well B may be caused by partial penetration of the pumping well. As mentioned, the completion depth of the pumping well is unknown and it may have been in the upper part of the aquifer, adjacent to well B.

Well 699-55-50

Several aquifer pumping tests have been conducted at the 699-55-50 site using various test design configurations. The site consists of four wells, A, B, C, and D, completed within the unconfined aquifer. The test selected for reanalysis was conducted in October 1956 and was one of the first pumping tests on the Hanford site (Biershcenk 1957). Well B was the pumping (stress) well and observation well data were collected from well A at a radial distance

of 25 ft, well C at a radial distance of 61.4 ft, and well D at a radial distance of 157 ft. At the time of the test, the pumping well and observation wells A and D completely penetrated the aquifer. The bottom of the aquifer was at 85 ft and the static depth to water prior to the test ranged from 45 to 47 ft. Therefore, the aquifer thickness was about 40 ft. The open depth interval for observation well C was 35 to 59 ft.

Pumping began at 9:00 a.m. on October 1, 1956 and continued for 48 h. The flow rate during pumping averaged 697 gal/min. Although the pump was off for a short period at about 8 h into the test, the flow rate varied by less than 5% over the remainder of the pumping period. Recovery data were recorded for 48 h after stopping the pump.

The original analyses (Bierschenk 1957) matched the composite recovery data from the observation wells with the Theis type curve. The early-time data deviated from the curve, as expected, because of the effects of delayed yield. The resulting transmissivity was 400,000 ft^2/d and storativity was 0.20. Straight-line semilog analyses of the late-time recovery data from wells A, C, and D were also conducted and yielded transmissivity values between 400,000 and 414,000 ft^2/d. The storativity values determined by this method ranged from 0.19 to 0.21.

The results of Bierschenk's (1957) analyses for the different observation wells agree very well for this test. To check the validity of the assumption of radial infinite-acting flow, a composite diagnostic plot (Figure 28) of the observation well responses and the derivative was prepared. The response predicted by the Theis equation for transmissivity of 400,000 ft^2/d and storativity of 0.2 is also shown on the plot. The derivative of well A shows a stabilization after time corresponding to $t/r^2 = 0.03$, and a depressed derivative at earlier time corresponding to the transition from elastic aquifer response to delayed yield. The recovery data from well C falls below that of well A and the two responses appear to be converging. This may reflect the partial penetration of well C. The derivative for well C also shows the delayed-yield effect. The results of the original analysis are believed to be valid.

Reanalysis Summary

Results of the pumping test reanalyses are summarized in Table 3. The reanalysis result agrees with the original analysis result for half of the tests examined. Reanalysis indicated that only limiting values of transmissivity could be determined for wells 699-33-56 and 699-35-9. The revised transmissivity estimate for well 699-31-53B is 50 to 25% lower than the original result. Results from one of the wells (699-28-40) did not represent the aquifer.

Different tests vary in many respects including the original purpose of the tests, accuracy and precision of the test equipment, test duration, well

TABLE 3. Results of Aquifer Test Reanalyses

WELL (699)	ORIGINAL ANALYSIS T (ft^2/d)	ORIGINAL ANALYSIS S	REANALYSIS T (ft^2/d)	REANALYSIS S	COMMENTS
-17-47	5,300 (D)	-	5,100	-	
-26-15	8,880 (D)	-	9,000	-	
-28-40	5 (D)	-	-	-	Data not representative of the aquifer
-31-53B	21,000 (D)	-	10,000-15,000	-	Result for pumping well
-33-56	20,700 (B)	-	> 5,000	-	Minimum limiting value
-35-9	2,250 (D)	-	< 12,400	-	Maximum limiting value
-42-40C	310 (G) 360	.009017	300	.02	Observation well
-55-50	400,000 (B)	.20	400,000	.20	Observation well

(D) = Deju (1974).

(B) = Bierschenk (1957).

(G) = Graham et al. (1981).

7.0 REFERENCES

Agarwal, R. G. 1980. "A New Method to Account for Producing Time Effect When Drawdown Type Curves are Used to Analyze Pressure Buildup and Other Test Data." SPE Paper 9289, Society of Pet. Engineers, Richardson, Texas.

Barton, K.R.O. 1990. Borehole Completion Data Package for Low-Level Burial Grounds - 1990. WHC-MR-0205, Westinghouse Hanford Company, Richland, Washington.

Bierschenk, W. H. 1957. Hydraulic Characteristics of Hanford Aquifers. HW-48916, General Electric Company, Hanford Atomic Products Operation, Richland Washington.

Bierschenk, W. H. 1959. Aquifer Characteristics and Ground-Water Movement at Hanford. HW-60601, General Electric Company, Hanford Atomic Products Operation, Richland Washington.

Borghese, J. V., and S. M. Goodwin. 1989. Hydrologic Testing at the 216-B-3 Pond, 1989. PNL-7180, Pacific Northwest Laboratory, Richland, Washington.

Borghese, J. V., D. R. Newcomer, W. E. Cronin, and S. M. Goodwin. 1990. Hydrologic Testing at the Low-Level Burial Grounds, 1989. PNL-7333, Pacific Northwest Laboratory, Richland, Washington.

Boulton, N. S. 1963. "Analysis of Data from Nonequilibrium Pumping Tests Allowing for Delayed Yield from Storage." Proc. Inst. Civil Eng. 26:469-482.

Bourdet, D., J. A. Ayoub, and Y. M. Pirad. 1984. "Use of Pressure Derivative in Well Test Interpretation." SPE Paper 12777, Society of Pet. Engineers, Richardson, Texas.

Bouwer, H. 1989. "The Bouwer and Rice Slug Test - An Update." Ground Water 27(3):304-309.

Bouwer, H., and R. C. Rice. 1976. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells." Water Resour. Res. 12(3):423-428.

Cearlock, D. B., K. L. Kipp, and D. R. Friedrichs. 1975. The Transmissivity Iterative Calculation Routine - Theory and Numerical Implementation. BNWL-1706, Pacific Northwest Laboratory, Richland, Washington.

Chapuis, R. P. 1992. "Using Cooper-Jacob Approximation to Take Account of Pumping Well Pipe Storage Effects in Early Drawdown Data of a Confined Aquifer." Ground Water 30(3):331-337.

Cooper, H. H., Jr., and C. E. Jacob. 1946. "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History." Trans. Amer. Geophys. Union 27:526-534.

Graham, M. J., G. V. Last, and K. R. Fecht. 1984. An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site. RHO-RE-ST-12P, Rockwell Hanford Operations, Richland, Washington.

Hall, M. D. 1981. Near Field Impact of 216-U-10 (U-Pond) Decommissioning on the Unconfined Aquifer. RHO-LD-157, Rockwell Hanford Operations, Richland, Washington.

Hantush, M. S. 1962. "Drawdown Around a Partially Penetrating Well." Amer. Soc. Civil Engrs. Trans. 127:268-283.

Hart, D. H. 1951. Pumping Tests on Wells 3000F and 3000G near North Richland, Washington. USGS typewritten report to AEC, U.S. Government Printing Office, Washington, D.C.

Hvorslev, M. J. 1951. "Time Lag and Soil Permeability in Groundwater Observations." U.S. Army Corps. of Engrs. Waterways Exper. Station Bulletin 36, Vicksburg, Mississippi.

Jacob, C. E. 1963. "Determining the Permeability of Water Table Aquifers." In Methods of Determining Permeability, Transmissibility, and Drawdown, ed. R. Bentall, USGS Water Supply Paper 1536-I, U.S. Government Printing Office, Washington D.C.

Jacobson, E. A. 1985. A Statistical Parameter Estimation Method Using Singular Value Decomposition with Application to Avra Valley Aquifer in Southern Arizona. Dissertation, University of Arizona, Tucson, Arizona.

Jacobson, E. A., and M. D. Freshley. 1990. An Initial Inverse Calibration of the Ground-Water Flow Model for the Hanford Unconfined Aquifer. PNL-7144, Pacific Northwest Laboratory, Richland, Washington.

Jenkins, O. P. 1922. "Underground Water Supply of the Region About White Bluffs and Hanford." Bulletin No. 26, Division of Geology, State of Washington Dept. of Conservation and Development, Olympia, Washington, 41 pp.

Kipp, K. L. 1973. "Unsteady Flow to a Partially Penetrating Finite Radius Well in an Unconfined Aquifer." Water Resour. Res. 9:448-462.

Kipp, K. L., and R. D. Mudd. 1973. Collection and Analysis of Pump Test Data for Transmissivity Values. BNWL-1709, Pacific Northwest Laboratory, Richland, Washington.

Kipp, K. L., A. E. Reisenauer, C. R. Cole, and C. A. Bryan. 1976. Variable Thickness Transient Groundwater Flow Model Theory and Numerical Implementation (Updated). BNWL-1703, Pacific Northwest Laboratory, Richland, Washington.

Last, G. V., B. N. Bjornstad, M. P. Bergeron, D. W. Wallace, D. R. Newcomer, J. A. Schramke, M. A. Chamness, C. S. Cline, S. P. Airhart, and J. S. Wilbur. 1989. Hydrogeology of the 200 Areas Low-Level Burial Grounds - An Interim Report. PNL-6820, Pacific Northwest Laboratory, Richland, Washington.

Newcomer, D. R., S. S. Teel, A. W. Pearson, K. R. Barton, B. N. Bjornstad, and T. J Gilmore. 1992. Unconfined Aquifer Hydrologic Test Data Package for the 200-West Area. PNL-7959, Pacific Northwest Laboratory, Richland, Washington.

Parker, G. G., and A. M. Piper. 1949. Geologic and Hydrologic Features of the Richland Area, Washington, Relevant to Disposal of Waste at the Hanford Operations Office of the Atomic Energy Commission. USGS-WP-7, U.S. Government Printing Office, Washington, D.C.

Piper, A. M. 1944. "Adequacy of Public Water Supplies in the Hanford Barracks and Richland Village Areas of the Hanford Engineer Works (Project 9536) Hanford, Washington." USGS typewritten memorandum, U.S. Government Printing Office, Washington, D.C.

Poeter, E., and D. R. Gaylord. 1990. "Influence of Aquifer Heterogeneity on Contaminant Transport at the Hanford Site." Ground Water 28:900-909.

Schalla, R., and D. W. Wallace. 1988. Interim Characterization Report for the 300 Area Process Trenches. PNL-6716, Pacific Northwest Laboratory, Richland, Washington.

Spane, F. A., Jr. 1992a. Applicability of Slug Interference Tests Under Hanford Site Test Conditions: An Analytical Assessment and Field Test Evaluation. PNL-8070, Pacific Northwest Laboratory, Richland, Washington.

Spane, F. A., Jr. 1992b. Hydrologic Test Results for Savage Island Wells 699-32-22B, 699-42-E9A, and 699-42-E9B. PNL-8173, Pacific Northwest Laboratory, Richland, Washington.

Strand, J. R., and D. H. Hart. 1952. Preliminary Report on the Aquifer Evaluation Test in the 100-K Area, AEC Hanford Reservation, Washington. USGS typewritten report to AEC, U.S. Government Printing Office, Washington, D.C.

Theis, C. V. 1935. "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage." Trans. Amer. Geophys. Union 16:519-524.

Trent, S. J. 1992. Hydrogeologic Model for the 200 West Groundwater Aggregate Area. WHC-SD-EN-TI-014, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

U.S. Department of Energy (DOE). 1988. Consultation Draft Site Characterization Plan, Reference Repository Location, Hanford Site, Washington, Vol. 1 and 2. DOE/RW-0164, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, D.C.

Walter, G. R., and G. M. Thompson. 1982. "A Repeated Pulse Technique for Determining the Hydraulic Properties of Tight Formations." Ground Water 20(2):186-193.

Weeks, E. P. 1969. "Determining the Ratio of Horizontal to Vertical Permeability by Aquifer-Test Analysis." Water Resour. Res. 5:196-214.

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