LA-UR-06-3789

Approved for public release; distribution is unlimited.

Title: A Catalog of Historical Aquifer Tests on Pajarito Plateau

Author(s): Stephen G. McLin

Submitted to: Los Alamos National Laboratory
ENV-ERS Pathway Protection Program
May 2006

11934

Los Alamos NATIONAL LABORATORY

093676

Peer Review Comments/Resolutions

Part 1 (to be completed by the ER Program Office) Date: 05/15/064

Title: A Catalog of Historical Aquifer Tests on Pajarito Plateau ID #: ____ - ____ Rev. #: ____

Reviewer's Name (Print): Steve Pearson Group: ENV-WQH MS: M992 Comments are due by: ____ 05/22/06

Return comments or questions to (Author): Steve McLin Phone: ____ 665-1721 FAX:

AND Ardyth Simmons AT 665-3935

Part 2 (to be completed by the Reviewer)

Received on (Date): 05/15/06 Review completed on: 05/24/06 Phone: 7-3005 Signature: Steve Pearson

Part 3 (If under time constraints, the Author signs) ☐ Not all comments resolved (atttach copy of this PR Comment Form to Document Signature Form)

Author Signature & Date: Stephen G. McLin 5/25/2006

Comment #	Location Page,para, line	Reviewer's Comment/Suggestion	A/R[3]	Preparer's Proposed Revision/Resolution	Final Resolution
1	p.3, p. 1, l. 3	The word "use" should be "used".		Change made.	
2.		Suggest adding references for all the R-well reports.		References have been added.	
3		Table 11 should be reformatted so that the blank spaces where there are no data are easier to read.		Table 11 has been reformatted.	
4					

Peer Review Comments/Resolutions

Part 1 (to be completed by the ER Program Office) Date: 05/15/064

Title: A Catalog of Historical Aquifer Tests on Pajarito Plateau ID #: ______ - ______ Rev. #: ____

Reviewer's Name (Print): David Rogers Group: ENV-WQH MS: M992 Comments are due by: ______ 05/22/06

Return comments or questions to (Author): Steve McLin Phone: ______ 665-1721 FAX:

AND Ardyth Simmons AT 665-3935 ______

Part 2 (to be completed by the Reviewer)

Received on (Date): 05/15/06 Review completed on: 05/23/06 Phone: 7-0313 Signature: ______

Part 3 (If under time constraints, the Author signs) ☐ Not all comments resolved (atttach copy of this PR Comment Form to Document Signature Form)

Author Signature & Date: [signature] 5-25-06

[signature] Stephen G. McLin 5/25/2006

Comment #	Location Page,para, line	Reviewer's Comment/Suggestion	A/R[3]	Preparer's Proposed Revision/Resolution	Final Resolution
1		Have you included the Shomaker data in Table 6?		Table 6 has been corrected so that the original Shomaker data is included.	
2.		You should add a note to Table 9 indicating that wells DT-5a, DT-9, and DT-10 have discontinuous screens.		Table 9 has been changed to reflect discontinuous screens.	
3		The footnote in Table 11 incorrectly refers to Table 9.		Table 11 has been corrected to reflect a reference to Table 10 and not Table 9.	
4		Why not put the information shown in Tables 12 and 13 with earlier results so that the comparisons are easier.		Tables 12 and 13 have been updated so that comparisons to earlier test results are more easily made.	

LA-UR-06-3789

Approved for public release; distribution is unlimited.

Title: A Catalog of Historical Aquifer Tests on Pajarito Plateau

Author(s): Stephen G. McLin

Submitted to: Los Alamos National Laboratory
ENV-ERS Pathway Protection Program
May 2006

Los Alamos NATIONAL LABORATORY

A CATALOG OF HISTORICAL AQUIFER TESTS ON PAJARITO PLATEAU

by

Stephen G. McLin

ABSTRACT

Between 1950 and 2005, numerous aquifer tests were conducted in wells that penetrate into the regional aquifer below the Pajarito Plateau. These tests were performed in order to characterize hydraulic transmitting properties of the saturated geological materials opposite individual well screens. Analyses of these test results have revealed a complex regional aquifer that is highly variable in response to pumping stresses because it is a highly stratified, heterogeneous system. The Jemez Mountains on the west provided most of the erosional debris that eventually formed the high-yielding units within the regional system. These include the Santa Fe Group sequences of the Puye fanglomerate and older fanglomerates. These units are highly stratified and thicken toward the west. They are also interbedded with ancestral Rio Grande deposits (i.e., the Totavi Lental of Griggs) that may also be highly productive. These units thin toward the east near the Rio Grande and overlie the generally less productive sands and silts in the Tesuque Formation.

Values for transmissivity (T) and storage coefficient (S) are tabulated from all historical aquifer tests from these Pajarito Plateau wells. In addition, important estimates for aquifer thickness (b) are also tabulated so that hydraulic conductivities (K) and specific storage (S_s) estimates can be assigned to individual geological units. These data show that T averages about 5,000 ft^2/day and S fluctuates between about 0.0005 and 0.005 for the most productive units. Dynamic spinner logs also reveal b values that generally vary from about 300-800 ft for these same units, and suggest that K and S_s vary between about 3-8 ft/day and 0.00002-0.0000005/ft, respectively. Many observation wells are completed to shallower depths and reflect lower T and b values, especially in the central and eastern portions of the plateau. These lower productive units correspond to those areas where leaky-aquifer type behavior has been recorded. Ultimately, these aquifer tests partially fulfill requirements for aquifer parameter identification that may be used for separate model simulation studies of the regional aquifer.

I. INTRODUCTION

Purpose and Scope

Over the years, numerous aquifer tests have been conducted in regional aquifer wells located on the Pajarito Plateau (e.g., Theis and Conover, 1962; Conover et al., 1963; and Cushman, 1965). A wide variety of alternative test procedures have been used to collect data and analyze individual test results. These methods have ranged from traditional constant-rate pumping, step-drawdown, recovery, injection, and specific capacity methods (e.g., Shomaker, 1999; McLin and Stone, 2004a; and McLin, 2006a, 2006b). Some tests have only relied on drawdown in the pumping well while others have used drawdown from both the pumping well and one or more observation wells (e.g., McLin, 2004; McLin 2005a). The duration of individual tests has also varied; hence, different tests have lasted anywhere from several minutes to hours, days, or even weeks. Pumping or injection rates have also varied between individual tests and range from a few gallons per minute (gpm) to over 1,600 gpm. Despite these differences, the primary purpose of each test was always the same: the experimental determination of regional aquifer parameters that characterize the saturated porous media opposite individual well screens. Typically, analysis of test data rely on an analogy between two-dimensional (2-D) heat and water flow to obtain an analytical solution to the governing partial differential equation that relates drawdown to aquifer transmissivity (T) and storage coefficient (S). Here T represents the rate of flow to a pumping well in gallons per minute through an imaginary, vertical cross-section of aquifer material one foot wide and extending the full saturated thickness of the aquifer that is subjected to a hydraulic gradient of one. Today T is commonly expressed in equivalent units of length squared per unit time. Hydraulic conductivity (K) is determined after dividing T by the aquifer thickness (b). Values for T and K are important because they define how the aquifer will respond to pumping, natural discharge, or recharge. In addition, S is defined as the volume of water yielded to a pumping well per unit area of saturated aquifer material per unit decline in water level. As such, S is dimensionless. Specific storage (S_s) is determined after dividing S by b, and has units of inverse length. Aquifer parameters like T and S were originally developed for confined aquifer conditions assuming radial, 2-D, horizontal flow. However, in complex, three-dimensional (3-D), stratified, groundwater representations, it is often best to use the parameters K and S_s because the influence of b has been removed.

The primary objective of this report is to tabulate and compare all historical values for the aquifer parameters T, K, b, S, and S_s from Pajarito Plateau wells that penetrate the regional aquifer. These parameters were originally obtained from aquifer tests. They are important because they provide experimental measurements of aquifer responses (i.e., drawdown and recovery) to controlled aquifer stresses (i.e., pumping or injection). A secondary objective is to validate these parameters for internal consistency with supporting data. These aquifer parameters can then be used in numerical models to simulate aquifer behavior and test the validity of alternative conceptual models. Once verified, these models can be used to simulate complex aquifer behavior (e.g., transitional behavior suggested by changes in S or boundary influences) with confidence, or to test alternative geometric configurations in the model or physical-chemical processes affecting potential contaminant transport. They can also be used to identify data gaps where additional aquifer tests might be helpful, or to evaluate alternative aquifer monitoring configurations. Ultimately, these aquifer tests partially fulfill requirements for aquifer parameter identification that may be used for model verification studies.

All wells compared in this report are located on the Pajarito Plateau and penetrate into the regional aquifer; individual well locations are shown in Figure 1. Some of these wells are used for municipal water supply. Other wells are used for monitoring water level fluctuations and recovering water samples for water quality analyses. For convenience, these wells are grouped as follows: (1) water supply wells in the old Los Alamos well field; (2) water supply wells in the old Guaje well field; (3) water supply wells in the new replacement Guaje well field; (4) water supply wells located in the Pajarito and Otowi well fields; (5) test wells; and (6) R-wells. Background information for these wells may be found elsewhere (e.g., Collins et al., 2006; Purtymun, 1995, 1984; Purtymun and Stoker, 1988; Purtymun and Johansen, 1974; and Griggs, 1964). The legend in Figure 1 reflects the current status of each well as of May 2006 (e.g., well G-4 is currently plugged and abandoned, ownership of well LA-2 has been transferred to San Ildefonso Pueblo, or other appropriate designation). Construction details from individual wells are contained in tables that summarize important hydrologic information. A detailed reference list at the end of this report also contains other important information or data from individual wells. Finally, a CD-ROM data disk attached at the end of this report summarizes important aquifer test information. Table A-1 in Appendix A summarizes the file names and data content of each file on the CD-ROM; these files are in ASC-II text format.

Description of Aquifer Parameters

Individual wells were initially grouped as indicated above. These groupings are used in the summary tables that follow. Aquifer parameters for individual wells are also summarized here. In addition, these summary tables identify the geologic unit where the parameters apply. Unfortunately, the supporting test data required to derive many of these aquifer parameters were never preserved. Hence, these parameters can not be validated or reinterpreted using alternative techniques. Fortunately, these aquifer parameters can be easily re-estimated using the specific capacity technique that only requires minimal information. These newly estimated aquifer parameters are then compared to original values in the summary tables presented below. In effect, this new estimation process may be viewed as a data validation step because most of the new and old parameter estimates are very similar. Significant differences between the old and new aquifer parameter estimates may sometimes occur and result in dramatic changes in T (physically unrealistic). These differences may occur for several reasons, including: (1) a change in well efficiency over time that may result in either a declining or increasing Q/s value (which may give the appearance that any new estimate for T has declined or increased over time, respectively); or (2) a typographical error in the old parameter estimate. In order to eliminate differences caused by changes in well efficiency, the data from the same time specified in Purtymun (1995, p. 31) are used in the following tables. If an error is present, it can often be detected by comparing the newly computed and originally listed Q/s values, or by noting any changes in the estimated value for T (especially if Q/s values are missing). A similar comparison of K values will reveal differences that were used to represent aquifer thickness (b). The original data sources often did not provide an estimate for b, or assumed that it was equal to total formation thickness. Modern estimates for b generally use dynamic spinner logs from water supply wells to obtain more accurate values for this critically important parameter; however, these logs are not universally available for all wells.

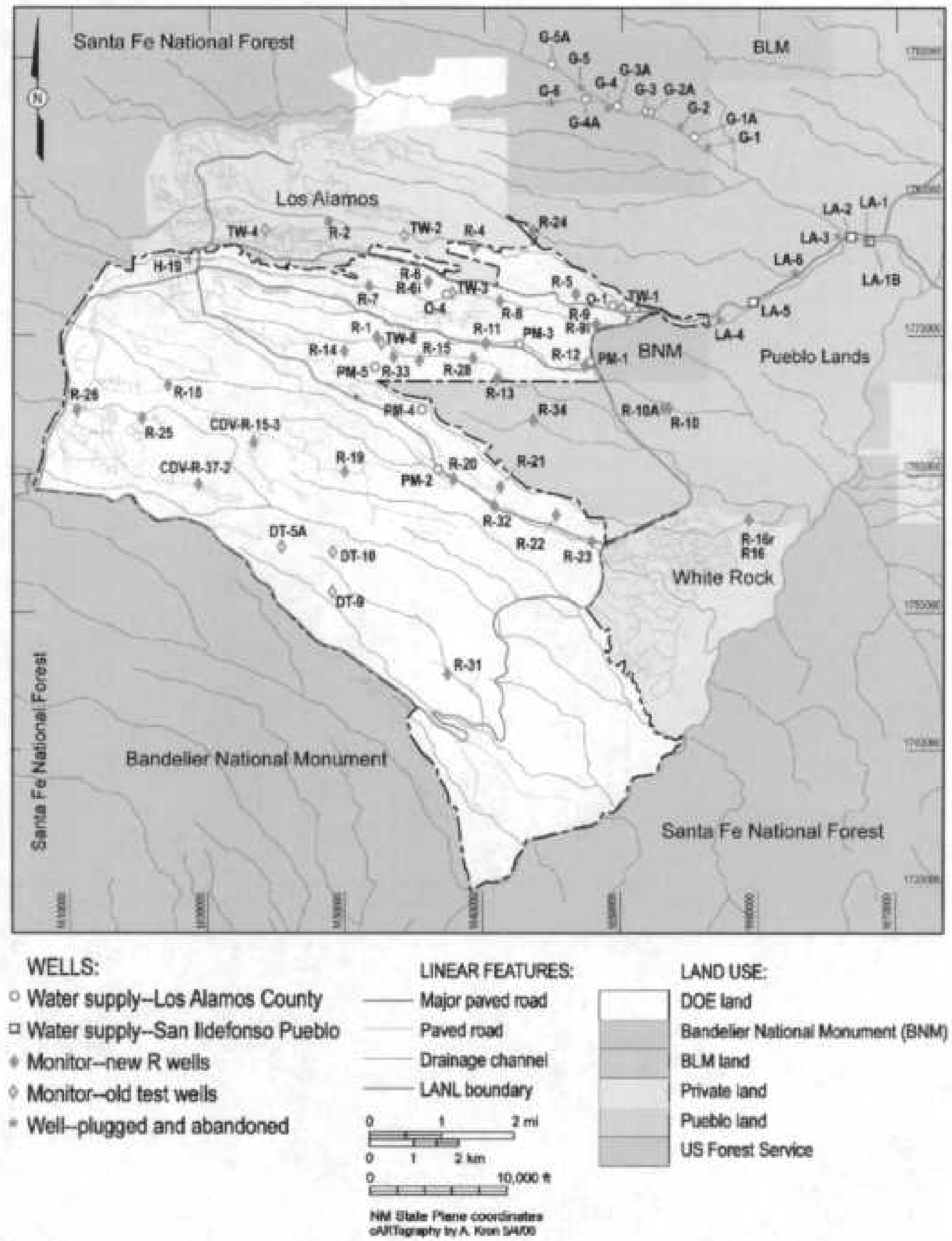

Figure 1. Locations of Pajarito Plateau wells that are discussed in this report.

In the validation technique mentioned above, specific capacity is defined as discharge (Q) divided by drawdown or injection up-coning (s), and has units of gpm/ft. This method was originally developed by Theis (1935, 1963) and modified by McLin (2005b). Appendix B contains a brief description of this method and the computer program used to compute new estimates for T from individual wells. Originally, this method was only applied to confined aquifers and was typically used to estimate a minimum value for *T* when the well was assumed to be fully penetrating and 100% efficient. In addition, this method was commonly applied to those situations where the pumping well was used as the observation well. Today it has been extended to include leaky or phreatic aquifer conditions with partially penetrating well screens. Once *T* has been found, then the parameter *K* is then obtained from the relationship $K = T/b$, where *b* is saturated thickness. Numerous authors (e.g., Walton 1970) have demonstrated that *T* values from the specific capacity technique are somewhat insensitive to changes in *S*. However, since *S* must be estimated prior to finding *T*, there is some added uncertainty in this approach. The primary advantage to this method is that it provides a uniform methodology for estimating *T* and *K* using information from many different types of aquifer tests. Individual tables for the well groups identified above are used to summarize these aquifer parameters. In addition, these tables also summarize all of the data required to estimate these parameters using the Matlab program listed in Appendix B. If an aquifer test was previously conducted at an individual well, then the original aquifer parameter values are also shown in the tables for comparison. These summary tables also list appropriate estimates for *b* and the geologic name of the formation where the parameter values apply. Table 1 defines symbols used in Tables 2-9 as described below. Similarly, Table 10 defines symbols used in Table 11. Likewise, Table 12 defines symbols used in Tables 13-14.

II. AQUIFER PARAMETER VALUES

Old Los Alamos Well Field

As seen in Figure 1, the original Los Alamos well field contained seven water supply wells, including wells LA-1, LA-1b, LA-2, LA-3, LA-4, LA-5, and LA-6 (Purtymun, 1995). Table 2 summarizes historical aquifer parameter estimates for each of these wells that are conveniently reported in Purtymun (1995, p. 31). These values were apparently taken from Griggs (1955), Theis and Conover (1962), and Cushman (1965); however, some of Purtymun's reported *T* values are different from these earlier values. The original aquifer tests were conducted in April and May of 1950 by the USGS. Much of the original data used to obtain these estimates has been lost. Hence, new estimates for *T* are made in this report in order to validate which older estimates are correct. Table 3 summarizes historical aquifer parameter estimates for each of the Los Alamos wells listed by Griggs (1955, p. 150). New parameter estimates were also obtained from these same wells using the specific capacity method described earlier. Tables 2 and 3 summarize all of these new estimates along with all supporting information. Similarities and differences between these old and new estimates are discussed below. In 1992, wells LA-3 and LA-4 were plugged and abandoned in accordance with State of New Mexico requirements as specified by the State Engineer. Wells LA-1 and LA-6 had been previously plugged and abandoned. Ownership of wells LA-1b, LA-2, and LA-5 were transferred from the Department of Energy (DOE) to San Ildefonso Pueblo in 1992.

Table 1. List of symbols used in Tables 2-9.

Parameter	Definition
Year	Year that the data were recorded in the cited reference.
Q/s (gpm/ft)	Specific capacity listed in reference.
b_r (ft)	Aquifer thickness listed in reference.
T_r (gpd/ft)	Aquifer transmissivity listed in reference.
K_r (gpd/ft^2)	Hydraulic conductivity listed in reference and computed from $K_r = T_r/b_r$.

Year	Year that the specific capacity data were recorded.
Ele (ft msl)	Elevation of wellhead (in ft above mean sea level, or ft msl).
WL (ft bgs)	Water level (in ft below ground surface, or ft bgs).
Q (gpm)	Average well discharge (gallons per minute, or gpm).
s (ft)	Quasi-steady state drawdown (ft) recorded at time t.
t (minutes)	Estimated or actual time of drawdown (min).
L (ft)	Screen length from well completion log (ft).
d_c (in)	Screen or casing diameter (in).
d_w (in)	Borehole diameter (in).
TOS (ft bgs)	Top of upper screen from well log (ft bgs).
BOS (ft bgs)	Bottom of lower screen from well log (ft bgs).
b_e (ft)	Aquifer thickness computed from b_e = BOS-TOS (ft).
b_s (ft)	Saturated aquifer thickness computed from b_s = BOS-WL (ft).
E (%)	Assumed well efficiency (%).
Geologic Unit	Geologic unit where screen is located and K value applies (see below).
Q/s (gpm/ft)	Specific capacity computed from data listed in this table.
T (ft^2/day)	Aquifer transmissivity estimated from specific capacity.
S (dim)	Storage coefficient from McLin (2005a, 2006a, 2006b) or estimated.
b (ft)	Effective aquifer thickness is the smaller of L, b_e, or b_s, or as noted.
K (ft/day)	Hydraulic conductivity computed from K = T/b. See tables.
S_s (1/ft)	Specific storage computed from S_s = S/b. See tables.
Tt1	Tschicoma Fm, volcanic rocks.
Tpl	Puye Fm, lacustrine and riverine deposits.
Tpf	Puye Fm, fanglomerate deposits.
Tpp	Puye Fm, pumiceous deposits.
Tpt	Puye Fm, ancestral Rio Grande deposits (Totavi Lentil).
Tf	Puye Fm, older fanglomerates.
Ts	Santa Fe Group (undifferentiated sands and silts).
T ratio	T ratio = historical T in reference/new T from specific capacity.
K ratio	K Ratio = historical K in reference/new K from specific capacity.

Table 2. Comparison of aquifer parameters from Los Alamos well field.

The following parameters are reported in Purtymun (1995, p. 31).

Parameter[a]	LA-1[b]	LA-1b[b]	LA-2[b]	LA-2[c]	LA-3[b]	LA-4[b]	LA-5[b]	LA-6[b]
Year	1950	1982	1982	1992	1982	1981	1982	1981
Q/s (gpm/ft)	0.8	4.5	1.4	1.4	1.9	5.6	3.4	10.2
b_r (ft)	830	1680	710	710	750	1680	1580	1700
T_r (gpd/ft)		15700	2500	2500	2500	9600	4800	15500
K_r (gpd/ft^2)		9.3	3.5	3.5	3.3	5.7	3.0	9.1
T_r (ft^2/day)		2099	334	334	334	1283	642	2072
K_r (ft/day)		1.2	0.5	0.5	0.4	0.8	0.4	1.2

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	LA-1[b]	LA-1b[b]	LA-2[b]	LA-2[c]	LA-3[b]	LA-4[b]	LA-5[b]	LA-6[b]
Year	1950	1982	1982	1992	1982	1981	1982	1981
Ele (ft msl)	5624	5622	5651	5651	5672	5975	5840	5770
WL (ft bgs)	19	71	161	142	118	289	168	84
Q (gpm)	366	486	269	276	247	579	467	580
s (ft)	203	109	187	196	128	104	136	57
t (minutes)	360	360	360	10080	360	360	360	360
L (ft)	805	591	760	760	760	350	350	400
d_c (in)	12	10	12	12	12	10	10	10
d_w (in)	22	20	22	22	22	20	20	20
TOS (ft bgs)	60	326	105	105	105	754	440	420
BOS (ft bgs)	865	1694	865	865	865	1964	1740	1778
b_e (ft)	805	1368	760	760	760	1210	1300	1358
b_s (ft)	846	1623	704	723	747	1675	1572	1694
E (%)	100	100	100	100	100	100	100	100
Geologic Unit	Ts	Ts	Ts	Ts	Ts	Ts	Ts	Ts
Q/s (gpm/ft)	1.8	4.5	1.4	1.4	1.9	5.6	3.4	10.2
T (ft^2/day)	337	2108	264	335	363	1179	700	2256
S (dim)	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
b (ft)	805	591	704	723	747	350	350	400
K (ft/day)	0.4	3.6	0.4	0.5	0.5	3.4	2.0	5.6
S_s (1/ft)	4.7E-06	6.4E-06	5.4E-06	5.3E-06	5.1E-06	1.1E-05	1.1E-05	9.5E-06
T ratio		1.0	1.3	1.0	0.9	1.1	0.9	0.9
K ratio		0.4	1.3	1.0	0.9	0.2	0.2	0.2

[a] See Table 1 for parameter definitions.

[b] Well completion data summarized from Purtymun (1995) and McLin et al. (1998).

[c] Test reported in Purtymun et al. 1995a; data in this report.

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

Table 3. Additional comparisons of aquifer parameters from Los Alamos well field.

The following parameters are reported in Griggs (1955, p. 150).

Parameter[a]	LA-2[b]	LA-2[b]	LA-2[b]	LA-3[b]	LA-3[b]	LA-3[b]	LA-5[b]
Year	1950	1950	1950	1950	1950	1950	1950
Q/s (gpm/ft)							
b_r (ft)[c]	760	754	760	760	749	760	350
T_r (gpd/ft)	4100	4100	2600	1400	2900	2600	6500
K_r (gpd/ft^2)	5.4	5.4	3.4	1.8	3.9	3.4	18.6
T_r (ft^2/day)	548	548	348	187	388	348	869
K_r (ft/day)	0.7	0.7	0.5	0.2	0.5	0.5	2.5

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	LA-2[b]	LA-2[b]	LA-2[b]	LA-3[b]	LA-3[b]	LA-3[b]	LA-5[b]
Year	1950	1951	1952	1950	1951	1952	1951
Ele (ft msl)	5651	5651	5651	5672	5672	5672	5840
WL (ft bgs)	59	111	101	97	116	94	162
Q (gpm)	424	398	390	345	314	389	520
s (ft)	226	194	199	134	117	124	110
t (minutes)	360	360	360	360	360	360	360
L (ft)	760	760	760	760	760	760	350
d_c (in)	12	12	12	12	12	12	10
d_w (in)	22	22	22	22	22	22	20
TOS (ft bgs)	105	105	105	105	105	105	440
BOS (ft bgs)	865	865	865	865	865	865	1740
b_e (ft)	760	760	760	760	760	760	1300
b_s (ft)	806	754	764	768	749	771	1578
E (%)	100	100	100	100	100	100	100
Geologic Unit	Ts	Ts	Ts	Ts	Ts	Ts	Ts
Q/s (gpm/ft)	1.9	2.1	2.0	2.6	2.7	3.1	4.7
T (ft^2/day)	356	393	374	503	526	623	999
S (dim)	0.00330	0.00330	0.00330	0.00330	0.00330	0.00330	0.00330
b (ft)	760	754	760	760	749	760	350
K (ft/day)	0.5	0.5	0.5	0.7	0.7	0.8	2.9
S_s (1/ft)	4.3E-06	4.4E-06	4.3E-06	4.3E-06	4.4E-06	4.3E-06	9.4E-06
T ratio	1.5	1.4	0.9	0.4	0.7	0.6	0.9
K ratio	1.5	1.4	0.9	0.4	0.7	0.6	0.9

[a] See Table 1 for parameter definitions.

[b] Well completion data summarized from Purtymun (1995) and McLin et al. (1998).

[c] Not reported by Griggs; we assume b_r = b (see Table 1 for definitions).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

Discussion. According to the comparisons shown in Table 2, there are only small differences between the old and new *T* estimates as expressed by the ratios in *T* values. These differences are related to the assumed values for *t* and *S* that were used in the specific capacity method (the original *t* and *S* values were not reported by Purtymun). Instead, our estimated values for *t* and *S* were obtained from operational characteristics of individual wells or from previous aquifer tests (i.e., Griggs, 1955; Purtymun et al., 1995a). Other critical data include discharge (*Q*), drawdown (*s*), and well construction details that were obtained from the cited references.

When the corresponding *K* values are compared in Table 2, there are somewhat larger discrepancies as seen in the *K* ratios. These differences are related to different values that were used for aquifer thickness by Purtymun (1995, p. 31) and in this report. Hence, the new *b* values used in the specific capacity method are considerably smaller than the old b_r values listed in Table 2. Purtymun originally computed these aquifer thickness values from the drilling logs in each well. These values are closely approximated by the b_s values shown in Table 2. However, these b_s values are slightly smaller than the b_r values because they represent saturated aquifer thickness (see the definitions for these parameters listed in Table 1). In this report, we represent these aquifer thickness values by total screen length (i.e., *L* or *b* in Table 2). Note that for individual wells shown in Table 2, sections of well screen alternate between sections of blank casing over the intervals indicated by the parameter b_s. This alternating well completion design is typically used in heterogeneous formations where short screen sections are placed opposite higher yielding zones and sections of blank casing are placed opposite lower yielding zones. In other words, this alternating screen-casing design tells us that the regional aquifer in the Los Alamos well field area is highly stratified. We have concluded that *b* more accurately represents this total aquifer thickness better than either b_s or b_r. As a result, our K values are somewhat higher than those reported by Purtymun.

Table 3 summarizes old and new *T* estimates using data from Griggs (1955). Values for *t*, *S*, and *b* were missing from the Griggs source and were estimated in the specific capacity method. In addition, there are three *T* estimates for wells LA-2 and LA-3; these correspond to analyses that used drawdown, recovery, and combined test data in the Griggs report. Finally, there is one estimate for well LA-5 in Table 3. There are no estimates for the other wells in the Los Alamos well field because Griggs did not report any other *T* values. The specific capacity analysis was made from historical pumping and drawdown records listed in Purtymun et al. (1995a, Appendix A). According to the *T* and *K* ratio values shown in Table 3, there are only small differences between historical and modern *T* and *K* estimates for these wells. Since *b* values are the same for both old and new parameter estimates in Table 3, we expect *K* values to follow the *T* trend. In other words, the specific capacity estimates for aquifer parameters are similar to the Griggs estimates for wells LA-2, LA-3, and LA-5 (and probably for the other wells too).

Old Guaje Well Field

The original Guaje well field contained seven water supply wells (see Figure 1), including wells G-1, G-1a, G-2, G-3, G-4, G-5, and G-6. Purtymun (1995, p. 31) has conveniently summarized historical aquifer parameter estimates for each of these old Guaje wells. The original aquifer tests were conducted in March 1950 by the USGS and reported in Griggs (1955, p. 155). Since there are some minor differences between the parameter values listed in Purtymun and Griggs, separate specific capacity analyses were made for each data set. Table 4 summarizes the comparison between the Purtymun data and new specific capacity results. A similar comparison

Table 4. Comparison of aquifer parameters from old Guaje well field.

The following parameters are reported in Purtymun (1995, p. 31) or Griggs (1955, p. 155).

Parameter[a]	G-1[b]	G-1[c]	G-1a[b]	G-2[b]	G-3[b]	G-4[b]	G-5[b]	G-5[c]	G-6[b]
Year	1982	1950	1982	1982	1982	1982	1982	1950	1982
Q/s (gpm/ft)	1.9	4.8	12.0	10.1	2.1	1.5	9.5	5.4	3.5
b_r (ft)	1702	400	1208	1608	1436	1539	1375	400	922
T_r (gpd/ft)	12000	11700	11000	15000	7500	17500	12000	7700	6300
K_r (gpd/ft^2)	7.1	29.3	9.1	9.3	5.2	11.4	8.7	19.3	6.8
T_r (ft^2/day)	1604	1564	1471	2005	1003	2340	1604	1029	842
K_r (ft/day)	0.9	3.9	1.2	1.2	0.7	1.5	1.2	2.6	0.9

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	G-1[b]	G-1[c]	G-1a[b]	G-2[b]	G-3[b]	G-4[b]	G-5[b]	G-5[c]	G-6[b]
Year	1982	1950	1982	1982	1982	1982	1982	1950	1982
Ele (ft msl)	5873	5873	6014	6056	6139	6229	6306	6306	6422
WL (ft bgs)	278	202	305	352	349	386	455	422	588
Q (gpm)	313	523	505	476	239	297	522	539	281
s (ft)	165	108	42	47	112	192	55	99	81
t (minutes)	360	6000	360	360	360	360	360	6000	360
L (ft)	490	490	563	425	400	360	400	400	810
d_c (in)	10	10	10	10	10	10	10	10	12
d_w (in)	20	20	20	20	20	20	20	20	22
TOS (ft bgs)	282	282	272	281	441	426	462	462	700
BOS (ft bgs)	1980	1980	1513	1960	1785	1925	1830	1830	1510
b_e (ft)	1698	1698	1241	1679	1344	1499	1368	1368	810
b_s (ft)	1702	1778	1208	1608	1436	1539	1375	1408	922
E (%)	100	100	100	100	100	100	100	100	100
Geologic Unit	Ts	Ts	Ts	Ts	Ts	Ts	Ts	Ts	Ts
Q/s (gpm/ft)	1.9	4.8	12.0	10.1	2.1	1.5	9.5	5.4	3.5
T (ft^2/day)	425	1469	3055	2445	482	341	2375	1601	790
S (dim)	0.00062	0.00020	0.00062	0.00062	0.00062	0.00062	0.00062	0.00040	0.00062
b (ft)	490	490	563	425	400	360	400	400	810
K (ft/day)	0.9	3.0	5.4	5.8	1.2	0.9	5.9	4.0	1.0
S_s (1/ft)	1.3E-06	4.1E-07	1.1E-06	1.5E-06	1.6E-06	1.7E-06	1.6E-06	1.0E-06	7.7E-07
T ratio	3.8	1.1	0.5	0.8	2.1	6.9	0.7	0.6	1.1
K ratio	1.1	1.3	0.2	0.2	0.6	1.6	0.2	0.6	0.9

[a] See Table 1 for parameter definitions.

[b] Well completion data summarized from Purtymun (1995) and McLin et al. (1998).

[c] Well completion data summarized from Griggs (1955) and McLin et al. (1998).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

is made in Table 5 for each of the Guaje wells listed by Griggs. Much of the original raw data used to obtain these estimates has been lost; however, graphical data are summarized in Figure 17 of Griggs (1955). Griggs only conducted two aquifer tests; these were at wells G-1 and G-5. But he used wells G-2, G-3, and G-4 as observation wells. Hence, new estimates for T are made here using the specific capacity method described earlier. Tables 4 and 5 also summarize all supporting information required in the specific capacity method. Similarities and differences between these old and new estimates are discussed below. In 1987, well G-3 was converted to an observation well because of damaged well screens. In 1998, new replacement wells were drilled and completed to replace the aging Guaje well field. In 1999, wells G-1, G-2, G-4, G-5, and G-6 were plugged and abandoned in accordance with State of New Mexico requirements as specified by the State Engineer. Well G-3 was retained as an observation well. Well G-1a was retained as a back-up water supply well.

Discussion. According to the comparisons made in Table 4 (i.e., see the changes in T ratio values), there are relatively small differences between old and new T estimates for wells G-1 (1950 data), G-1a, G-2, G-3, G-5, and G-6; however, there are substantial differences in T values from wells G-1 (i.e., compare 1950 and 1982 values) and G-4. Obviously, any new estimates for T depend on the assumed values for t and S (in addition to the reported data summarized in Purtymun and in Table 4). However, the large differences in T for wells G-1 and G-4 can not be fully explained by these observed and assumed values alone. Instead, these differences result from deteriorating well performance over time as explained below.

According to McLin (2005b), T can be estimated from,

$$T = \frac{Q}{4\pi(s_t - s_w)}\left[\ln\left(\frac{2.25Tt}{r_w^2 S}\right) + 2s_p\right] \tag{1}$$

where all terms have been previously defined (see Appendix B). Since $s_w = CQ^2$ and $C = s_t(1 - E/100)/Q^2$, we can rewrite Equation (1) as,

$$\left(\frac{E}{100}\right) = \left(\frac{Q}{s_t}\right)\frac{\left[\ln\left(2.25Tt/r_w^2 S\right) + 2s_p\right]}{4\pi T} \tag{2}$$

Here E is well efficiency and Q/s_t is specific capacity. According to Equation (2), any temporal changes in Q/s_t must result from changes in E because all other terms are fixed. In other words, if we repeat an aquifer test at some well after several years of operational use, we should obtain the same T value from Equation (1) because aquifer parameters do not change over time. If apparent changes in T are obtained, then according to Equation (2) they must result from changes in E (i.e., assuming no test performance errors have occurred or assumptions have be violated). Figure 2 shows a plot of changes in Q/s_t over time from wells G-1 and G-4. These data were reported in McLin et al. (1998) and clearly show that changes in Q/s_t over time have occurred.

Table 5. Additional comparisons of aquifer parameters from the Guaje well field.

The following parameters are reported in Griggs (1955, p. 155) using recovery data.

Parameter[a]	G-1	G-1a	G-2	G-3	G-4	G-5	G-6
Year	1950		1950		1950	1950	
Q/s (gpm/ft)	4.8					5.4	
b_r (ft)	400		400		400	400	
T_r (gpd/ft)	14700		16500		25000	12000	
K_r (gpd/ft^2)	36.8		41.3		62.5	30.0	
T_r (ft^2/day)	1965		2206		3342	1604	
K_r (ft/day)	4.9		5.5		8.4	4.0	

The following transmissivity[c] values are estimated using the data listed below.

Parameter[a]	G-1[b]	G-1a[b]	G-2[b]	G-3[b]	G-4[b]	G-5[b]	G-6[b]
Year	1951	1955	1952	1952	1952	1952	1964
Ele (ft msl)	5873	6014	6056	6139	6229	6306	6422
WL (ft bgs)	202	265	279	310	374	422	581
Q (gpm)	538	577	550	458	395	477	392
s (ft)	107	51	48	48	100	58	78
t (minutes)	360	360	360	360	360	360	360
L (ft)	490	563	425	400	360	400	810
d_c (in)	10	10	10	10	10	10	12
d_w (in)	20	20	20	20	20	20	22
TOS (ft bgs)	282	272	281	441	426	462	700
BOS (ft bgs)	1980	1513	1960	1785	1925	1830	1510
b_e (ft)	1698	1241	1679	1344	1499	1368	810
b_s (ft)	1778	1248	1681	1475	1551	1408	929
E (%)	100	100	100	100	100	100	100
Geologic Unit	Ts	Ts	Ts	Ts	Ts	Ts	Ts
Q/s (gpm/ft)	5.0	11.3	11.5	9.5	4.0	8.2	5.0
T (ft^2/day)	1299	3072	3113	2501	960	2098	1211
S (dim)	0.00020	0.00020	0.00020	0.00030	0.00040	0.00040	0.00040
b (ft)	490	563	425	400	360	400	810
K (ft/day)	2.7	5.5	7.3	6.3	2.7	5.2	1.5
S_s (1/ft)	4.1E-07	3.6E-07	4.7E-07	7.5E-07	1.1E-06	1.0E-06	4.9E-07

[a] See Table 1 for parameter definitions.

[b] Well completion data summarized from Purtymun (1995) and McLin et al. (1998).

[c] Transmissivity from specific capacity; see McLin (2005b) for details.

T ratio	1.5		0.7		3.5	0.8	
K ratio	1.9		0.8		3.1	0.8	

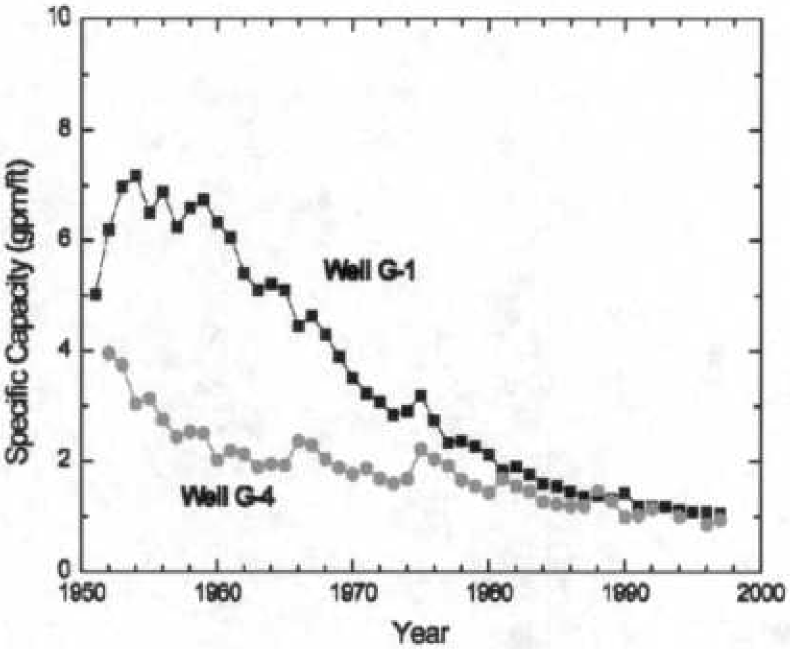

Figure 2. Changes in specific capacity over time in wells G-1 and G-4 according to well performance data reported in McLin et al. (1998).

According to the above discussion, deteriorating well performance over time in well G-1 explains the apparent reduction in *T* over time (which is not physically realistic). As seen in Figure 2, *Q/s* decreased from 4.8 to 1.9 gpm/ft between 1950 and 1982 (i.e., *Q* decreased while *s* increased over this period). If we use the 1982 data with the specific capacity method, then we obtain an underestimated *T* value that is physically unrealistic (i.e., *T* seems to decrease in value from 1469 to 425 ft^2/day between 1950 and 1982). Instead, the filter pack and well screen surrounding this well have become clogged and encrusted with fine-grained sediments and precipitated silica from the formation (perhaps originating with a poorly designed and/or installed filter-pack). In addition, Purtymun (1995, p. 31) has reported a 1982 *T* value of 12,000 gpd/ft; a similar value of 11,700 gpd/ft was originally reported by Griggs (1955, p. 155). Purtymun apparently reported the Griggs *T* value along with a 1982 *Q/s* value of 1.6 gpm/ft that is smaller than the 1950 value of 4.8 gpm/ft. The resulting specific capacity analysis yields a lower 1982 estimate for *T* compared to the real 1950 value. In fact, it is well efficiency that has declined and not *T*. This raises an important point: individual estimates for *T* obtained from a particular well need to be associated with the original aquifer test data so that *T* values can be validated.

The *T* values shown in Tables 4 and 5 for well G-4 also change for a similar reason. However, this change is more difficult to detect. Again, Purtymun (1995, p. 31) reports a *T* value for this well that Griggs found in his 1950 test; Purtymun also reports a 1982 *Q/s* value for this well. However, Griggs never reported a *Q/s* value for well G-4 because this well was used as an observation well while well G-5 was pumped (hence there was no *Q* at well G-4). We can see a deterioration in G-4 well performance when we compare the apparent decrease in specific capacity T values from 1952 (i.e., 960 ft^2/day from Table 5) and 1982 (i.e., 341 ft^2/day from Table 4); this deterioration is reflected in an apparent T ratio of 2.8 (recall that T is not really decreasing). The differences in T values for well G-4 that are shown in Table 5 have a T ratio of 3.5, whereas differences from Table 4 have a T ratio of 6.9. However, these ratios also differ because we are commingling the effects of different methods of analysis with declining well performance. Certainly we would not expect the same dramatic deterioration in well performance indicated in Table 5 from 1950-52 compared to that in Table 4 from 1950-82 (and the T ratio values support this view). In addition, recent aquifer tests (McLin, 2006b) in the Guaje well field have revealed the presence of barrier boundary effects that may have slowly become more pronounced over time as upper units began to dewater (i.e., resulting in larger s values versus slightly declining Q values over time).

Changes in K values that are shown in Tables 4 and 5 are represented by the K ratio parameter. As was the case in the Los Alamos well field, these changes are strongly influenced by differences in b values. The new b values used in Tables 4 and 5 are considerably smaller than the old b_r estimates listed in Purtymun (1995, p. 31); however, they closely approximate the value of about 400 ft that was suggested by Griggs. These new b values are based on dynamic spinner logs (McLin, 2006b) from the replacement Guaje well field. Again, these logs tell us that the regional aquifer in the Guaje well field is strongly heterogeneous and vertically stratified.

Replacement Guaje Well Field

As indicated above, replacement water supply wells were installed in Guaje Canyon in 1998 (see Figure 1). These new wells included G-2a, G-3a, G-4a, and G-5a (Shomaker, 1999). Note that these wells were originally called GR-2, GR-3, GR-4, and GR-1, respectively; however, Los Alamos County officially renamed these wells in 1999. Table 6 summarizes all of these new estimates along with all supporting information. In addition, the similarities and differences between these old and new estimates are discussed below.

Well G-1a from the old Guaje well field was retained as a backup municipal water supply well. Table 6 summarizes important aquifer parameter estimates from each of these wells. Original aquifer test data and analyses are contained in McLin (2006b).

Discussion. According to the comparisons shown in Table 6, there are only small differences between the old and new T estimates as expressed by the ratios in T values. The lone exception may be with well G-1a values. Unlike before, these small differences are not related to the assumed values for t and S that were used in the specific capacity method (because these values were measured and reported). Instead, differences in estimated T values are due to the different methods used to obtain these estimates (i.e., Theis curve matching versus specific capacity). The differences in T from well G-1a are probably related to changes in Q/s over time. Note than Purtymun gives a Q/s value of 12.0 gpd/ft in 1982 while McLin reports a Q/s value of 16.0 gpd/ft in 2001. According to Equation (2), well efficiency at G-1a has improved over time because Q/s_t has increased (see McLin et al., 1998). Similar increases were previously reported in wells G-2a and G-3a between 1998 and 2005 (McLin, 2006b). In addition, decreases in well efficiency were noted in wells G-4a and G-5a over the same time period.

Table 6. Comparison of aquifer parameters from water supply wells in the new replacement Guaje well field.

The following parameters are reported in Purtymun (1995) or Shomaker (1999).

Parameter[a]	G-1a[b, c]	G-2a[b, c]	G-3a[b, c]	G-4a[b, c]	G-5a[b, c]
Year	1982	1998	1998	1998	1998
Q/s (gpm/ft)	12.0	8.4	6.6	5.8	2.8
b_r (ft)	1208	435	261	245	325
T_r (gpd/ft)	11,000	3,900	13,200	7,000	4,400
K_r (gpd/ft^2)	9.1	9.0	50.6	28.6	13.5
T_r (ft^2/day)	1471	521	1765	936	588
K_r (ft/day)	1.2	1.2	6.8	3.8	1.8

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	G-1a[b, c]	G-2a[b, c]	G-3a[b, c]	G-4a[b, c]	G-5a[b, c]
Year	2001	1998	1998	1998	1998
Ele (ft msl)	6014	6140	6212	6299	6416
WL (ft bgs)	302	323	397	461	552
Q (gpm)	400	901	800	752	408
s (ft)	25	107	122	129	144
t (minutes)	360	2880	2880	2880	2880
L (ft)	563	435	261	245	325
d_c (in)	10	16	16	16	16
d_w (in)	12	26	26	26	26
TOS (ft bgs)	272	565	589	655	765
BOS (ft bgs)	1513	1980	1980	1980	1980
b_e (ft)	1241	1415	1391	1325	1215
b_s (ft)	1211	1657	1583	1519	1428
E (%)	100	100	100	100	100
Geologic Unit	Ts	Ts	Ts	Ts	Ts
Q/s (gpm/ft)	16.0	8.4	6.6	5.8	2.8
T (ft^2/day)	4140	2247	1723	1521	706
S (dim)	0.00062	0.00062	0.00062	0.00062	0.00062
b (ft)	563	435	261	245	325
K (ft/day)	7.4	5.2	6.6	6.2	2.2
S_s (ft/day)	1.1E-06	1.4E-06	2.4E-06	2.5E-06	1.9E-06

[a] See Table 1 for parameter definitions.

[b] Well data summarized from Purtymun (1995), Shomaker (1999), and McLin (2006b).

[c] Spinner log data used to define effective screen length (L); see McLin (2006b).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

T ratio	0.4	0.2	1.0	0.6	0.8
K ratio	0.2	0.2	1.0	0.6	0.8

Pajarito and Otowi Well Fields

As seen in Figure 1, the original Pajarito well field contains five water supply wells, including wells PM-1, PM-2, PM-3, PM-4, and PM-5. These wells were installed between 1960 and 1985 (Purtymun, 1995). In addition, two new water supply wells (O-4 and O-1, respectively) were installed in the Otowi well field in 1989 and 1990 (Purtymun, 1995). Tables 7 and 8 summarize important historical aquifer parameter estimates (Purtymun, 1995) from each of these wells, and compare them to new parameter estimates obtained from the specific capacity technique. Recent parameter estimates from long-term aquifer tests at wells PM-2 and PM-4 are also contained in these tables. These data were reported in McLin (2005a, 2006a) using multiple observation wells. These results are discussed below.

Discussion. According to the comparisons shown in Tables 7 and 8, there are only small differences between the old and new *T* estimates as expressed by the ratios in *T* values. As previously mentioned, these small differences are related to the assumed values for *t* and *S* that were used in the specific capacity method. In addition, several tests (i.e., the 2003 test at PM-2, the 2005 test at PM-4, and the 2006 test at O-1) have observed *t* and *S* values from independent aquifer tests. These additional observations confirm that *T* estimates obtained with the specific capacity method yield reliable results using approximations for *t* and *S*. Finally, all of these tests contain more accurate estimates for *b* that were obtained from dynamic spinner logs at wells PM-4 (Koch et al., 1999) and O-1 (Kleinfelder, 2006). Hence, the differences in *K* estimates as seen in the *K* ratio values reflect small differences in old and new *b* estimates.

It is also interesting to note that *T* values have apparently increased in well PM-2 between 1982 and 2003, in well PM-5 between 1982 and 1987, and in well O-4 between 1990 and 1994. These apparent increases are actually the result of small improvements in well efficiency. Likewise, the *T* values have apparently decreased in well PM-4 between 1982 and 2005, and in well O-1 between 1990 and 2005. These apparent decreases are actually the result of a deterioration in well efficiency.

Finally, the new *b* values shown in Tables 7 and 8 are based on dynamic spinner logs at wells PM-4 (Koch et al., 1999) and O-1 (Kleinfelder, 2006).

Test Wells

In addition to the water supply wells listed above, numerous observation wells have been installed over the years. Beginning in 1960, the US Geological Survey installed 8 observation wells (Purtymun, 1995), including wells TW-1, TW-2, TW-3, TW-4, TW-8, DT-5a, DT-9, and DT-10 (see Figure 1). Table 9 summarizes important aquifer parameter estimates from each of these wells and compares them to the original parameter estimates reported in Purtymun (1995, p. 31). These wells have been used for many years to monitor water levels in the regional aquifer and to collect water quality samples. These results are discussed below.

Table 7. Comparison of aquifer parameters from the Pajarito well field.

The following parameters are reported in Purtymun (1995, p. 31).

Parameter[a]	PM-1[b]	PM-2[b]	PM-2[b]	PM-3[b]	PM-4[b]	PM-4[b]
Year	1982	1982	1982	1982	1982	1982
Q/s (gpm/ft)	26.8	23.1	23.1	60.9	36.8	36.8
b_r (ft)	1731	1406	1406	1770	1804	1804
T_r (gpd/ft)	55000	40000	40000	320000	44000	44000
K_r (gpd/ft^2)	31.8	28.4	28.4	180.8	24.4	24.4
T_r (ft^2/day)	7353	5348	5348	42781	5882	5882
K_r (ft/day)	4.2	3.8	3.8	24.2	3.3	3.3

The following transmissivity[c] values are estimated using the data listed below.

Parameter[a]	PM-1[b, d]	PM-2[b, d]	PM-2[d, e]	PM-3[b, d]	PM-4[b, d]	PM-4[d, e]
Year	1982	1982	2003	1982	1982	2005
Ele (ft msl)	6520	6715	6715	6640	6920	6920
WL (ft bgs)	748	874	868	762	1050	1075
Q (gpm)	589	1386	1249	1402	1460	1494
s (ft)	22	60	84	23	40	66
t (minutes)	360	360	5300	360	360	4333
L (ft)	848	741	741	874	690	690
d_c (in)	12	14	14	14	16	16
d_w (in)	22	24	24	24	26	26
TOS (ft bgs)	945	1004	1004	956	1260	1260
BOS (ft bgs)	2479	2280	2280	2532	2854	2854
b_e (ft)	1534	1276	1276	1576	1594	1594
b_s (ft)	1731	1406	1412	1770	1804	1779
E (%)	100	100	100	100	100	100
Geologic Unit	Tpf	Tpf	Tpf	Tpf	Tpf	Tpf
Q/s (gpm/ft)	26.8	23.1	14.9	61.0	36.5	22.7
T (ft^2/day)	7242	6077	4454	16997	9464	6762
S (dim)	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035
b (ft)	848	741	741	874	690	690
K (ft/day)	8.5	8.2	6.0	19.4	13.7	9.8
S_s (1/ft)	4.1E-07	4.7E-07	4.7E-07	4.0E-07	5.1E-07	5.1E-07

[a] See Table 1 for parameter definitions

[b] Well completion data summarized from Purtymun (1995) and McLin et al. (1998).

[c] Transmissivity from specific capacity; see McLin (2005b) for details.

[d] Spinner logs used to define effective screen length (L); see Koch et al. 1999 or McLin (2006a).

[e] Test reported in McLin (2005a, 2006a).

T ratio	1.0	0.9	1.2	2.5	0.6	0.9
K ratio	0.5	0.5	0.6	1.2	0.2	0.3

Table 8. Additional comparisons of aquifer parameters from the Pajarito and Otowi well fields.

The following parameters are reported in Purtymun (1995, p. 31).

Parameter[a]	PM-5[b]	PM-5[b]	O-4[b]	O-4[b]	O-1[b]	O-1[b]
Year	1982	1982	1990	1990	1990	1990
Q/s (gpm/ft)	8.5	8.5	46.2	46.2	8.1	8.1
b_r (ft)	1864	1864	1836	1836	1802	1802
T_r (gpd/ft)	10000	10000	62000	62000	9000	9000
K_r (gpd/ft^2)	5.4	5.4	33.8	33.8	5.0	5.0
T_r (ft^2/day)	1337	1337	8289	8289	1203	1203
K_r (ft/day)	0.7	0.7	4.5	4.5	0.7	0.7

The following transmissivity[c] values are estimated using the data listed below.

Parameter[a]	PM-5[b, d]	PM-5[b, d]	O-4[d, e]	O-4[d, e]	O-1[d, e]	O-1[d, e, f]
Year	1982	1987	1990	1994	1990	2006
Ele (ft msl)	7095	7095	6627	6627	6396	6396
WL (ft bgs)	1208	1237	760	760	675	675
Q (gpm)	1225	1220	1500	1396	1000	505
s (ft)	144	108	33	21	123	105
t (minutes)	360	360	360	360	360	7570
L (ft)	325	325	1068	1068	250	250
d_c (in)	16	16	16	16	16	16
d_w (in)	26	26	26	26	26	26
TOS (ft bgs)	1440	1440	1115	1115	1017	1017
BOS (ft bgs)	3072	3072	2596	2596	2477	2477
b_e (ft)	1632	1632	1481	1481	1460	1460
b_s (ft)	1864	1835	1836	1836	1802	1802
E (%)	100	100	100	100	100	100
Geologic Unit	Tpf	Tpf	Tpf	Tpf	Tpf	Ts
Q/s (gpm/ft)	8.5	11.3	45.5	66.5	8.1	4.8
T (ft^2/day)	2062	2791	12261	18341	1965	1360
S (dim)	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035
b (ft)	325	325	1068	1068	250	250
K (ft/day)	6.3	8.6	11.5	17.2	7.9	5.4
S_s (1/ft)	1.1E-06	1.1E-06	3.3E-07	3.3E-07	1.4E-06	1.4E-06

[a] See Table 1 for parameter definitions

[b] Well completion data summarized from Purtymun (1995) and McLin et al. (1998).

[c] Transmissivity from specific capacity; see McLin (2005b) for details.

[d] Spinner logs used to define effective screen length (L); see Koch et al. 1999 or McLin (2006a).

[e] Test reported in Purtymun et al (1995b) and McLin (2005a, 2006a); data in this report.

[f] Test performed by Schafer (2005); spinner log and data in this report.

T ratio	0.6	0.5	0.7	0.5	0.6	0.9
K ratio	0.1	0.1	0.4	0.3	0.1	0.1

Table 9. Parameter estimates for regional aquifer test wells drilled prior to about 1965.

The following parameters are reported in Purtymun (1995, p. 31).

Parameter[a]	TW-1[b]	TW-2[b]	TW-3[b]	TW-4[b]	TW-8[b]	DT-5a[b,c]	DT-9[b,c]	DT-10[b,c]
Year	1951	1951	1951	1951	1960	1960	1960	1960
Q/s (gpm/ft)	<1	1.0	0.5	0.6	2.0	6.0	22.0	16.0
b_r (ft)	49	30	65	34	95	643	498	324
T_r (gpd/ft)	200	7,000	7,800	700	2,400	11,000	61,000	36,100
K_r (gpd/ft^2)	4.1	233.3	120.0	20.6	25.3	17.1	122.5	111.4
T_r (ft^2/day)	27	936	1043	94	321	1471	8155	4826
K_r (ft/day)	0.5	31.2	16.0	2.8	3.4	2.3	16.4	14.9

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	TW-1[b]	TW-2[b]	TW-3[b]	TW-4[b]	TW-8[b]	DT-5a[b,c]	DT-9[b,c]	DT-10[b,c]
Year	1951	1951	1951	1951	1960	1960	1960	1960
Ele (ft msl)	6369	6648	6569	7245	6878	7144	6935	7020
WL (ft bgs)	585	759	743	1171	968	1173	1003	1085
Q (gpm)	2.4	6.7	6.6	2.8	16.0	81.0	88.0	78.0
s (ft)	39	7	15	5	8	14	4	5
t (minutes)	360	360	360	360	360	360	360	360
L (ft)	10	56	10	10	97	220	183	191
d_c (in)	6	6	6	6	8	8	8	8
d_w (in)	6	6	6	6	8	8	8	8
TOS (ft bgs)	632	768	805	1195	953	1172	1040	1080
BOS (ft bgs)	642	824	815	1205	1065	1821	1501	1409
b_e (ft)	10	56	10	10	112	649	461	329
b_s (ft)	57	65	72	34	97	648	498	324
E (%)	100	100	100	100	100	100	100	100
Geologic Unit	Tpf	Tpf	Tpf	Tt1	Tpf	Tpf	Tpf	Tpf
Q/s (gpm/ft)	0.1	1.0	0.4	0.6	2.0	5.8	22.0	15.6
T (ft^2/day)	7	150	63	82	318	1024	4382	3018
S (dim)	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
b (ft)	10	56	10	10	97	220	183	191
K (ft/day)	0.7	2.7	6.3	8.2	3.3	4.7	23.9	15.8
S_s (ft/day)	5.0E-03	8.9E-04	5.0E-03	5.0E-03	5.2E-04	2.3E-04	2.7E-04	2.6E-04
T ratio	4.0	6.2	16.6	1.1	1.0	1.4	1.9	1.6
K ratio	0.8	11.6	2.5	0.3	1.0	0.5	0.7	0.9

[a] See Table 1 for parameter definitions.

[b] Well completion & test data from Weir and Purtymun (1962) or Purtymun (1995).

[c] Well screens are not continuous; see Purtymun (1995).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

Discussion. According to the comparisons shown in Table 9, there are relatively large differences between the old and new *T* estimates at wells TW-1, TW-2, and TW-3 as seen in the changes in the *T* ratios. As previously mentioned, some of these differences are related to the assumed values for *t* and *S* that were used in the specific capacity method. However, this explanation does not fully account the large differences shown in Table 9 for these wells. According to recent long-term aquifer tests at wells PM-2 and PM-4 (McLin, 2005a, 2006b), the regional aquifer responded like a leaky-confined aquifer near these production wells. These results were confirmed in both pumping and numerous observation wells during both aquifer tests. These results imply that the top of the regional aquifer near wells PM-2 and PM-4 has a relatively small *T* value that increases with depth. These test results were independently confirmed by a dynamic spinner log from well PM-4 (Koch et al., 1999) that show higher water yields originate in deeper zones that have higher *T* values (McLin, 2006). In addition, multi-screened observation wells showed increasing responses to pumping with depth. Hence, the specific capacity results for *T* that are shown in Table 9 are consistent with these independent observations. These results are also consistent with the *T* values shown in Table 8 for wells PM-2 and PM-4 (i.e., higher *T* values with depth). Finally, the *T* values shown in Purtymun are inconsistent with his *Q/s* values according to the technique described by McLin (2005b).

According to the *T* ratios seen in Table 9 for wells TW-4, TW-8, DT-5a, DT-9, and DT-10, there are only small differences between the old and new *T* estimates. These results are also consistent with the PM-4 aquifer test (McLin, 2006a) because drawdown was observed in well TW-8 and numerous other observation wells in response to pumping at PM-4. These drawdown values imply that *T* values near the water table are larger near well TW-8 than near TW-1, TW-2, and TW-3. Furthermore, historical drawdown associated with municipal water production has created an extensive trough near TW-8 (Rogers et al. 1996) that extends laterally as far as wells DT-5s, DT-9, and DT-10 (McLin et al., 1998). In other words, the regional aquifer in the central plateau area is characterized by a phreatic aquifer that is highly stratified and spatially variable. This variability is characterized by a horizontal to vertical ratio in hydraulic conductivity that is also highly variable, and probably ranges from about 25:1 to as much as 1000:1. This transitional behavior has not been adequately defined for the entire Pajarito Plateau.

These observations confirm that *T* estimates obtained with the specific capacity method yield reliable results using approximations for *t* and *S*. Finally, all of these tests contain more accurate estimates for *b* that were obtained from dynamic spinner logs at wells PM-4 (Koch et al., 1999) and O-1 (Kleinfelder, 2006). Hence, the differences in *K* estimates as seen in the *K* ratio values reflect small differences in old and new *b* estimates.

R-Wells

Beginning in 1998, numerous additional observation wells have been installed in and around Los Alamos County as part of an extensive regional aquifer characterization and water quality monitoring network (Collins et al., 2006). Locations of these R-wells are shown in Figure 1. Some of these R-wells contain single screens while others contain multiple screens located at different elevations within the same or an adjacent wellbore. All of the multiple well screens are hydraulically isolated from adjacent well screens that are in the same well. Hence, if a given R-well has three screens, then this well is equivalent to three wells. Table 10 defines all symbols that are used in Table 11, and Table 11 summarizes important aquifer parameter estimates from each of these well screens. In Table 11, there are multiple entries for a well if it has multiple screens (i.e., one entry per screen). Detailed well completion and testing reports are maintained within the Water Stewardship Program at Los Alamos National Laboratory.

Table 10. List of symbols used in Table 11.

Parameter	Definition
Date	Date that the data were reported or test was performed.
Test Type	Pumping (P); Injection (I); Falling Head (FH); None (N).
Ele (ft msl)	Elevation of wellhead brass pin (in ft above mean sea level, or ft msl).
TD (ft bgs)	Total depth of borehole (in ft below ground surface, or ft bgs).
WL (ft bgs)	Water level (ft bgs).
TOS (ft bgs)	Top of screen from well log (ft bgs).
BOS (ft bgs)	Bottom of screen from well log (ft bgs).
T_r (ft^2/day)	Aquifer transmissivity listedy in well completion report.
S_r (dim)	Storage coefficient listed in well completion report.
b_r (ft)	Effective aquifer thickness listed in well completion report.
K_r (ft/day)	Hydraulic conductivity listed in well completion report.

Q (gpm)	Average well discharge (in gallons per minute, or gpm).
s (ft)	Quasi-steady state drawdown (ft).
t (minutes)	Estimated or actual time of drawdown (min).
L (ft)	Screen length from well completion log (ft).
d_c (in)	Screen or casing inside diameter (in).
d_p (in)	Riser pipe casing inside diameter (in).
d_w (in); d_e (in)	Borehole diameter (in); effective diameter used in well completion report.
Geologic Unit	Geologic unit where screen is located and K value applies (see below).
Q/s (gpm/ft)	Specific capacity (gpm/ft).
T (ft^2/day)	Aquifer transmissivity estimated from specific capacity.
S (dim)	Storage coefficient from McLin (2005a, 2006a, 2006b) or estimated.
b (ft)	Effective aquifer thickness from b = TD-WL (ft), or BOS-TOS (ft).
K (ft/day)	Hydraulic conductivity computed from K = T/b or K = T/L. See text.
S_s (1/ft)	Specific storage computed from $S_s = S/b$.
Qbtu	Bandelier Tuff (undifferentiated)
Qbt	Bandelier Tuff, Tshirege Member
Qct	Cerro Toledo interval
Qbo	Bandelier Tuff, Otowi member
Qct	Cerro Toledo interval
Tb4	Cerros del Rio basalt.
Tpl	Puye Fm, lacustrine and riverine deposits.
Tpf	Puye Fm, fanglomerate deposits.
Tpp	Puye Fm, pumiceous deposits.
Tpt	Puye Fm, ancestral Rio Grande deposits (Totavi Lentil).
Tb2	Miocene basalt
Tf	Puye Fm, older fanglomerates.
Ts	Santa Fe Group (undifferentiated sands and silts).
T ratio	T ratio = T_r/T.
K ratio	K ratio = K_r/K.

Table 11. Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R1[b]	R2[b]	R2[b]	R4[b]	R5-1[b]	R5-2[b]	R5-3[b]
Date	01/18/04	01/10/04	01/11/04	01/06/04	09/05/01	09/05/01	09/05/01
Test Type[c]	P	P	P	P	N	N	N
Ele (ft msl)	6881.2	6770.4	6770.4	6577.5	6472.6	6472.6	6472.6
TD (ft bgs)	1165.0	944.0	944.0	845.0	902.0	902.0	902.0
WL (ft bgs)	1003.3	892.5	892.5	732.0	685.0	685.0	685.0
TOS (ft bgs)	1031.1	906.4	906.4	792.9	326.4	372.8	676.9
BOS (ft bgs)	1057.4	929.6	929.6	816.0	331.5	388.8	720.3
T_r (ft^2/day)	900	50	57	2020			
S_r (dim)	0.1000	0.1000	0.1000	0.1000			
b_r (ft)	200	10	10	200			
K_r (ft/day)	4.5	5.0	5.7	10.1			

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R1[b]	R2[b]	R2[b]	R4[b]	R5-1[b]	R5-2[b]	R5-3[b]
Q (gpm)	6.78	1.10	2.90	13.90			
s (ft)	6.85	3.00	11.50	7.15			
t (min)	100	143	1440	360			
L (ft)	26.3	23.2	23.2	23.1	5.1	16.0	43.4
d_c (in)	4.50	4.50	4.50	4.50	4.50	4.50	4.50
d_p (in)							
d_w (in)	12.25	12.25	12.25	12.25	12.25	12.25	12.25
d_e (in)[e]		6.30	6.30				6.30
Geologic Unit	Tpf	Tf	Tf	Tf	Tpf	Tpt	Ts
Q/s (gpm/ft)	0.99	0.37	0.25	1.94			
T (ft^2/day)	881	105	81	1394			
S (dim)	0.0500	0.0500	0.0500	0.0500	dry	dry	0.0500
b (ft)	161.7	51.5	51.5	113.0	175.0	75.0	35.0
K (ft/day)	5.4	2.0	1.6	12.3			
S_s (1/ft)	3.1E-04	9.7E-04	9.7E-04	4.4E-04			1.4E-03

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio	1.0	0.5	0.7	1.4			
K ratio	0.8	2.5	3.6	0.8			

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R5-4[b]	R-6i[b]	R-6[b]	R7-1[b]	R7-2[b]	R7-3[b]	R8-1[b]
Date	09/05/01	02/17/05	02/11/05	10/10/01	10/10/01	10/10/01	04/22/02
Test Type[c]	N	P	P	N	N	N	N
Ele (ft msl)	6472.6	6996.9	6995.8	6779.2	6779.2	6779.2	6544.7
TD (ft bgs)	902.0	660.0	1303.0	1097.0	1097.0	1097.0	1022.0
WL (ft bgs)	685.0	593.0	1158.0	902.8	902.8	902.8	709.0
TOS (ft bgs)	858.7	602.0	1205.0	363.2	730.4	895.5	705.3
BOS (ft bgs)	863.7	612.0	1228.0	379.2	746.4	937.4	755.7
T_r (ft^2/day)		222	2440				
S_r (dim)		0.1000	0.1000				
b_r (ft)		4.2	400				
K_r (ft/day)		52.9	6.1				

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R5-4[b]	R-6i[b]	R-6[b]	R7-1[b]	R7-2[b]	R7-3[b]	R8-1[b]
Q (gpm)		1.50	5.50				
s (ft)		2.09	5.08				
t (min)		1440	1500				
L (ft)	5.0	10.0	23.0	16.0	16.0	41.9	50.4
d_c (in)	4.50	4.50	4.50	4.50	4.50	4.50	4.50
d_p (in)							
d_w (in)	12.25	12.25	12.25	12.25	12.25	12.25	12.25
d_e (in)[e]				6.30	6.30		6.30
Geologic Unit	Tb2	Tpf	Tf	Tpf	Tpf	Tpp	Tpf
Q/s (gpm/ft)		0.72	1.08				
T (ft^2/day)		607	1018				
S (dim)	0.0500	0.0500	0.0500	dry	dry		
b (ft)	55.0	67.0	145.0	150.0	215.0	184.0	313.0
K (ft/day)		9.1	7.0				
S_s (1/ft)	9.1E-04	7.5E-04	3.4E-04				

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio		0.4	2.4				
K ratio		5.8	0.9				

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R8-2[b]	R9i-1[b]	R9i-1[b]	R9i-2[b]	R-9[b]	R-10a[b]	R10-1[b]
Date	04/22/02	04/10/00	04/11/00	04/10/00	03/03/98	10/16/05	10/01/05
Test Type[c]	N	I	P	FH	N	P	P
Ele (ft msl)	6544.7	6383.2	6383.2	6383.2	6382.8	6363.7	6362.3
TD (ft bgs)	1022.0	322.0	322.0	322.0	771.0	765.0	1165.0
WL (ft bgs)	709.0	142.0	142.0	264.0	688.0	622.3	650.9
TOS (ft bgs)	821.3	189.1	189.1	269.6	683.0	690.0	874.0
BOS (ft bgs)	828.0	199.5	199.5	280.3	748.5	700.0	897.0
T_r (ft^2/day)		589	1091			256	629
S_r (dim)		0.0010	0.0500			0.0005	0.0005
b_r (ft)		83	58	25		200	68
K_r (ft/day)		7.1	18.8	0.11		1.3	9.3

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R8-2[b]	R9i-1[b]	R9i-1[b]	R9i-2[b]	R-9[b]	R-10a[b]	R10-1[b]
Q (gpm)		19.00	15.40			2.30	17.75
s (ft)		25.72	24.90			19.65	12.60
t (min)		30.0	421.0			1520.0	1440.0
L (ft)	6.7	10.4	10.4	10.7	65.5	10.0	23.0
d_c (in)	4.50	5.00	5.00	5.00	4.50	4.50	4.50
d_p (in)							
d_w (in)	12.25	12.25	12.25	12.25	9.63	10.60	10.60
d_e (in)[e]					5.58		
Geologic Unit	Tpf	Tb4	Tb4	Tb4	Tb2	Ts	Ts
Q/s (gpm/ft)		0.74	0.62			0.12	1.41
T (ft^2/day)		498	443			225	2671
S (dim)		0.0500	0.0500	0.0500		0.0005	0.0005
b (ft)	313.0	61.9	61.9	25.9	83.0	142.7	273.1
K (ft/day)		8.0	7.2			1.6	9.8
S_s (1/ft)		8.1E-04	8.1E-04	1.9E-03		3.5E-06	1.8E-06

[a] See Table 10 for parameter definitions.
[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).
[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).
[d] Transmissivity from specific capacity; see McLin (2005b) for details.
[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.
[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio		1.2	2.5			1.1	0.2
K ratio		0.9	2.6			0.8	0.9

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R10-2[b]	R-11[b]	R12-1[b]	R12-2[b]	R12-3[b]	R-13[b]	R14-1[b]
Date	10/01/05	12/02/03	09/20/00	09/20/00	09/20/00	10/31/01	11/13/02
Test Type[c]	P	P	N	N	N	P	N
Ele (ft msl)	6362.3	6673.7	6499.6	6499.6	6499.6	6673.1	7062.1
TD (ft bgs)	1165.0	926.0	886.0	886.0	886.0	1029.0	1315.6
WL (ft bgs)	664.8	817.5	424.0	dry	805.0	833.0	1182.0
TOS (ft bgs)	1042.0	855.0	459.0	504.5	801.0	958.3	1200.6
BOS (ft bgs)	1065.0	877.9	467.5	508.0	839.0	1018.7	1233.1
T_r (ft^2/day)	74	7470				5391	
S_r (dim)	0.0005	0.1000				0.0500	
b_r (ft)	23	100				300	
K_r (ft/day)	3.2	74.7				18.0	

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R10-2[b]	R-11[b]	R12-1[b]	R12-2[b]	R12-3[b]	R-13[b]	R14-1[b]
Q (gpm)	13.80	19.20				19.10	
s (ft)	48.69	1.60				2.47	
t (min)	1375.0	1000.0				11.5	
L (ft)	23.0	22.9	8.5	3.5	38.0	60.4	32.5
d_c (in)	4.50	4.50	4.50	4.50	4.50	4.50	4.50
d_p (in)						2.375	
d_w (in)	10.60	12.25	12.75	12.75	10.63	12.75	12.75
d_e (in)[e]					5.84		
Geologic Unit	Ts	Tpf	Tb4	Tpt	Tpf	Tpf/Tpp	Tpf/Tpp
Q/s (gpm/ft)	0.28	12.00				7.74	
T (ft^2/day)	292	8887				3937	
S (dim)	0.0005	0.1000		dry		0.0500	0.0500
b (ft)	151.0	108.5			81.0	196.0	32.5
K (ft/day)	1.9	81.9				20.1	
S_s (1/ft)	3.3E-06	9.2E-04				2.6E-04	1.5E-03

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio	0.3	0.8				1.4	
K ratio	1.7	0.9				0.9	

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R14-2[b]	R15[b,f]	R-16r[b]	R-16r[b]	R16-1[b]	R16-2[b]	R16-3[b]
Date	11/13/02	02/19/00	10/21/05	10/24/05	11/25/02	11/25/02	11/26/02
Test Type[c]	I	P	P	P	N	I	I
Ele (ft msl)	7062.1	6820.0	6257.0	6257.0	6256.9	6256.9	6256.9
TD (ft bgs)	1315.6	1107.0	655.0	655.0	1276.7	1276.7	1276.7
WL (ft bgs)	1182.0	964.0	563.6	563.6	none	614.0	695.2
TOS (ft bgs)	1286.5	958.6	600.0	600.0	641.0	863.4	1014.8
BOS (ft bgs)	1293.1	1020.3	617.6	617.6	648.6	870.9	1022.4
T_r (ft^2/day)	143	306	59	60		879	1092
S_r (dim)	0.0100	0.0500	0.0005	0.0005		0.0030	0.0030
b_r (ft)	130	136	17.6	17.6		559	559
K_r (ft/day)	1.1	2.2	3.4	3.4		1.6	2.0

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R14-2[b]	R15[b,f]	R-16r[b]	R-16r[b]	R16-1[b]	R16-2[b]	R16-3[b]
Q (gpm)	10.10	11.71	3.60	7.70		8.45	9.74
s (ft)	186.33	13.73	12.98	23.25		122.47	111.92
t (min)	68.8	2503.0	1440.0	198.0		60.0	60.0
L (ft)	6.6	56.3	17.6	17.6	7.6	7.5	7.6
d_c (in)	4.50	5.00	4.50	4.50	4.50	4.50	4.50
d_p (in)	1.375	2.375				1.375	1.375
d_w (in)	12.75	12.75	9.63	9.63	10.63	10.63	10.63
d_e (in)[e]		6.76					
Geologic Unit	Tpp	Tpp	Tpt	Tpt	Tpf	Ts	Ts
Q/s (gpm/ft)	0.05	0.85	0.28	0.33		0.07	0.09
T (ft^2/day)	127	325	159	181		809	1008
S (dim)	0.0500	0.0500	0.0005	0.0005		0.0050	0.0050
b (ft)	130.0	127.0	63.4	63.4		559.0	559.0
K (ft/day)	1.0	2.6	2.5	2.8		1.4	1.8
S_s (1/ft)	3.8E-04	3.9E-04	7.9E-06	7.9E-06		8.9E-06	8.9E-06

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio	1.1	0.9	0.4	0.3		1.1	1.1
K ratio	1.1	0.9	1.3	1.2		1.1	1.1

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R16-4[b]	R17-1[b]	R17-2[b]	R-18[b]	R19-1[b]	R19-2[b]	R19-3[b]
Date	11/27/02	02/23/06	01/23/06	01/19/05	07/27/00	07/27/00	07/27/00
Test Type[c]	I	P	P	P	N	N	N
Ele (ft msl)	6256.9	pending	pending	7404.8	7066.3	7066.3	7066.3
TD (ft bgs)	1276.7	1167.0	1167.0	1440.0	1902.5	1902.5	1902.5
WL (ft bgs)	709.3	1036.2	1037.7	1288.0	dry	dry	dry
TOS (ft bgs)	1237.0	1057.0	1124.0	1358.0	827.3	893.3	1171.4
BOS (ft bgs)	1244.6	1080.0	1134.0	1381.0	843.6	909.6	1215.4
T_r (ft^2/day)	916	31	5880	2120			
S_r (dim)	0.0030	0.0005	0.0005	0.1000			
b_r (ft)	559	23	40	400			
K_r (ft/day)	1.6	1.3	147.0	5.3			

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R16-4[b]	R17-1[b]	R17-2[b]	R-18[b]	R19-1[b]	R19-2[b]	R19-3[b]
Q (gpm)	8.04	3.20	15.80	8.00			
s (ft)	108.59	16.00	1.90	8.40			
t (min)	60.0	463.0	480.0	1470.0			
L (ft)	7.6	23.0	10.0	23.0	16.3	16.3	44.0
d_c (in)	4.50	4.50	4.50	4.50	5.00	5.00	5.00
d_p (in)	1.375						
d_w (in)	10.63	12.25	12.25	12.25	12.25	12.25	12.25
d_e (in)[e]				6.12			
Geologic Unit	Ts	Tpf	Tpf	Tpf	Qbt	Tpf	Tpf
Q/s (gpm/ft)	0.07	0.20	8.32	0.95			
T (ft^2/day)	857	44	5109	936			
S (dim)	0.0050	0.0005	0.0005	0.0500	dry	dry	dry
b (ft)	559.0	23.0	40.0	152.0			
K (ft/day)	1.5	1.9	127.7	6.2			
S_s (1/ft)	8.9E-06	2.2E-05	1.3E-05	3.3E-04			
T ratio	1.1			2.3			
K ratio	1.1			0.9			

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R19-4[b]	R19-5[b]	R19-6[b]	R19-7[b]	R20-1[b]	R20-2[b]	R20-3[b]
Date	07/27/00	07/27/00	07/27/00	07/27/00	12/09/02	12/10/02	12/11/02
Test Type[c]	N	N	I	I	I/FH	I	I
Ele (ft msl)	7066.3	7066.3	7066.3	7066.3	6694.3	6694.3	6694.3
TD (ft bgs)	1902.5	1902.5	1902.5	1902.5	1353.3	1353.3	1353.3
WL (ft bgs)	1185.1	1188.2	1195.7	1199.8	825.3	829.6	849.8
TOS (ft bgs)	1410.2	1582.6	1726.8	1832.4	904.6	1147.1	1328.8
BOS (ft bgs)	1417.4	1589.8	1733.9	1839.5	912.2	1154.7	1336.5
T_r (ft^2/day)			1775	932	18	188	71
S_r (dim)			0.0030	0.0030		0.0030	0.0030
b_r (ft)			373	373	107	115	123
K_r (ft/day)			4.8	2.5	0.17	1.6	0.6

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R19-4[b]	R19-5[b]	R19-6[b]	R19-7[b]	R20-1[b]	R20-2[b]	R20-3[b]
Q (gpm)			11.80	14.60	0.66	10.00	11.60
s (ft)			10.49	10.54	106.53	117.60	139.26
t (min)			20.0	30.0	2.3	60.0	30.0
L (ft)	7.2	7.2	7.1	7.1	7.6	7.6	7.7
d_c (in)	5.00	5.00	5.00	5.00	5.00	5.00	5.00
d_p (in)			1.375	1.375	1.375	1.375	1.375
d_w (in)	12.25	12.25	12.25	12.25	12.25	12.25	12.25
d_e (in)[e]							
Geologic Unit	Tpf	Tpp	Tpp	Tpp	Tb4	Tpp	Tpt
Q/s (gpm/ft)			1.12	1.39	0.01	0.09	0.08
T (ft^2/day)			1840	2280	10	159	165
S (dim)			0.0050	0.0050	0.0500	0.0050	0.0050
b (ft)			100.0	100.0	106.7	115.0	123.0
K (ft/day)			18.4	22.8	0.09	1.4	1.3
S_s (1/ft)			5.0E-05	5.0E-05	4.7E-04	4.3E-05	4.1E-05

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio			1.0	0.4	1.9	1.2	0.4
K ratio			0.3	0.1	1.9	1.2	0.4

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R-21[b]	R22-1[b]	R22-2[b]	R22-3[b]	R22-4[b]	R22-5[b]	R-23i-1[b]
Date	01/16/03	11/15/00	11/15/00	11/16/00	11/17/00	11/17/00	12/08/05
Test Type[c]	P	N	I/FH	I/FH	I/FH	I/FH	N
Ele (ft msl)	6656.2	6650.5	6650.5	6650.5	6650.5	6650.5	6527.9
TD (ft bgs)	995.0	1489.0	1489.0	1489.0	1489.0	1489.0	425.3
WL (ft bgs)	796.9	883.0	899.6	948.0	955.5	955.5	405.9
TOS (ft bgs)	888.8	872.3	947.0	1272.2	1378.2	1447.3	400.3
BOS (ft bgs)	906.8	914.2	988.9	1278.9	1384.9	1452.3	420.0
T_r (ft^2/day)	None		3	16	26	12	
S_r (dim)	Reported						
b_r (ft)		290	70	49	49	43	
K_r (ft/day)			0.04	0.32	0.54	0.27	

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R-21[b]	R22-1[b]	R22-2[b]	R22-3[b]	R22-4[b]	R22-5[b]	R-23i-1[b]
Q (gpm)	15.67		9.12	12.00	16.00	17.00	
s (ft)	81.29		276.86	313.57	139.78	154.36	
t (min)	144.0		22.2	9.2	7.2	5.0	
L (ft)	18.0	41.9	41.9	6.7	6.7	5.0	19.7
d_c (in)	6.00	4.50	4.50	4.50	4.50	4.50	2.10
d_p (in)			2.375	2.375	2.375	2.375	
d_w (in)	12.25	12.25	12.25	12.25	12.25	12.25	12.25
d_e (in)[e]							
Geologic Unit	Tpf	Tb4	Tb4	Tpf	Tb2	Tf	Tb4
Q/s (gpm/ft)	0.19		0.03	0.04	0.11	0.11	
T (ft^2/day)	152		35	117	126	197	
S (dim)	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	
b (ft)	110.0		290.0	165.0	68.0	83.0	
K (ft/day)	1.4		0.12	0.71	1.85	2.37	
S_s (1/ft)	4.5E-05		1.7E-05	3.0E-05	7.4E-05	6.0E-05	

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio			0.1	0.1	0.2	0.1	
K ratio			0.3	0.5	0.3	0.1	

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R-23i-2[b]	R-23i-3[b]	R-23[b]	R-24[b]	R25-1[b]	R25-2[b]	R25-3[b]
Date	12/16/05	12/08/05	12/19/02	09/29/05	04/09/01	04/09/01	04/09/01
Test Type[c]	N	P	N	P	N	N	N
Ele (ft msl)	6527.9	6527.9	6527.8	6547.4	7516.1	7516.1	7516.1
TD (ft bgs)	695.0	695.0	935.0	719.6	1942.0	1942.0	1942.0
WL (ft bgs)	449.8	454.0	829.0	716.9	722.1	762.2	1062.4
TOS (ft bgs)	470.2	524.0	816.0	825.0	737.6	882.6	1054.6
BOS (ft bgs)	480.1	547.0	873.2	848.0	758.4	893.4	1064.6
T_r (ft^2/day)		29		23			
S_r (dim)		0.0005		0.0005			
b_r (ft)		100		60			
K_r (ft/day)		0.29		0.39			

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R-23i-2[b]	R-23i-3[b]	R-23[b]	R-24[b]	R25-1[b]	R25-2[b]	R25-3[b]
Q (gpm)		1.53		4.65			
s (ft)		27.90		32.10			
t (min)		1440.0		30.0			
L (ft)	9.9	23.0	57.2	23.0	20.8	10.8	10.0
d_c (in)	4.50	4.50	4.50	4.50	5.00	5.00	5.00
d_p (in)							
d_w (in)	12.25	12.25	12.25	10.63	12.75	12.75	12.75
d_e (in)[e]				6.12			
Geologic Unit	Tb4	Tb4	Tsf	Tsf	Qbo	Tpf	Tpf
Q/s (gpm/ft)		0.05		0.14			
T (ft^2/day)		37		55			
S (dim)		0.0005		0.0005			
b (ft)		100.0		60.0			
K (ft/day)		0.37		0.91			
S_s (1/ft)		5.0E-06		8.3E-06			

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio	0.4
K ratio	0.4

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R25-4[b]	R25-5[b]	R25-6[b]	R25-7[b]	R25-8[b]	R25-9[b]	R26-1[b]
Date	04/09/01	04/09/01	04/09/01	04/09/01	04/09/01	04/09/01	02/18/04
Test Type[c]	N	N	N	N	N	N	P
Ele (ft msl)	7516.1	7516.1	7516.1	7516.1	7516.1	7516.1	7641.6
TD (ft bgs)	1942.0	1942.0	1942.0	1942.0	1942.0	1942.0	1490.5
WL (ft bgs)	1168.0	1279.1	1279.1	1333.7	1361.9	1410.3	604.0
TOS (ft bgs)	1184.6	1294.7	1404.7	1604.7	1794.7	1871.5	651.8
BOS (ft bgs)	1194.6	1304.7	1414.7	1614.7	1804.7	1875.0	669.9
T_r (ft^2/day)							619.2
S_r (dim)							0.0100
b_r (ft)							258
K_r (ft/day)							2.40

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R25-4[b]	R25-5[b]	R25-6[b]	R25-7[b]	R25-8[b]	R25-9[b]	R26-1[b]
Q (gpm)							15.70
s (ft)							43.36
t (min)							100.0
L (ft)	10.0	10.0	10.0	10.0	10.0	3.5	18.1
d_c (in)	5.00	5.00	5.00	5.00	5.00	5.00	4.50
d_p (in)							
d_w (in)	10.75	10.75	10.75	10.75	10.75	10.75	12.25
d_e (in)[e]							6.12
Geologic Unit	Tpf	Tpf	Tpf	Tpf	Tpf	Tpf	Qct
Q/s (gpm/ft)							0.36
T (ft^2/day)							763
S (dim)							0.0100
b (ft)							261.0
K (ft/day)							2.92
S_s (1/ft)							3.8E-05

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio	0.8
K ratio	0.8

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R26-2[b]	R-27[b]	R-28[b]	R31-1[b]	R31-2[b]	R31-3[b]	R31-4
Date	02/20/04	11/09/05	03/01/04	03/28/00	03/28/00	03/28/00	03/28/00
Test Type[c]	P	N	P	N	N	I/FH	I
Ele (ft msl)	7641.6	6713.7	6728.2	6362.5	6362.5	6362.5	6362.5
TD (ft bgs)	1490.5	987.0	1005.0	1103.0	1103.0	1103.0	1103.0
WL (ft bgs)	604.0	810.8	888.2	dry	523.0	523.0	523.0
TOS (ft bgs)	1421.8	852.0	934.3	439.1	515.0	666.3	826.6
BOS (ft bgs)	1445.0	875.0	958.1	454.4	545.7	676.3	836.6
T_r (ft^2/day)	0.8		13400.0			81	576
S_r (dim)	0.0005		0.1000				
b_r (ft)	400		117	187	120	168	120
K_r (ft/day)	2.1E-03		114.53			0.48	4.8

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R26-2[b]	R-27[b]	R-28[b]	R31-1[b]	R31-2[b]	R31-3[b]	R31-4
Q (gpm)	0.10		12.90			10.90	9.80
s (ft)	127.50		0.97			25.85	9.57
t (min)	31.2		300.0			2.0	30.0
L (ft)	23.2	23.0	23.8	15.3	30.7	10.0	10.0
d_c (in)	4.50	4.50	4.50	4.75	4.75	4.75	4.75
d_p (in)			1.000			2.375	2.375
d_w (in)	8.50	12.25	12.25	13.13	13.13	13.13	10.75
d_e (in)[e]	6.12						
Geologic Unit	Tpf	Tpf	Tpf	Tb4	Tb4	Tb4	Tpt
Q/s (gpm/ft)	0.00		13.30			0.42	1.02
T (ft^2/day)	3		10014			1017	1545
S (dim)	0.0005		0.0500	dry		0.0050	0.0050
b (ft)	535.5		117.0			187.0	120.0
K (ft/day)	5.3E-03		85.6			5.4	12.9
S_s (1/ft)	9.3E-07		4.3E-04			2.7E-05	4.2E-05
T ratio	0.3		1.3			0.1	0.4
K ratio	0.4		1.3			0.1	0.4

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	R31-5	R32-1	R32-2	R32-3	R33-1	R33-2
Date	03/10/00	11/05/02	11/04/02	11/04/02	12/02/04	11/16/04
Test Type[c]	I	I	N	I	P	P
Ele (ft msl)	6362.5	6637.6	6637.6	6637.6	6853.3	6853.3
TD (ft bgs)	1103.0	1002.0	1002.0	1002.0	1140.0	1140.0
WL (ft bgs)	523.0	783.4	783.4	783.4	979.0	979.0
TOS (ft bgs)	1007.1	867.5	931.8	972.9	995.5	1112.4
BOS (ft bgs)	1017.1	875.2	934.9	980.6	1018.5	1122.3
T_r (ft^2/day)	160	30		105	360.0	260.0
S_r (dim)					0.0005	0.0005
b_r (ft)	168	7	85	85	80	200
K_r (ft/day)	1.0	4.2		1.2	4.5	1.3

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	R31-5	R32-1	R32-2	R32-3	R33-1	R33-2
Q (gpm)	9.00	4.73		5.11	3.30	12.90
s (ft)	12.10	55.82		163.72	9.30	100.10
t (min)	30.3	120.0		74.0	925.0	1440.0
L (ft)	10.0	7.7	3.1	7.7	23.0	9.9
d_c (in)	4.75	4.50	4.50	4.50	4.50	4.50
d_p (in)	2.375	1.375		1.375	1.375	1.375
d_w (in)	10.75	10.63	10.63	10.63	15.00	11.00
d_e (in)[e]					6.12	6.12
Geologic Unit	Tpf	Tpt	Tpf	Tpf	Tpp	Tpp
Q/s (gpm/ft)	0.74	0.08		0.03	0.35	0.13
T (ft^2/day)	1627	16		41	319	250
S (dim)	0.0050	0.0005	0.0005	0.0005	0.0005	0.0005
b (ft)	168.0	7.0	85.0	85.0	143.0	143.0
K (ft/day)	9.7	2.2		0.5	2.2	1.7

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosi

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

	R31-5	R32-1	R32-2	R32-3	R33-1	R33-2
T ratio	0.1	1.9		2.6	1.1	1.0
K ratio	0.1	1.9		2.6	2.0	0.7

Table 11 (continued). Aquifer parameter estimates for R-wells drilled after 1997.

The following parameters are listed in individual well completion reports.

Parameter[a]	CdV-R15-3-6[b]	CdV-R37-2-1[b]	CdV-R37-2-2[b]	CdV-R37-2-3[b]	CdV-R37-2-4[b]
Date	09/01/00	09/01/00	09/01/00	09/01/00	09/01/00
Test Type[c]	I/FH	N	N	I/FH	I/FH
Ele (ft msl)	7258.9	6630.6	6630.6	6630.6	6630.6
TD (ft bgs)	1722.0	1664.0	1664.0	1664.0	1664.0
WL (ft bgs)	1272.9	dry	492.8	493.6	494.7
TOS (ft bgs)	1637.9	914.4	1188.7	1353.7	1549.3
BOS (ft bgs)	1644.8	936.5	1213.8	1377.1	1556.0
T_r (ft^2/day)					
S_r (dim)					
b_r (ft)					
K_r (ft/day)	0.10			7.00	11.4

The following transmissivity[d] values are estimated using the data listed below.

Parameter[a]	CdV-R15-3-6[b]	CdV-R37-2-1[b]	CdV-R37-2-2[b]	CdV-R37-2-3[b]	CdV-R37-2-4[b]
Q (gpm)				11.50	18.40
s (ft)					
t (min)					
L (ft)	6.9	22.1	25.1	23.4	6.7
d_c (in)	4.50	4.50	4.50	4.50	4.50
d_p (in)	2.375			2.375	2.375
d_w (in)	12.250	12.250	12.250	12.250	12.250
d_e (in)[e]					
Geologic Unit	Tpt	Tpf	Tt	Tt	Tt
Q/s (gpm/ft)					
T (ft^2/day)					
S (dim)		dry			
b (ft)	204.0	170.0	7.0	165.0	250.0
K (ft/day)					
S_s (1/ft)					

[a] See Table 10 for parameter definitions.

[b] Well number (e.g., R1), hyphen, and screen number (if multiple screens are present).

[c] Test type = P (pumping); I (injection); FH (falling head); N (no test performed).

[d] Transmissivity from specific capacity; see McLin (2005b) for details.

[e] Effective borehole diameter from $d_e^2 = d_c^2 + n[d_w^2 - d_c^2]$, where n = filter pack porosity.

[f] Water level in screen; Jacob correction applied, $s = s_a - s_a^2/2b$ (Walton, 1970).

T ratio	
K ratio	

Discussion. According to the comparisons shown in Table 11, there are only small differences between the old and new T estimates as expressed by the ratios in T values. As previously mentioned, these small differences are related to the assumed values for t and S that were used in the specific capacity method. Unfortunately, hydraulic tests were not done at each of the R-wells so this comparison is incomplete. However, the data shown in Table 11 confirms a picture of the regional aquifer that suggests it is highly stratified and locally variable.

II. OTHER CONVENTIONAL AQUIFER TESTS

Aquifer Test at Los Alamos Well LA-2

A 15-day aquifer test was conducted at well LA-2 in the old Los Alamos well field from March 16-23, 1992 (Purtymun et al, 1995a). This test consisted of seven days of pumping at well LA-2 at an average rate of 237 gpm. This pumping interval was followed by an 8 day recovery period. Water levels were recorded in observation wells LA-1b and LA-3 at 15-minute intervals during the entire test. LA-1b is located approximately 1,200 east of LA-2, while LA-3 is located about 950 northwest of LA-2. The Los Alamos well field was shut down from October 1991 until the start of this test because of highway construction. Well LA-5 was occasionally used as a source of construction water during this initial shut-down period; however, pumping at this well did not produce any observable drawdown effect in any of the wells used in this aquifer test. Once the test started at well LA-2, no other wells in the well field were pumped. Hence, the water levels in wells LA-1b, LA-2, and LA-3 had more than 5 months to recover to their initial static levels before the test was started. All of the data from this test are listed on the CD-ROM attached to this report. In addition, these data are also tabulated in Purtymun et al. (1995a).

Water discharge rates in LA-2 continuously declined throughout the pumping interval because of declining water levels in the well. Data analysis procedures followed that of Aron and Scott (1965) for variable discharge rates; this method is a variation of the widely utilized Cooper-Jacob (1946) method for a constant discharge rate test. Table 12 defines all symbols that are used in Tables 13-14 as seen below. Results from the LA-2 aquifer tests are summarized in Table 13.

Recovery Test at Los Alamos Well LA-1b

In 1993, the Department of Energy transferred ownership of water supply wells LA-1b, LA-2, and LA-5 to San Ildefonso Pueblo. With the concurrence of San Ildefonso Pueblo, the Laboratory installed a mechanical packer in LA-1b and recording pressure transducer. Water levels in LA-1b were recorded at 1-hour intervals from July 27, 1993 to August 27, 1996. These water levels document the slow recovery of the old Los Alamos well field back to initial artesian conditions that existed at the time LA-1b was installed. These data also document pumping influences from the Buckman well field. These data are included in the CD-ROM data disk attached to this report.

Table 12. List of symbols used in Tables 13-14.

Parameter	Definition
Year	Year that the data were recorded in the cited reference.
Well Status	Pumping well (P) or Observation well (O).
r (ft)	Distance from pumping well.
b_r (ft)	Aquifer thickness listed in reference.
T_r (gpd/ft)	Aquifer transmissivity listed in reference.
K_r (gpd/ft^2)	Hydraulic conductivity listed in reference and computed from $K_r = T_r/b_r$.
Year	Year that the specific capacity data were recorded.
Ele (ft msl)	Elevation of wellhead (in ft above mean sea level, or ft msl).
WL (ft bgs)	Water level (in ft below ground surface, or ft bgs).
Q (gpm)	Average well discharge (gallons per minute, or gpm).
s (ft)	Quasi-steady state drawdown (ft) recorded at time t.
t (minutes)	Estimated or actual time of drawdown (min).
L (ft)	Screen length from well completion log (ft).
d_c (in)	Screen or casing diameter (in).
d_w (in)	Borehole diameter (in).
TOS (ft bgs)	Top of upper screen from well log (ft bgs).
BOS (ft bgs)	Bottom of lower screen from well log (ft bgs).
b_e (ft)	Aquifer thickness computed from b_e = BOS-TOS (ft).
b_s (ft)	Saturated aquifer thickness computed from b_s = BOS-WL (ft).
E (%)	Assumed well efficiency (%).
Geologic Unit	Geologic unit where screen is located and K value applies (see below).
Q/s (gpm/ft)	Specific capacity computed from data listed in this table.
T (ft^2/day)	Aquifer transmissivity estimated from specific capacity.
S (dim)	Storage coefficient from McLin (2005a, 2006a, 2006b) or estimated.
b (ft)	Effective aquifer thickness is the smaller of L, b_e, or b_s, or as noted.
K (ft/day)	Hydraulic conductivity computed from K = T/b. See tables.
S_s (1/ft)	Specific storage computed from S_s = S/b. See tables.
Tpl	Puye Fm, lacustrine and riverine deposits.
Tpf	Puye Fm, fanglomerate deposits.
Tpp	Puye Fm, pumiceous deposits.
Tpt	Puye Fm, ancestral Rio Grande deposits (Totavi Lentil).
Tf	Puye Fm, older fanglomerates.
Ts	Santa Fe Group (undifferentiated sands and silts).
T ratio	T ratio = historical T in reference/new T from specific capacity.
K ratio	K Ratio = historical K in reference/new K from specific capacity.

Table 13. Comparison of aquifer parameters from the LA-2 aquifer test.

The following parameters are reported in Purtymun et al. (1995a) and Purtymun (1995).

Parameter[a]	LA-2[b]	LA-3[b]	LA-1b[b]
Year	1992	1992	1992
Well Status	P	O	O
r (ft)	1	950	1200
b_r (ft)	760	760	591
T_r (gpd/ft)	2506	3748	6680
K_r (gpd/ft^2)	3.3	4.9	11.3
S (dim)	0.0038	0.0033	0.0042
T_r (ft^2/day)	335	501	893
K_r (ft/day)	0.4	0.7	1.5

The following transmissivity[c] values are estimated using the data listed below.

Parameter[a]	LA-2[b]	LA-3[b]	LA-1b[b]
Year	1992	1982	1982
Ele (ft msl)	5651	5672	5622
WL (ft bgs)	142	118	71
Q (gpm)	276	247	486
s (ft)	196	128	109
t (minutes)	10080	360	360
L (ft)	760	760	591
d_c (in)	12	12	10
d_w (in)	22	22	20
TOS (ft bgs)	105	105	326
BOS (ft bgs)	865	865	1694
b_e (ft)	760	760	1368
b_s (ft)	723	747	1623
E (%)	100	100	100
Geologic Unit	Ts	Ts	Ts
Q/s (gpm/ft)	1.4	1.9	4.5
T (ft^2/day)	335	363	2108
S (dim)	0.0038	0.0038	0.0038
b (ft)	723	747	591
K (ft/day)	0.5	0.5	3.6
S_s (1/ft)	5.3E-06	5.1E-06	6.4E-06

[a] See Table 1 for parameter definitions.

[b] Well completion data summarized from Purtymun (1995) and McLin et al. (1998).

[c] Transmissivity from specific capacity; see McLin (2005b) for details.

T ratio	1.0	1.4	0.4
K ratio	1.0	1.4	0.4

Table 14. Comparison of aquifer parameters from the O-4 aquifer test.

The following parameters are reported in Stoker et al. (1992) or Purtymun (1995).

Parameter[a]	O-4[b]	TW-3[b]	TW-2[b]	TW-8[b]	PM-3[b]	PM-5[b]
Year	1990	1951	1951	1960	1982	1982
Well Status	P	O	O	O	O	O
r (ft)	1	413	5,380	5,929	6,029	6,714
b_r (ft)	1068	65	30	95	1770	1864
T_r (gpd/ft)	82760	7800	7000	2400	320000	10000
K_r (gpd/ft^2)	77.5	120.0	233.3	25.3	180.8	5.4
S (dim)	0.0053	0.0500	0.0500	0.0500	0.0035	0.0035
T_r (ft^2/day)	11064	1043	936	321	42781	1337
K_r (ft/day)	10.4	16.0	31.2	3.4	24.2	0.7

The following transmissivity[c] values are estimated using the data listed below.

Parameter[a]	O-4[b]	TW-3[b]	TW-2[b]	TW-8[b]	PM-3[b]	PM-5[b]
Year	1990	1951	1951	1960	1982	1987
Ele (ft msl)	6627	6569	6648	6878	6640	7095
WL (ft bgs)	760	743	759	968	762	1237
Q (gpm)	1500	7	7	16	1402	1220
s (ft)	33	15	7	8	23	108
t (minutes)	360	360	360	360	360	360
L (ft)	1068	10	56	97	874	325
d_c (in)	16	6	6	8	14	16
d_w (in)	26	6	6	8	24	26
TOS (ft bgs)	1115	805	768	953	956	1440
BOS (ft bgs)	2596	815	824	1065	2532	3072
b_e (ft)	1481	10	56	112	1576	1632
b_s (ft)	1836	72	65	97	1770	1835
E (%)	100	100	100	100	100	100
Geologic Unit	Tpf	Tpf	Tpf	Tpf	Tpf	Tpf
Q/s (gpm/ft)	45.5	0.4	1.0	2.0	61.0	11.3
T (ft^2/day)	12261	63	150	318	16997	2791
S (dim)	0.00035	0.05000	0.05000	0.05000	0.00035	0.00035
b (ft)	1068	10	56	97	874	325
K (ft/day)	11.5	6.3	2.7	3.3	19.4	8.6
S_s (1/ft)	3.3E-07	5.0E-03	8.9E-04	5.2E-04	4.0E-07	1.1E-06
T ratio	0.9	16.6	6.2	1.0	2.5	0.5
K ratio	0.9	2.5	11.6	1.0	1.2	0.1

[a] See Table 1 for parameter definitions

[b] Well completion data summarized from Purtymun (1995).

[c] Transmissivity from specific capacity; see McLin (2005b) for details.

Aquifer Tests at Well Otowi-4

A preliminary 12-hour step drawdown aquifer test was conducted at O-4 on April 5, 1990 (Stoker et al., 1992). According to these test results, T is about 8,360 ft^2/day and S is about 0.0019. It is important to recognize that the value for S was not based on drawdown data from an observation well and is only approximate. These estimates were also based on the first step in the step-drawdown procedure and were very short. Data from this test are included in Stoker et al. (1992).

A follow-up 22-day constant-rate aquifer test was conducted at municipal water supply well O-4 from February 24 to March 18, 1993 (Purtymun et al, 1995b). The pumping rate during this test averaged about 1660 gpm and varied less than 30 gpm. Water levels were recorded at 1-hour intervals in wells O-4, TW-3, TW-2, TW-8, PM-3, and PM-5. However, drawdown was only recorded in the pumping well because TW-3 is too shallow. In addition, the other observations wells are either too far away from O-4 or are also too shallow. For example, test well TW-3 only penetrates about 40 ft into the regional aquifer. This lack of response at TW-3 was similar to water level responses in screen 1 at well R-20 in reaction to pumping at well PM-2 (McLin, 2005a). In addition, the leaky aquifer behavior that was observed at wells PM-2 and PM-4 (McLin, 2005a, 2006a) was also observed at well O-4 during this aquifer test. The leaky aquifer behavior took longer to develop at O-4 than at either PM-2 or PM-4, however. The Cooper-Jacob (1946) method was used to analyze data from this test and these results are summarized in Table 13. Additional details are reported in Purtymun et al. (1995b). Again, the value for S is only approximate because no drawdown data were obtained from any observation well. All of the water level responses and pumping rates from this test are summarized on the CD-ROM attached to this report.

Aquifer Test at Well Otowi-1

A 14-hour step drawdown aquifer test was conducted at O-1 on July 19, 1990 (Purtymun et al, 1993). According to these test results, T is about 1,177 ft^2/day and S is about 0.088. Again, it is important to recognize that the value for S was not based on drawdown data from any observation well and is only approximate. These parameter estimates were also based on the first step in the step-drawdown procedure and were very short. These parameters are summarized in Table 8. Data from this test are included in Purtymun et al. (1993).

Aquifer Test at Well PM-3

An 8-day constant-rate aquifer test was conducted at municipal water supply well PM-3 from March 23 to April 2, 1994 (McLin et al, 1996). The pumping rate during this test averaged about 1395 gpm and varied less than 2%. Water levels were recorded at 1-hour intervals in well PM-1; unfortunately, no drawdown data were recorded at well PM-3. Well PM-1 was used as an observation well and is located about 5,250 ft east of PM-3. However, no drawdown was recorded in PM-1 and suggests that T values are relatively high here as previously shown in Table 7.

III. SUMMARY AND CONCLUSIONS

This report summarizes all historical aquifer tests that have been performed on Pajarito Plateau wells that penetrate into the regional aquifer. Results from these tests have been summarized into tables that are generally grouped as follows: (1) wells in the old Los Alamos well field; (2) wells in the old Guaje well field; (3) wells in the new replacement Guaje well field; (4) wells in the Pajarito and Otowi well fields; (5) test wells; and (6) R-wells. In addition to summarizing important historical estimates for transmissivity (T), these tables also list early estimates for aquifer thickness, discharge, and drawdown.

Unfortunately, much of the original test data have not been preserved. Hence, the specific capacity method was applied to the early tests in order to validate these estimates. Supporting data required to use this method are also summarized in these same tables so that direct comparisons can be made. These comparisons are listed in the form of *T*-ratio and *K*-ratio values. In addition, modern estimates for aquifer thickness (*b*) are also listed in these tables. If a particular *T* ratio is less than one, then the historical estimate for this parameter is less than the estimate obtained from the specific capacity method. Likewise, if it is larger than one, then the specific capacity estimate is the larger value. However, in most of these comparisons, these *T*-ratio vales are very close to one and validate the original estimate. Occasionally, there are significant differences between the historical and modern estimated *T* values. These differences are addressed in the discussion section for each well group.

Similarly, historical and modern estimates for *K* are evaluated using the *K*-ratio values in each table. However, any significant differences between individual values are generally the result of differences in estimated *b* values.

The following general conclusions can be drawn from this comparison of historical and modern aquifer parameter estimates.

1. Historical estimates for aquifer transmissivity (*T*) are generally reliable and have been validated using the specific capacity method described in the report. This validation step was taken because most of the supporting data from these historical aquifer tests have not been preserved. In addition, all supporting information required in the specific capacity methodology is summarized in the tables. Occasionally, there are departures between historical and modern estimates for *T*. These differences are documented in the discussion section of each grouped set of wells. In these cases, we recommend that the specific capacity estimates be used rather than the historical values.

2. Historical estimates for aquifer storage coefficient (*S*) are rare because of the requirement of one or more observation wells. Generally, observation wells are only available when a municipal water supply well is tested and an adjacent production well serves as the observation well. In virtually all cases where a test well or R-well was tested, there was no observation well located sufficiently close to record any response to either pumping or injection. Hence, *S* estimates from these tests are only approximate. The specific capacity method provides these estimates so that a corresponding estimate for *T* can be obtained. Fortunately, this approach is not overly sensitive to variations in the *S* estimate and *T* values from this method favorably compare to historical values.

3. The modern estimates for aquifer thickness (*b*) that are listed in this report are based on dynamic spinner logs from several wells, including logs from PM-4, O-1, G-2a, G-3a, G-4a, and G-5a. All of these logs demonstrate that the regional aquifer is highly stratified and that the high-yielding units in water supply wells is much smaller than the total screen length in individual wells. The exceptions are in the old Los Alamos and Guaje well fields where an alternating design of screen and blank casing was employed for all wells. Here the total screen length was taken as an approximation for *b*.

4. In all of the summary tables listed here, the date of the test was prominently displayed. This was done so that specific capacity (*Q/s*) could be linked to historical estimates for *T* and *S* values. This same time was used to summarize information from water supply reports that are required in the specific capacity methodology. This procedure was followed so the estimated aquifer parameters from both approaches would be directly comparable. This procedure therefore eliminated any variability associated with well efficiencies that may have changed over time.

IV. ACKNOWLEDGEMENTS

This work was supported by the Pathways Protection Program within the Environmental Stewardship Division at Los Alamos National Laboratory. Special thanks are extended to David Rogers and Steven Pearson for their invaluable discussions and critical reviews of this report. The Laboratory number for this report is LA-UR-06-3789.

V. REFERENCES

Aron, G., and V.H. Scott, 1965. Simplified solution for decreasing flow in wells. Proc. American Society of Civil Engineers, vol. 91, no. HY 5, p. 1-12.

Ball, T., M. Everett, P. Longmire, D. Vaniman, W. Stone, D. Larssen, K. Greene, N. Clayton, and S. McLin, 2002. Characterization Well R-22 Completion Report. Los Alamos National Laboratory Report, LA-13893-MS, Los Alamos, NM.

Broxton, D., D. Vaniman, W. Stone, S. McLin, M. Everett, and A. Crowder, 2001. Characterization Well R-9i Completion Report. Report No. LA-13821-MS, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., R. Warren, D. Vaniman, B. Newman, A. Crowder, M. Everett, R. Gilkeson, P. Longmire, J. Marin, W. Stone, S. McLin, and D. Rogers, 2001. Characterization Well R-12 Completion Report. Report No. LA-13822-MS, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., D. Vaniman, W. Stone, S. McLin, J. Marin, R. Koch, R. Warren, P. Longmire, D. Rogers, and N. Tapia, 2001. Characterization Well R-19 Completion Report. Report No. LA-13823-MS, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., R. Gilkeson, P. Longmire, J. Marin, R. Warren, D. Vaniman, A. Crowder, B. Newman, B. Lowery, D. Rogers, W. Stone, S. McLin, G. WoldeGabriel, D. Daymon, and D.

Wycoff, 2002. Characterization Well R-9 Completion Report. Report No. LA-13742-MS, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., R. Warren, P. Longmire, R. Gilkeson, S. Johnson, D. Rogers, W. Stone, B. Newman, M. Everett, D. Vaniman, S. McLin, J. Skalski, and D. Larssen, 2002. Characterization Well R-25 Completion Report. Report No. LA-13909-MS, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., A. Groffman, S. Pearson, W. Stone, and D. Vaniman, 2003. Characterization Well R-5 Completion Report. Report No. LA-UR-03-1600, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., P. Longmire, S. Pearson, W. Stone, and D. Vaniman, 2003. Characterization Well R-13 Completion Report. Report No. LA-UR-03-1373, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., A. Groffman, S. Pearson, W. Stone, and D. Vaniman, 2003. Characterization Well R-16 Completion Report. Report No. LA-UR-03-1841, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., P. Longmire, S. Pearson, W. Stone, and D. Vaniman, 2003. Characterization Well R-20 Completion Report. Report No. LA-UR-03-1839, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., A. Groffman, S. Pearson, W. Stone, and D. Vaniman, 2003. Characterization Well R-23 Completion Report. Report No. LA-UR-03-2059, Los Alamos National Laboratory, Los Alamos, NM.

Broxton, D., P. Longmire, S. Pearson, W. Stone, and D. Vaniman, 2003. Characterization Well R-32 Completion Report. Report No. LA-UR-03-3984, Los Alamos National Laboratory, Los Alamos, NM.

Collins, K.A., A.M. Simmons, B.A. Robinson, and C.L. Nylander (editors), 2006. Los Alamos National Laboratory's hydrogeologic studies of the Pajarito Plateau: A synthesis of hydrogeologic work plan activities, 1998-2004. Los Alamos National Laboratory Report, LA-14263-MS, Los Alamos, NM.

Conover, C.S., C.V. Theis, and R.L. Griggs, 1963. Geology and hydrology of the Valle Grande and Valle Toledo, Sandoval County, New Mexico. USGS Water Supply Paper 1619-Y, 37 p., US Government Printing Office, Washington, D.C.

Cooper, H.H., and C.E. Jacob, 1946. A generalized graphical method for evaluating formation constants and summarizing well-field history. Transactions of the American Geophysical Union, vol. 27, number 4.

Cushman, R.L., 1965. An evaluation of aquifer and well characteristics of municipal well fields in Los Alamos and Guaje Canyon near Los Alamos, New Mexico. USGS Water Supply Paper 1809-D, 50 p., US Government Printing Office, Washington, D.C.

Cushman, R.L., and W.D. Purtymun, 1975. Evaluation of yield and water-level relations. Los Alamos National Laboratory Report, LA-6086-MS, Los Alamos, NM.

Griggs, R.L., 1955. Geology and ground-water resources of the Los Alamos area, New Mexico; USGS Open File Report to US Atomic Energy Commission, 219 p. On-file with Los Alamos National Laboratory, ENV-WQH Group, Los Alamos, NM.

Griggs, R.L., 1964. Geology and ground-water resources of the Los Alamos area, New Mexico; USGS, Water Supply Report 1753, 107 p., US Government Printing Office, Washington, D.C.

John, E.C., E.A. Enyart, and W.D. Purtymun, 1969. Records of wells, test holes, springs, and surface-water stations in the Los Alamos area, New Mexico. USGS Open File Report, Los Alamos National Laboratory, Los Alamos, NM.

Kleinfelder, Inc., 2003a. Final Completion Report Characterization Well R-21. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 22461 (June 2003).

Kleinfelder, Inc., 2003b. Final Completion Report Characterization Well CdV-16-2(i)r; Appendix D, Aquifer Testing Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 49436 (November 2003).

Kleinfelder, Inc., 2004a. Final Completion Report Characterization Well CdV-16-1(i); Appendix E, Aquifer Testing Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151/9.12 (May 2004).

Kleinfelder, Inc., 2004b. Final Completion Report Characterization Well R-34; Appendix E, Aquifer Testing Report and Test Data. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151 (November 2004).

Kleinfelder, Inc., 2005a. Final Completion Report Characterization Well R-4; Appendix D, Hydrologic Testing Report and Test Data (revision 2). Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151/7.12 (January 2005).

Kleinfelder, Inc., 2005b. Final Completion Report Characterization Well R-26; Appendix E, Aquifer Testing Report and Aquifer Test Data. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151 (January 2005).

Kleinfelder, Inc., 2005c. Final Completion Report Characterization Well R-28 (revision 1); Appendix E, Aquifer Testing Report and Test Data. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151/16.12 (February 2005).

Kleinfelder, Inc., 2005d. Well R-1 Completion Report (revision 1); Appendix E, Hydrologic Testing Report and Test Data. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151/17.12 (February 2005).

Kleinfelder, Inc., 2005e. Well R-2 Completion Report (revision 1); Appendix D, Hydrologic Testing Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151, Task 6.12 (February 2005).

Kleinfelder, Inc., 2005f. Final Completion Report Characterization Well R-11; Appendix E, Aquifer Testing Report and Aquifer Test Data. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151 (February 2005).

Kleinfelder, Inc., 2005g. Final Completion Report Characterization Well R-33; Appendix E, Aquifer Testing Report and Test Data. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151 (February 2005).

Kleinfelder, Inc., 2005h. Final Completion Report Characterization Well R-6/R-6i; Appendix E, Aquifer Testing Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151 (April 2005).

Kleinfelder, Inc., 2005i. Final Completion Report Characterization Well R-18; Appendix E, Aquifer Testing Report and Aquifer Test Data. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 37151 (April 2005).

Kleinfelder, Inc., 2006a. Final Completion Report Characterization Wells R-10a/R-10; Appendix E, Aquifer Testing Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 49436 (January 2006).

Kleinfelder, Inc., 2006b. Final Completion Report Characterization Well R-24; Appendix E, Aquifer Testing Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 49436 (January 2006).

Kleinfelder, Inc., 2006c. Final Completion Report Characterization Well R-16r; Appendix D, Aquifer Testing Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 49436 (February 2006).

Kleinfelder, Inc., 2006d. Final Completion Report Characterization Well R-23i; Appendix E, Aquifer Test Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 49436 (March 2006).

Kleinfelder, Inc., 2006e. Final Completion Report Characterization Well R-27. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 49436 (March 2006).

Kleinfelder, Inc., 2006f. Final Completion Report Characterization Well R-17; Appendix E, Aquifer Testing Report. Private consulting report to U.S. Department of Energy and National Nuclear Security Administration through U.S. Army Corps of Engineers, Sacramento District, Project No. 49436 (May 2006).

Koch, R.J., P. Longmire, D.B. Rogers, and K. Mullen, 1999. Report of Testing and Sampling of Municipal Supply Well PM-4. Los Alamos National Laboratory, report LA-13648, Los Alamos, NM.

Kopp, B., A. Crowder, M. Everett, D. Vaniman, D. Hickmott, W. Stone, N. Clayton, S. Pearson, and D. Larssen, 2002. Characterization Well CdV-R-15-3 Completion Report. Los Alamos National Laboratory Report, LA-13906-MS, Los Alamos, NM.

Kopp, B., M. Everett, J. Lawrence, G. WoldeGabriel, D. Vaniman, J. Heikoop, W. Stone, S. McLin, N. Clayton, and D. Larssen, 2003. Characterization Well CdV-R-37-2 Completion Report. Los Alamos National Laboratory Report, LA-14023-MS, Los Alamos, NM.

Longmire, P., D. Broxton, W. Stone, B. Newman, R. Gilkeson, J. Marin, D. Vaniman, D. Counce, D. Rogers, R. Hull, S. McLin, and R. Warren, 2001. Characterization Well R-15 Completion Report. Los Alamos National Laboratory Report, LA-13749-MS, Los Alamos, NM.

McLin, S.G., 2004. Aquifer Test Analysis for Well R-15. Los Alamos National Laboratory, report LA-14074-MS, Los Alamos, NM.

McLin, S.G., 2005a. Analysis of the PM-2 Aquifer Test Using Multiple Observation Wells. Los Alamos National Laboratory Report, LA-14225-MS, Los Alamos, NM.

McLin, S.G., 2005b. Estimating transmissivity from specific capacity using Matlab. Ground Water, vol. 43, no. 4, p. 611-614.

McLin, S.G., 2005c. Hydrologic Tests at Characterization Well R-16. Los Alamos National Laboratory, report LA-14183-MS, Los Alamos, NM.

McLin, S.G., 2005d. Hydrologic Tests at Characterization Well R-20. Los Alamos National Laboratory, report LA-14201-MS, Los Alamos, NM.

McLin, S.G., 2006a. Analysis of the PM-4 Aquifer Test Using Multiple Observation Wells. Los Alamos National Laboratory Report, LA-14252-MS, Los Alamos, NM.

McLin, S.G., 2006b. Analyses of Sequential Aquifer Tests from the Guaje Well Field. Los Alamos National Laboratory Report, LA-UR-06-2494, Los Alamos, NM.

McLin, S.G., W.D. Purtymun, and M.N. Maes, 1998. Water Supply at Los Alamos during 1997. Los Alamos National Laboratory Report, LA-13548-PR, Los Alamos, NM.

McLin, S.G., W.D. Purtymun, A.K. Stoker, and M.N. Maes, 1996. Water Supply at Los Alamos during 1994. Los Alamos National Laboratory Report, LA-13057-PR, Los Alamos, NM.

McLin, S.G., and W.J. Stone, 2004a. Hydrologic Tests at Characterization Well R-32. Los Alamos National Laboratory, report LA-14106-MS, Los Alamos, NM.

McLin, S.G., and W.J. Stone, 2004b. Hydrologic Tests at Characterization Well R-14. Los Alamos National Laboratory, report LA-14107-MS, Los Alamos, NM.

McLin, S.G., and W.J. Stone, 2004c. Hydrologic Tests at Characterization Wells R-9i, R-13, R-19, R-22, and R-31, Revision 1. Los Alamos National Laboratory, report LA-14121-MS, Los Alamos, NM.

Purtymun, W.D., 1984. Hydrologic characteristics of the main aquifer in the Los Alamos area: Development of ground water supplies. Los Alamos National Laboratory Report, LA-9957-MS, Los Alamos, NM.

Purtymun, W.D., 1995. Geologic and Hydrologic Records of Observation Wells, Test Holes, Test Wells, Supply Wells, Springs, and Surface Water Stations in the Los Alamos Area. Los Alamos National Laboratory Report, LA-12883-MS, Los Alamos, NM.

Purtymun, W.D., and S. Johansen, 1974. General geohydrology of the Pajarito Plateau. New Mexico Geological Society, 25th Field Conference Guidebook to Ghost Ranch. New Mexico Bureau of Mines, Socorro, NM, pp. 347-349.

Purtymun, W.D., and A.K. Stoker, 1988. Water Supply at Los Alamos: Current Status of Wells and Future Water Supply. Los Alamos National Laboratory Report LA-11332-MS, Los Alamos, NM.

Purtymun, W.D., S.G. McLin, A.K. Stoker, M.N. Maes, and B.G. Hammock, 1993. Water Supply at Los Alamos during 1990, Los Alamos National Laboratory Report, LA-12471-PR, Los Alamos, NM.

Purtymun, W.D., S.G. McLin, A.K. Stoker, and M.N. Maes, 1995a. Water Supply at Los Alamos during 1992, Los Alamos National Laboratory Report, LA-12926-PR, Los Alamos, NM.

Purtymun, W.D., A.K. Stoker, S.G. McLin, M.N. Maes, and T.A. Glasco, 1995b. Water Supply at Los Alamos during 1993, Los Alamos National Laboratory Report, LA-12951-PR, Los Alamos, NM.

Stoker, A.K., S.G. McLin, W.D. Purtymun, M.N. Maes, and B.G. Hammock, 1992. Water Supply at Los Alamos during 1989, Los Alamos National Laboratory Report, LA-12276-PR, Los Alamos, NM.

Shomaker, J., 1999. Well report: Construction details and testing, Guaje replacement wells GR-1, GR-2, GR-3, and GR-4, Santa Fe County, New Mexico. Private consulting report to Los Alamos National Laboratory, John Shomaker and Associates, Inc., Albuquerque, NM.

Stone, W.J., D.T. Vaniman, P.A. Longmire, D.E. Broxton, M.C. Everett, R. Lawrence, and D.E. Larssen, 2002. Characterization Well R-7 Completion Report. Los Alamos National Laboratory Report, LA-13932-MS, Los Alamos, NM.

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. American Geophysical Union Transactions, vol. 16, pp. 519–524.

Theis, C.V., 1963. Estimating the transmissivity of a water table aquifer from the specific capacity of a well. U.S. Geological Survey, Water Supply Paper 1536-I, p. 332-336, US Government Printing Office, Washington, D.C.

Theis, C.V., and C.S. Conover, 1962. Pumping tests in the Los Alamos canyon well field near Los Alamos, New Mexico. U.S. Geological Survey, Water Supply Paper 1619-I, p. 24, US Government Printing Office, Washington, D.C.

Thompson, D., C. Schultz, P. Schuh, E. Tow, and R. Lawrence, 2003. Characterization Well R-8 Completion Report. Los Alamos National Laboratory Report, LA-UR-03-1162, Los Alamos, NM.

Thompson, D., C. Schultz, P. Schuh, E. Tow, and R. Lawrence, 2003. Characterization Well R-14 Completion Report. Los Alamos National Laboratory Report, LA-UR-03-1664, Los Alamos, NM.

Vaniman, D., J. Marin, W. Stone, B. Newman, P. Longmire, N. Clayton, R. Lewis, R. Koch, S. McLin, G. WoldeGabriel, D. Counce, D. Rogers, R. Warren, E. Kluk, S. Chipera, D. Larssen, and B. Kopp, 2002. Characterization Well R-31 Completion Report. Los Alamos National Laboratory Report, LA-13910-MS, Los Alamos, NM.

Walton, W.C., 1970. Groundwater Resource Evaluation. McGraw-Hill, New York. 664 p.

Weir, J.E., and W.D. Purtymun, 1962. Geology and Hydrology of Technical Area 49, Frijoles Mesa, Los Alamos County, New Mexico. USGS Open File Report, Los Alamos National Laboratory, Los Alamos, NM.

VI. APPENDICES

Appendix A. Description of Data Files on CD-ROM

Table A-1 lists data files that are contained in the CD-ROM located in the inside back cover of this report. These drawdown and recovery data were collected from numerous wells during the aquifer tests described in the report. Table A-1 describes the naming convention used to identify these data files. Each data file contains important data in tab-delimited, text format. The file name tells which well the data came from. For example, Qla2.txt contains discharge data from well LA-2. The first column in this file contains elapsed time (days) since pumping began; the second column contains discharge (gpm). Other data files contain simple drawdown data (i.e. La1b.txt); however, all files are structured similarly (i.e., time in column one is time since pumping began and drawdown in column two). One file contains only recovery data that was collected after the Los Alamos well field was shut down in 1992 (i.e., La1bWL.txt). The data may appear different from individual aquifer tests. These differences are explained in the report.

Table A-1. Data files contained on the CD-ROM located with this report.

File Name	Well	Remarks
Qla2.txt	LA-2	1992 aquifer test: time (days) and discharge (gpm) from pumping well LA-2, in columns 1 and 2, respectively.
La1b.txt	LA-1b	1992 aquifer test: time (days) and drawdown (ft) from well LA-1b, in columns 1 and 2, respectively.
La3.txt	LA-3	1992 aquifer test: time (days) and drawdown (ft) from well LA-3, in columns 1 and 2, respectively.
La1bWL.txt	LA-1b	1993-96 recovery data: time (hrs) and water level (ft above MSL), in columns 1 and 2, respectively.
Qo4.txt	O-4	1993 constant rate test: time (days) and discharge (gpm) from pumping well O-4, in columns 1 and 2, respectively.
O4.txt	O-4	1993 constant rate test: time (days) and drawdown (ft) from well O-4, in columns 1 and 2, respectively.

B. Specific Capacity Method and Computer Program

ground water

Computer Note/

Estimating Aquifer Transmissivity from Specific Capacity Using MATLAB

by Stephen G. McLin[1]

Abstract

Historically, specific capacity information has been used to calculate aquifer transmissivity when pumping test data are unavailable. This paper presents a simple computer program written in the MATLAB programming language that estimates transmissivity from specific capacity data while correcting for aquifer partial penetration and well efficiency. The program graphically plots transmissivity as a function of these factors so that the user can visually estimate their relative importance in a particular application. The program is compatible with any computer operating system running MATLAB, including Windows, Macintosh OS, Linux, and Unix. Two simple examples illustrate program usage.

Introduction

A computer technique for estimating transmissivity from specific capacity data is currently available (Bradbury and Rothschild 1985). However, it is written in BASIC and does not graphically display results. This paper presents a modified version of the Bradbury-Rothschild iterative solution technique that is written in the MATLAB language and listed in the Appendix. A useful new feature includes a three-dimensional graphical display of results so that the user can quickly estimate the relative importance of aquifer penetration and well efficiency. Potential users should be aware that MATLAB must be installed on their computers before the program will function. Alternately, users may convert either the original or revised code to any convenient programming language (e.g., C++, Fortran, Excel, or MathCad). However, MATLAB is a powerful tool with numerous capabilities that are not readily found in other languages.

Recall that total drawdown (s_t) observed in a production well can be written (Bouwer 1978) as the sum of drawdown due to formation loss (s_f) and drawdown due to well loss (s_w), or:

$$s_t = s_f + s_w = BQ + CQ^n \tag{1}$$

[1]Los Alamos National Laboratory, P.O. Box 1663 MS-K497, Los Alamos, NM 87544; sgm@lanl.gov

Received August 2003, accepted December 2003

where B = formation loss coefficient (T/L^2), C = well loss coefficient (T^2/L^5 if $n = 2$), Q = well discharge (L^3/T), and n = an exponent related to wellbore turbulence (typically, $1.5 \leq n \leq 3.5$).

When well efficiency (E) is defined as $E = 100(s_f/s_t)$ and $n = 2$, then C is related to E by:

$$C = \left(\frac{s_t}{Q^2}\right)\left(1 - \frac{E}{100}\right) \tag{2}$$

When s_f is given by the Jacob approximation for the Theis solution, then B can be found from (Sternberg 1973):

$$s_f = BQ = \frac{Q}{4\pi T}\left[\ln\left(\frac{2.25Tt}{r_w^2 S}\right) + 2s_p\right] \tag{3}$$

where T = aquifer transmissivity (L^2/T), S = aquifer storage coefficient (dimensionless), t = time since pumping began (T), r_w = effective wellbore radius (L), and s_p = a partial penetration factor (dimensionless).

In Equation 3, the effect of partial penetration may be represented by (Brons and Marting 1961):

$$s_p = \left(\frac{D-L}{L}\right)\left[\ln\left(\frac{D}{r_w}\right) - G\left\{\frac{L}{D}\right\}\right] \tag{4}$$

where D = aquifer thickness (L), L = well screen length (L), and G = a function of the L/D ratio (dimensionless).

Using available data, Bradbury and Rothschild (1985) expressed G as the polynomial $G = a + b(L/D) +$

Table 1
Properties for Well 1 (metric) Were Used in the MATLAB Program to Generate Figure 1. A Similar Figure Can Be Generated with Well 2 data

Parameter	Well 1 (metric)	Well 1 (U.S.)	Well 2 (metric)	Well 2 (U.S.)
Q (lpm or gpm)	37.853	10	37.853	10
s_t (m or feet)	4.572	15	2.743	9
t (min)	480	480	480	480
L (m or feet)	14.326	47	20.726	68
r_w (cm or inch)	7.62	3	7.62	3
S (dimensionless)	0.0002	0.0002	0.0002	0.0002
D (m or feet)	62.484	205	35.052	115
C (min^2/m^5 or s^2/ft^5)	3.453	32.7	3.453	32.7

$c(L/D)^2 + d(L/D)^3$, where the fitting coefficients were $a = 2.948$, $b = -7.363$, $c = 11.447$, and $d = -4.675$. Substituting Equation 1 into Equation 3 yields:

$$T = \frac{Q}{4\pi(s_t - s_w)}\left[\ln\left(\frac{2.25Tt}{r_w^2 S}\right) + 2s_p\right] \quad (5)$$

Well efficiency is embedded in Equation 5 since $s_w = CQ^2$, and C is defined by Equation 2. Hence, a step-drawdown test is not required if E can be estimated. In addition, the effect of partial penetration is represented by Equation 4 using the Bradbury-Rothschild polynomial for G. In Equation 5, T appears on both sides of the equation; hence, an iterative solution is required (Bradbury and Rothschild 1985). Initially, a guess is made for T (Tguess in the program) on the right-hand side of Equation 5, and an updated solution for T (Tcalc in the program) is obtained from the left-hand side. This updated solution is again used on the right-hand side of Equation 5, and a new T is again computed. This iterative process continues until some suitable tolerance criterion for error (Err in the program) is reached. For the MATLAB program shown in the Appendix, either metric or customary U.S. units may be employed.

Program Usage

The program is executed from the MATLAB command line by typing in the m-file program name (i.e., [A, T] = TQs). The user is prompted to select a system of units and then enter input values for Q, s_t, t, L, r_w, S, D (optional), and C (optional). Walton (1970) showed that T is relatively insensitive to variations in S; hence, this value may be estimated. Tabulated and graphed output consists of a range of T values that correspond to a range of expected well efficiencies and aquifer penetration values. The two original examples shown in Bradbury and Rothschild (1985) are used as illustrations. Input data for these tests are summarized in Table 1. The MATLAB program is executed once for each test, and the user is prompted to enter appropriate data from Table 1. Figure 1 is a graphical representation of the tabulated output for well 1. Output for well 2 was omitted because it is similar to Figure 1. If known values for D and C are entered, then single best estimates for T and E are also obtained. Using well 1 metric units from Table 1, we find $T = 46.6$ m^2/d at $E = 99.9\%$ and $L/D = 23\%$ and for well 2, $T = 36.2$ m^2/d at $E = 99.9\%$ and $L/D = 59\%$. Bradbury and Rothschild originally reported T values of 47.6 and 36.7 m^2/d for wells 1 and 2, respectively. Well efficiencies were determined from Equation 2 using their C value.

One may question the choice of having partial penetration as a variable in Figure 1 since a single value for this parameter should be known from the driller's log. However, we often have difficulty actually deciding where aquifer boundaries are located. This is especially true in horizontally stratified aquifers where vertical changes in hydraulic conductivity may not be obvious. In

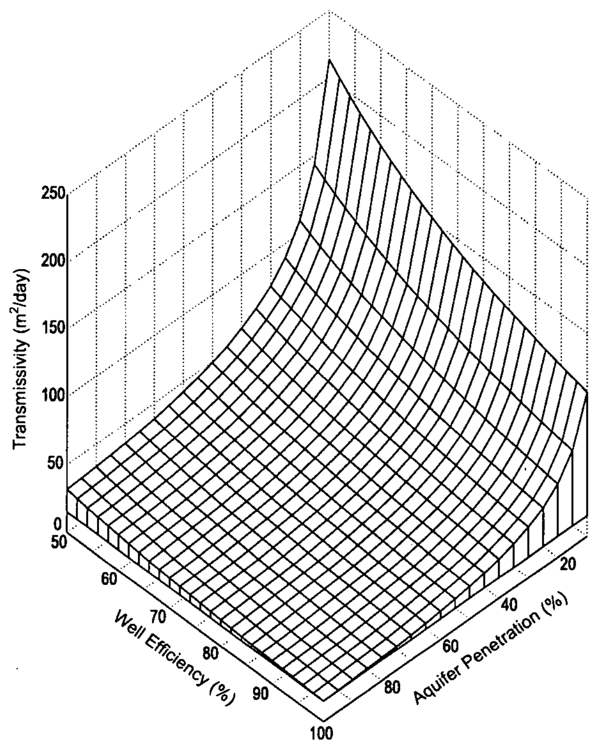

Figure 1. Transmissivity as a function of aquifer penetration and well efficiency for well 1.

addition, step-drawdown tests that determine C are the exception rather than the rule, especially in monitoring well applications. This program simply provides a range of estimated T values that can assist us in overcoming these difficulties. As aforementioned, we can narrow the range of possible T values to a single best estimate if we know partial penetration and well efficiency. Alternately, we may determine partial penetration from Figure 1 if we have independent estimates for T and E. The real value of this exercise, however, may be the recognition of uncertainty in the estimation process.

Conclusions

Specific capacity data are often used in hydrogeological studies to estimate T. The major criticism of this method is that it assumes a quasi–steady state condition has been established. This is in contrast to a conventional aquifer test where transient s and t values are matched to an appropriate theoretical type-curve. However, the MATLAB program presented here is really a parameter sensitivity analysis because it translates specific capacity into a range of T values that reflect the combined influence of the formation, aquifer penetration, and well efficiency. This type of analysis simply gives us another way to determine T. These T estimates can be valuable in those situations where conventional aquifer tests are unavailable.

Acknowledgments

This work was supported by the Groundwater Protection Program at Los Alamos National Laboratory (LANL). LANL is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. Special thanks are extended to David Schafer for fruitful discussions during this effort. Review comments by Ken Bradbury and Mary Anderson are especially appreciated. The LANL document number for this computer note is LA-UR-03-6116.

Editor's Note: The use of brand names in peer-reviewed papers is for identification purposes only and does not constitute endorsement by the authors, their employers, or the National Ground Water Association.

References

Bouwer, H. 1978. *Groundwater Hydrology*. New York: McGraw-Hill.

Bradbury, K.R., and E.R. Rothschild. 1985. A computerized technique for estimating the hydraulic conductivity of aquifers from specific capacity data. *Ground Water* 23, no. 2: 240–246.

Brons, F., and V.E. Marting. 1961. The effect of restricted fluid entry on well productivity. *Journal of Petroleum Technology* 13, no. 2: 172–174.

Sternberg, Y.M. 1973. Efficiency of partially penetrating wells. *Ground Water* 11, no. 3: 5–7.

Walton, W.C. 1970. *Groundwater Resource Evaluation*. New York: McGraw-Hill.

Appendix

```
function [A, T]=TQs
%TQs computes Transmissivity (T) from Specific Capacity (Q/s) data.
%
%   This m-file was written in the MATLAB language by:
%   Stephen G. McLin, 8 May 2003, e-mail: sgm@lanl.gov
%
%   A = a matrix of T values as a function of R and E.
%   Note that R is the last row of A and E is the last column of A
%   T = transmissivity (sq m/day or sq ft/day).
%   Q = well pump rate (lps or gpm).
%   s = wellbore drawdown (m or ft).
%   t = time (minutes).
%   D = aquifer thickness (m or ft).
%   L = well screen length (m or ft).
%   R = L/D (dimensionless penetration).
%   r = wellbore radius (cm or in).
%   S = aquifer storage coefficient (or specific yield).
%   E = well efficiency (%).
%   C = well loss coefficient (min^2/m^5 or sec^2/ft^5).
%
format short;
Units=input('Enter 1 for metric units and 2 for US units.......');
if Units = =1
  Q=input('Enter Q (lpm) now.......'); conv=1000;
  s=input('Enter drawdown (m) now.......');
  t=input('Enter time (minutes) now.......');
```

```
  L=input('Enter well screen length (m) now.......');
  r=input('Enter wellbore radius (cm) now.......'); r=r/100;
  S=input('Enter storage coefficient S now.......');
  Do=input('Enter observed aquifer thickness (m) now (enter 1 if unknown).......');
  Co=input('Enter step-test C (min^2/m^5) now (enter 1 if unknown).......');
  if Co~=1; Co=Co*3600; end; str='Transmissivity (sq m/day)';
elseif Units ==2
  Q=input('Enter Q (gpm) now.......'); conv=7.48;
  s=input('Enter drawdown (ft) now.......');
  t=input('Enter time (minutes) now.......');
  L=input('Enter well screen length (ft) now.......');
  r=input('Enter wellbore radius (in) now.......'); r=r/12;
  S=input('Enter storage coefficient S now.......');
  Do=input('Enter observed aquifer thickness (ft) now (enter 1 if unknown).......');
  Co=input('Enter step-test C (sec^2/ft^5) now (enter 1 if unknown).......');
  str='Transmissivity (sq ft/day)';
else
  error('You have entered an incorrect response.  Please start again.');
end
E=[50:2:100]'; [n1,m1]=size(E);
R=[0.1:0.05:1.0]'; [n2,m2]=size(R); D=L./R;
A=zeros(n1+1,n2+1); err=0.000001; Tguess=1.0;
a=2.948; b=-7.363; c=11.447; d=-4.675;
C=(1-E./100).*(s/Q^2); sw=C.*Q^2;
G=(a+b*(L./D)+c*(L./D).^2+d*(L./D).^3);
sp=((D-L)./L.*(log(D./r)-G));
for j=1:n2; for i=1:n1;
  Tcalc(i,j)=1440*Q*(log(2.25*Tguess*t/(1440*r^2*S))+2*sp(j))/(4*conv*pi*(s-sw(i)));
  diff=abs(Tcalc(i,j)-Tguess); test=diff;
  while test>err
    Tcalc(i,j)=1440*Q*(log(2.25*Tguess*t/(1440*r^2*S))+2*sp(j))/(4*conv*pi*(s-sw(i)));
    diff=abs(Tcalc(i,j)-Tguess); Tguess=Tcalc(i,j); test=diff;
  end; A(i,j)=Tcalc(i,j);
end; end
A(1:n1,(n2+1))=E; A((n1+1),1:n2)=100.*R';
z=A(1:n1,1:n2); x=100.*R; y=E; h=figure;
set(h,'PaperPosition',[0.25,0.25,8.00,10.50]);
meshz(x,y,z); zlabel(str);
ylabel('Well Efficiency (%)'); xlabel('Aquifer Penetration (%)');
if Do ==1; T=1; return;
elseif Co ==1; T=1; return;
else
fac=60*60*conv*conv;
Eo=100*(1-Co*Q^2/(s*fac)); swo=Co*Q^2/fac;
Go=a+b*(L/Do)+c*(L/Do)^2+d*(L/Do)^3;
spo=(Do-L)/L*(log(Do/r)-Go);
Tcalco=1440*Q*(log(2.25*Tguess*t/(1440*r^2*S))+2*spo)/(4*conv*pi*(s-swo));
  diff=abs(Tcalco-Tguess); test=diff;
  while test>err
    Tcalco=1440*Q*(log(2.25*Tguess*t/(1440*r^2*S))+2*spo)/(4*conv*pi*(s-swo));
    diff=abs(Tcalc-Tguess); Tguess=Tcalco; test=diff;
  end; T=[Tcalco Eo L*100/Do]; end;
% Tcalco=best single estimate for transmissivity;
% Eo=well efficiency; 100L/Do=aquifer penetration;
```

EP Document Signature Form **Read/Write Access Person Making Entry is WIN/106229/Unknown (Created on 8/25/2006)**

Home | Update | Delete | Reset | Bottom

Printable Page

Document Catalog Number EP2006-0794 **(Please prefix the name of all electronic versions of this document with this number.)**

* Required Field

***Document Title / Subject**	A Catalog of HIstorical Aquifer Tests on Pajarito Plateau
PRSs	None
Associated Document Catalog Number(s)	None
***Author**	Simmons, Ardyth 665 3935 asimmons@lanl.gov
***Organization**	LANL Water Stewardship Project (EP-WSP), Pkg1729
Document Team	McLin, Steve 665 1721 sgm@lanl.gov
***Document Type** Misc. Document w/Peer Review	**Former OU** N/A
Date Due **Date Final Complete** **Date Sent to DOE**	
Date Sent to NMED **Date Sent to RPF (Paper & Electronic)**	
Received Per RPF **RPF ER ID Number**	
CT No **LA-UR Number**	LA-UR-06-3789
Performance Measure No	
AA Deliverable ☐ **Certification Required** ☐ **Force Peer Review** ☐	
Distribution TO:	
Distribution FROM:	
Distribution COPY:	
Distribution THRU:	
Attachment Notes	
Status/Comments	

Reviewer Signatures: (By signing, the reviewer indicates that he/she **reviewed** and **approves** the document.)

Reviewer (Print reviewer's name under title)	**Signature**	**Date**
Author [signature] →	[signature]	8/25/06
Peer Review Chair		
Solid Waste Regulatory Compliance (SWRC)		
LANL Legal Reviewer		
DOE/LASO Reviewer		
Project Leader		
Program Manager		

Document Catalog Number EP2006-0794

Top