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Reduction of the Well Test Data for Test Well USW H–1, Adjacent to Nevada Test Site, Nye County, Nevada

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REDUCTION OF THE WELL TEST DATA FOR TEST WELL USW H-1, ADJACENT TO NEVADA TEST SITE, NYE COUNTY, NEVADA

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Abstract

The drawdown and recovery data for three pump tests, three recovery tests and six injection tests in well USW H-1 are reduced to determine hydraulic conductivity and storativity, assuming the medium is homogeneous, isotropic, and porous. Conductivity ranges from about 10^{-5} m/s in the upper zone tested to 10^{-10} m/s in the lower test zone, and storativity ranges from about 5×10^{-7} to about 0.5. This study was conducted to support assessment of the behavior of the groundwater system at Yucca Mountain near the Nevada Test Site in southwest Nevada. After the work for the report was completed, the U.S. Geological Survey published estimates of hydraulic conductivity based on the same test data analyzed here. This report is therefore also an independent confirmation of hydraulic conductivity estimates for well USW H-1 for the saturated zone, as well as a listing of storativity estimates.

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PURPOSE

The work described in this report was performed by Sandia National Laboratories (SNL) as a part of the Nevada Nuclear Waste Storage Investigations (NNWSI) project. Sandia is one of the principal organizations participating in the project, which is managed by the U.S. Department of Energy's (DOE) Nevada Operations Office. The project is a part of the DOE's program to safely dispose of the radioactive waste from nuclear power plants. The NNWSI project is conducting detailed studies of an area on and near the Nevada Test Site (NTS) in southern Nevada to determine the feasibility of developing a repository.

In the investigation of a site for a waste repository, it is necessary to understand the movement of fluids in the surrounding rocks. As part of the investigation in the NNWSI Project, a number of wells have been drilled to determine the hydraulic characteristics of the rock near Yucca Mountain, the current potential site. The hydraulic characteristics are necessary for estimating transport of waste from a repository. Drawdown and recovery test data from one of the wells, USW H-1 (Rush et al. 1983a), have been published. It is necessary to reduce these test data to obtain estimates of K (hydraulic conductivity) and S (storativity) for the stratigraphic units tested. The purpose of this report is to so reduce the test data from USW H-1, which was drilled by the U.S. Geological Survey (USGS). The analyses were done to supply performance assessment with hydraulic parameters for use in studies. After the initial analyses for this report were complete, Rush and others (1983b) published the USGS analyses of hydraulic conductivity for USW H-1. This report therefore provides an independent confirmation of hydraulic conductivity estimates for well USW H-1, as well as a listing of storativity estimates.

Single-well pump tests are often carried out without any observation wells. In these cases, the data available for reduction are the pumping rate, the history of water levels within the well, and the physical characteristics of the well and characteristics of the rock surrounding the well. Data for the tests on USW H-1 were obtained from 3 pump tests, 3 recovery tests, and 6 injection tests. From such data, hydraulic conductivities (K) are commonly deduced graphically by matching the drawdown or recovery curves to standard curves appropriate to certain aquifer conditions. Storativity (S) is difficult to estimate graphically, and sensitivity analyses of this deduced parameter generally are not possible by graphical methods.

Data reduction for this report was done using a computer code, PUMP (Barr, Miller, and Gonzalez, 1983), patterned after the analyses of Rushton and Redshaw (1979). A listing of input parameters for the code is provided in Appendix A. Appendix B lists the actual data values for input for two examples. The particular version of the code used for this report is given in Appendix C. This code describes axially-symmetric, horizontal flow during well tests in a saturated, porous medium. By alteration of the input, it can account for changes in K and S at various distances from the test well, delayed yield, and well-bore damage, as well as other parameters. This code allows investigations of the sensitivity of the results to changes in hydraulic conductivity and storativity and of the subsurface location of possible water sources of different magnitude that may occur near the wall. In effect, the integrated effects of large blocks are approximated as an equivalent porous medium.

The mathematical model used for calculations of K and S assumes that there is no vertical infiltration, the medium is vertically homogeneous, and the following differential equation describes drawdown and recovery [Rushton and Redshaw, 1979]:

$$\frac{\partial}{\partial r}\left(Kb\,\frac{\partial s}{\partial r}\right) + \frac{bK}{r}\frac{\partial s}{\partial t} = \bar{S}\,\frac{\partial s}{\partial t} + q$$

where

s = drawdown (L)

r = radial coordinate (L)

b = thickness of aquifer (L)

K = hydraulic conductivity (L/T)

$\bar{S}$ = storage coefficient or storativity

t = time (T)

q = recharge per unit area (L^3/L^2T).

In applying the code it is necessary to assume starting values for the hydraulic conductivity, storativity, and distance to any hydraulic barrier (or source). Since the graphical output of calculated drawdown or recovery curves is displayed with the observed data, it is easy to see the degree of agreement between the calculated curves and those representing the actual test data. By trial and error, values of hydraulic conductivity and storativity can be found which give an approximate fit between the calculated and observed values.

When a reasonable match for conductivity and storativity is obtained, the possible hydraulic distance to a source or barrier, R_{max}, may be changed to determine whether the existence of such features improves the fit between calculated and observed data. Such features, located at some distance from the well, are likely to be fractures or faults that serve as conduits or as barriers to flow. They characteristically show up in well tests as horizontal sections at the end of a drawdown or recovery test. K and S can be varied independently to determine sensitivity to each of these hydraulic parameters. Similar variations may be conducted for recovery curves with the additional requirement that a good match requires a good estimate of the original head distribution in the aquifer as a function of radius from the well at the start of the recovery. A few runs of the code give indications of how the initially unknown head distribution should be adjusted so that a reasonable match can be obtained.

Pump-test data used in this report are presented in Table 1. Injection test data are presented in Table 2 and described in Rush and others (1983a). For the injection tests the initial head conditions in the injection tubing, as well as in the aquifer, must be specified, and the head must be corrected for the volumetric ratio of the test zone to the producing zone; otherwise the problem is solved the same way as are the recovery tests. Testing procedures and the presumed geologic structure also described in Rush and others (1983a).

Tests Examined. The tests examined consist of three pump tests and three recovery tests over the depth intervals of 572-688 m, 687-1829 m, and 687-1829 m and six injection tests over the intervals 687-697 m, 811-1829 m,

Table 1
Pump-Test Parameters
(from Rush et al. 1983a)

Test Number	Test Interval (meters)	Stratigraphic unit(s) tested	Type of Test	Pumping rate, Q (liters per second)	Pumping period, t (minutes)
P1	572-688	Prow Pass Member	Drawdown	3.4	2,880
P1	572-688	Prow Pass Member	Recovery	1/3.4	1/2,880
P2	687-1829	Prow Pass Member and underlying penetrated units	Drawdown	2.3	3,383
P2	687-1829	Same	Recovery	1/2.3	1/3,383
P3	687-1829	Same	Drawdown	3.1	90
P3	687-1829	Same	Recovery	1/3.1	1/ 90

1/ for pumping prior to recovery test

Table 2
Injection Test Data
(from Rush et al. 1983a)

Test Number	Test Interval (meters)	Stratigraphic Unit(s) Tested	Length of Injection Period (minutes)
I1	*687- 697	Prow Pass Member	60
I2	811-1829	Bullfrog Member and underlying penetrated units	910
I3	926-1829	Tram unit and underlying penetrated units	334
I4	1200-1829	Flow breccia and underlying penetrated units	198
I5	1407-1829	Tuff of Lithic Ridge and older tuffs	350
I6	1621-1829	Older tuffs	273

* All tests are single-packer tests. The experimental configuration and the details of the tests are discussed at length in Rush et al. (1983a, 1983b)

926–1829 m, 1200–1829 m, 1407–1829 m, and 1621–1829 m. The tests are numbered in sequence in accordance with the figures in Rush and others (1983a). The test data, taken from the report by Rush and others (1983a), are displayed as solid lines on each of the following figures showing the calculations.

SPECIFIC RESULTS

Test 1. Figure 1 shows the calculated curves for three values of hydraulic conductivity and a fixed storativity. The well radius was 0.23 m. Figure 2 shows curves for fixed hydraulic conductivity and three values of storativity. These curves show no apparent sources.

Figures 3 and 4 display curves for three values of hydraulic conductivity and a fixed storativity (Figure 3) and three values of storativity with a fixed hydraulic conductivity (Figure 4). No distant source appeared in these calculations. The large value of S is not physically consistent with the normal understanding of storativity in a porous medium. Such large values should be viewed as possible indicators of fractures, and representation of the medium as a fractured medium should be considered.

Test 2. Drawdown data for test 2 show an inflection at about 250 minutes with little additional drawdown continuing to the end of the test, suggesting a fluid source at some distance (to be determined in the analysis) from the well. Figure 5 shows the drawdown curves for fixed S and three values of K. Figure 6 shows the drawdown curves for fixed K and three values of S. Figure 7 shows drawdown curves for fixed K and fixed S for four values of Rmax. Rmax is the estimated radial distance of the fluid source from the well. These curves indicate that a fluid-filled fracture system or fault may occur roughly 200 m from the well.

Figure 8 shows the comparison with the recovery data for fixed storativity and three values of hydraulic conductivity, and Figure 9 shows the comparison for fixed hydraulic conductivity and three values of storativity. Figure 10 shows a comparison with the data for fixed K and S and three values of Rmax. Figure 10 indicates that a source is probably located about 150 m from the well.

Test 3. The calculations for drawdown data of test 3 are shown in Figure 11. Drawdown occurred at such a rapid rate that it was not possible to match the drawdown portion of the test. It appears that water was pumped from the well at a high enough rate that fluids were not able to move from the rock to the well to compensate. This is shown in Figure 11, where the calculated curves for two values of K, which differ by two orders of magnitude, essentially coincide. The pumping rate probably was too rapid on this test to allow meaningful interpretations of the data. The comparison to the recovery data for three different values of K and a fixed S is shown in Figure 12; the comparison of three values of S and a fixed K is shown in Figure 13.

INJECTION TESTS

A summary of the injection test data appears in Table 2. The test zones were isolated with one or more plugs and the tubing for the injection test extended above the surface. This tubing was filled with fluid to a level about 14 to 16 ft (about 5 m) above the ground surface (F. E. Rush, USGS, personal communication). The static water level observed in the well is assumed to represent the heads everywhere around the test well in the unit being tested.

Test 1. Figure 14 shows the comparison of calculated curves with recovery data for a fixed S and three values of K. Figure 15 shows the same comparison for fixed K and three values of S.

Test 2. Figure 16 shows the comparison of calculated curves with recovery data for a fixed S, and three values of K.. Figure 17 shows the same comparison for fixed K and two values of S.

Test 3. Figure 18 shows the comparison of calculated curves with the recovery data for a fixed S and K and with injection assumed to start from 5 m above ground surface. Figure 19 shows the comparison for a fixed S and three values of K. Figure 20 shows the comparison for a fixed K and three values of S. It appears that the actual starting head was lower than the nominal value.

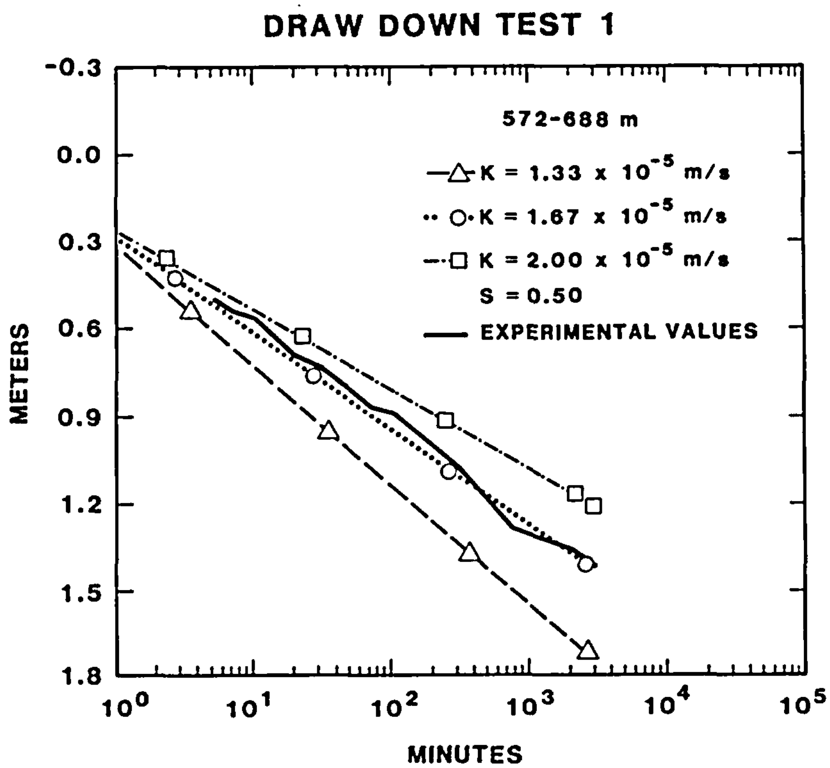


Figure 1. Calculated values of drawdown for three values of K (hydraulic conductivity) and fixed S (storativity) are shown with the drawdown data for test 1.

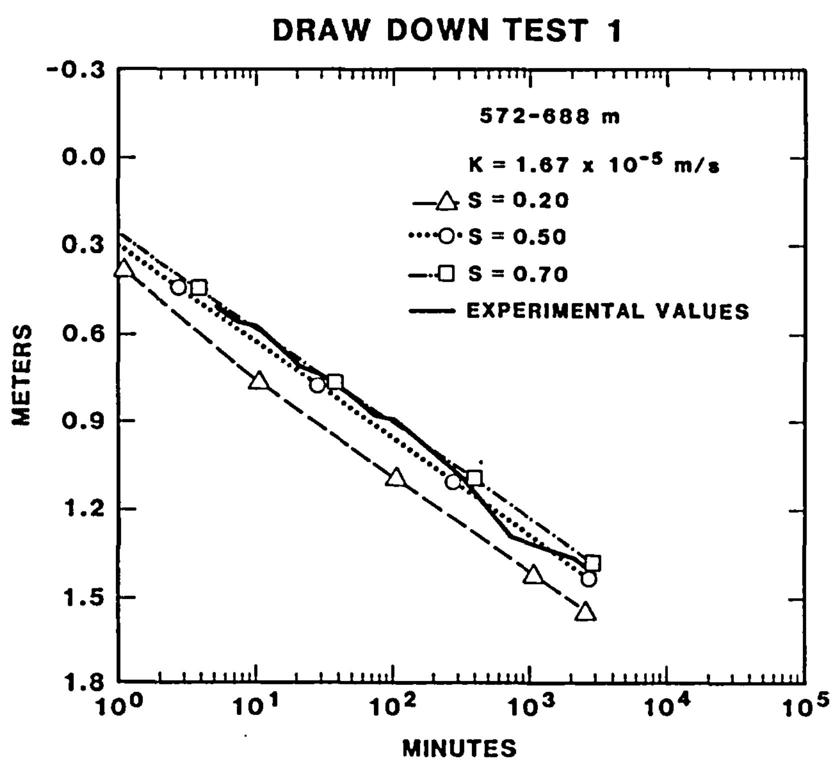


Figure 2. Calculated values of drawdown for three values of storativity (S) for fixed hydraulic conductivity (K) are shown with the drawdown data for test 1.

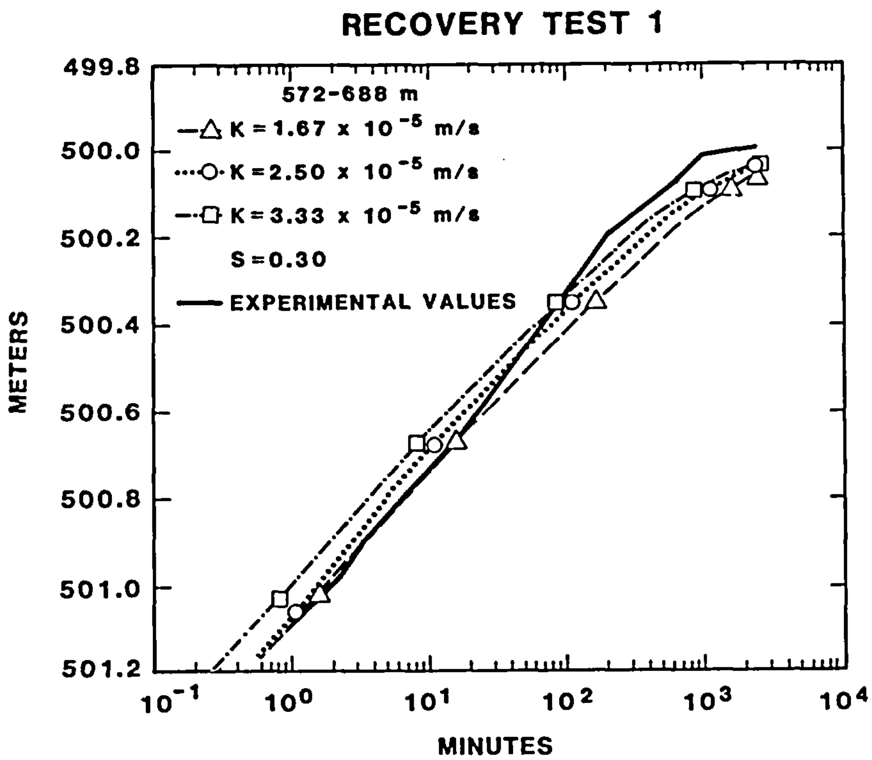


Figure 3. Calculated values of recovery for three values of hydraulic conductivity (K) for fixed storativity (S) are shown with the recovery data for test 1.

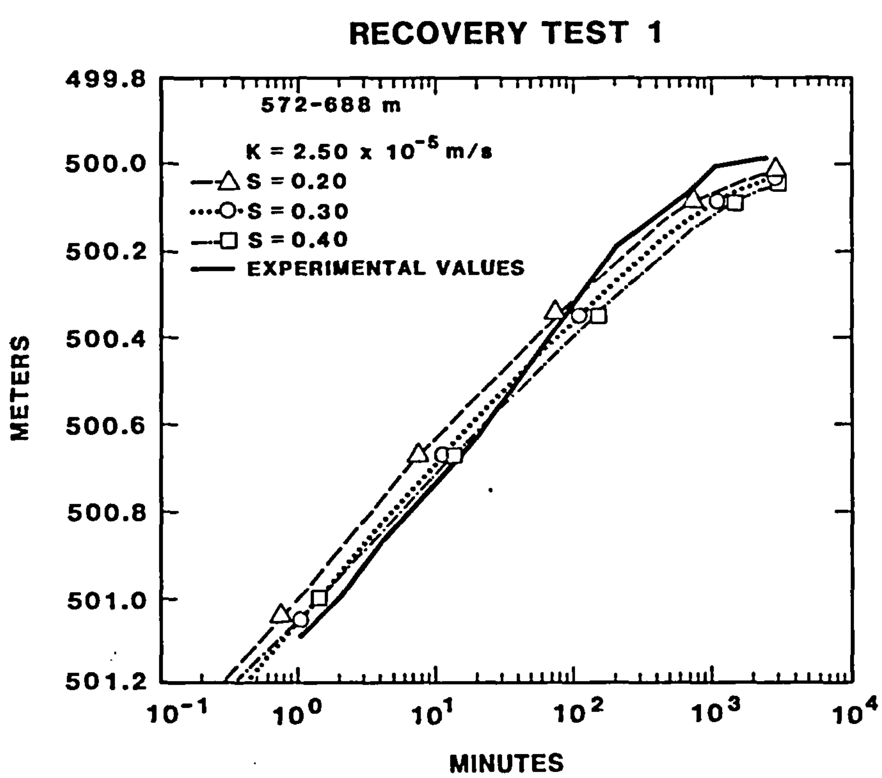


Figure 4. Calculated values of recovery for three values of storativity (S) for fixed hydraulic conductivity (K) are shown with the recovery data for test 1.

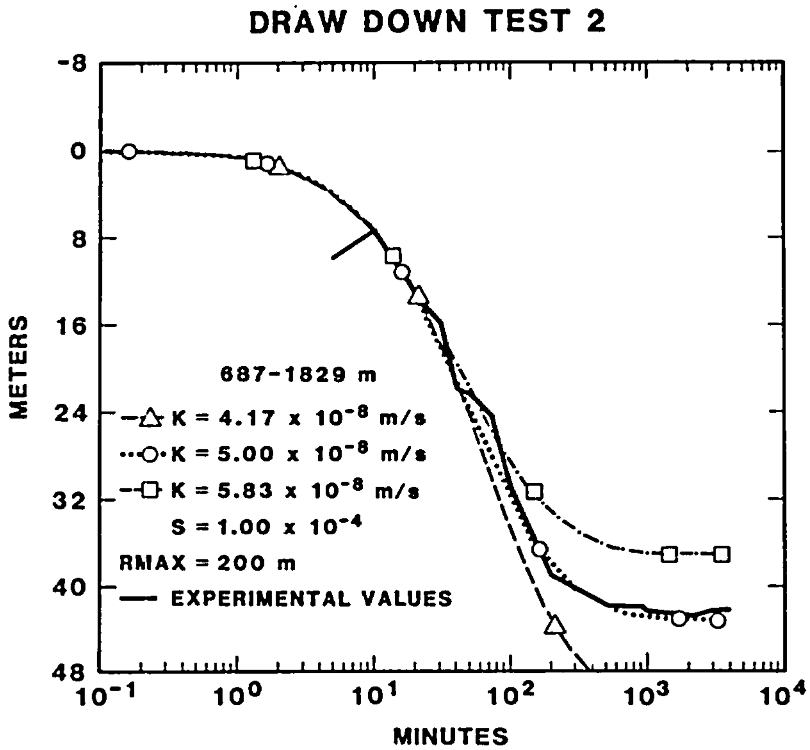


Figure 5. Calculated values of drawdown for three values of hydraulic conductivity (K) for fixed storativity (S) are shown with the drawdown data for test 2.

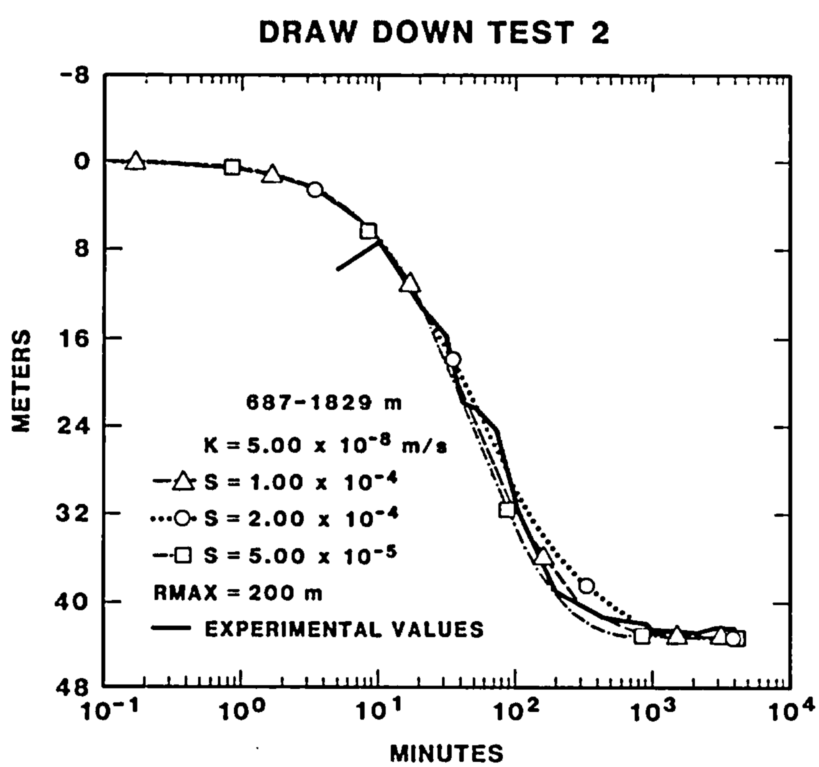


Figure 6. Calculated values of drawdown for three values of storativity (S) for fixed hydraulic conductivity (K) are shown with the drawdown data for test 2.

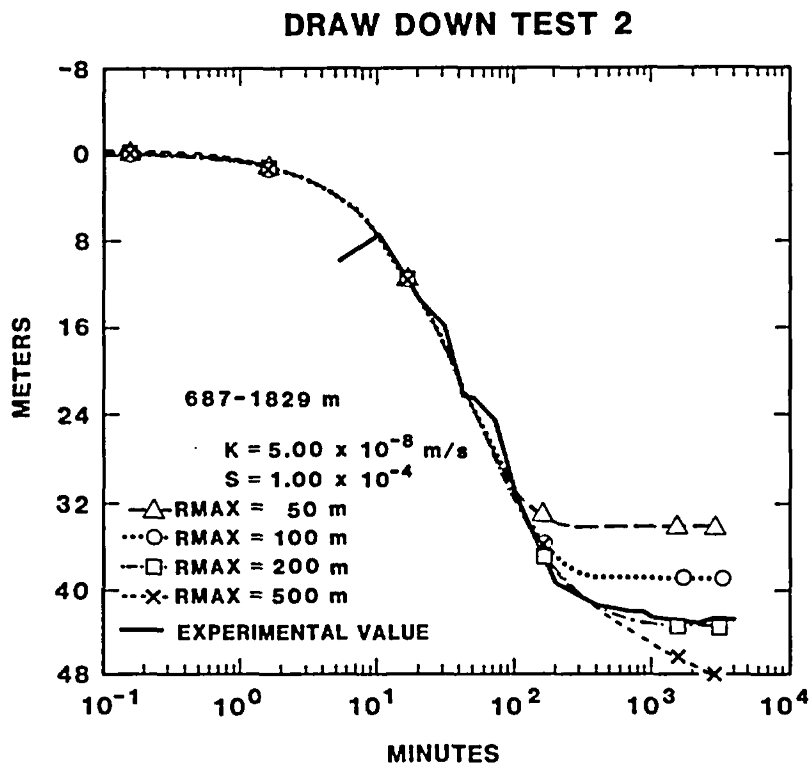


Figure 7. Calculated values of drawdown for four values of distance to a source for fixed hydraulic conductivity (K) and fixed storativity (S) are shown with the drawdown data for test 2.

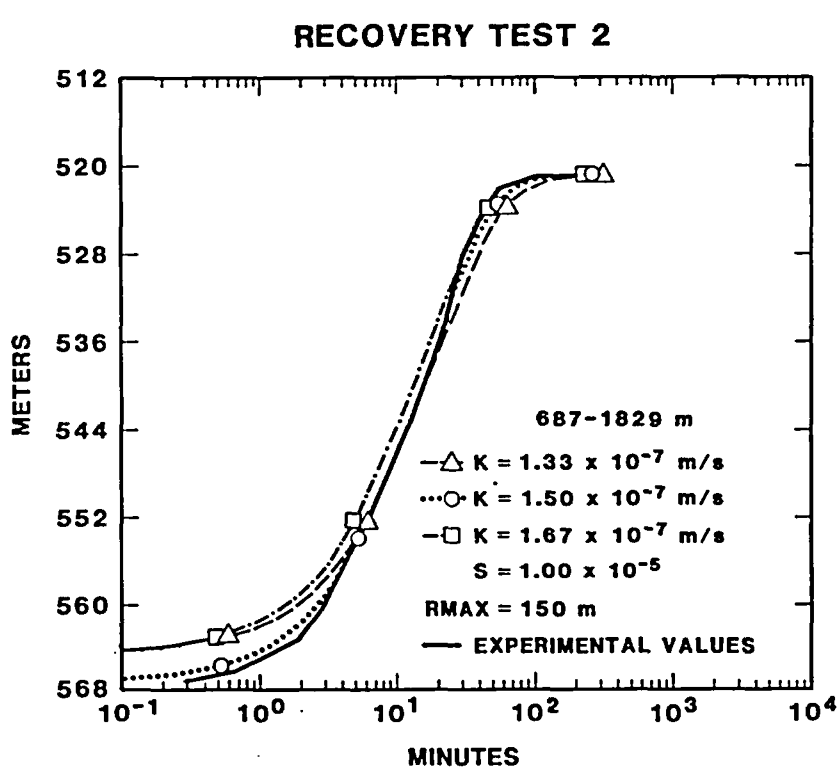


Figure 8. Calculated values of recovery for three values of hydraulic conductivity (K) for fixed storativity (S) are shown with the recovery data for test 2.

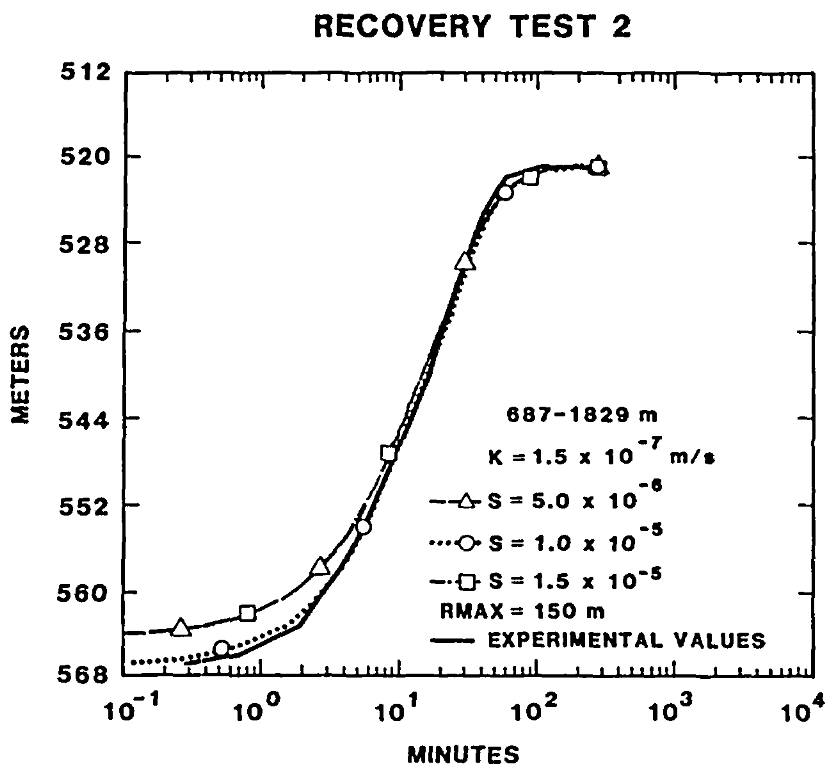


Figure 9. Calculated values of recovery for three values of storativity (S) for fixed hydraulic conductivity (S) are shown with the recovery data for test 2.

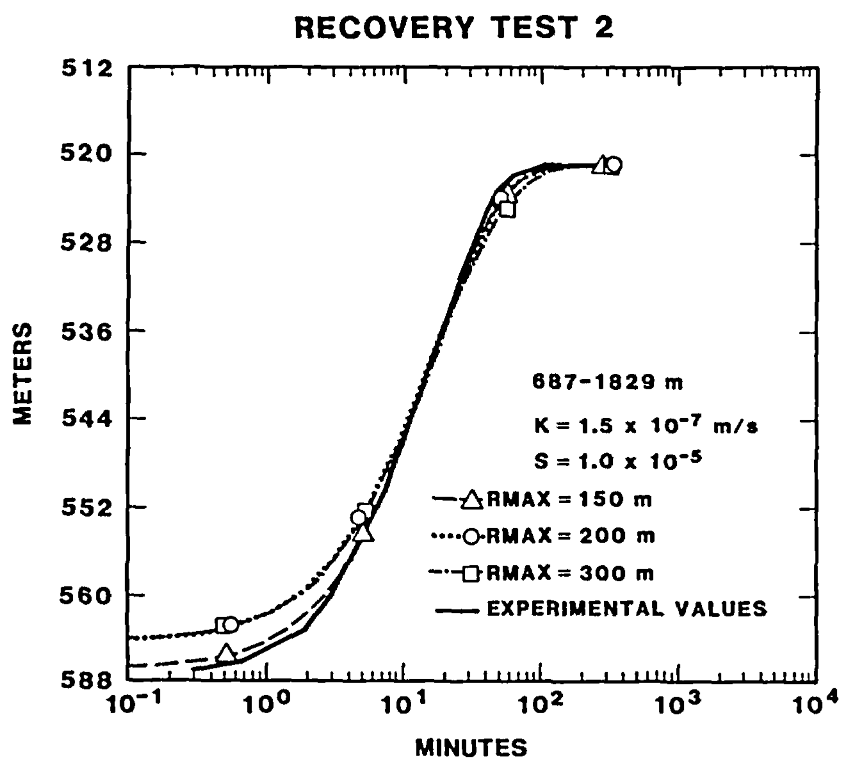


Figure 10. Calculated values of recovery for three values of distance to a source for fixed hydraulic conductivity (K) and fixed storativity (S) are shown with the recovery data for test 2.

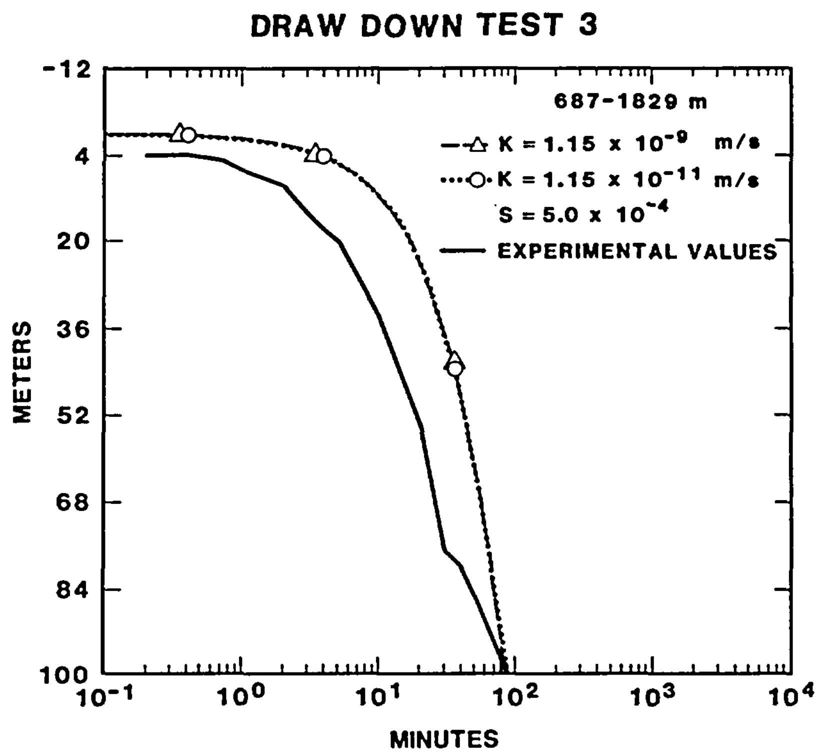


Figure 11. Calculated values of drawdown for two values of hydraulic conductivity (K) and fixed storativity (S) are shown with the drawdown data for test 3.

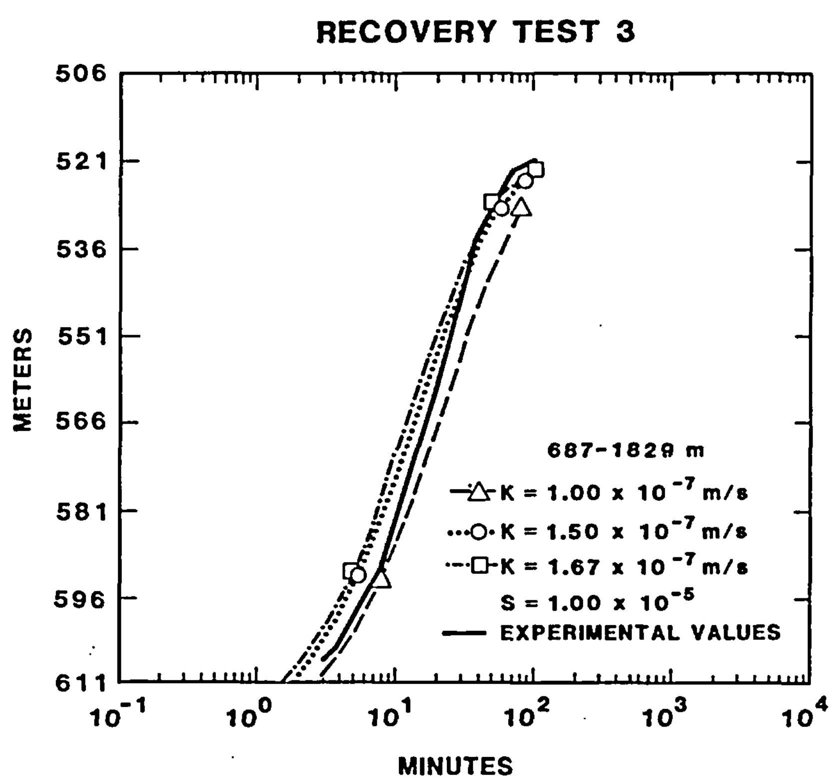


Figure 12. Calculated values of recovery for three values of hydraulic conductivity (K) and fixed storativity (S) are shown with the recovery data for test 3.

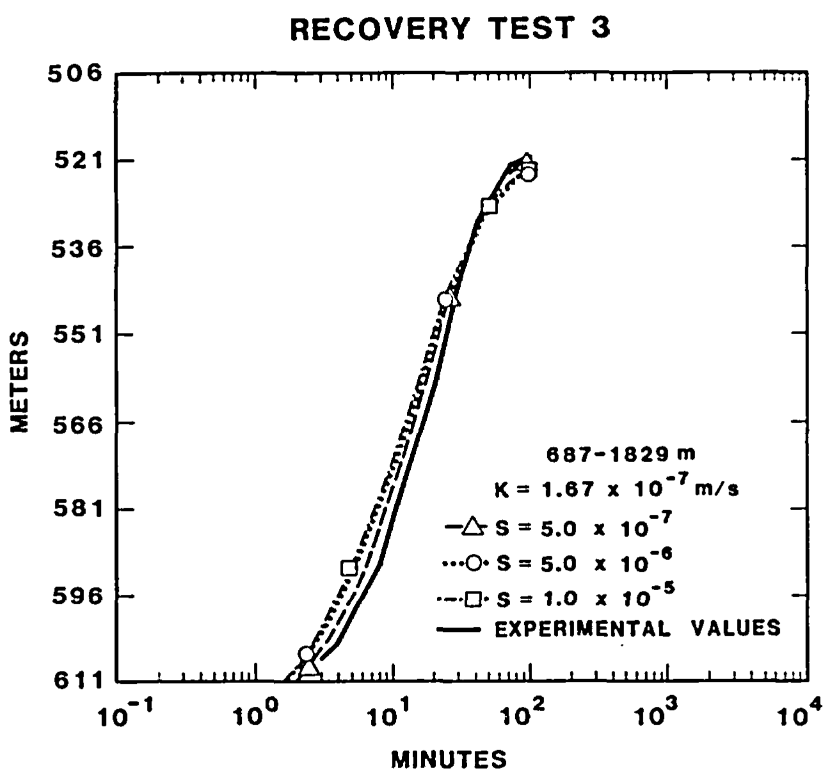


Figure 13. Calculated values of recovery for three values of storativity (S) and fixed hydraulic conductivity (K) are shown with the recovery data for test 3.

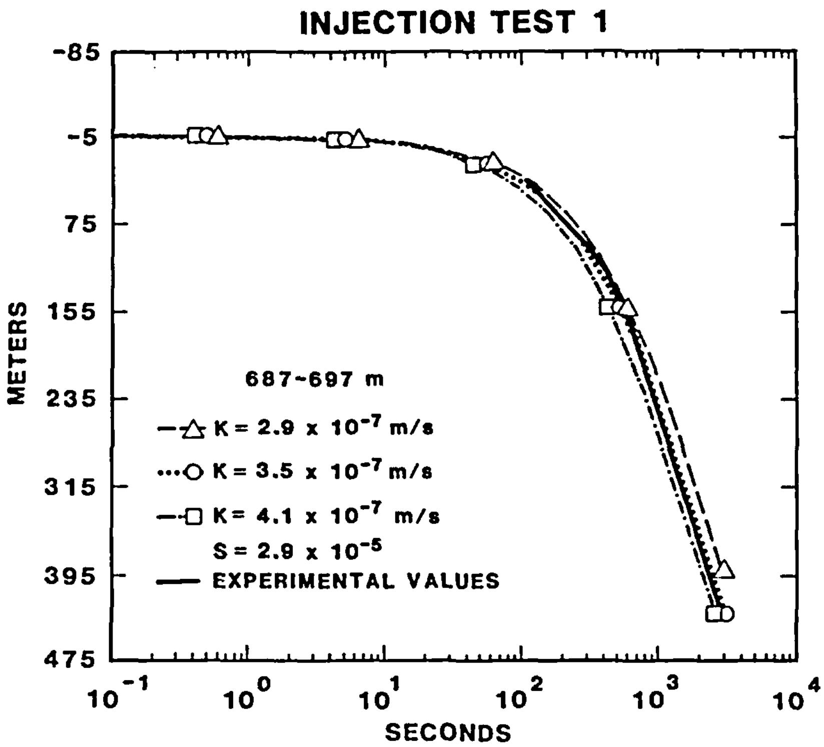


Figure 14. Calculated values of recovery for injection test 1 for three values of hydraulic conductivity (K) and fixed storativity (S) are shown with the recovery data for injection test 1.

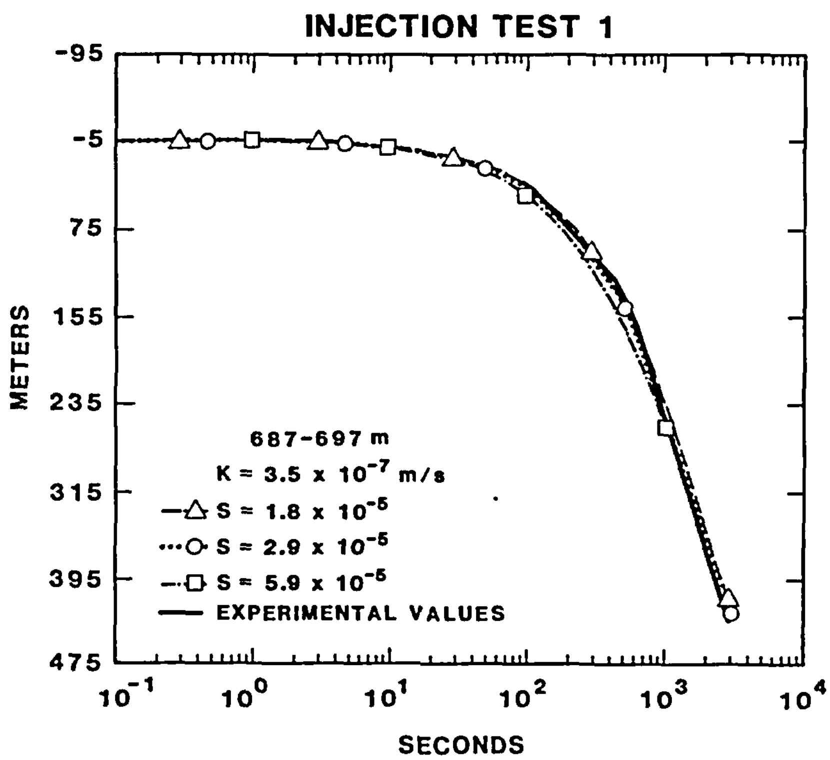


Figure 15. Calculated values of recovery for three values of storativity (S) and fixed hydraulic conductivity (K) are shown with the recovery data for injection test 1.

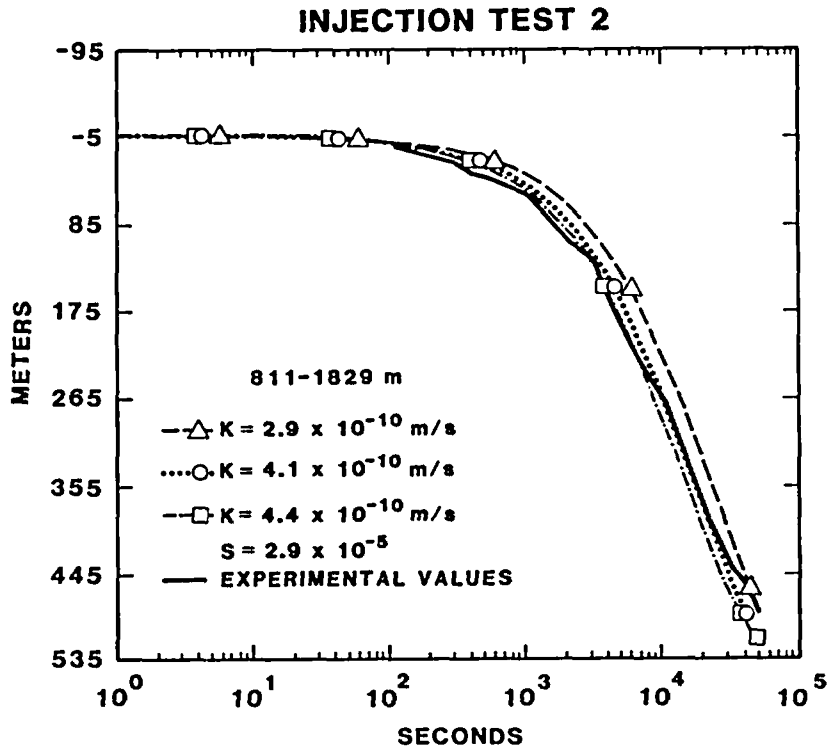


Figure 16. Calculated values of recovery for three values of hydraulic conductivity (K) and fixed storativity (S) are shown with the recovery data for injection test 2.

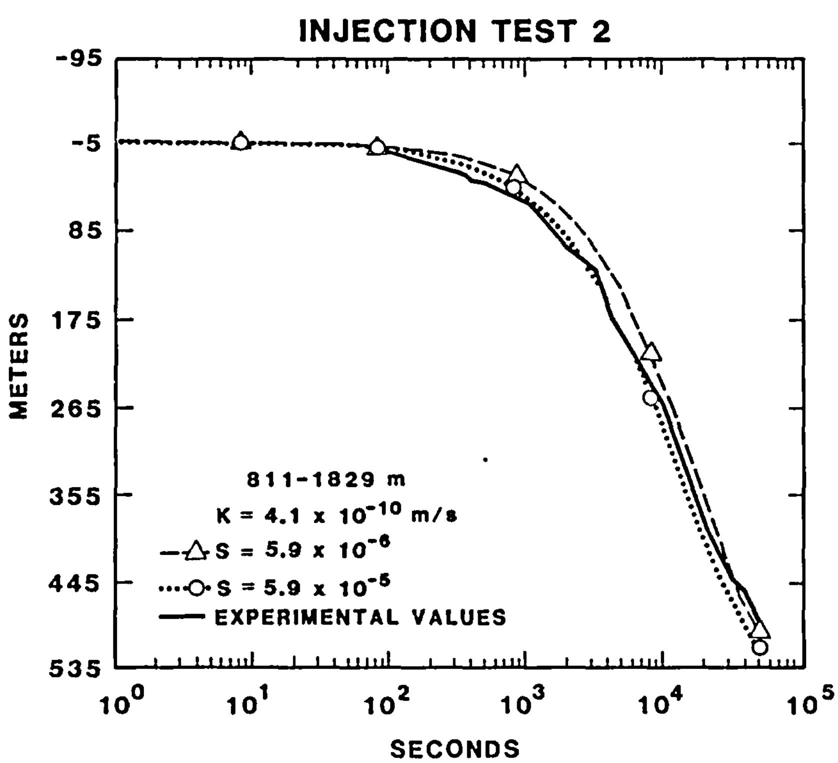
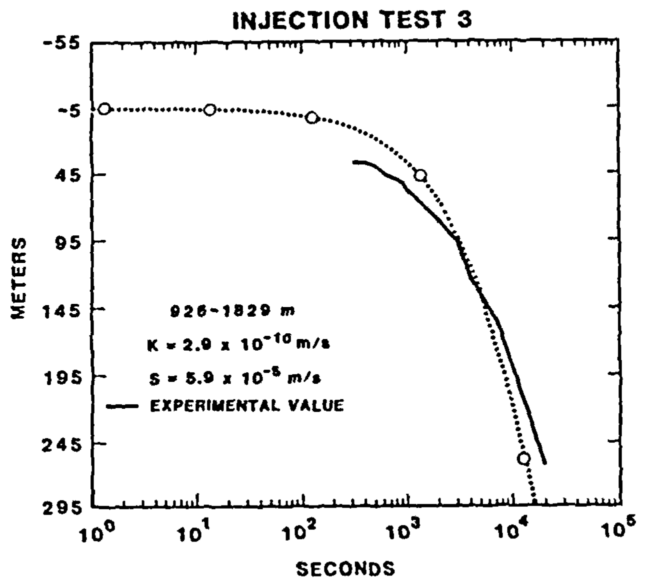


Figure 17. Calculated values of recovery for two values of storativity (S) and fixed hydraulic conductivity (K) are shown with the recovery data for injection test 2.



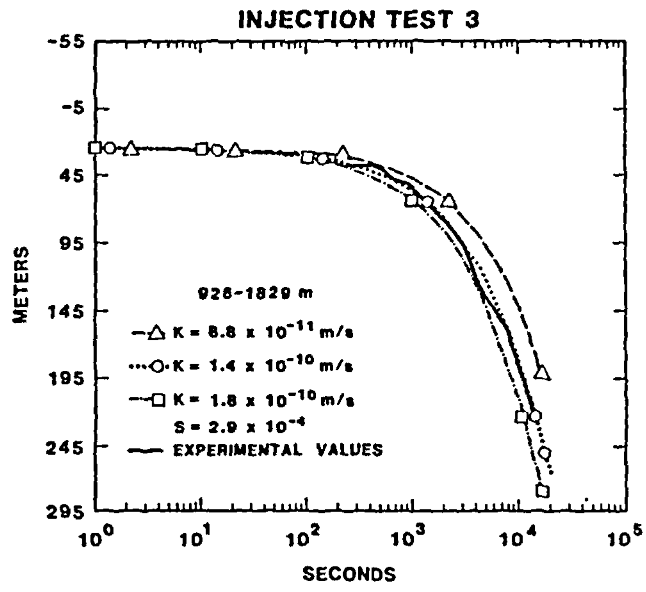


Figure 18. A calculated value of recovery for single values of hydraulic conductivity (K) and storativity (S) is shown with the recovery data for injection test 3 to illustrate that the nominal value of the starting head must be lowered.

Figure 19. Calculated values of recovery for three values of hydraulic conductivity (K) and fixed storativity (S) are shown with the recovery data for injection test 3. The starting head value has been corrected from the nominal value.

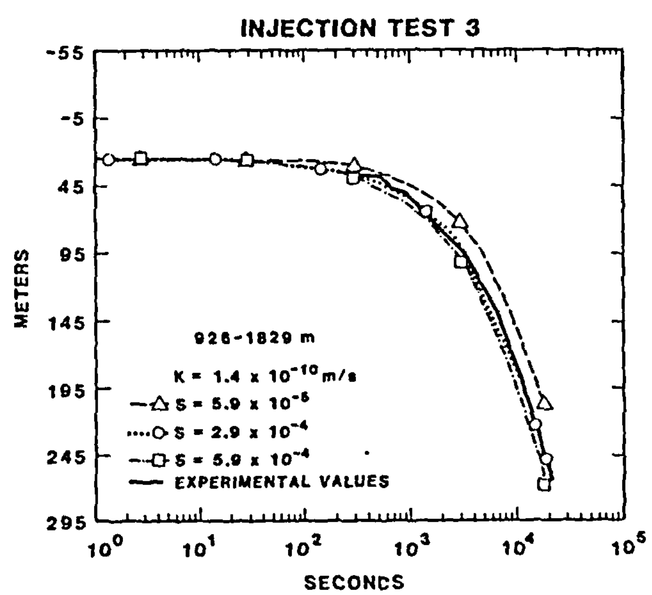


Figure 20. Calculated values of recovery for three values of storativity (S) and fixed hydraulic conductivity (K) are shown with the recovery data for injection test 3. The starting head value has been corrected from the nominal value.

Test 4. Figure 21 shows the comparison of calculated curves with recovery data for a fixed S and three values of K. Figure 22 shows the comparison with data for a fixed K and three values of S.

Test 5. Figure 23 shows the comparison of calculated curves with recovery data for a fixed K and S and with the injection starting at 5 m above surface. Figure 24 shows a comparison of calculated curves with data for a fixed S and three values of K for injection starting at 12 m below land surface. Figure 25 shows a comparison with data for a fixed K and three values of S for injection starting at 12 m below land surface. On the basis of these figures, it appears that injection in this test started below the nominal value of 5 m above land surface.

Test 6. Figure 26 shows a comparison of calculated curves with recovery data for a fixed S and K and with injection starting 5 m above the land surface. Figure 27 shows a comparison for a fixed S and two values of K with injection starting 18 m below land surface. Figure 28 shows a comparison with data for a fixed K and two values of S with injection starting 18 m below land surface. From these figures it appears that injection in this test started at 18 m below the land surface rather than at the nominal value of 5 m above land surface.

SUMMARY

The data for well USW H-1, provided in Rush and others (1983a), were reduced to estimate values for K and S. The reductions, using a numerical technique, were done as if the packed-off sections of the well were integrated to represent an effective porous medium in a saturated, confined aquifer. The results of the analysis are compared in Table 3 with the results of the analyses in Rush and others (1983b). The integrated total hydraulic conductivity (K) of the penetrated portion of the saturated zone (687 - 1829 m) obtained here and by Rush and others (1983b) is essentially the same, 1.67×10^{-7} m/s (this report) compared with 1.16×10^{-7} m/s (Rush et al., 1983b). Reduction of data from some individual tests, however, differ

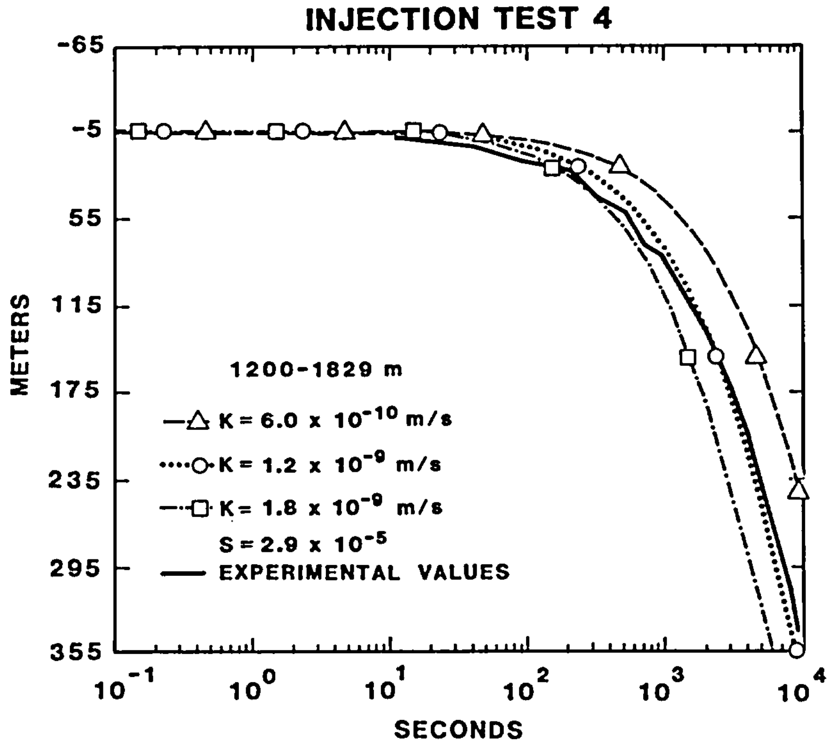


Figure 21. Calculated values of recovery for three values of hydraulic conductivity (K) and fixed storativity (S) are shown with the recovery for injection test 4.

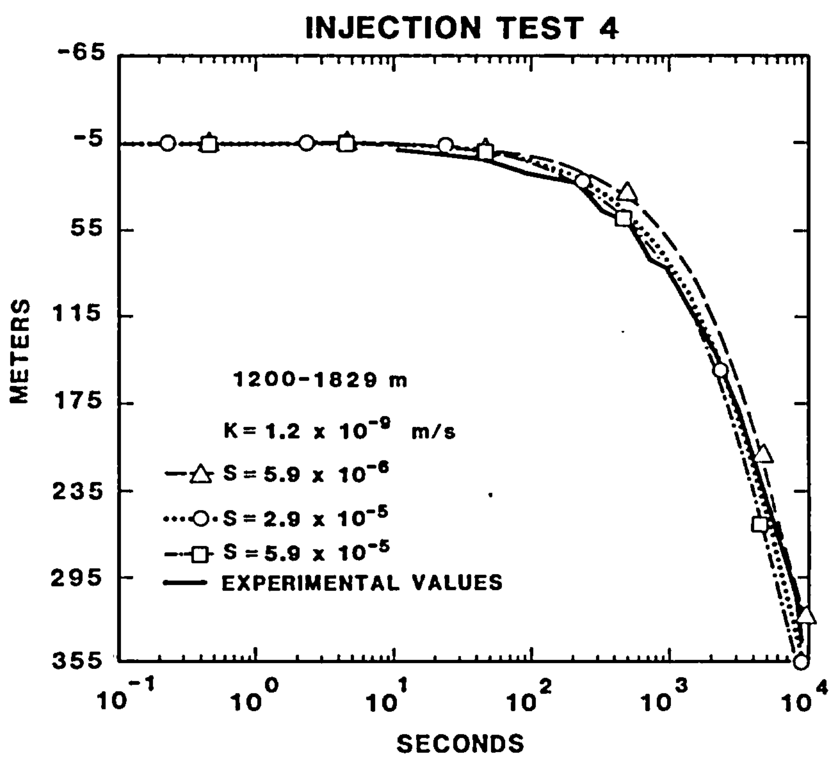


Figure 22. Calculated values of recovery for three values of storativity (S) and fixed hydraulic conductivity (K) are shown with the recovery data for injection test 4.

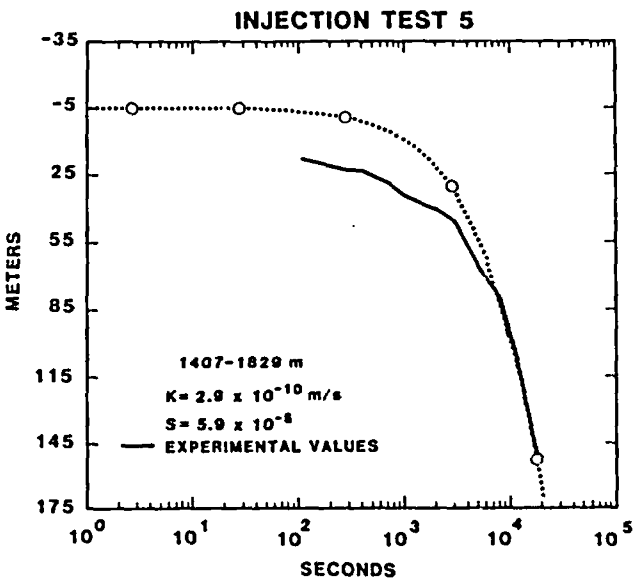


Figure 23. A calculated value of recovery for single values of hydraulic conductivity (K) and storativity (S) is shown with the recovery data for injection test 5. The nominal value of starting head appears to be incorrect and must be lowered.

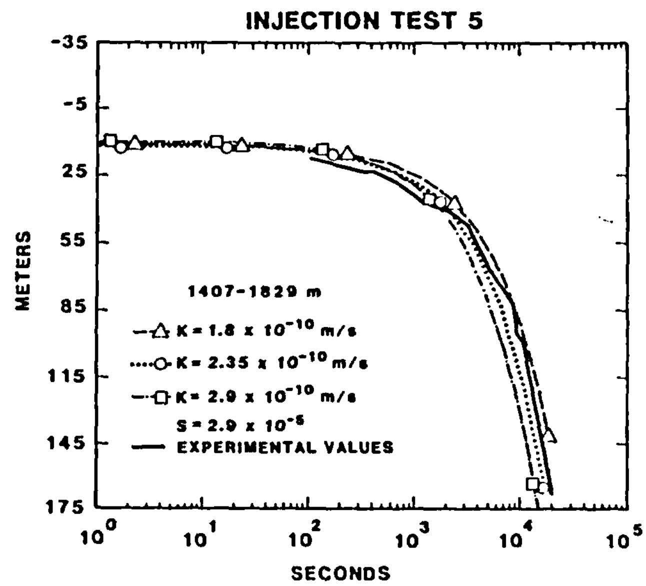


Figure 24. Calculated values of recovery for three values of hydraulic conductivity (K) and fixed storativity (S) are shown with the recovery data for injection test 5. The starting head value was corrected from the nominal value.

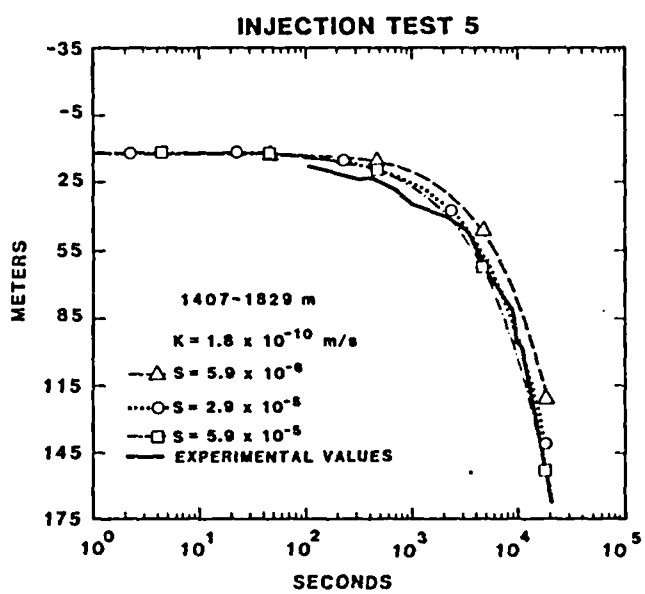


Figure 25. Calculated values of recovery for three values of storativity (S) and fixed hydraulic conductivity (K) are shown with the recovery data for injection test 5. The starting head value was corrected from the nominal value.

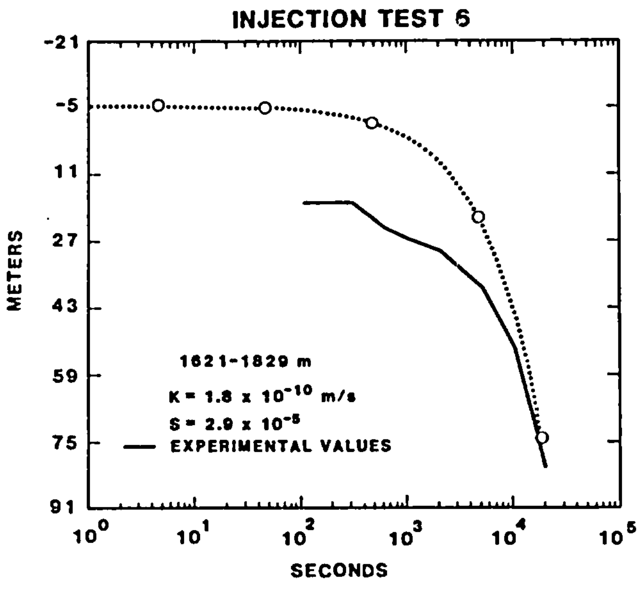


Figure 26. A calculated value of recovery for single values of hydraulic conductivity (K) and storativity (S) is shown with the recovery data for injection test 6. The nominal starting head value appears to be incorrect and must be lowered.

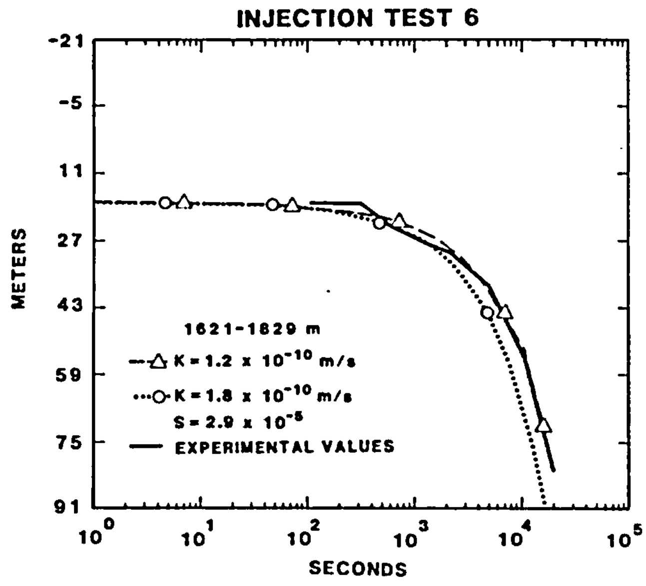


Figure 27. Calculated values of recovery for two values of hydraulic conductivity (K) and fixed storativity (S) are shown with the recovery data for injection test 6. The starting head value has been corrected from the nominal value.

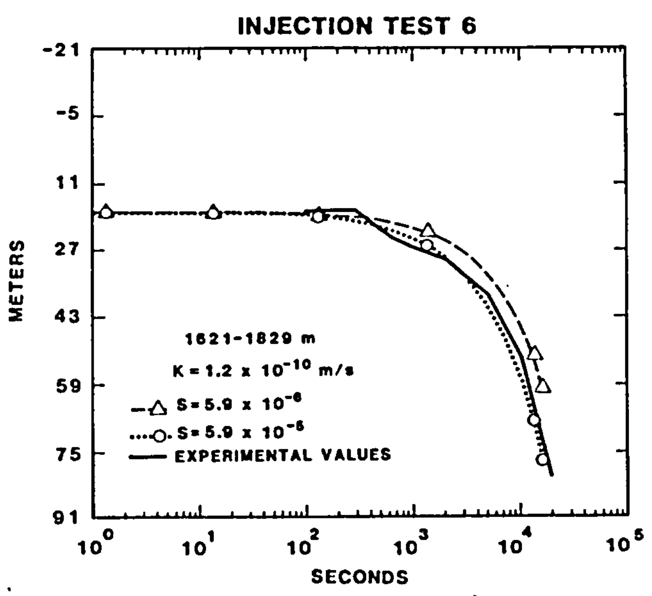


Figure 28. Calculated values of recovery for two values of storativity (S) and fixed hydraulic conductivity (K) are shown with the recovery data for injection test 6. The starting head value has been corrected from the nominal value.

Table 3. Summary of hydraulic conductivity and storativity values at well USW H-1, obtained in this report and by Rush et al. (1983b)

		This Report			Rush et al., 1983b	
Interval(m)	Test Type	K(m/s)	S	RMAX(m)	K (m/s)	S
P1 572- 688	Drawdown	1.67×10^{-5}	0.5		2.08×10^{-4}	
	Recovery	3.3×10^{-5}	0.3		4.63×10^{-7}	
P2 687- 697	Injection	3.5×10^{-7}	2.9×10^{-5}		2.31×10^{-7}	
P2 687-1829	Drawdown	5×10^{-8}	2×10^{-4}	200		
	Recovery	1.5×10^{-7}	1×10^{-5}	150		
P3 687-1829	Drawdown	---				
	Recovery	1.67×10^{-7}	5×10^{-7}		1.16×10^{-7}	7×10^{-6}
I2 811-1829	Injection	4.06×10^{-10}	2.9×10^{-5}		8.1×10^{-11}	9×10^{-4}
I3 926-1829	Injection	1.35×10^{-10}	2.9×10^{-4}		6.9×10^{-11}	6×10^{-3}
I4 1200-1829	Injection	1.17×10^{-9}	5.9×10^{-5}		3.47×10^{-11}	6×10^{-4}
I5 1407-1829	Injection	1.76×10^{-10}	5.9×10^{-5}		2.31×10^{-11}	9×10^{-4}
I6 1621-1829	Injection	1.17×10^{-10}	2.9×10^{-5}		1.16×10^{-11}	2×10^{-3}

by up to a factor of ten or so, although no systematic differences are apparent. The differences most likely are due to the quality of the source data for this study; the data used in the calculations for this report were derived from graphical representations given by Rush and others (1983a) rather than a digital list. Difficulty in obtaining exact values from the graphs may have caused the slight differences between the values of K given in this report and those presented by Rush and others (1983b). Also, the differences may reflect the difficulties of using graphical techniques, rather than numerical techniques, to obtain matches between theoretical and observed values. Finally, the apparent disparity between the actual starting point of water levels and the reported nominal starting point in certain recovery tests may account for some of the differences in K values reported here and by Rush and others (1983b). Storativity reported here and by Rush and others (1983b) differs typically by one order of magnitude. Given the difficulties inherent in deriving storativity graphically, this difference is not surprising. The apparent physically unrealistic values of storativity calculated from certain tests (see Figures 1, 2, 3, 4) for this report should add to the conclusion already derived from geologic observation that fractures, particularly small fractures, may be important in the system at well USW H-1. A recent paper, Barker and Black (1983), presents arguments that the hydraulic conductivities similar to those calculated here and obtained graphically by Rush and others (1983b) may be used with some confidence, but the physically unrealistic values of storativity should be treated with caution.

In general, the differences between the values reported here and by Rush and others (1983b) are well within a reasonable range of uncertainty for hydraulic testing of deep aquifers. In fact, the general similarity of results obtained by the two data reduction methods increases confidence in the proper values to assign to the hydraulic conductivity of the saturated tuff aquifer at USW H-1.

According to the well tests, it appears that an upper zone about 100 meters thick is characterized by relatively high hydraulic conductivities, in the range of about 10^{-4} to 10^{-5} m/sec, with some indication of fracture connectivity. Below this zone, the volcanic rocks appear to be less conductive by several orders of magnitude down to about 10^{-10} m/sec. These values should not be applied regionally without additional data from surrounding wells.

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APPENDIX A
INPUT OF PUMP CODE

Card 1 M.K	2I5	M = -1 for drawdown = 0 for recovery K = Number of terms for data for recovery
Card 2	I5	Number of value pairs for experimental drawdown or Recovery curve
Card 3 STDTIME STDANS(I)	(I)*	Time for drawdown datum, drawdown for water level or recovery values from surface (N)
Card 4 COND,SCON,	3F10.5	Hydraulic conductivity, storativity
Card 5 RWELL RMAX	2F10.5	Well radius Maximum radius of problem
Card 6 TOP,		Top of aquifer measured from surface
BASE,	4F10.5	Base of aquifer measured from surface
WLEVEL		Water level of aquifer measured from surface
RCH		Recharge
Card Set 7 D(I)	8F10.3	Initial drawdown values for recovery, K in number
Card Set 8 OLD D(I)	8F10.3	Previous initial drawdown values for recovery, K in number
Card 9 JFIX (RMAX)	I1	= 1 for a fixed outer boundary = 0 for a free outer boundary
Card 10 NOB	6I3	Node numbers of six observation wells
Card 11 QPUMP	2F10.3	QPUMP = pumping rate (= 0. for recovery
TSTOP		TSTOP = time at which pumping is stopped.

SAMPLE INPUT FOR AN EXAMPLE OF A DRAWDOWN TEST

```
INPUT FOR WIPP28   DRAWDOWN
    7
 0.1 0.0  1.0 15.0  10.0 51.0  100.0 85.0  200.0 93.0  300.0 98.0  600.0 101.0
  .550E-03  .100E-00   1.0E-05
   .46E-00   .50E+04
 .4200E+03  .446E+03  .000E+00   1.0E-21
1
  1  2 05 10 25 30
  2.330000  .100E+04
    -1.0       0.0
END OF FILE
>?
```

SAMPLE INPUT FOR AN EXAMPLE OF A RECOVERY TEST

```
INPUT FOR USWH1 TEST1    RECOVERY
    0   16
   12
1.0 501.10 2.0 501.0 4.0 500.87 9.0 500.75 20.0 500.63 40.0 500.5 80.0 500.37
200. 500.2 400. 500.13 600. 500.09 1000. 500.02  2500. 500.
  1.00E-03 0.500E-00
 0.23E-00  0.500E+03
  5.72E+02  6.88E+02  5.00E+02  1.00E-20
 5.0144E+2 5.0144E+2 5.0133E+2 5.0122E+2 5.0111E+2 5.0101E+2 5.0089E+2 5.0079E+2
 5.0068E+2 5.0058E+2 5.0047E+2 5.0037E+2 5.0027E+2 5.0017E+2 5.0009E+2 5.0000E+2
 5.0144E+2 5.0144E+2 5.0133E+2 5.0122E+2 5.0111E+2 5.0101E+2 5.0089E+2 5.0079E+2
 5.0068E+2 5.0058E+2 5.0047E+2 5.0037E+2 5.0027E+2 5.0017E+2 5.0009E+2 5.0000E+2
1
  1  2  5 10 25 30
 0.000E+00  3.00E+03
   -1.0        0.0
END OF FILE
>?
```

APPENDIX C

LISTING OF THE WELL-TEST CODE--PUMP

```
 PROGRAM NEWPUMP (INPUT=101B,OUTPUT=101B,TAPE77=OUTPUT,
+                TAPE66=INPUT, TAPE1,TAPE2)
C------------------------------------------------------------------
C---INPUT FILE = TAPE1
C---OUTPUT FILE = TAPE2
C
C   TO EXECUTE THIS PROGRAM FROM A 4014 TERMINAL AT SNL:
C
C      1) MAKE PROGRAM "NEWPUMP" THE PRIMARY FILE, AND
C         MAKE THE INPUT FILE "TAPE1" A LOCAL FILE.
C      2) IN THE "FTNTS" SUBSYSTEM TYPE;
C            RUN,B=LGO
C      3) CHANGE TO THE "BATCH" SUBSYSTEM AND TYPE;
C            A) RA
C            B) DISS,TK4,F=F4
C
C      AND IN A LITTLE WHILE A GRAPH WILL BEGIN TO APPEAR ON
C      THE SCREEN......
C                                                          1-7-83
C------------------------------------------------------------------
C
C  NUMERICAL PUMPING TEST, NO VERTICAL FLOW, WATER IN WELL
C
 DIMENSION R(100),RR(100),D(100),OLDD(100),T(100),H(100),RECH(100),
+ A(100),B(100),C(100),E(100),U(100),V(100),NOB(6),ARRAY(6),
+  STDTIME(20), STDANS(20), CALTIME(200), CALANS(200)
C
 READ(1,997) M,K
 997 FORMAT (2I5)
C  M=-1 FOR PUMP TEST, M=0 FOR RECOVERY
 READ (1,999) N
 999 FORMAT (I5)
 READ (1,*) (STDTIME(I), STDANS(I), I=1,N)
>?
```

```
C
 CALL VSTART (0.,0)
 IF(M.LT.0) GO TO 2420
 CALL TITLE(17H RECOVERY SLUG18 ,-17,10H MINUTES  ,11
+             ,21H        METERS        ,21,8.0,6.0)
 GO TO 2440
 2420 CALL TITLE(17HDRAW DOWN WIPP 30,-17,9H MINUTES ,10
+             ,6H FEET ,6,8.0,6.0)
 2440 CALL XLOG (0.1,1.6,091.0,-16.0)
 CALL CURVE (STDTIME,STDANS,N,0)
 CALL SETDEV (0,0)
 ICOUNT=0
C
C  INPUT AQUIFER PARAMETERS
C
 READ (1,510) COND,SCON,SUNCON
 510 FORMAT (4F10.5)
 WRITE (2,515) COND,SCON,SUNCON
 515 FORMAT (1X,14HCONDUCTIVITY =  ,E12.4,19H  CONFINED STORAGE=  ,
+ E12.4,22H   UNCONFINED STORAGE=  ,F10.5)
C
C INPUT OF RADII AND SETTING UP THE MESH
C
  READ (1,500) RWELL,RMAX
 500 FORMAT (2F10.3)
 WRITE (2,505) RWELL,RMAX
 505 FORMAT (1X,14HWELL RADIUS =   ,E12.4,13H  MAX RADIUS=  ,E12.4)
C
C SET UP RADIAL MESH
C
 DO 10 N=1,100
    AN=0.1666666667*FLOAT(N-2)
    R(N)=RWELL*10.0**AN
)?
```

```
   R(N)=RMAX
   RR(N)=RMAX*RMAX
   NMAX=N
   NMONE=N-1
   GO TO 20
10 RR(N)=R(N)*R(N)
20 DELA=0.383765
DELA2=DELA*DELA
C
C LEVELS MEASURED BELOW DATUM
C
READ (1,520) TOP,BASE,WLEVEL,RCH
520 FORMAT(4F10.5)
WRITE (2,525) TOP,BASE,WLEVEL,RCH
525 FORMAT (1X,16HTOP OF AQUIFER  ,E12.4,17H  BASE OF AQUIFER   ,
+ E12.4,22H INITIAL WATER LEVEL=  ,E12.4,11HRECHARGE=  ,E12.4)
C
C SET INITIAL CONDITIONS
C
DO 30 N=1,NMAX
   RECH(N)=RCH
   D(N)=WLEVEL
30 OLDD(N)=WLEVEL
IF(M.LT.0) GO TO 2929
READ (1,998) (D(I),I=1,K)
READ (1,998)(OLDD(I),I=1,K)
998 FORMAT (8F10.3)
2929 CONTINUE
C
C CONDITIONS ON OUTER BOUNDARY
C
C IF JFIX=1 LEVEL AT OUTER BOUNDARY REMAINS AT WLEVEL
>?
```

```
00970C
00980 READ (1,530) JFIX
00990 530 FORMAT (I1)
01000 IF (JFIX.EQ.1) WRITE (2,532)
01010 IF (JFIX.NE.1) WRITE (2,534)
01020 532 FORMAT (22H  ** FIXED BOUNDARY**    )
01030 534 FORMAT (22H  ** FREE BOUNDARY **   )
01040C
01050C GIVE NODE NUMBER OF SIX OBS WELLS
01060C
01070 READ (1,540) (NOB(J),J=1,6)
01080 540 FORMAT (6I3)
01090C
01100C INPUT PUMPING  RATE
01110C
01120 TSTART=0.0
01130 READ (1,550) QPUMP,TSTOP
01140 550 FORMAT (2F10.3)
01150 WRITE (2,555) QPUMP,TSTOP
01160 555 FORMAT(1X,15HPUMPING RATE=   ,E12.4,14H TILL TIME OF   ,E12.4,
01170+ 5H MINS   )
01180C
01190C CONVERTING PUMPING  RATE TO QABST
01200C
01210 PI=4.0*ATAN(1.0)
01220 QABST=0.5*QPUMP/(PI*DELA)
01230 IND=0
01240C
01250C INTIAL TIME AND DELT
01260C
01270 TIME=0.0
01280 DELI=0.025*RR(1)*SCON/(COND*(BASE-TOP))
01290 DELT=DELI
>?
```

```
T(1)=2.0*DELT*DELA/RR(2)
T(2)=2.0*T(2)
H(NMAX-1)=(ALOG(R(NMAX))-ALOG(R(NMAX-1)))*(ALOG(R(NMAX))-ALOG
+ (R(NMAX-1)))/(SD*COND)
H(NMAX)=1.0E+10
T(NMONE)=2.0*DELT*DELA/((R(NMAX)-R(NMONE-1))*STOR*R(NMONE))
T(NMAX )=1.0*DELT*DELA/((R(NMAX)-R(NMONE))*STOR*R(NMAX))
IF (JFIX.EQ.1) T(NMAX)=1.0E-10*T(NMAX)
C
C GAUSSIAN ELIMINATION
C
C CALCULATION OF COEFFICIENTS
C EQUN IS -A(N)*D(N-1) + B(N)*D(N) - C(N)*D(N+1) = E(N)
C
B(1)=1.0/H(1) +1.0/T(1)
C(1)=1.0/H(1)
E(1)=OLDD(1)/T(1) + QABST
DO 90 N=2,NMONE
   A(N)=1.0/H(N-1)
   B(N)=1.0/H(N-1) + 1.0/H(N) + 1.0/T(N)
   C(N)=1.0/H(N)
90 E(N)=OLDD(N)/T(N) - RR(N)*RECH(N)
A(NMAX)=1.0/H(NMONE)
B(NMAX)=1.0/H(NMONE) + 0.5/T(NMAX)
E(NMAX)=0.5*OLDD(NMAX)/T(NMAX) - 0.5*RR(NMAX)*RECH(NMAX)
C
C ELIMINATION
C
U(1)=B(1)
V(1)=E(1)
DO 100 N=2,NMAX
   U(N)=B(N) - (A(N)*C(N-1))/U(N-1)
>?
```

```
100 V(N)=E(N) + (A(N)*V(N-1))/U(N-1)
D(NMAX)=V(NMAX)/U(NMAX)
DO 110 NN=1,NMONE
    N=NMONE-NN+1
110 D(N)=(V(N) + C(N)*D(N+1))/U(N)
C
C TEST FOR EXCESSIVE DRAWDOWNS
C
DRAWMX=0.9*BASE + 0.1*TOP
IF (D(1).LT.DRAWMX) GO TO 60
WRITE (2,580)
580 FORMAT (1X,20H EXCESSIVE DRAWDOWN   )
WRITE (2,565)
DO 105 N=1,NMAX
105 WRITE (2,570) N,R(N),H(N),T(N),D(N)
STOP
C
60 CONTINUE
C
C OUTPUT AND CHANGE PARAMETERS
C
TIMIN=TIME - TSTART
DO 120 I=1,6
    I1=NOB(I)
120 ARRAY(I)=D(I1)
ICOUNT = ICOUNT + 1
IF(ICOUNT.GT.200) GO TO 125
CALTIME(ICOUNT) = TIME
CALANS (ICOUNT) = D(1)
125 CONTINUE
C
C
WRITE (2,560) TIME,TIMIN,D(1),(ARRAY(J),J=1,6),D(NMAX)
>?
```

```
WRITE (2,560) TIME,TIMIN,D(1),(ARRAY(J),J=1,6),D(NMAX)
560 FORMAT (1X,10E12.4)
DO 130 N=1,NMAX
130 OLDD(N)=D(N)
DELT=TIMIN*0.25892
IF (IND.EQ.0) GO TO 40
C
C END OF CALCULATIONS FOR A SPECIFIC TIME
C
WRITE (2,565)
565 FORMAT (1X,8HNODE NO.,4X,6HRADIUS,14X,14HRADIUS SQUARED,6X,
+ 13HHORIZ HYD RES,7X,15HTIME RESISTANCE,5X,8HDRAWDOWN)
DO 140 N=1,NMAX
140 WRITE (2,570) N,R(N),RR(N),H(N),T(N),OLDD(N)
570 FORMAT (1X,I4,5E20.6)
C
C NEW PUMPING PHASE
C RESET PARAMETERS
C
DELT=DELI
IND=0
TSTART=TIME
READ (1,550) QPUMP,TSTOP
WRITE (2,555) QPUMP,TSTOP
QABST=0.5*QPUMP/(PI*DELA)
IF (QPUMP.GE.0.0) GO TO 40
C
IF (ICOUNT.GT.200)  ICOUNT = 201
ICOUNT = ICOUNT - 1
C
IF(M.EQ.0) GO TO 2611
DO 150 I=1,ICOUNT
150 CALANS(I)=CALANS(I)-WLEVEL
>?
```

```
02610C
02611 2611 CONTINUE
02620 CALL CURVE (CALTIME,CALANS,ICOUNT,10)
02630 CALL STRTPT (0.0,0.0)
02640 CALL ENDPL
02650 CALL DONEPL
02660C
02670 STOP
02680 END
END OF FILE
>?
```

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