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Water Supply at Los Alamos During 1989

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***Cover photo:** Drilling of new supply well, Otowi-4, in Los Alamos Canyon.*

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WATER SUPPLY AT LOS ALAMOS DURING 1989

by

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ABSTRACT

Municipal and industrial water supply during 1989 was 1 686 $\times 10^6$ gal. from wells in three fields, and 23 $\times 10^6$ gal. from the spring gallery in Water Canyon. About 4.6 $\times 10^6$ gal. of water from the Guaje Reservoir and 3.3 $\times 10^6$ gal. from the Los Alamos Reservoir were used for irrigation; thus, the total water usage in 1989 was about 1 716 $\times 10^6$ gal. Water supply was satisfactory in that the production met the demand and water quality in the distribution system was in compliance with State and Federal regulations. A new well, Otowi-4, was completed in early 1990 at a depth of 2 585 ft with a water level of 790 ft. Testing indicated a high production yield of about 1 500 gpm when construction is completed.

I. INTRODUCTION

This report summarizes production and aquifer conditions for water wells in the Los Alamos, Guaje, and Pajarito well fields (Fig. 1). The wells supply most of the water used for municipal and industrial purposes in Los Alamos County and the Los Alamos National Laboratory. The spring gallery in Water Canyon supplies the rest of the water to the system. A summary of the data on the surface water from Guaje and Los Alamos Reservoirs that is used for irrigation is included in this report. The quality of water in the distribution system is compared with drinking water standards set by the U.S. Environmental Protection Agency (EPA).

This report is a joint effort between the Laboratory's Environmental Protection Group and the Utilities Department of Johnson Controls World Services Inc. (JCI) (a support contractor to the Laboratory). The purpose of this report is to ensure a continuing historical record and to provide guidance for management of water resources in long-range planning for the water supply system. We have issued one summary report for the period 1947–1971 and 18 annual reports that contain the results of our studies of these water supplies. [1–19] An additional report summarized the hydrology of the main aquifer with reference to future development of groundwater supplies. [20] A 1987 report examined the status of wells at that time and projected future water supply requirements. [21] On the basis of that report, we planned two new supply wells to be drilled and equipped.

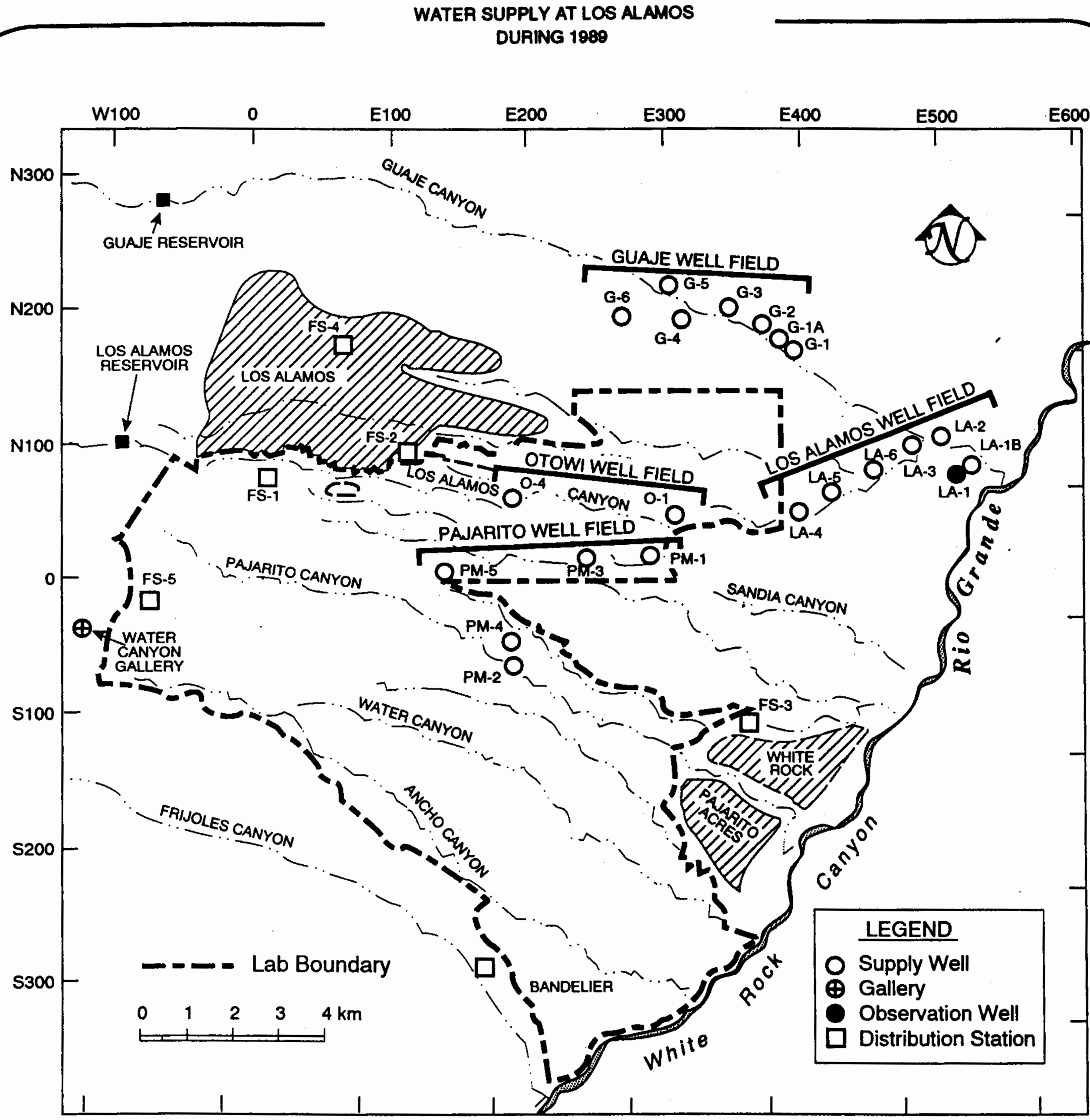

Fig. 1. Locations of reservoirs, well fields, water supply wells, and gallery water supply. Letter designations on the figure indicate wells in the Guaje (G), Pajarito (PM), Los Alamos (LA), and Otowi (O) well fields; some distribution stations are labeled (FS) to indicate fire station locations.

Construction of the first well, Otowi-4, began in September 1989; the well was completed and tested by March 1990. Construction data, testing data, and geologic and hydrologic data from this well are included as part of this report. However, the well will probably not be added to the system until 1991 after the remaining construction (equipping with pump, transmission lines, and storage tanks) has been completed.

Construction of the second well, Otowi-4, began in 1989. Construction and testing of this well should be completed by early fall 1990.

JCI maintains and operates the water supply system. Water from the system is sold to Los Alamos County for the communities of Los Alamos and White Rock and to the National Park Service for water supply at Bandelier National Monument.

After the water is pumped from the wells into the distribution lines, it is lifted by booster pumps into reservoirs for storage and distribution to the Laboratory and the community. The entire water supply is disinfected before distribution to Los Alamos, White Rock, Bandelier National Monument, and Laboratory areas (Fig. 1).

Before 1989, water from the gallery flowed by gravity through a microfilter and chlorination station into one of the system reservoirs for distribution. However, during 1989, the flow from the gallery was redirected and is now used only as industrial water for the boiler at the TA-16 Steam Plant. It is no longer used for potable water.

JCI maintains a record of the hours of operation for each well along with records of daily and monthly water production. The monthly averages of nonpumping and pumping water levels are computed from air line pressure or transducer data recorded at each well. We then used these data to calculate the pumping rates, drawdown, and other well field statistics that are included in this report. The Appendix contains annual pumping and production information for each water supply well and the gallery for the period of record through 1989.

Water for the Laboratory, the communities of Los Alamos and White Rock, and Bandelier National Monument for 1989 was supplied from 16 deep wells in three well fields and from the spring gallery in Water Canyon. The well fields are located on the Pajarito Plateau and in the Los Alamos and Guaje Canyons east of the plateau (Fig. 1). The wells are completed into the main aquifer of the Los Alamos Area, the only aquifer capable of municipal and industrial water supply. The depths to water range from 25 to 30 ft (semiartesian) in the well field in lower Los Alamos Canyon to about 760 ft along the eastern edge of the plateau, and increases to about 1 200 ft near the center of the plateau at Well PM-5. Water in the aquifer moves from the recharge area in the Caldera eastward beneath the plateau to the Rio Grande, where a part is discharged into the river through seeps and springs.[20] The gallery, which is located west of the Laboratory on the flanks of the Sierra de los Valles, discharges water from a small aquifer perched in the volcanic rocks.

Water from the two reservoirs is used for irrigation of lawns during the summer. The reservoirs are in canyons on the flanks of the mountains. Los Alamos Reservoir is located west, and the Guaje Reservoir, northwest of Los Alamos. The source of water in the reservoirs is from springs, snowmelt, and summer run-off.

II. WELL FIELD CHARACTERISTICS

Production from the three well fields increased 227×10^6 gal., from $1\,459 \times 10^6$ gal. in 1988 to $1\,686 \times 10^6$ gal. in 1989 (Table 1). An estimated 24.9×10^6 gal. of this increase was due to water requirements for construction, drilling and development of Well Otowi-4. The months of heaviest production in 1989 were May, June, and July. The production during these months was

Table I. Production from Wells and Gallery 1947–1989 (in Millions of Gallons)

Year	Los Alamos Field	Guaje Field	Pajarito Field	Water Canyon Gallery	Production Total
1947	147	0	0	84	231
1948	264	0	0	97	361
1949	302	0	0	92	394
1950	547	3	0	54	604
1951	702	68	0	39	809
1952	448	350	0	48	846
1953	444	372	0	39	855
1954	380	374	0	40	794
1955	407	375	0	33	815
1956	437	506	0	23	966
1957	350	378	0	40	768
1958	372	395	0	60	827
1959	391	478	0	54	923
1960	530	533	0	48	1 111
1961	546	624	0	54	1 224
1962	577	597	0	67	1 241
1963	539	654	0	51	1 244
1964	627	665	0	45	1 337
1965	447	571	99	72	1 189
1966	450	613	127	82	1 272
1967	373	464	481	56	1 374
1968	345	474	584	65	1 468
1969	331	435	569	80	1 415
1970	360	423	595	65	1 443
1971	412	484	657	37	1 590
1972	380	467	662	40	1 549
1973	406	475	685	49	1 615
1974	369	453	802	35	1 659
1975	356	431	749	42	1 578
1976	343	531	817	41	1 732
1977	345	515	614	57	1 531
1978	302	444	690	45	1 481
1979	289	456	662	44	1 451
1980	339	485	743	32	1 599
1981	336	469	701	45	1 551
1982	317	422	773	46	1 558
1983	221	338	904	38	1 501
1984	326	460	780	34	1 600
1985	290	456	841	37	1 624
1986	179	460	858	28	1 525
1987	217	485	892	34	1 628
1988	158	477	824	34	1 493
1989	219	506	961	23	1 709
Total	16 120	18 166	17 070	2 129	53 485

635 × 10^6 gal., an increase from 507 × 10^6 gal. for a similar period of heavy production in 1988. The months of lightest production were January, February, and November, with a production of 280 × 10^6 gal., an increase from 269 × 10^6 gal. for a similar period in 1988.

The difference in demand between periods of heavy and light production (summer and winter, respectively) is mainly because of water usage for lawn irrigation. The water levels in the wells respond accordingly, with the highest water levels observed during months of least production and the lowest water levels during months of greater production.

The production and use of water at the Laboratory and community increased from about 230 × 10^6 gal. in 1947 to 1 700 × 10^6 gal. in 1976. Water usage in 1977 declined to about 1 500 × 10^6 gal., and since then has varied from about 1 450 × 10^6 gal. in 1979 to about 1 700 × 10^6 gal. in 1989 (Fig. 2). The production decline in 1977 and lower demand through 1989 have been attributed largely to a rate increase for water used in the community and to water-saving measures in the community and the Laboratory. Much of the landscaping in the community and Laboratory has changed from lawns and shrubs, which require watering, to southwestern landscaping (native plants and gravels), which require little if any water other than normal rainfall. However, regardless of the yearly variation in water demand for the past several years, in the long term there will be a increase in water usage.

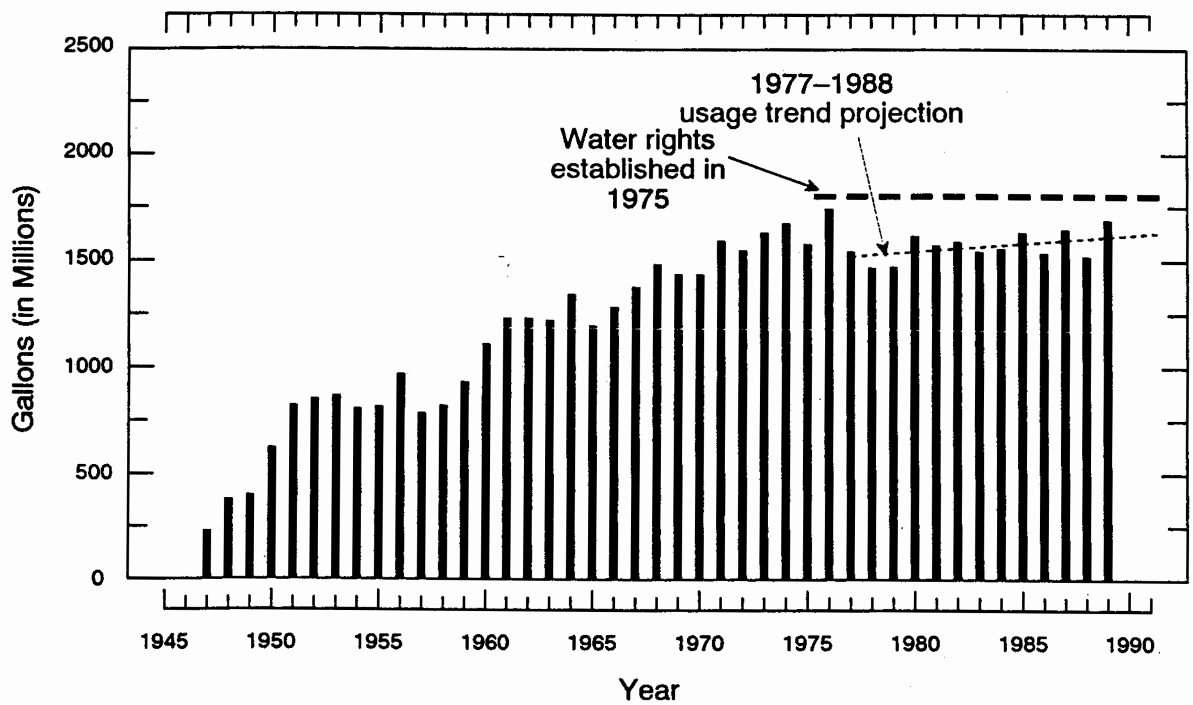

Fig. 2. Water production and usage from 1947 to 1989

A projection of future water demand is shown in Fig. 2. This line is an extrapolation of a least-squares line fitted to the actual data for 1977 through 1987, which had a rate of increase of about 10 million gallons a year or slightly more than one-half percent a year. Water usage in 1989 was slightly greater than the ten-year trend. During the ten-year period analyzed for long range water supply planning, it was noted that Laboratory usage was almost constant at about 485 million gallons a year, with the least-squares trend line declining by about 1.7 million gallons a year. The County usage showed a steady increase of about 13 million gallons a year or about 0.8 percent a year increase. About 60 percent of total annual water use occurs during the spring and summer quarters. The annual variation in water usage, however, is not correlated in any statistically significant way with the amount of precipitation received during the year.

The peak demand period for 1989 was a 24-day period, June 18 through July 11, when production was 216×10^6 gal., or about 9.0×10^6 gal./day (Table II). This was the longest peak demand period since 1982, and production during this period reflects below-normal rainfall from mid-June to mid-July.

Although cumulative well field productions are nearly equal (Table 1), they do not reflect current proportionate contributions because production generally declines with the age of the well field. The wells in the Los Alamos field were constructed in the period 1947 through 1960, with production peaking in 1951 and generally declining since (Fig. 3); wells in Guaje field were constructed in the period 1950 through 1964, with production peaking in 1964 and declining since; and wells in the Pajarito field were constructed in the period 1965 through 1982, with peak production occurring in 1989.

The present yield generally reflects the age of the wells in the three fields. In 1989 about 56% of the total production came from the Pajarito field, 30% from the Guaje field, 13% from the Los Alamos field, and 1% from the Water Canyon gallery (Table III).

A. Los Alamos Well Field

The Los Alamos well field includes six supply wells and one observation well. Three wells (LA-1, -2, and -3) were completed in 1947 to depths of about 870 ft. Because Well LA-1 produced excessive sand with water, which rapidly wore out the pumps, it was replaced by Well LA-1B in 1960. Well LA-1B was completed to a depth of 1 750 ft. During the period 1948 through 1950, Wells LA-4, -5, and -6 were completed to depths of about 2 000 ft.

Production in 1988 was from four of these wells (LA-1B, -2, -3, and -5). Attempts to rehabilitate Well LA-4 in 1986 resulted in separation of the casing which permitted excessive sand to enter the well. The amount of sand could not be controlled and the age of the well prevented repair of the casing; thus, it was necessary to take the well out of production. Well LA-6 was placed on standby in 1976 as the water contained an excess amount of natural arsenic.[22]

Production from the Los Alamos well field increased about 61×10^6 gal. from 158×10^6 gal. in 1988 to 219×10^6 gal. in 1989 (Table III). The well field contributed about 13% of the total 1989 production.

Table II. Peak Demand Periods 1982–1989

	Demand Period							
	June 23– July 11 1982	June 30– July 11 1983	June 8– June 18 1984	June 29– July 16 1985	July 28– August 10 1986	July 2– July 17 1987	June 18– June 26 1988	June 18– July 11 1989
No. of days	19	12	11	18	14	16	9	24
Total production (gal.)	145×10^6	91×10^6	81×10^6	138×10^6	91×10^6	134×10^6	63×10^6	216×10^6
Average daily production (gal.)	8.1×10^6	7.6×10^6	7.4×10^6	7.7×10^6	6.5×10^6	8.4×10^6	7.0×10^6	9.0×10^6
No. of days exceeding								
10×10^6 gal.	—	—	—	—	—	—	—	4
9×10^6 gal.	1	—	—	3	—	4	—	9
8×10^6 gal.	9	6	2	4	2	7	2	10
7×10^6 gal.	9	2	6	9	2	4	3	0
$<7 \times 10^6$ gal.	0	4	3	2	10	1	4	1

WATER SUPPLY AT LOS ALAMOS
DURING 1989

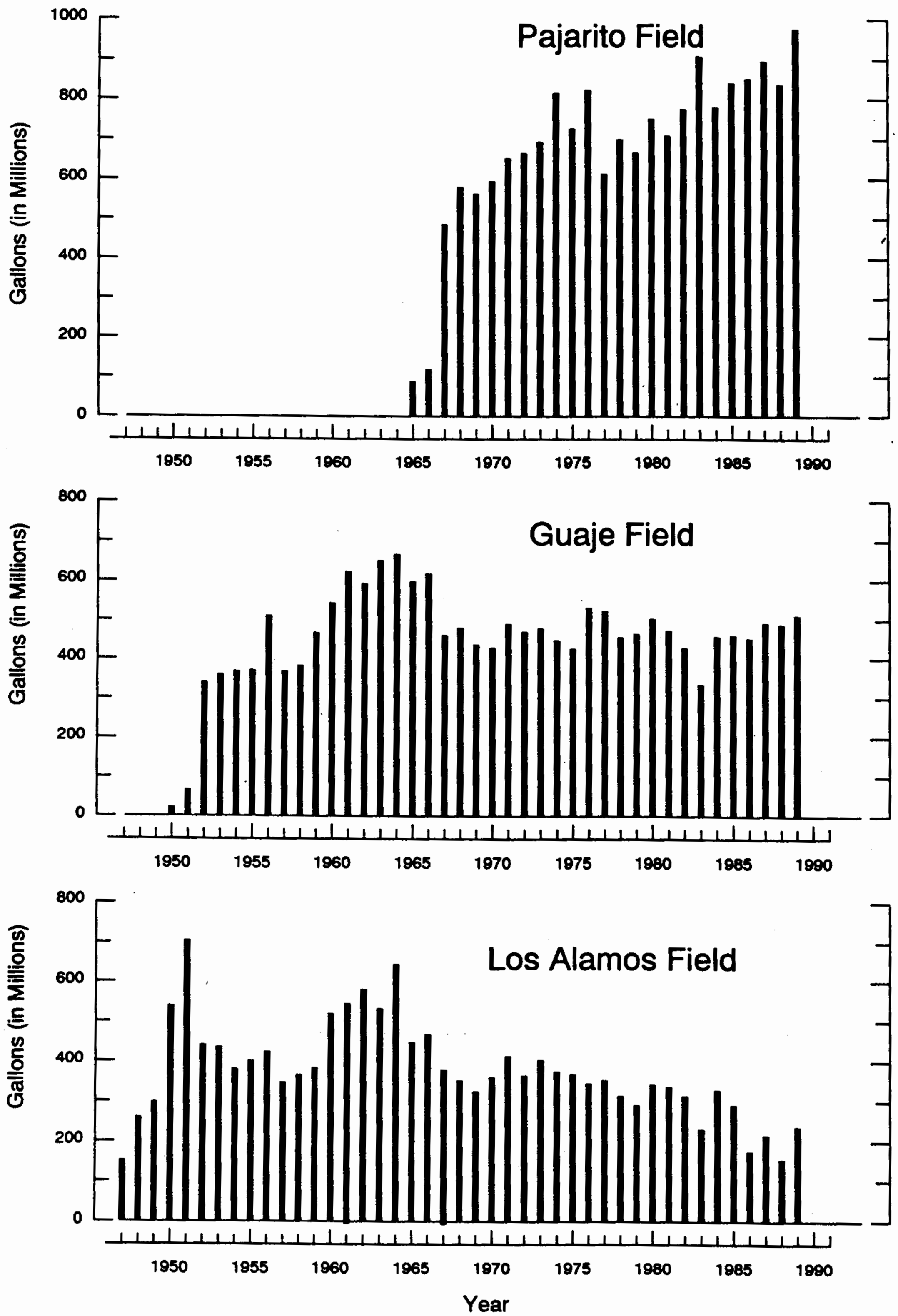

Fig. 3. Comparison of annual production from three well fields.

Average pumping rates in 1989 ranged from 272 to 569 gallons per minute (gpm). The combined pumping rate of the field decreased slightly from 1 577 gpm in 1988 to 1 560 gpm in 1989 (Table IV). There was no significant change in the specific capacities of the wells in use in 1989 when compared with the capacities of same wells in 1988.

Table III. Production Characteristics for 1988 and 1989

	Production					
	Amount (10^6 gal.)		Well Field (%)		Total Production (%)	
	1988	1989	1988	1989	1988	1989
Los Alamos Field						
Well LA-1	—	—	—	—	—	—
Well LA-1B	75.4	97.8	48	45	5	6
Well LA-2	33.0	43.2	21	19	2	2
Well LA-3	40.1	51.9	25	24	3	3
Well LA-4	0.0	0.0	0	0	0	0
Well LA-5	9.9	26.5	6	12	<1	2
Well LA-6	0.0	<0.1	0	0	0	0
Subtotal	158.4	219.4	100	100	11	13
Guaje Field						
Well G-1	5.4	26.9	1	6	<1	2
Well G-1A	133.5	131.2	28	26	9	8
Well G-2	132.8	133.9	28	26	9	8
Well G-3	3.4	<0.1	<1	<1	<1	<1
Well G-4	4.1	21.6	<1	4	2	1
Well G-5	115.3	110.9	24	22	7	6
Well G-6	82.1	81.6	17	16	5	5
Subtotal	476.6	506.1	100	100	32	30
Pajarito Field						
Well PM-1	98.0	104.9	12	11	7	6
Well PM-2	146.8	130.0	18	13	10	8
Well PM-3	232.0	221.0	28	23	15	13
Well PM-4	218.7	418.9	26	44	14	24
Well PM-5	128.6	86.2	16	9	9	5
Subtotal	824.1	961.0	100	100	55	56
Water Canyon (Gallery)	34.5	23.0	100	100	2	1
Total	1 493.6	1 709.5	—	—	100	100

The water levels fluctuate with the amount of production (Fig. 4). The average water levels declined about 13 ft in the Los Alamos well field from 1988 to 1989.

B. Guaje Well Field

The Guaje well field includes seven wells ranging in depth from 1 500 to 2 000 ft. Wells G-1, -2, -3, -4, and -5 were completed in 1950, Well G-1A was completed in 1954, and Well G-6 was placed in service in 1964.

The 1989 production came from six of these wells. Attempts to rehabilitate Well G-3 damaged the casing beyond repair and the well was taken out of production. The damage caused large amounts of sand to enter the well.

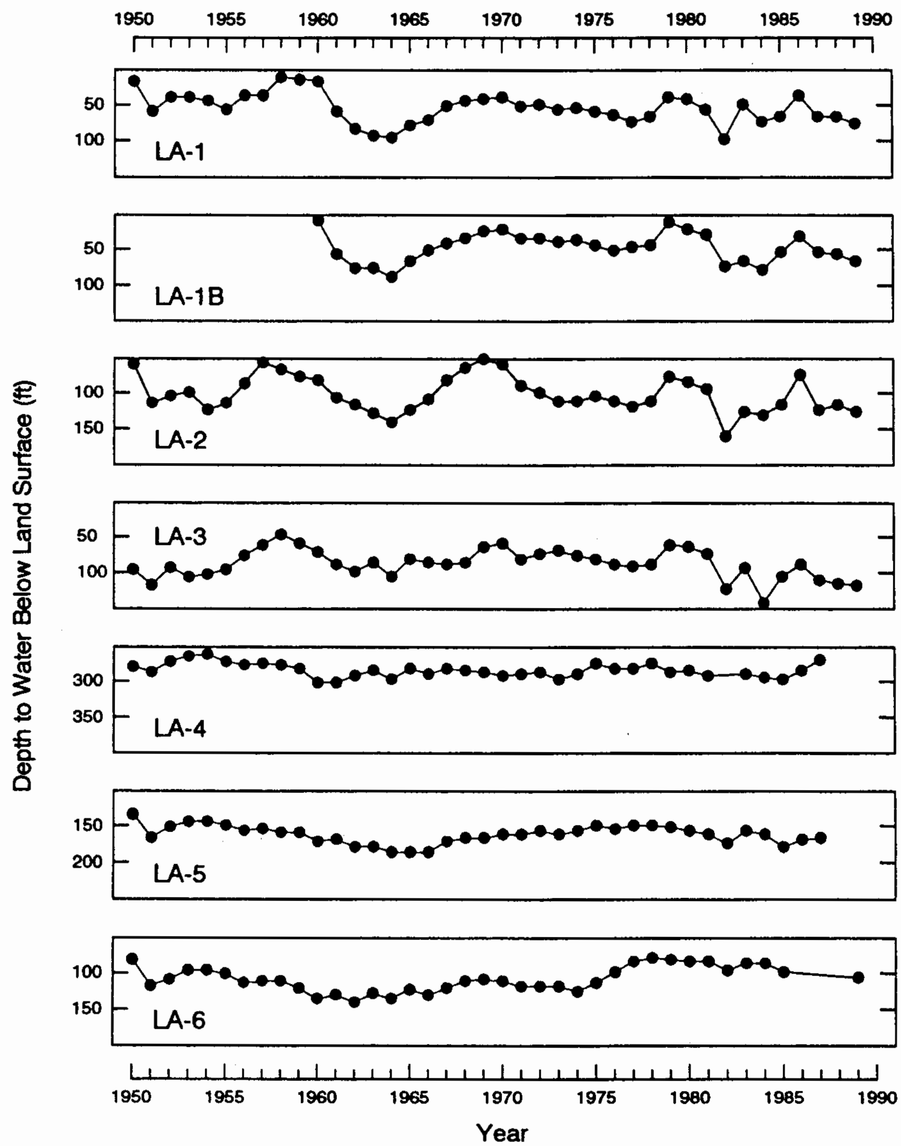

Fig. 4. Nonpumping water levels in wells in the Los Alamos well field.

The production from the Guaje field increased about 29 × 10[6] gal. from 477 × 10[6] gal. in 1988 to 506 × 10[6] gal. in 1989. The well field contributed about 30% of the total production in 1989 (Table III).

The average pumping rate of the six wells ranged from 207 to 470 gpm (Table IV). The overall combined pumping rate increased 10 gpm from 2 017 gpm in 1989 to 2 027 gpm in 1989. There was no significant change in the specific capacities of the individual wells from 1988 to 1989.

In 1989, water levels in the wells during nonpumping periods remained about the same or declined slightly (Fig. 5). The slight decline in the field was due to the slight increase in production from the field. The overall average water level decline in the field was about 4 ft (Table V).

Table IV. Average Pumping Rate and Specific Capacity, 1988 and 1989

	Average Pumping Rate (gpm)		Average Specific Capacity (gpm/ft of drawdown)	
	1988	1989	1988	1989
Los Alamos Field				
Well LA-1	—	—	—	—
Well LA-1B	574	569	4.4	4.6
Well LA-2	284	272	1.6	1.4
Well LA-3	313	308	2.0	1.8
Well LA-4	—	—	—	—
Well LA-5	406	411	—	—
Subtotal	1577	1560		
Guaje Field				
Well G-1	227	223	1.4	1.3
Well G-1A	443	470	10.8	13.1
Well G-2	457	463	11.5	14.0
Well G-3	—	—	—	—
Well G-4	227	207	1.4	1.3
Well G-5	396	392	9.7	9.8
Well G-6	267	272	3.4	3.5
Subtotal	2017	2027		
Pajarito Field				
Well PM-1	592	580	24.7	27.6
Well PM-2	1328	1322	21.4	22.0
Well PM-3	1397	1386	58.2	53.3
Well PM-4	1313	1296	34.6	35.0
Well PM-5	1221	1213	—	—
Subtotal	5851	5797		
Water Canyon (Gallery)	66	44	—	—
Total	9511	9428		

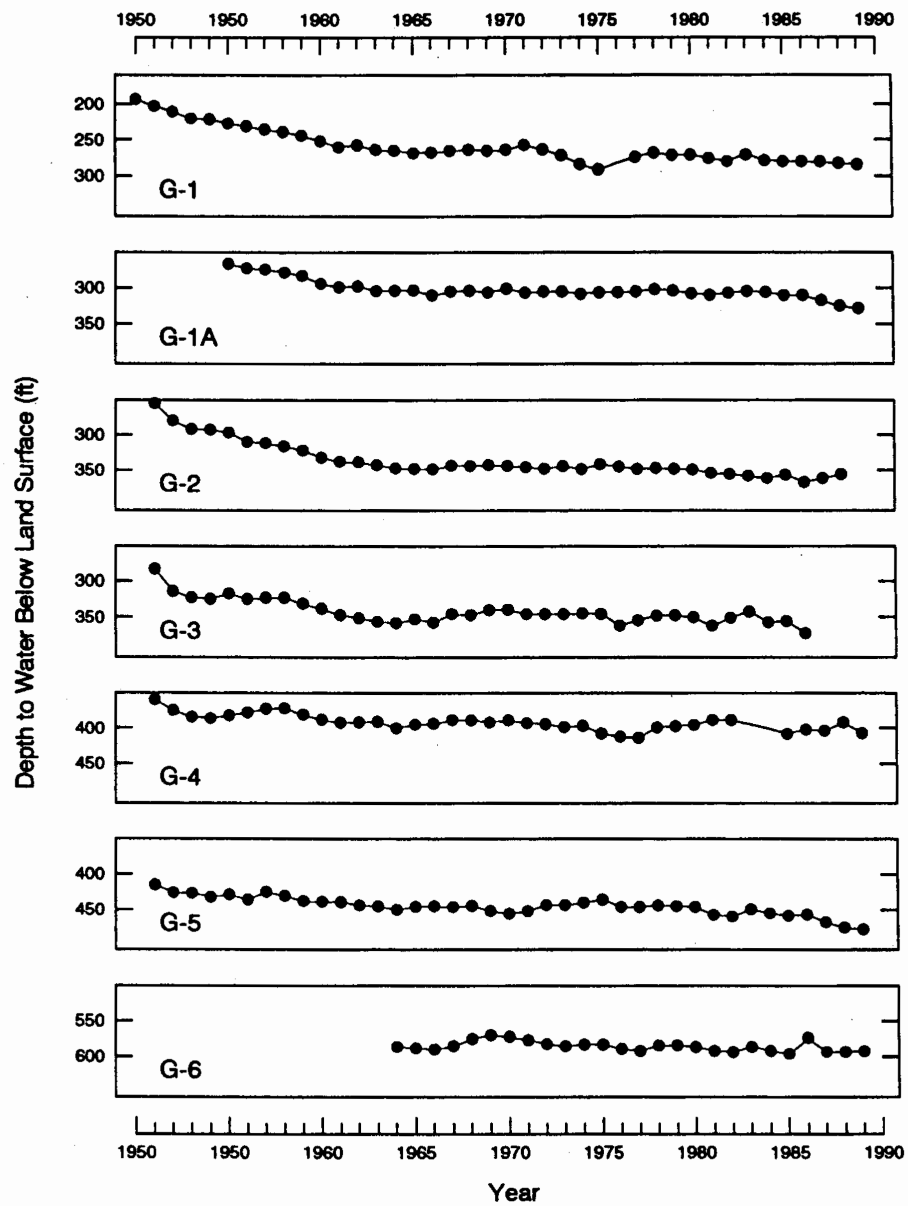

Fig. 5. Nonpumping water levels in wells in the Guaje well field.

C. Pajarito Well Field

The Pajarito well field includes five wells. The wells, which were completed over a 17-year period from 1965 through 1982, range in depth from 2 300 to 3 100 ft. Because they are located on the Pajarito Plateau, depths to water range from about 750 ft at Well PM-1 to more than 1 200 ft at Well PM-5.

Production from the Pajarito well field in 1989 was about 961 $\times 10^6$ gal., an increase of 137 $\times 10^6$ gal. from the 824 $\times 10^6$ gal. produced in 1988 (Table III). The field contributed about 56% of the total 1989 production. The production from Well PM-4 represented 44% of the total Pajarito field production and 24% of the total water produced at Los Alamos in 1989.

The average pumping rates of the Pajarito wells ranged from 580 to 1 386 gpm. Four of the wells (PM-2, -3, -4, and -5) are high yield wells with pumping rates over 1 000 gpm (Table IV). The pumping rates for the individual wells varied slightly from 1988 to 1989; the combined pumping rate showed a slight decrease of 54 gpm, from 5 851 gpm in 1988 to 5 797 gpm in 1989.

Specific capacities of the wells in 1989 ranged from 22.0 to 53.3 gpm/ft of drawdown. There was no significant change in the specific capacities from 1988 to 1989, although there was some variation in the specific capacities of individual wells (Table IV).

Water levels in these wells fluctuated as would be expected from the amount of production (Fig. 6). Water levels declined slightly in Wells PM-1,-3, and -4 and rose slightly in Well PM-2. The overall water level remained about the same when the average water levels in the field in 1988 were compared to the 1989 data (Table V).

D. Well and Well Field Conditions

The gear drive of the natural gas engine on Well PM-4 failed in December 1989. The well had not been returned to service by the end of 1989.

The line shaft in Well LA-5 cannot be adjusted. As a result, the line vibrates when pumping, so the well is only pumped for short periods of time. Because of the increased demand in 1989, production from the well was up when compared with the 1988 production.

It is not economical to operate Wells G-1 and -4 because of their low pumping rates. The low rates are due the age of the wells, which has resulted in plugging of screens, screen damage, and accumulation of sand that has reduced the depth of the wells. Although operation is uneconomical, the two wells have remained in production, but the low pumping rates caused 1989 production from these two wells to be lower than the production from the remaining wells in Guaje field (Table III). However, the increased demand in 1989 required that production from Wells G-1 and G-4 was greater in 1989 than in 1988.

No water level data in Wells LA-5, LA-6, and PM-5 were obtained in 1989 because either the recorders or transducers logging continuous water level data on these wells were not working, or calibrations were in error. Also, no data were taken on Wells LA-4 and G-3 as these wells were not used due to screen and casing damage. No water level data for any of these wells were collected in 1989.

III. WATER CANYON GALLERY

The spring gallery in Water Canyon is dug about 30 ft into the Bandelier Tuff. The gallery, or tunnel, is framed with timbers and sheet metal to keep the walls and overhead from collapsing. The floor of the gallery is constructed to form a basin to collect the spring flow. About one mile of water line connects the gallery to the industrial water supply used for the boiler at the TA-16 Steam Plant located at S-Site at the southwestern corner of the Laboratory.

Water from the spring gallery is perched in the fractures of a dense welded tuff, which is underlain by a massive nonwelded tuff that does not have fractures. The recharge to the perched aquifer is rapid. In the spring when snowmelt occurs, the discharge from the gallery increases

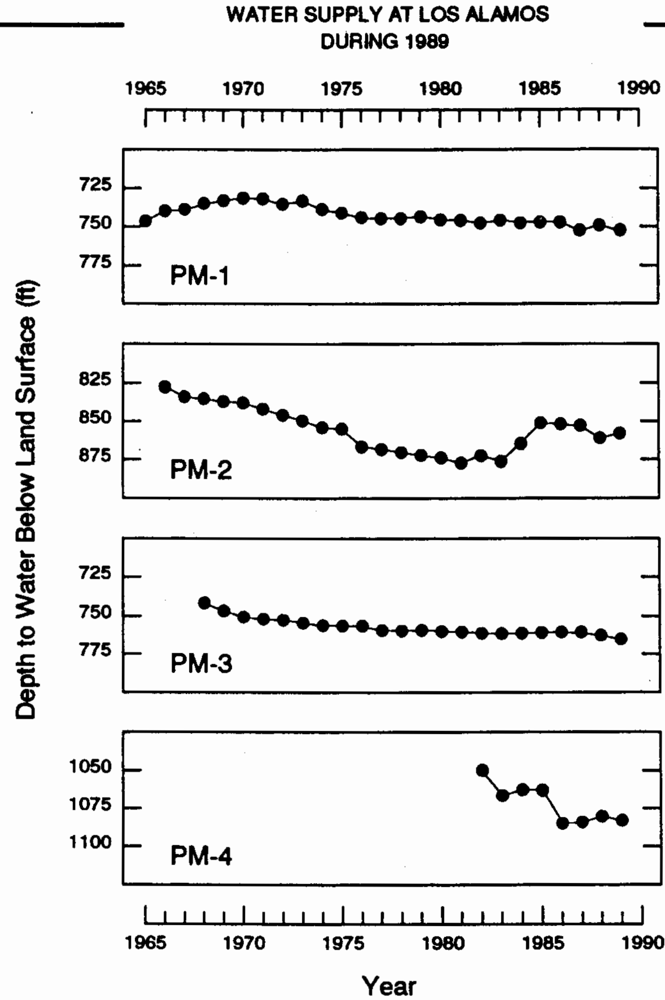

Fig.6. Nonpumping water levels in wells in the Pajarito well field (no water level data are available for well PM-5).

and elevates suspended sediment in the water. The water from the gallery is now used only for industrial supply at the steam plant at TA-16 as the suspended sediment concentrations could not be controlled.

During 1989, the gallery furnished about 1% of the total industrial and municipal water supply (Table III). The production decreased 11 $\times 10^6$ gal., from 34 $\times 10^6$ in 1988 to 23 $\times 10^6$ gal. in 1989 (Table I). This production in 1989 of 23 $\times 10^6$ was the same as that in 1956 and represents the lowest production from the gallery in 43 years of use (1947-1989).

IV. GUAJE AND LOS ALAMOS RESERVOIRS

Water from Guaje and Los Alamos reservoirs was used for municipal and industrial water supply at Los Alamos during the early days of the Manhattan Project. Use of water from the reservoirs for the municipal supply was discontinued about 1959 because of intermittent periods of turbidity caused by storm run-off and because of difficulties in maintaining bacteriological levels below limits allowed for municipal supply.

Table V. Average Water Levels for Nonpumping and Pumping Wells and Average Drawdown, 1988 and 1989

	Average Water Levels				Average Drawdown (ft)	
	Nonpumping (ft)		Pumping (ft)			
	1988	1989	1988	1989	1988	1989
Los Alamos Field						
Well LA-1	66	77	—	—	—	—
Well LA-1B	60	73	192	197	132	124
Well LA-2	117	141	296	322	179	188
Well LA-3	119	122	272	288	153	176
Well LA-4	—	—	—	—	—	—
Well LA-5	—	—	—	—	—	—
Well LA-6	—	—	—	—	—	—
Average per field	90	103				
Guaje Field						
Well G-1	280	282	445	451	165	169
Well G-1A	323	323	364	359	41	36
Well G-2	353	354	393	387	40	33
Well G-3	—	—	—	—	—	—
Well G-4	390	401	545	562	161	161
Well G-5	466	474	507	514	41	40
Well G-6	591	592	669	669	78	77
Average per field	400	404				
Pajarito Field						
Well PM-1	751	752	775	774	24	21
Well PM-2	869	860	931	920	62	60
Well PM-3	764	765	788	791	24	26
Well PM-4	1 079	1 085	1 117	1 122	38	37
Well PM-5	—	—	—	—	—	—
Average per field	866	865				

Both of the reservoirs and adjacent areas are now open for recreational use. The water from the reservoirs is also available for irrigation of lawns and shrubs in the community and the Laboratory. However, parts of the water lines are above ground and are subject to freezing; thus, water use from the reservoirs is limited to the period from late spring to early fall.

Guaje Reservoir in upper Guaje Canyon has a capacity of 0.25×10^6 gal. and a drainage area of 5.6 square miles. The reservoir is for diversion rather than storage, as perennial flow is maintained by springs in the canyon above the reservoir. Water flows by gravity through 6.8 miles of water line for irrigation of lawns and shrubs at Los Alamos Middle School and Guaje Pines Cemetery. The line from the reservoir is not a part of, nor is it connected to, the distribution system for municipal supply.

Annual production from Guaje Reservoir when it was used for municipal water supply from 1947 through 1958 ranged from an estimated 24×10^6 gal. to 213×10^6 gal. (Table VI). There is no record of the amounts of water used for irrigation from 1959 through 1971. Since 1972 the amount of water used for irrigation has ranged from 2.4 $\times 10^6$ gal. to 9.7 $\times 10^6$ gal. The amount used in 1989 was 4.6 $\times 10^6$ gal., up from the 2.4 $\times 10^6$ gal. used in 1988.

Los Alamos Reservoir in upper Los Alamos Canyon has a capacity of 13.4 $\times 10^6$ gal. and has a drainage area of 6.4 square miles. The water flows by gravity through about 2.6 miles of distribution lines for irrigation of lawns and shrubs at the Laboratory's Health Research Building, the Los Alamos High School, and Mesa School. The line from the reservoir is not a part of, nor is it connected to, the distribution system for the municipal water supply.

The annual production from the Los Alamos Reservoir when it was used for the municipal water supply from 1947 through 1958 ranged from 4.8 $\times 10^6$ gal. to 54.8 $\times 10^6$ gal. (Table VI). There is no record of water usage from the reservoir from 1959 through 1978, but since 1978 the amount of water used for irrigation has ranged from 0.9 $\times 10^6$ gal. to 3.3 $\times 10^6$ gal. The amount of water from the reservoir used for irrigation in 1989 was 3.3 $\times 10^6$ gal., up from the 1.4 $\times 10^6$ gal. used in 1988.

V. QUALITY OF WATER

The Laboratory conducts two separate programs to monitor groundwater quality of the area and to meet regulatory requirements. The first program, under the Laboratory's long-term environmental surveillance program, includes sampling of each water supply well and special monitoring wells. The results of this program are documented in detail in the annual environmental surveillance report.[23]

The second program monitors the quality of water in the Laboratory and County distribution system to ensure compliance with the Safe Drinking Water Act (SDWA). The EPA is responsible for enforcement of the SDWA and has established standards for water quality. These standards have been adopted by the state of New Mexico and are included in the New Mexico Regulations Governing Water Supplies. The New Mexico Environmental Improvement Division has been authorized by the EPA to administer federal drinking water regulations and standards in New Mexico. During 1989, all water samples collected under the SDWA program at Los Alamos were in compliance with the regulations. The following paragraphs summarize the results of this compliance program.

Water samples were collected from three locations in the distribution system (Los Alamos Airport, White Rock Fire Station, and Barranca School). These samples were analyzed by the state Scientific Laboratory Division (SLD).

At the three distribution system locations, we are in compliance with all federal and state regulations[23] pertaining to water quality as determined by the EPA's primary, secondary, and radiochemical standards. (Primary drinking and radiochemical water standards are directly related to the safety of drinking water supply; secondary standards are related more to the esthetic quality of water, as determined by public acceptance of the municipal supply.)

Water samples were collected between November 1988 and June 1989 from all of the wells and the Water Canyon Gallery and analyzed for organic compounds by the SLD. No organic contamination was present in any of the samples. Additionally, a total of 20 samples was

Table VI. Production from Guaje and Los Alamos Reservoirs for 1947–1958 and 1972–1989

Year	Guaje Reservoir[a] (10⁶ gal.)	Los Alamos Reservoir (10⁶ gal.)
Municipal Water-Supply Production		
1947	87.8	21.7
1948	119.8	21.9
1949	116.1	14.7
1950	79.9	20.6
1951	41	10.5
1952	131	33.6
1953	58	14.8
1954	66	16.9
1955	71	18.1
1956	24	4.8
1957	213	54.8
1958	193	49.4
Irrigation Production		
1972	5.8	—
1973	9.7	—
1974	4.9	—
1975	5.3	—
1976	4.4	—
1977	4.1	—
1978	2.8	—
1979	3.7	1.3
1980	4.7	2.3
1981	2.7	2.1
1982	3.4	2.8
1983	3.4	1.4
1984	3.0	1.3
1985	2.8	0.9
1986	2.4	1.5
1987	2.8	3.2
1988	2.4	1.4
1989	4.6	3.3

[a]Production from Guaje Reservoir for 1951–1958 is estimated.

collected from the distribution system and analyzed by the SLD for total trihalomethanes. All results were below the regulatory limit.[23]

Microbiological quality was monitored by JCI by collecting approximately 45 samples a month for analysis by the JCI laboratory. The samples were examined for the presence of coliform bacteria, which are used as an indicator to determine if harmful bacteria could be present. During 1989, only one sample contained coliform bacteria. This sample was from the distribution system at TA-33, and the single coliform bacterium was found to be a nonfecal, soil-related coliform. All analytical results from coliform testing showed compliance with regulations. [23]

During 1989, approximately 6% of the microbiological samples collected were found to have noncoliform bacteria present. This does not violate drinking water regulations but it does indicate stagnant water and possibly dirt in the distribution lines. Both JCI Utilities and Los Alamos County have established water system flushing programs to reduce stagnant water in lines. These programs have been effective in reducing stagnant water and associated noncoliform bacteria. [23]

VI. CONSTRUCTION AND DEVELOPMENT OF SUPPLY WELL OTOWI-4

Drilling and construction of Well Otowi-4 began in September 1989 and was completed in March 1990. Descriptions of the construction and development of the well are included in this report as part of the reporting of water supply activities. The construction of the well fulfills part of the "Restoration Water Well Replacement Program," which is a long-range plan to replace the Los Alamos well field and boost declining production of the Guaje well field. The capacity of wells in both fields has deteriorated significantly with time.[21] The ages of the wells to be replaced range from 29 to 43 years. The Otowi well field, which will replace the Los Alamos field, is located west of the Los Alamos field and north of the Pajarito well field. When complete, the Otowi well field will be composed of four wells (Fig. 1).[21]

Well Otowi-4 was drilled to a depth of 2 806 ft and was completed at a depth of 2 585 ft (Fig. 7 and Table VII). Surface water and near-surface groundwater were cased out of the wells with a surface conductor pipe cemented around the well to a depth of 60 ft. A second conductor pipe inside the first pipe is cemented to a depth of 723 ft. Blank casing lines the well from the surface to a depth of 115 ft; the screened section of the well extends from 1 115 to 2 585 ft.

Well Otowi-4 was completed into the main aquifer of the Los Alamos area, as are the other supply wells. The top of the main aquifer is about 780 ft below land surface. A geologic log of the well indicated that the borehole penetrated alluvium on the canyon floor and extended down through the Bandelier Tuff, Puye Conglomerate (fanglomerate member and Totavi Lentil), and the basaltic rocks of Chino Mesa,which are interbedded with the Puye Conglomerate. The well is completed in the sediments of the Tesuque Formation, which, at this location, is typical conglomerate (boulders and gravels), with some basalts, sandstones, siltstones, and clays. The Tesuque Formation is also penetrated by the high-yield wells of the Pajarito well field (Table VIII). The geophysical logs (temperature, microlog, dual-induction, and compensated neutron-formation density), together with an analysis of the cuttings indicated the lower part of the Puye Conglomerate and the upper part of the Tesuque Formation consisted of permeable conglomerates and basalts with an increasing amount of less permeable silts and clays below 2 460 ft.

VII. ANALYSIS OF THE OTOWI-4 STEP-DRAWDOWN PUMP TEST

We conducted a 12-hour step-drawdown pump test on Well Otowi-4 on April 5, 1990, immediately after well development procedures were completed and the water level became static. Water levels

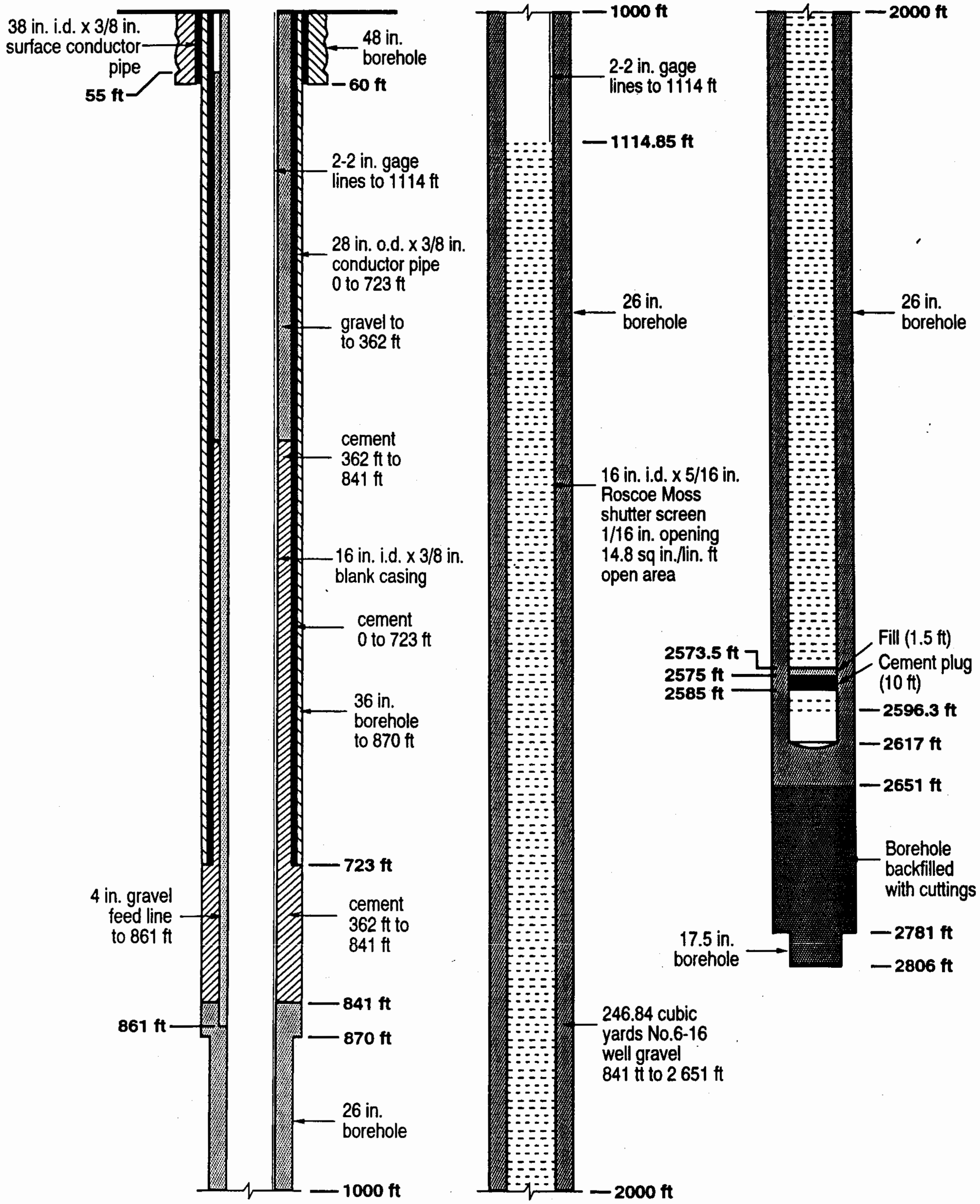

Fig. 7. Well Construction of Well Otowi-4.

Table VII. Construction Data for Well Otowi-4

Hole Log

Depth (ft)		Hole
From	To	Diameter (in)
0	60	48
60	870	36
870	2 781	26
2 781	2 806	17.5

Casing Log

Depth (ft)		Casing	
From	To	Dimension	Material
0	60	38 in I.D. by 0.375 in.	Surface conductor pipe, 3/8" wall thickness cemented in from 0 to 60 ft
0	723	28 in 0.D.	Conductor pipe, cemented in 0 to 723 ft
0	2 617	16 in I.D.	Production string: 0 to 1 115 ft blank pipe; 1 115 to 2 596 ft screen (Roscoe Moss shutter, 0.0625-in. opening [14.8 sq in./linear ft]); 2 596 to 2 617 ft blank pipe with steel plate on bottom end. The steel plate was broken off the bottom and a cement plug was set from in the production string from 2 575 to 2 578 ft.

Construction Log

- Cement or gravel fills the space between the borehole or production string and the conductor pipe (see Fig. 7):

Cement	0 to 55 ft
Gravel	55 to 362 ft
Cement	362 to 841 ft
Gravel	841 to about 2 651, with backfill or cuttings from 2 651 to 2 806 ft.

- Gravel feed line, 4 in O.D., extends from 0 to 861 ft, where it is set 20 ft into the gravel pack that surrounds the production string from 861 to 2 585 ft.
- Two gage lines, 2 in I.D., are welded to the outside of the production string from 0 to 1 114 ft where they enter the production string.

were recorded over time in the pumping well using an electric water level meter. Four different pumping rates were used during this test, with each step lasting about three hours. Observed drawdowns versus time are plotted in Fig. 8; recorded pumping rates versus time are shown in Fig. 9.

In this test, we used the step-drawdown procedure described by Bear [24] and the data analysis procedures are described by Bouwer.[25] Basically, the step-drawdown test procedure is used to characterize well losses and to establish the success of well development activities. Future step-drawdown tests can be directly compared to those reported here. Temporal changes in the well-loss coefficient, C, as defined below, would be an indication of changes in the well's gravel pack over time. A large increase in the value of this coefficient over time would indicate wellbore clogging in the production screen or gravel pack.[26] Hence, the current step-drawdown test is not only useful in evaluating the present condition of the gravel pack but it should also prove helpful in future performance evaluations of Well Otowi-4.

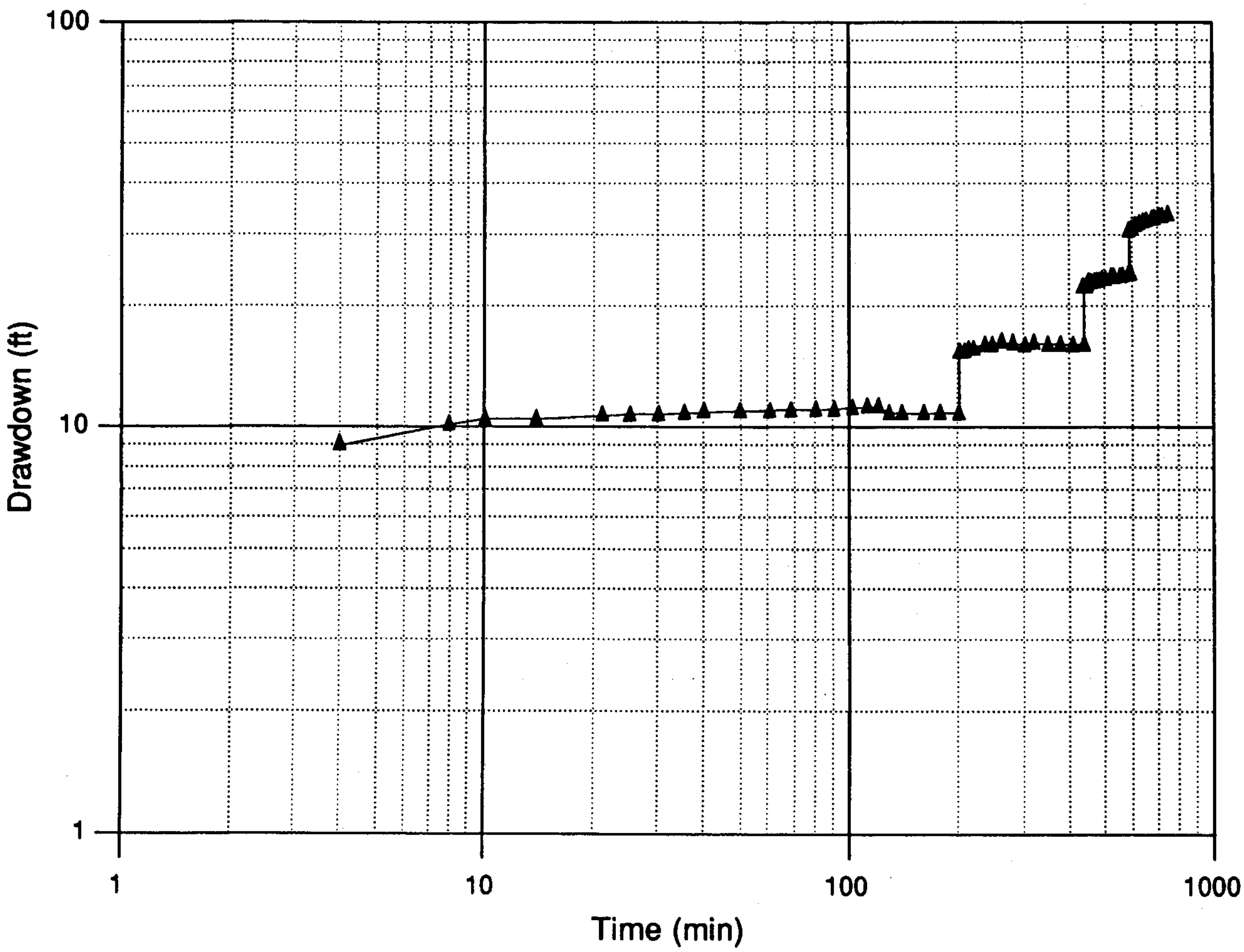

Fig. 8. Observed drawdown, over time, recorded for well Otowi-4 on April 5, 1990.

Table VIII. Geologic Log of Otowi-4 (land surface 6 627 ft)

	Thickness (ft)	Depth from Surface (ft)
Recent Alluvium		
Boulders and cobbles in a matrix of gravels, sand, silt, and clay; shallow water in the alluvium at 27 to 28 ft	28	28
Bandelier Tuff		
Tuff, light tan to light gray; some pumice, quartz, and sanidine crystals and crystal fragments; small rock fragments of latite and rhyolite in an ash matrix, in some places weathered to silt and clay	155	183
Puye Conglomerate		
Fanglomerate Member		
Fanglomerate; cobbles and boulders of latite and rhyolite in a matrix of gravel, sand, silt, and clay; clay and silt from 234 to 240 ft	107	290
(Some perched water was visible in a video log of the 48-in. hole at about 253 ft where the water cascaded in from large gravel.)		
Basaltic Rocks of Chino Mesa		
Basalt, black to dark gray, vesicular to dense; some scoria and pumice, probably represents several basaltic flows with thin interbedded sediments	123	413
Puye Conglomerate		
Fanglomerate Member		
Fanglomerate; cobbles and boulders of latites and rhyolites in a matrix of gravel, sand, silt, and clay; thin lenses of silty sand from 580 to 590 ft, 610 to 620 ft, and 660 to 670 ft	299	712
Totavi Lentil		
Conglomerate; gray, cobbles and boulders of quartzite; rocks fragments of granite, latite, rhyolite in a matrix of sand, silt, and clay; sand lenses from 710 to 730 ft	98	810
Tesuque Formation		
Conglomerate; gray to dark gray cobbles and boulders of quartzite; dark gray latite and rhyolite, angular to well-rounded, in a matrix of silt, clay, sand, and gravel, with some thin interbedded lenses of silty sandstone, siltstone, and claystone; clay and siltstone from 845 to 850 ft, 915 to 932 ft, 1 144 to 1 154 ft, and 1 160 to 1 170 ft	344	1 154

Basalt		
Basalt, dark gray to black, dense to vesicular; a series of basaltic flows containing thin to thick interflow breccias of clay and gravel; thick interflow breccias of clay and gravel from 1 305 to 1 318 ft; basaltic fragments, red scoria, gravel, and clay at base of flow from 1 338 to 1 347 ft	193	1 347
Conglomerate		
Conglomerate, gray, consisting of cobbles in a matrix of gravel, sand, silt, and clay; rock fragments angular to subrounded; siltstone and claystone from 1 358 to 1 370 ft, 1 392 to 1 400 ft, and 1 410 to 1 421 ft	74	1 421
Basalt		
Basalt, gray, dense containing some vesicules; some thin interflow breccias of gravels in silt and clay	44	1 465
Conglomerate		
Conglomerate, gray consisting of gravels in a matrix of silt and clay; rock fragments, angular to well-rounded; gravel in silts and clay underlying basalts from 1 465 to 1 472 ft; siltstone or silty sandstone from 1 545 to 1 552 ft, 1 610 to 1 614 ft, 1 722 to 1 730 ft, 1 792 to 1 798 ft, and 1 810 to 1 825 ft	387	1 852
Sandstone		
Silty sandstone, gray, with sand-size fragments, subangular to subrounded; quartz, clear to milky; quartzite pink to white; sand, gray, tan to small gravel subangular to rounded	22	1 874
Conglomerate		
Conglomerate; gray to dark gray, boulders and cobbles in a matrix of gravel, sand, silt, and clay; rock fragments angular to rounded; lenses of silt and clay; several thin beds of gray ash; silty sandstone at 2 335 to 2 345 ft, 2 375 to 2 382 ft, and 2 435 to 2 342 ft	686	2 560
Sandstone		
Sandstone, silty, light gray to light tan; quartzite multicolored gray to pink; some pink feldspar; minerals and small rock fragments subangular to subrounded; silty clay in sandstone increases from 2 560 to 2 600 ft	40	2 600
Silty sandstone and siltstone lenses with thin lenses of gravel, sand, and clay	20	2 620
Siltstone		
Siltstone, tan, with thin lenses of sand, silt, and white ash	40	2 660

Sandstone		
Silty sandstone, tan, containing lenses of gravel, sand, and clay; gray quartzite, angular to subrounded; fragments of latite, ryholite, and basalt; clear and milky quartz fragments; also some thin lenses of white ash	90	2 750
Ash		
Ash, white, weathered, with small quartz crystal fragments. Ash matrix contains small fragments of biotite.	20	2 770
Claystone		
Claystone, gray to tan, alternating with thin lenses of siltstone and silty sandstone; claystone contains some thin lenses of white ash	36	2 806

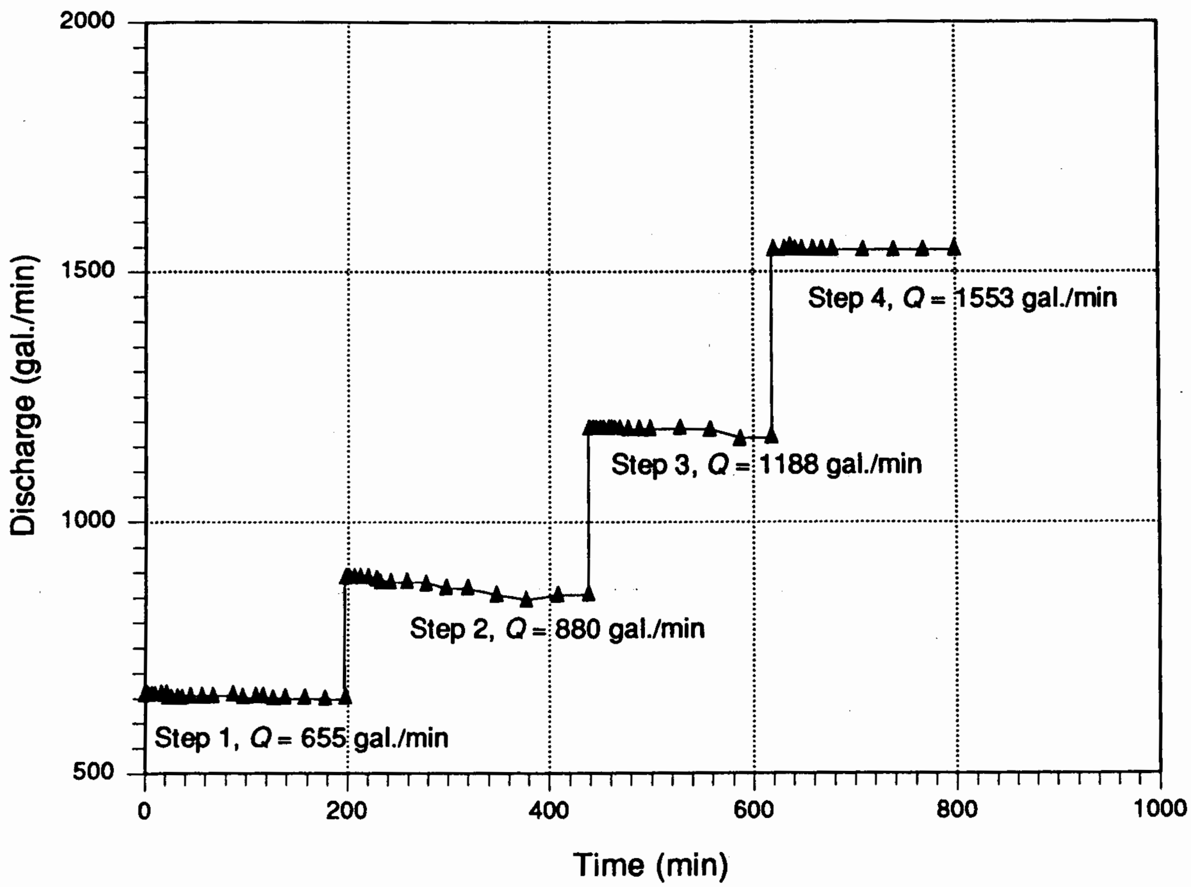

Fig. 9. Observed discharge, over time, recorded for well Otowi-4 on April 5, 1990.

Table IX. Summary of Step-Drawdown Pump Test on Well Otowi-4

Step	Discharge, Q (gal./min)	Total s_{iw} at $t^* = 190$ min (ft)	Capacity (gal.min/ft)	Summed s_{iw} at $t^* = 180$ min (ft)
1.	655	11.26	58.2	11.26
2.	880	16.30	54.0	16.09
3.	1 188	23.77	50.0	23.40
4.	1 553	33.59	46.2	32.95

Pumping-induced drawdown inside a water well (s_{iw}) is the vertical distance between the static piezometric surface in the formation and the water level inside the well during production. This distance is effectively the sum of drawdown in the aquifer (s_a) and drawdown caused by friction losses in the gravel pack (s_{wl}). Water flow in the aquifer varies linearly with discharge (Q), and is described by various well flow equations (for example, the Theis equation for confined aquifers). Hence, when s_a varies linearly with Q, flow will be laminar. However, flow through the gravel pack and well screen will usually be turbulent. In equation form these losses are expressed as

$$s_{iw} = BQ + CQ_n \tag{1}$$

where $B*Q$ represents drawdown in the well caused by the aquifer loss, while $C*Q_n$ represents drawdown in the well due to wellbore entrance losses. The parameters B, C, and n can be uniquely determined from a step-drawdown pump test for a particular well at a given time. [25] During the Otowi-4 test, the well was pumped at a constant Q (that is, with less than a 5% variation in Q for any given step, as seen in Figs. 8 and 9) until s_{iw} changed relatively little. Then Q was increased to a higher value, and s_{iw} was again measured after the same time interval (in this test, $t^* = 180$ minutes). This procedure was repeated until incremental s_{iw} values resulting from the new Q at t^* were known for four different values of Q. These incremental s_{iw} values were then summed for use in the final analysis. These data are summarized in Table IX.

Equation (1) can be easily manipulated into a more convenient form, which is

$$\mathrm{Log}(s_{iw}/Q - B) = \mathrm{Log}(C) + (n-1)\mathrm{Log}(Q). \tag{2}$$

Values of Q and summed s_{iw} from the Table IX were then used in Eq.(2) in order to find B, C, and n. Initially B was assumed to be zero, and Q versus $(s_{iw}/Q - B)$ was plotted on double-logarithmic paper. This initial value of B was successively increased until a straight line was finally obtained. The value that yields this straight line is the correct value for B. The corresponding slope of this straight line equals ($n-1$). Finally Eq. (2) is solved for C, using the computed B and n values, and any of the known Q and summed s_{iw} data pairs. Results of this analysis are shown in Fig. 10.

Because the step-drawdown value of n is less than 2, it indicates that full wellbore turbulence did not completely develop over the entire well screen length during this test. These results indicate that a good gravel pack condition exists in the Otowi-4 well. However, at calculated discharges above 2 600 gpm, well losses due to entrance velocity turbulence effects are projected to exceed formation losses. A water production rate of 1 500 to 1 600 gpm is recommended for Otowi-4 because gravel pack losses are less than formation losses and wellbore entrance velocities over the entire well screen length are laminar at this pumping rate.

Fig. 11 shows the observed values of specific capacity versus discharge. Specific capacity, defined as discharge divided by drawdown, is an indication of well yield per foot of drawdown.

Using the step-drawdown test data, we can compute preliminary values for formation transmissivity (T) and storage coefficient (S) from the first pumping cycle. The time-drawdown data from this first pumping-test cycle are shown in Fig. 12; the corresponding leaky, confined-aquifer type curves are shown in Fig. 13.[26] Using the type-curve matching procedure, we

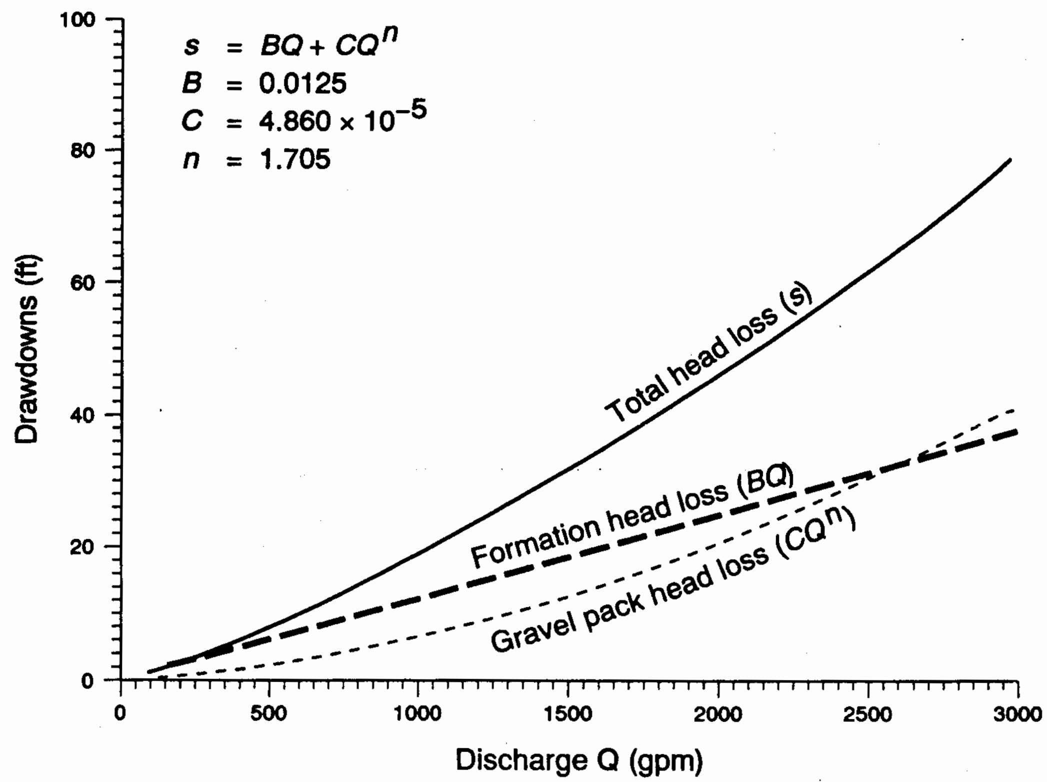

Fig. 10. Step-drawdown test results recorded for Well Otowi-4 on April 5.

obtained a match point corresponding to the $r/B = 0.010$ curve is obtained; hence at $s = 1.2$ ft and $t = 8.3$ minutes (see Fig. 12), $W(u,r/B) = 1.0$ and $1/u = 10\,000$ (see Fig. 13). Thus at $Q = 655$ gpm and $r = 1$ ft, values for T and S are computed from

$$s = QW(u,r/B)/(4\pi T); \quad u = r^2S/4Tt. \tag{3}$$

Eq. (3) yields $T = 62\,548$ gpd/ft and $S = 1.93 \times 10^{-3}$. The value for S represents a storage coefficient midway between a fully confined and phreatic aquifer and is consistent with other hydrogeological observations from adjacent production wells. The type-curve matching procedure used here also implies that the main aquifer is presumably leaky or that an unidentified recharge boundary is located near Otowi-4. The aquifer production zone is highly stratified; hence, it may only appear leaky. This apparent leaky aquifer behavior may have also resulted from wellbore storage effects that did not completely dissipate in 180 minutes. It should be emphasized that these values for T and S represent preliminary estimates made from a very short

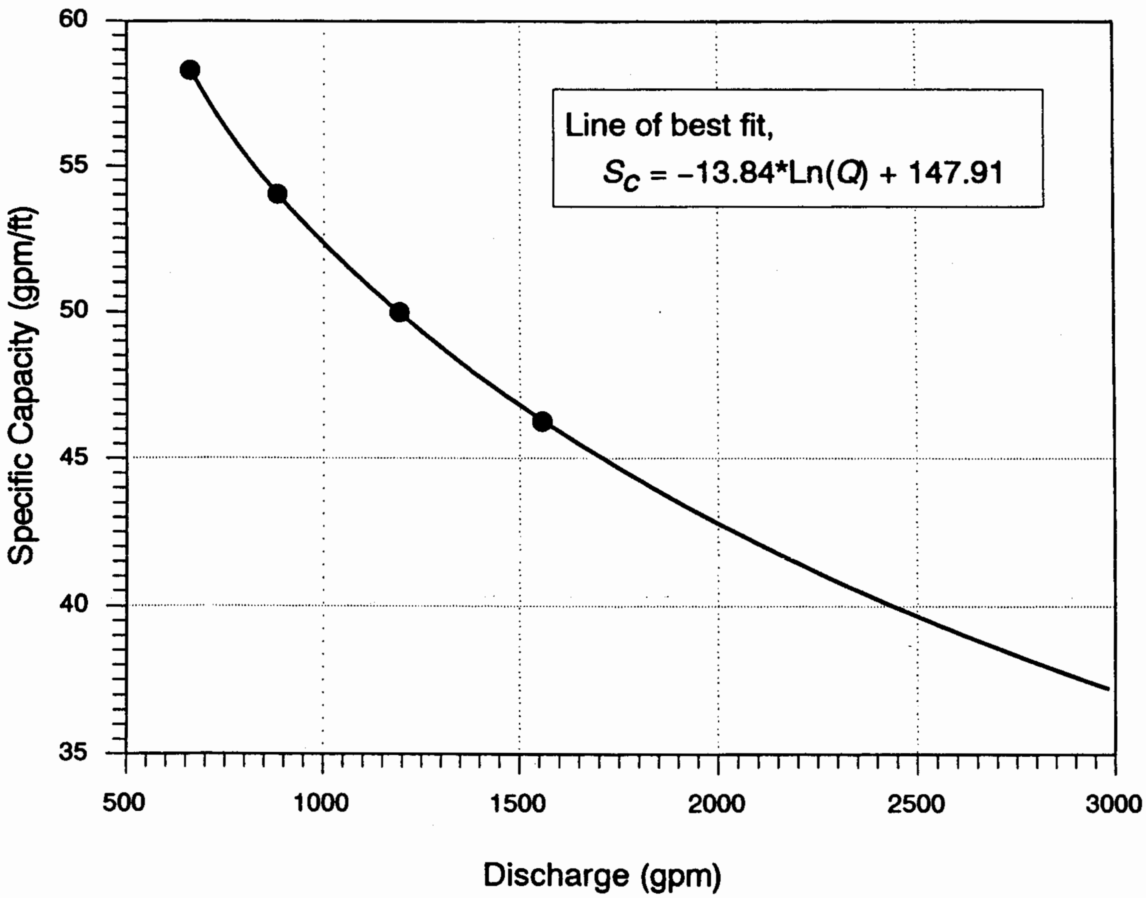

Fig 11. Discharge versus specific capacity (S_C) as recorded for Well Otowi-4 on April 5, 1990.

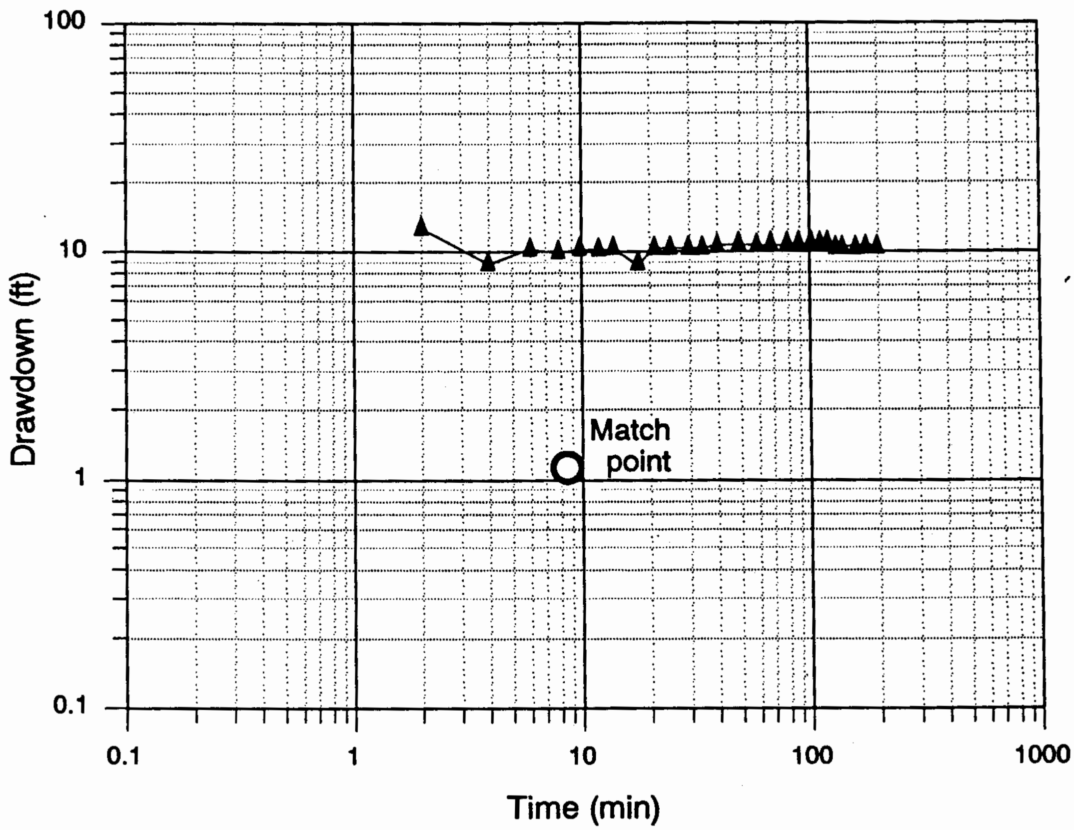

Fig. 12. Curve showing field drawdown versus time as recorded for well Otowi-4 on April 5, 1990. Note that the indicated match point corresponds with the match point in Fig. 13.

pumping test cycle. Furthermore, water level observations were recorded in the production well, and these are not as desirable as those from a separate, fully penetrating observation well. More precise values for these parameters should be available when a longer-term constant – Q pump test is performed.

Observation test Well TW-3, located approximately 400 feet east of Otowi-4, is completed to a depth of about 800 feet. Well TW-3 did not show any pumping-induced drawdown effects during the Otowi-4 test. It showed only water level fluctuations attributable to barometric pressure fluctuations. Furthermore, recovery data in the Otowi-4 well were not collected because the pump used in the test did not have a check valve to prevent water from returning to the well. Hence, once the pump was turned off, a column of water approximately 700 feet long immediately flowed back into the well.

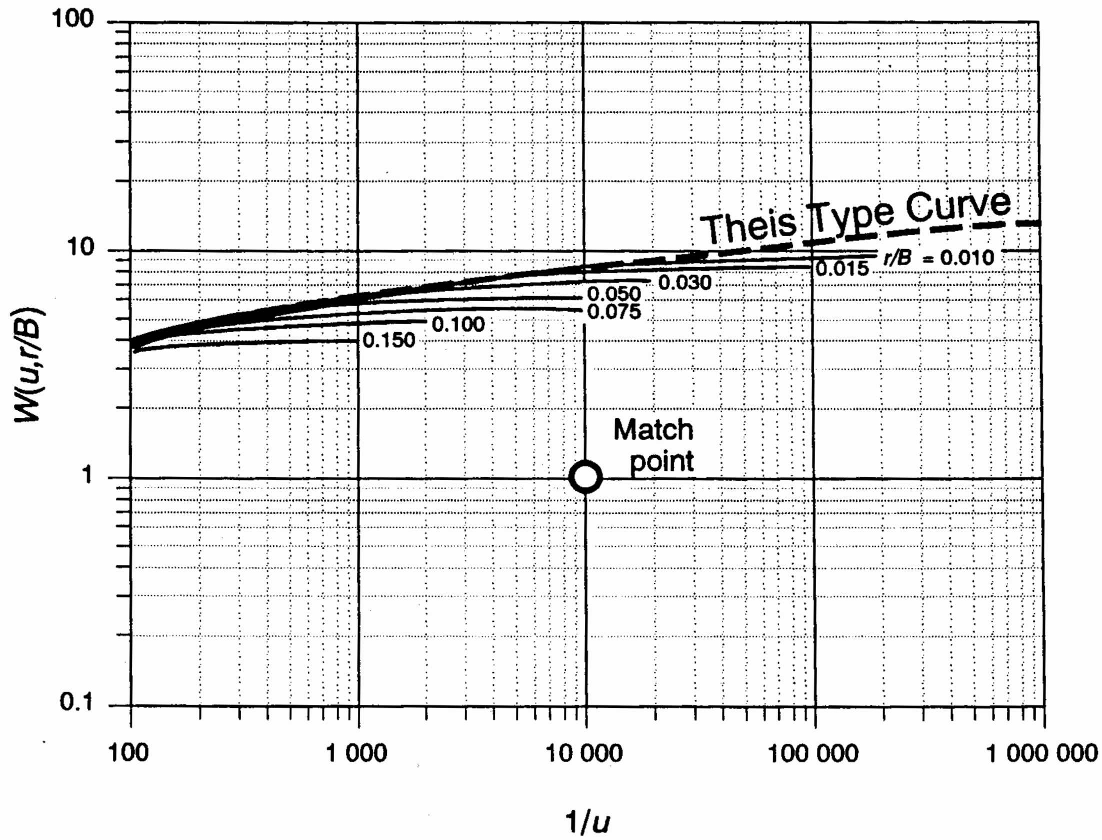

Fig. 13. Leaky, confined-aquifer type curves. Note that the indicated match point corresponds with the match point in Fig. 12.

VIII. SUMMARY

Operations of wells and well fields in 1989 were satisfactory. Water level trends in the wells were as expected under the current amount of annual production. Future operations of the wells and water supply system should be continued as in the past. Continued collection of data from wells and well fields will be necessary to evaluate changing conditions and actions required to assure a reliable water supply in the future.

ACKNOWLEDGEMENTS

Statistics on well production were collected by personnel from Johnson Control World Services Inc. and were compiled for this report by the Laboratory's Environmental Protection Group.

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Appendix

Annual Statistics on Aquifer Characteristics

Well LA-1

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level (Nonpumping) (ft)
1947	3 468	54.0	259.5	—
1948	2 988	34.7	193.6	—
1949	1 361	26.7	327.0	—
1950	563	10.5	310.8	19.0
1951	1 215	14.6	200.3	59.0
1952	286	3.4	198.1	40.0
1953	0	0.0	0.0	36.0
1954	0	0.0	0.0	44.0
1955	690	9.7	234.3	51.0
1956	39	0.0	0.0	33.0
1957	0	0.0	0.0	33.0
1958	0	0.0	0.0	10.0
1959	0	0.0	0.0	13.0
1960	0	0.0	0.0	13.0
1961	0	0.0	0.0	59.0
1962	0	0.0	0.0	84.0
1963	0	0.0	0.0	90.0
1964	0	0.0	0.0	95.0
1965	0	0.0	0.0	76.0
1966	0	0.0	0.0	70.0
1967	0	0.0	0.0	52.0
1968	0	0.0	0.0	42.0
1969	0	0.0	0.0	38.0
1970	0	0.0	0.0	37.0
1971	0	0.0	0.0	51.0
1972	0	0.0	0.0	49.0
1973	0	0.0	0.0	55.0
1974	0	0.0	0.0	53.0
1975	0	0.0	0.0	58.0
1976	0	0.0	0.0	69.0
1977	0	0.0	0.0	74.0
1978	0	0.0	0.0	68.0
1979	0	0.0	0.0	38.0
1980	0	0.0	0.0	40.0
1981	0	0.0	0.0	51.0
1982	0	0.0	0.0	98.0
1983	0	0.0	0.0	46.0
1984	0	0.0	0.0	71.0
1985	0	0.0	0.0	63.0
1986	0	0.0	0.0	34.0
1987	0	0.0	0.0	70.0
1988	0	0.0	0.0	66.0
1989	0	0.0	0.0	77.0

Appendix (Cont)

Well LA-1B

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1960	415	36.3	1457.8	7.0	111.0	104.0	14.0
1961	3727	124.7	557.6	54.0	154.0	100.0	5.6
1962	3936	129.1	546.7	72.0	169.0	97.0	5.6
1963	3649	117.4	536.2	74.0	170.0	96.0	5.6
1964	4174	130.3	520.3	81.0	183.0	102.0	5.1
1965	3007	97.9	542.6	63.0	170.0	107.0	5.1
1966	2589	83.9	540.1	50.0	169.0	119.0	4.5
1967	2519	84.9	561.7	39.0	153.0	114.0	4.9
1968	2183	74.0	565.0	32.0	147.0	115.0	4.9
1969	2244	75.7	562.2	22.0	142.0	120.0	4.7
1970	2369	79.7	560.7	22.0	143.0	121.0	4.6
1971	2633	89.1	564.0	31.0	162.0	131.0	4.3
1972	2215	75.3	566.6	31.0	163.0	132.0	4.3
1973	2628	87.2	553.0	37.0	170.0	133.0	4.2
1974	2282	73.9	539.7	35.0	161.0	126.0	4.3
1975	2308	74.4	537.3	42.0	168.0	126.0	4.3
1976	2521	79.6	526.2	50.0	176.0	126.0	4.2
1977	2782	84.2	504.4	47.0	167.0	120.0	4.2
1978	2306	75.6	546.3	42.0	162.0	120.0	4.6
1979	1354	45.9	564.6	13.0	134.0	121.0	4.7
1980	1955	62.9	536.3	21.0	146.0	125.0	4.3
1981	2299	73.9	537.7	26.0	144.0	118.0	4.5
1982	3707	108.1	486.0	71.0	180.0	109.0	4.5
1983	407	12.1	495.0	61.0	160.0	99.0	5.0
1984	2673	96.9	604.0	75.0	201.0	126.0	4.8
1985	1919	68.5	595.0	55.0	179.0	124.0	4.8
1986	1598	54.9	573.0	25.0	144.0	119.0	4.8
1987	2753	97.3	589.0	66.0	187.0	121.0	4.9
1988	2187	75.4	574.0	60.0	192.0	132.0	4.4
1989	2864	97.8	569.0	73.0	197.0	124.0	4.6

Appendix (Cont)

Well LA-2

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1947	963	27.6	477.7	—	—	—	—
1948	3659	59.3	270.1	—	—	—	—
1949	1654	41.8	421.2	—	—	—	—
1950	614	15.6	423.5	59.0	285.0	226.0	1.9
1951	2415	57.7	398.2	111.0	305.0	194.0	2.1
1952	1980	46.3	389.7	101.0	300.0	199.0	2.0
1953	2201	47.2	357.4	100.0	301.0	201.0	1.8
1954	2601	56.8	364.0	116.0	—	—	—
1955	2223	49.4	370.4	110.0	—	—	—
1956	1805	44.2	408.1	84.0	—	—	—
1957	1066	29.6	462.8	53.0	277.0	224.0	2.1
1958	1166	31.1	444.5	60.0	270.0	210.0	2.1
1959	1599	40.7	424.2	71.0	303.0	232.0	1.8
1960	2169	51.6	396.5	76.0	305.0	229.0	1.7
1961	2149	44.4	344.3	101.0	313.0	212.0	1.6
1962	1823	35.7	326.4	111.0	314.0	203.0	1.6
1963	1999	40.7	339.3	127.0	332.0	205.0	1.7
1964	1924	34.2	296.3	137.0	347.0	210.0	1.4
1965	1911	39.8	347.1	121.0	330.0	209.0	1.7
1966	1070	21.4	333.3	108.0	340.0	232.0	1.4
1967	238	4.9	343.1	78.0	304.0	226.0	1.5
1968	502	11.3	375.2	64.0	305.0	241.0	1.6
1969	155	3.8	408.6	50.0	297.0	247.0	1.7
1970	341	7.2	351.9	59.0	310.0	251.0	1.4
1971	1787	31.8	296.6	88.0	318.0	230.0	1.3
1972	2189	39.3	299.2	96.0	322.0	226.0	1.3
1973	2625	46.7	296.5	106.0	334.0	228.0	1.3
1974	2033	36.8	301.7	109.0	325.0	216.0	1.4
1975	2310	40.2	290.0	103.0	320.0	217.0	1.3
1976	2488	39.9	267.3	113.0	322.0	209.0	1.3
1977	2775	42.5	255.3	118.0	314.0	196.0	1.3
1978	2299	39.5	286.4	112.0	338.0	226.0	1.3
1979	1353	26.2	323.0	75.0	316.0	241.0	1.3
1980	1960	33.8	287.4	84.0	318.0	234.0	1.2
1981	1991	34.4	300.0	94.0	336.0	242.0	1.2
1982	3174	51.2	269.0	161.0	348.0	187.0	1.4
1983	2752	54.5	330.0	121.0	321.0	200.0	1.6
1984	2753	53.7	325.0	130.0	323.0	193.0	1.7
1985	2027	37.1	305.0	112.0	291.0	179.0	1.7
1986	1289	24.1	312.0	74.0	252.0	178.0	1.8
1987	2619	39.6	252.0	129.0	319.0	190.0	1.3
1988	1936	33.0	284.0	117.0	296.0	179.0	1.6
1989	2647	43.2	272.0	141.0	329.0	188.0	1.4

Appendix (Cont)

Well LA-3

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1947	1 476	64.9	732.8	—	—	—	—
1948	3 647	82.5	377.0	—	—	—	—
1949	1 505	41.7	461.8	—	—	—	—
1950	2 793	57.8	344.9	97.0	231.0	134.0	2.6
1951	3 554	66.9	313.7	116.0	233.0	117.0	2.7
1952	2 514	58.6	388.5	94.0	218.0	124.0	3.1
1953	3 104	69.7	374.2	103.0	229.0	126.0	3.0
1954	2 595	57.3	368.0	101.0	225.0	124.0	3.0
1955	2 195	48.7	369.8	91.0	226.0	135.0	2.7
1956	1 849	42.1	379.5	74.0	222.0	148.0	2.6
1957	1 080	26.1	402.8	56.0	219.0	163.0	2.5
1958	1 612	33.6	347.4	49.0	225.0	176.0	2.0
1959	1 821	35.0	320.3	54.0	231.0	177.0	1.8
1960	2 174	38.4	294.4	68.0	230.0	162.0	1.8
1961	1 939	34.7	298.3	85.0	189.0	104.0	2.9
1962	2 361	45.4	320.5	93.0	192.0	99.0	3.2
1963	2 128	42.5	332.9	81.0	197.0	116.0	2.9
1964	2 574	50.4	326.3	104.0	217.0	113.0	2.9
1965	1 961	43.3	368.9	79.0	220.0	141.0	2.6
1966	2 236	46.1	343.6	81.0	219.0	138.0	2.5
1967	2 274	47.4	347.4	86.0	218.0	132.0	2.6
1968	2 127	42.7	334.6	82.0	251.0	169.0	2.0
1969	2 072	40.1	322.6	58.0	246.0	188.0	1.7
1970	2 303	44.0	318.4	55.0	241.0	186.0	1.7
1971	2 556	45.4	296.0	77.0	250.0	173.0	1.7
1972	2 205	39.7	300.1	73.0	251.0	178.0	1.7
1973	977	20.3	346.3	65.0	248.0	183.0	1.9
1974	2 291	43.5	316.5	73.0	244.0	171.0	1.9
1975	2 306	43.3	313.0	80.0	253.0	173.0	1.8
1976	2 474	42.3	285.0	88.0	260.0	172.0	1.7
1977	2 779	47.3	283.7	89.0	248.0	159.0	1.8
1978	2 308	42.4	306.4	87.0	250.0	163.0	1.9
1979	1 343	28.1	348.1	58.0	243.0	185.0	1.9
1980	1 952	35.1	299.9	61.0	237.0	176.0	1.7
1981	2 297	41.5	301.1	70.0	240.0	170.0	1.8
1982	3 691	54.9	247.0	118.0	246.0	128.0	1.9
1983	949	14.7	258.0	89.0	203.0	129.0	2.0
1984	838	16.6	329.0	142.0	301.0	159.0	2.0
1985	2 078	41.9	336.0	104.0	280.0	176.0	1.9
1986	1 328	26.9	338.0	88.0	255.0	167.0	2.0
1987	2 710	50.9	313.0	118.0	289.0	171.0	1.8
1988	2 130	40.1	313.0	119.0	272.0	153.0	2.0
1989	2 808	51.9	308.0	122.0	298.0	176.0	1.8

Appendix (Cont)

Well LA-4

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1948	1 570	42.7	453.3	—	—	—	—
1949	940	37.5	664.9	—	—	—	—
1950	4 350	164.9	631.8	278.0	353.0	75.0	8.4
1951	4 909	173.6	589.4	285.0	357.0	72.0	8.2
1952	3 429	119.6	581.3	267.0	339.0	72.0	8.1
1953	3 034	109.1	599.3	264.0	335.0	71.0	8.4
1954	2 133	78.2	611.0	255.0	329.0	74.0	8.3
1955	2 647	94.5	595.0	268.0	341.0	73.0	8.2
1956	3 402	120.0	588.9	273.0	346.0	73.0	8.1
1957	2 844	105.4	617.7	270.0	345.0	75.0	8.2
1958	2 973	110.3	618.3	270.0	342.0	72.0	8.6
1959	3 084	113.5	613.4	275.0	346.0	71.0	8.6
1960	4 084	145.6	594.2	296.0	365.0	69.0	8.6
1961	3 687	129.7	586.3	296.0	365.0	69.0	8.5
1962	3 688	129.3	584.3	286.0	359.0	73.0	8.0
1963	3 718	130.5	585.0	280.0	351.0	71.0	8.2
1964	4 500	155.0	574.1	291.0	361.0	70.0	8.2
1965	3 110	111.4	597.0	279.0	349.0	70.0	8.5
1966	3 279	115.6	587.6	285.0	356.0	71.0	8.3
1967	2 127	77.1	604.1	278.0	350.0	72.0	8.4
1968	2 276	81.7	598.3	280.0	351.0	71.0	8.4
1969	1 694	61.8	608.0	282.0	358.0	76.0	8.0
1970	2 333	83.5	596.5	286.0	363.0	77.0	7.7
1971	2 519	89.0	588.9	287.0	373.0	86.0	6.8
1972	2 322	82.6	592.9	282.0	367.0	85.0	7.0
1973	2 616	92.4	588.7	294.0	377.0	83.0	7.1
1974	2 306	82.2	594.1	286.0	367.0	81.0	7.3
1975	2 319	82.3	591.5	272.0	355.0	83.0	7.1
1976	2 802	98.2	584.1	277.0	373.0	96.0	6.1
1977	2 741	96.4	586.2	278.0	374.0	96.0	6.1
1978	2 248	80.1	594.2	271.0	368.0	97.0	6.1
1979	2 964	104.6	587.9	280.0	376.0	96.0	6.1
1980	3 322	115.3	578.5	284.0	385.0	101.0	5.7
1981	2 573	89.4	579.1	289.0	393.0	104.0	5.6
1982	0	0	0	—	—	—	—
1983	1 840	61.5	577.0	287.0	392.0	105.0	5.3
1984	2 695	87.1	539.0	290.0	383.0	93.0	5.8
1985	2 667	86.4	540.0	292.0	378.0	86.0	6.3
1986	1 172	38.8	552.0	284.0	377.0	93.0	5.9
1987	38	1.6	—	269.0	357.0	88.0	—
1988	0	0.0	—	—	—	—	—
1989	0	0.0	—	—	—	—	—

Appendix (Cont)

Well LA-5

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1948	1 171	40.4	575.0	—	—	—	—
1949	1 763	58.5	553.0	—	—	—	—
1950	4 052	130.1	535.1	131.0	254.0	123.0	4.4
1951	6 004	187.4	520.2	162.0	272.0	110.0	4.7
1952	3 425	109.6	533.3	147.0	259.0	112.0	4.8
1953	3 278	103.9	528.3	141.0	257.0	116.0	4.6
1954	2 546	80.1	524.4	137.0	259.0	122.0	4.3
1955	3 158	97.3	513.5	145.0	267.0	122.0	4.2
1956	3 476	104.5	501.1	150.0	276.0	126.0	4.0
1957	2 868	86.0	499.8	150.0	277.0	127.0	3.9
1958	3 009	89.9	498.0	151.0	277.0	126.0	4.0
1959	3 088	93.5	504.6	155.0	280.0	125.0	4.0
1960	4 088	119.1	485.6	168.0	288.0	120.0	4.0
1961	3 534	100.3	473.0	165.0	288.0	123.0	3.8
1962	3 735	107.7	480.6	172.0	—	—	—
1963	3 726	105.0	469.7	171.0	—	—	—
1964	4 236	118.8	467.4	184.0	—	—	—
1965	1 740	50.5	483.7	180.0	—	—	—
1966	2 817	79.3	469.2	180.0	—	—	—
1967	2 533	73.7	484.9	168.0	—	—	—
1968	2 233	63.3	472.5	161.0	300.0	139.0	3.4
1969	2 402	68.5	475.3	161.0	298.0	137.0	3.5
1970	2 353	66.1	468.2	157.0	300.0	143.0	3.3
1971	2 659	74.4	466.3	155.0	302.0	147.0	3.2
1972	2 301	64.4	466.5	153.0	304.0	151.0	3.1
1973	2 476	68.3	459.7	156.0	308.0	152.0	3.0
1974	1 903	52.5	459.8	154.0	306.0	152.0	3.0
1975	2 318	63.9	459.4	149.0	309.0	160.0	2.9
1976	2 799	77.6	462.1	150.0	310.0	160.0	2.9
1977	2 665	74.8	467.8	147.0	303.0	156.0	3.0
1978	2 274	64.9	475.8	145.0	299.0	154.0	3.1
1979	2 964	84.0	472.4	149.0	301.0	152.0	3.1
1980	3 316	92.2	463.6	153.0	300.0	147.0	3.2
1981	3 523	96.5	456.5	158.0	304.0	146.0	3.1
1982	3 654	102.3	467.0	168.0	299.0	136.0	3.4
1983	2 842	78.1	458.0	154.0	295.0	141.0	3.2
1984	2 889	72.1	416.0	156.0	281.0	125.0	3.1
1985	2 153	55.8	432.0	174.0	308.0	134.0	3.2
1986	1 376	34.6	419.0	168.0	310.0	142.0	2.9
1987	1 148	27.9	405.0	167.0	314.0	147.0	2.8
1988	351	9.9	406.0	—	—	—	—
1989	1 074	26.5	411.0	—	—	—	—

Appendix (Cont)

Well LA-6

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1948	116	4.9	704.0	—	—	—	—
1949	2 451	95.8	651.4	—	—	—	—
1950	4 490	167.9	623.2	83.0	136.0	53.0	11.8
1951	5 882	201.6	571.2	115.0	160.0	45.0	12.7
1952	3 168	110.3	580.3	108.0	151.0	43.0	13.5
1953	3 177	113.8	597.0	95.0	139.0	44.0	13.6
1954	2 894	107.1	616.8	92.0	135.0	43.0	14.3
1955	2 911	108.0	618.3	97.0	140.0	43.0	14.4
1956	3 438	125.8	609.9	106.0	149.0	43.0	14.2
1957	2 833	102.4	602.4	107.0	152.0	45.0	13.4
1958	2 957	106.9	602.5	108.0	131.0	43.0	14.0
1959	3 096	108.3	583.0	115.0	158.0	43.0	13.6
1960	4 084	138.6	565.6	130.0	172.0	42.0	13.5
1961	3 284	112.5	571.0	129.0	171.0	42.0	13.6
1962	3 886	129.4	555.0	135.0	175.0	40.0	13.9
1963	2 953	102.9	580.8	125.0	171.0	46.0	12.6
1964	4 244	138.3	543.1	132.0	172.0	40.0	13.6
1965	3 145	103.8	550.1	120.0	160.0	40.0	13.8
1966	3 173	104.0	546.3	129.0	169.0	40.0	13.7
1967	2 511	85.4	566.8	118.0	158.0	40.0	14.2
1968	2 111	71.6	565.3	109.0	150.0	41.0	13.8
1969	2 402	81.6	566.2	109.0	151.0	42.0	13.5
1970	2 337	79.1	564.1	106.0	149.0	43.0	13.1
1971	2 472	82.5	556.2	119.0	160.0	41.0	13.6
1972	2 317	79.2	569.7	117.0	155.0	38.0	15.0
1973	2 638	90.6	572.4	118.4	155.0	37.0	15.5
1974	2 337	79.8	569.1	120.0	156.0	36.0	15.8
1975	1 571	51.9	550.6	113.0	151.0	38.0	14.5
1976	175	5.1	485.7	96.0	—	—	—
1977	—	—	—	82.0	—	—	—
1978	33	1.1	572.7	77.0	142.0	65.0	8.8
1979	6	0.2	555.6	80.0	146.0	66.0	8.4
1980	4	0.1	520.8	82.0	142.0	60.0	8.7
1981	2.3	0.08	579.8	84.0	141.0	57.0	10.2
1982	—	—	—	90.0	—	—	—
1983	—	—	—	81.0	—	—	—
1984	—	—	—	83.0	—	—	—
1985	—	—	—	92.0	—	—	—
1986	—	—	—	—	—	—	—
1987	—	<0.1	—	—	—	—	—
1988	—	<0.1	—	—	—	—	—
1989	—	<0.1	—	—	—	—	—

Appendix (Cont)

Well G-1

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1950	0	2.8	0.0	195.0	—	—	—
1951	1 168	37.7	538.0	202.0	309.0	107.0	5.0
1952	2 476	75.5	508.2	213.0	295.0	82.0	6.2
1953	3 275	97.3	495.2	221.0	292.0	71.0	7.0
1954	2 616	77.8	495.7	221.0	290.0	69.0	7.2
1955	2 406	70.5	448.4	226.0	295.0	69.0	7.1
1956	2 958	83.2	468.8	235.0	303.0	68.0	6.9
1957	2 098	55.9	444.1	236.0	307.0	71.0	6.3
1958	2 460	68.1	461.4	238.0	308.0	70.0	6.6
1959	2 952	82.4	465.2	245.0	314.0	69.0	6.7
1960	3 564	96.0	448.9	254.0	325.0	71.0	6.3
1961	4 236	112.4	442.2	260.0	333.0	73.0	6.1
1962	3 431	93.6	454.7	258.0	342.0	84.0	5.4
1963	4 519	114.9	423.8	265.0	348.0	83.0	5.1
1964	4 374	113.8	433.6	269.0	352.0	83.0	5.2
1965	3 530	90.7	428.2	268.0	352.0	84.0	5.1
1966	4 074	102.6	419.7	269.0	363.0	94.0	4.5
1967	2 615	69.9	445.5	266.0	362.0	96.0	4.6
1968	2 996	78.9	438.9	264.0	366.0	102.0	4.3
1969	2 657	68.3	428.4	266.0	376.0	110.0	3.9
1970	2 712	64.7	397.6	264.0	377.0	113.0	3.5
1971	2 908	67.9	389.2	258.0	378.0	120.0	3.2
1972	2 865	66.1	384.5	264.0	389.0	125.0	3.1
1973	2 997	67.5	375.4	271.0	403.0	132.0	2.8
1974	2 767	62.3	375.3	283.0	412.0	129.0	2.9
1975	2 467	55.7	376.3	293.0	411.0	118.0	3.2
1976	2 962	65.1	366.3	—	—	—	—
1977	2 734	57.9	353.0	275.0	426.0	151.0	2.3
1978	2 656	56.0	351.4	270.0	419.0	149.0	2.4
1979	2 998	61.7	342.9	271.0	422.0	151.0	2.3
1980	3 459	68.3	329.0	273.0	428.0	155.0	2.1
1981	4 427	81.6	307.2	275.0	444.0	169.0	1.8
1982	3 678	69.0	313.0	278.0	443.0	165.0	1.9
1983	2 871	52.2	303.0	272.0	443.0	171.0	1.8
1984	3 804	62.8	275.0	276.0	448.0	172.0	1.5
1985	3 004	48.3	268.0	278.0	450.0	172.0	1.6
1986	2 027	30.3	249.0	279.0	450.0	171.0	1.5
1987	2 070	29.2	235.0	280.0	451.0	171.0	1.4
1988	395	5.4	227.0	280.0	445.0	165.0	1.4
1989	2 010	26.9	223.0	282.0	451.0	169.0	1.3

Appendix (Cont)

Well G-1A

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1954	108	4.6	709.0	—	—	—	—
1955	1 531	53.0	577.0	265.0	316.0	51.0	11.3
1956	3 130	107.7	573.5	273.0	323.0	50.0	11.5
1957	2 470	87.0	587.0	274.0	327.0	53.0	11.1
1958	2 670	92.5	577.4	279.0	331.0	52.0	11.1
1959	2 965	102.7	577.3	284.0	333.0	49.0	11.8
1960	3 641	122.8	562.1	291.0	342.0	51.0	11.0
1961	4 297	147.3	571.3	298.0	350.0	52.0	11.0
1962	3 972	136.1	571.1	295.0	344.0	49.0	11.7
1963	4 525	149.7	551.4	301.0	350.0	49.0	11.3
1964	3 852	129.3	559.4	302.0	353.0	51.0	11.0
1965	3 505	116.5	554.0	302.0	353.0	51.0	10.9
1966	3 964	133.4	560.9	306.0	355.0	49.0	11.4
1967	2 720	91.3	559.4	302.0	351.0	49.0	11.4
1968	3 089	103.2	556.8	302.0	352.0	50.0	11.1
1969	2 695	90.7	560.9	303.0	356.0	53.0	10.6
1970	2 772	92.5	556.2	300.0	357.0	57.0	9.8
1971	3 313	111.8	562.4	303.0	361.0	58.0	9.7
1972	2 879	94.0	544.2	302.0	361.0	59.0	9.2
1973	2 760	87.9	530.8	302.0	362.0	60.0	8.8
1974	2 974	92.7	519.5	307.0	355.0	48.0	10.8
1975	2 740	85.3	518.9	304.0	351.0	47.0	11.0
1976	2 983	91.6	511.8	302.0	350.0	48.0	10.7
1977	2 942	88.7	502.5	302.0	350.0	48.0	10.5
1978	2 631	77.9	493.5	300.0	345.0	45.0	11.0
1979	2 974	88.0	493.9	301.0	345.0	44.0	11.0
1980	3 480	103.2	494.4	305.0	345.0	40.0	12.4
1981	4 212	131.2	519.1	307.0	347.0	40.0	13.0
1982	3 618	109.7	505.0	305.0	347.0	42.0	12.0
1983	2 901	86.7	498.0	301.0	336.0	35.0	14.2
1984	3 789	113.9	501.0	302.0	345.0	43.0	11.7
1985	4 430	128.4	483.0	306.0	348.0	42.0	11.5
1986	4 644	130.4	468.0	310.0	351.0	41.0	11.4
1987	4 468	122.5	457.0	320.0	362.0	42.0	10.9
1988	5 016	133.5	443.0	323.0	364.0	41.0	10.8
1989	4 663	131.5	470.0	323.0	359.0	36.0	13.1

Appendix (Cont)

Well G-2

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1951	123	3.9	528.5	259.0	—	—	—
1952	2 372	78.3	550.2	279.0	327.0	48.0	11.5
1953	3 254	105.6	540.9	290.0	334.0	44.0	12.3
1954	2 682	86.3	536.3	291.0	335.0	44.0	12.2
1955	2 487	78.8	528.1	299.0	345.0	46.0	11.5
1956	3 109	95.8	513.6	310.0	357.0	47.0	10.9
1957	2 458	76.1	516.0	311.0	360.0	49.0	10.5
1958	2 707	80.1	493.2	315.0	361.0	46.0	10.7
1959	2 938	84.6	479.9	320.0	363.0	43.0	11.2
1960	3 535	96.6	455.4	328.0	370.0	42.0	10.8
1961	3 982	105.3	440.7	336.0	375.0	39.0	11.3
1962	4 076	99.8	408.1	338.0	374.0	36.0	11.3
1963	4 563	105.7	386.1	344.0	379.0	35.0	11.0
1964	4 541	105.3	386.5	346.0	380.0	34.0	11.4
1965	3 535	82.6	389.4	346.0	381.0	35.0	11.1
1966	3 994	94.7	395.2	349.0	383.0	34.0	11.6
1967	2 743	67.6	410.7	344.0	379.0	35.0	11.7
1968	2 732	66.5	405.7	344.0	379.0	35.0	11.6
1969	2 679	68.6	426.8	344.0	381.0	37.0	11.5
1970	2 431	62.8	430.5	343.0	381.0	38.0	11.3
1971	3 420	87.4	425.9	345.0	384.0	39.0	10.9
1972	2 887	73.4	423.7	348.0	388.0	40.0	10.6
1973	2 816	72.4	428.5	344.0	385.0	41.0	10.5
1974	3 056	82.0	447.2	347.0	390.0	43.0	10.4
1975	2 724	74.5	455.8	341.0	384.0	43.0	10.6
1976	2 990	81.1	452.1	344.0	388.0	44.0	10.3
1977	2 981	80.4	449.5	346.0	388.0	42.0	10.7
1978	2 562	71.6	451.9	345.0	386.0	41.0	11.0
1979	2 975	80.0	448.0	347.0	388.0	41.0	11.0
1980	3 478	92.4	443.0	350.0	389.0	39.0	11.4
1981	1 432	38.3	445.8	352.0	390.0	38.0	11.7
1982	2 833	25.7	476.0	352.0	399.0	47.0	10.1
1983	624	16.5	441.0	356.0	399.0	43.0	10.3
1984	2 018	43.7	361.0	358.0	385.0	27.0	13.4
1985	4 339	96.6	371.0	352.0	381.0	29.0	12.8
1986	4 769	109.3	382.0	369.0	395.0	26.0	14.7
1987	4 526	109.7	404.0	366.0	399.0	33.0	12.2
1988	4 836	132.8	457.0	353.0	393.0	40.0	11.5
1989	4 820	133.9	463.0	354.0	387.0	33.0	14.0

Appendix (Cont)

Well G-3

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1951	192	7.3	633.7	281.0	—	—	—
1952	2 379	65.4	458.2	310.0	358.0	48.0	9.5
1953	3 192	76.4	398.9	322.0	360.0	38.0	10.5
1954	2 675	66.1	411.8	322.0	370.0	48.0	8.6
1955	2 369	69.4	488.3	316.0	368.0	52.0	9.4
1956	3 149	87.9	465.2	324.0	380.0	56.0	8.3
1957	2 517	70.2	464.8	324.0	385.0	61.0	7.6
1958	2 562	69.5	452.1	323.0	386.0	63.0	7.2
1959	2 931	74.6	424.2	326.0	395.0	69.0	6.1
1960	3 591	82.5	382.9	335.0	407.0	72.0	5.3
1961	3 612	79.9	368.7	343.0	414.0	71.0	5.2
1962	4 057	83.7	343.9	348.0	418.0	70.0	4.9
1963	4 555	86.7	317.2	352.0	422.0	70.0	4.5
1964	4 487	78.6	292.0	355.0	424.0	69.0	4.2
1965	3 498	65.6	312.6	350.0	419.0	69.0	4.5
1966	3 991	73.7	307.8	353.0	420.0	67.0	4.6
1967	2 752	52.9	320.4	344.0	418.0	74.0	4.3
1968	3 086	56.5	305.1	341.0	418.0	77.0	4.0
1969	2 672	50.8	316.9	338.0	417.0	79.0	4.0
1970	2 736	55.4	337.5	336.0	419.0	83.0	4.1
1971	3 337	64.2	320.6	342.0	423.0	81.0	4.0
1972	2 838	50.9	298.9	341.0	421.0	80.0	3.7
1973	2 843	47.3	277.3	341.0	418.0	77.0	3.6
1974	3 006	49.3	273.3	342.0	424.0	82.0	3.3
1975	2 632	43.1	272.9	341.0	428.0	87.0	3.1
1976	2 971	82.6	463.4	359.0	447.0	88.0	5.3
1977	2 961	78.9	444.1	353.0	448.0	95.0	4.7
1978	2 590	66.4	427.5	345.0	443.0	98.0	4.4
1979	3 014	69.0	381.0	345.0	450.0	105.0	3.6
1980	3 448	61.8	298.6	348.0	453.0	105.0	2.8
1981	4 315	66.6	257.2	357.0	467.0	110.0	2.3
1982	3 550	51.0	239.0	349.0	459.0	110.0	2.2
1983	2 183	31.3	239.0	340.0	463.0	123.0	1.9
1984	1 211	19.0	267.0	355.0	475.0	120.0	2.2
1985	1 587	22.1	232.0	351.0	470.0	119.0	2.0
1986	2 266	26.7	196.0	375.0	492.0	117.0	1.7
1987	—	<0.1	—	—	—	—	—
1988	—	3.4	—	—	—	—	—
1989	—	<0.1	—	—	—	—	—

Appendix (Cont)

Well G-4

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1951	—	12.5	—	357.0	477.0	120.0	—
1952	2 401	56.9	395.0	374.0	474.0	100.0	3.9
1953	2 677	55.2	343.7	380.0	472.0	92.0	3.7
1954	2 256	58.8	434.4	383.0	526.0	143.0	3.0
1955	1 172	22.7	322.8	378.0	481.0	103.0	3.1
1956	1 800	33.9	313.9	377.0	491.0	114.0	2.8
1957	1 324	24.2	304.6	373.0	498.0	125.0	2.4
1958	1 970	35.9	303.7	370.0	490.0	120.0	2.5
1959	1 819	31.6	289.5	378.0	494.0	116.0	2.5
1960	2 457	37.0	251.0	385.0	509.0	124.0	2.0
1961	2 787	45.0	269.1	389.0	512.0	123.0	2.2
1962	2 738	41.7	253.8	386.0	505.0	119.0	2.1
1963	3 519	46.4	219.8	388.0	504.0	116.0	1.9
1964	3 561	42.9	200.8	396.0	499.0	103.0	1.9
1965	2 100	23.8	188.9	394.0	492.0	98.0	1.9
1966	2 219	33.6	252.4	391.0	498.0	107.0	2.4
1967	2 690	44.8	277.6	388.0	509.0	121.0	2.3
1968	2 083	31.4	251.2	386.0	509.0	123.0	2.0
1969	1 309	17.4	221.5	387.0	505.0	118.0	1.9
1970	606	7.7	211.8	384.0	504.0	120.0	1.8
1971	1 640	21.0	213.4	389.0	503.0	114.0	1.9
1972	2 840	33.3	195.4	391.0	507.0	116.0	1.7
1973	3 006	37.2	206.3	392.0	521.0	129.0	1.6
1974	2 672	34.3	213.9	392.0	519.0	127.0	1.7
1975	1 977	41.0	345.6	403.0	559.0	156.0	2.2
1976	2 859	57.8	336.9	406.0	571.0	165.0	2.0
1977	2 954	62.4	352.1	406.0	589.0	183.0	1.9
1978	2 607	49.5	316.5	398.0	589.0	191.0	1.7
1979	2 974	52.9	296.4	395.0	586.0	191.0	1.6
1980	2 235	35.6	265.7	394.0	580.0	186.0	1.4
1981	432	8.2	316.4	385.0	573.0	188.0	1.7
1982	3 657	65.2	297.0	386.0	578.0	192.0	1.5
1983	2 604	42.2	270.0	—	—	—	—
1984	3 766	49.7	220.0	—	—	—	—
1985	1 747	21.7	207.0	402.0	572.0	170.0	1.2
1986	2 678	33.9	211.0	396.0	574.0	178.0	1.2
1987	2 011	25.1	208.0	398.0	573.0	175.0	1.2
1988	301	4.1	227.0	390.0	545.0	155.0	1.4
1989	1 739	21.6	207.0	401.0	562.0	161.0	1.3

Appendix (Cont)

Well G-5

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1951	—	6.7	—	414.0	—	—	—
1952	2 579	73.8	476.9	422.0	480.0	58.0	8.2
1953	1 433	37.8	439.6	425.0	467.0	42.0	10.5
1954	2 617	80.9	515.2	429.0	473.0	44.0	11.7
1955	2 529	80.4	529.9	427.0	472.0	45.0	11.8
1956	3 052	97.0	529.7	431.0	478.0	47.0	11.3
1957	2 385	64.1	447.9	424.0	466.0	42.0	10.7
1958	1 523	49.1	537.3	428.0	477.0	49.0	11.0
1959	2 917	101.7	581.1	435.0	495.0	60.0	9.7
1960	2 828	98.0	577.6	437.0	501.0	64.0	9.0
1961	3 908	134.0	571.5	438.0	507.0	69.0	8.3
1962	4 186	142.0	565.4	440.0	511.0	71.0	8.0
1963	4 528	151.0	555.8	441.0	513.0	72.0	7.7
1964	4 532	150.4	553.1	446.0	516.0	70.0	7.9
1965	3 520	117.1	554.5	443.0	516.0	73.0	7.6
1966	2 555	83.2	542.7	445.0	520.0	75.0	7.2
1967	2 405	80.0	554.4	444.0	519.0	75.0	7.4
1968	2 513	81.2	538.5	443.0	517.0	74.0	7.3
1969	2 649	83.3	524.1	450.0	520.0	70.0	7.5
1970	2 771	88.9	534.7	453.0	521.0	68.0	7.9
1971	2 657	88.3	553.9	450.0	521.0	71.0	7.8
1972	2 902	92.4	530.7	441.0	514.0	73.0	7.3
1973	3 003	97.5	541.1	444.0	515.0	71.0	7.6
1974	2 054	69.0	559.9	440.0	513.0	73.0	7.7
1975	2 266	74.7	549.4	433.0	500.0	67.0	8.2
1976	2 955	95.0	535.8	442.0	504.0	62.0	8.6
1977	2 836	92.1	541.3	444.0	504.0	60.0	9.0
1978	2 608	84.2	538.4	442.0	502.0	60.0	9.0
1979	2 766	86.5	521.5	442.0	502.0	60.0	8.7
1980	2 896	89.0	512.4	442.0	502.0	60.0	8.5
1981	2 124	66.7	523.4	451.0	528.0	77.0	6.8
1982	1 219	38.2	522.0	455.0	510.0	55.0	9.5
1983	2 904	73.2	420.0	445.0	492.0	47.0	8.9
1984	3 838	115.4	501.0	452.0	507.0	55.0	9.4
1985	2 193	67.9	516.0	453.0	509.0	56.0	9.2
1986	2 219	52.5	394.0	453.0	494.0	41.0	9.6
1987	5 732	116.7	379.0	462.0	504.0	42.0	9.0
1988	4 841	115.3	396.0	466.0	507.0	41.0	9.7
1989	4 715	110.9	392.0	474.0	514.0	40.0	9.8

Appendix (Cont)

Well G-6

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1964	1 912	45.0	392.3	581.0	659.0	78.0	5.0
1965	3 200	74.9	390.1	582.0	660.0	78.0	5.0
1966	3 931	92.2	390.9	585.0	658.0	73.0	5.4
1967	2 454	57.8	392.6	580.0	653.0	73.0	5.4
1968	2 597	56.2	360.7	574.0	647.0	73.0	4.9
1969	2 698	55.6	343.5	568.0	636.0	68.0	5.1
1970	2 765	51.0	307.4	569.0	634.0	65.0	4.7
1971	2 932	42.8	243.3	573.0	629.0	56.0	4.3
1972	2 516	57.0	377.6	578.0	670.0	92.0	4.1
1973	2 991	65.3	363.9	579.0	667.0	88.0	4.1
1974	2 950	63.8	360.5	579.0	665.0	86.0	4.2
1975	2 717	56.7	347.8	577.0	659.0	82.0	4.2
1976	2 966	57.8	324.8	584.0	662.0	78.0	4.2
1977	2 954	54.4	306.9	586.0	659.0	73.0	4.2
1978	2 218	38.4	288.9	581.0	645.0	64.0	4.5
1979	1 030	18.2	295.1	579.0	645.0	66.0	4.8
1980	1 789	34.5	321.5	583.0	670.0	87.0	3.7
1981	4 302	76.5	296.4	586.0	673.0	87.0	3.4
1982	3 763	63.6	281.0	588.0	669.0	81.0	3.5
1983	1 960	35.4	301.0	582.0	668.0	86.0	3.5
1984	3 010	55.3	306.0	589.0	666.0	77.0	3.9
1985	3 980	71.4	299.0	586.0	664.0	78.0	3.8
1986	4 420	76.7	293.0	576.0	654.0	78.0	3.8
1987	5 100	81.4	266.0	595.0	671.0	76.0	3.5
1988	5 121	82.1	267.0	591.0	669.0	78.0	3.4
1989	5 000	81.6	272.0	592.0	669.0	77.0	3.5

Appendix (Cont)

Well PM-1

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1965	2 754	99.2	600.3	746.0	786.0	40.0	15.0
1966	3 086	108.0	583.3	740.0	779.0	39.0	15.0
1967	2 870	111.0	644.6	737.0	781.0	44.0	14.6
1968	1 846	68.1	614.8	735.0	769.0	34.0	18.1
1969	951	34.4	602.9	733.0	766.0	33.0	18.3
1970	1 781	66.2	619.5	733.0	769.0	36.0	17.2
1971	2 728	101.0	617.1	733.0	766.0	33.0	18.7
1972	2 415	84.9	585.9	735.0	762.0	27.0	21.7
1973	1 688	46.5	459.1	736.0	755.0	19.0	24.2
1974	2 649	96.3	605.9	740.0	768.0	28.0	21.6
1975	2 567	94.8	615.5	741.0	766.0	25.0	24.6
1976	2 933	106.8	606.9	744.0	767.0	23.0	26.4
1977	2 969	105.4	591.7	745.0	767.0	22.0	26.9
1978	2 544	90.6	593.3	745.0	767.0	22.0	27.0
1979	2 350	83.4	591.5	744.0	766.0	22.0	26.9
1980	2 786	98.5	588.6	746.0	769.0	23.0	25.7
1981	2 789	98.5	588.6	747.0	769.0	22.0	26.8
1982	2 820	99.6	589.0	748.0	770.0	22.0	26.8
1983	2 464	86.5	585.0	747.0	769.0	22.0	26.6
1984	2 667	92.8	580.0	749.0	772.0	23.0	25.6
1985	2 760	95.4	576.0	749.0	770.0	21.0	27.4
1986	2 130	73.9	578.0	748.0	770.0	22.0	26.3
1987	2 912	102.4	586.0	752.0	773.0	21.0	27.9
1988	2 758	98.0	592.0	751.0	775.0	24.0	24.7
1989	3 014	104.9	580.0	752.0	774.0	22.0	26.4

Appendix (Cont)

Well PM-2

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1966	221	18.9	1 425.3	826.0	889.0	63.0	22.6
1967	4 336	370.0	1 422.2	834.0	888.0	54.0	26.3
1968	3 865	328.2	1 415.3	838.0	889.0	51.0	27.8
1969	3 304	279.9	1 411.9	838.0	890.0	52.0	27.2
1970	3 529	300.6	1 419.7	839.0	893.0	54.0	26.3
1971	4 035	339.5	1 402.3	841.0	898.0	57.0	24.6
1972	4 611	385.3	1 392.7	845.0	902.0	57.0	24.4
1973	4 571	380.6	1 387.7	849.0	907.0	58.0	23.9
1974	5 443	450.9	1 380.7	853.0	912.0	59.0	23.4
1975	4 644	385.3	1 382.8	854.0	913.0	59.0	23.4
1976	5 382	442.0	1 368.8	866.0	924.0	58.0	23.6
1977	3 306	272.8	1 375.3	868.0	924.0	56.0	24.6
1978	4 743	388.4	1 364.9	871.0	928.0	57.0	23.9
1979	4 671	381.8	1 262.2	872.0	924.0	52.0	26.2
1980	5 023	409.6	1 359.2	873.0	931.0	58.0	23.4
1981	4 551	370.1	1 355.4	876.0	934.0	58.0	23.4
1982	4 319	359.3	1 386.0	874.0	934.0	60.0	23.1
1983	1 922	157.9	1 369.0	876.0	935.0	59.0	23.2
1984	996	81.6	1 365.0	866.0	930.0	64.0	21.7
1985	1 749	143.3	1 365.0	851.0	916.0	65.0	21.0
1986	1 036	84.4	1 359.0	851.0	915.0	64.0	21.2
1987	351	28.3	1 340.0	851.0	907.0	56.0	23.9
1988	1 843	146.8	1 328.0	869.0	931.0	62.0	21.4
1989	1 639	130.0	1322.0	860.0	920.0	60.0	22.0

Appendix (Cont)

Well PM-3

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1968	2 327	187.4	1 342.2	743.0	771.0	28.0	47.9
1969	3 241	254.7	1 309.8	746.0	772.0	26.0	50.4
1970	2 905	227.8	1 306.9	750.0	774.0	24.0	54.5
1971	2 774	216.3	1 299.6	751.0	774.0	23.0	56.5
1972	2 445	192.1	1 309.5	752.0	775.0	23.0	56.9
1973	3 256	257.8	1 319.6	755.0	778.0	23.0	57.4
1974	3 241	255.3	1 312.9	756.0	779.0	23.0	57.1
1975	3 421	269.3	1 312.0	757.0	780.0	23.0	57.0
1976	3 171	268.3	1 410.2	758.0	784.0	26.0	54.2
1977	2 792	235.5	1 405.8	758.0	784.0	26.0	54.1
1978	2 516	211.0	1 397.6	759.0	784.0	25.0	55.9
1979	2 359	197.2	1 393.0	760.0	784.0	24.0	58.0
1980	2 796	234.4	1 397.2	760.0	785.0	25.0	55.9
1981	2 784	232.4	1 391.3	761.0	786.0	25.0	55.6
1982	2 831	238.1	1 402.0	762.0	785.0	23.0	60.9
1983	2 496	207.6	1 386.0	762.0	785.0	23.0	60.3
1984	3 317	275.6	1 385.0	762.0	787.0	25.0	55.4
1985	2 643	221.2	1 395.0	762.0	784.0	22.0	63.4
1986	2 920	244.8	1 397.0	763.0	787.0	24.0	58.2
1987	2 984	250.2	1 397.0	763.0	788.0	25.0	55.9
1988	2 766	232.0	1 397.0	764.0	788.0	24.0	58.2
1989	2 656	221.0	1 386.0	765.0	791.0	26.0	53.3

Appendix (Cont)

Well PM-4

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1982	869	76.2	1 460	1 050	1 091	41	35.6
1983	5 267	452.5	1 432	1 066	1 101	35	40.9
1984	4 059	325.8	1 338	1 065	1 104	39	34.3
1985	4 759	379.2	1 328	1 066	1 101	35	37.9
1986	3 925	307.4	1 305	1 084	1 119	35	37.3
1987	5 071	392.2	1 289	1 081	1 117	36	35.8
1988	2 435	218.7	1 313	1 079	1 117	38	34.6
1989	5 387	418.9	1 296	1 085	1 122	37	35.0

Appendix (Cont)

Well PM-5

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1985	—	2.0	—	—	—	—	—
1986	2 047	147.3	1 199	—	—	—	—
1987	1 620	118.6	1 220	—	—	—	—
1988	1 754	128.6	1 221	—	—	—	—
1989	1 184	86.2	1 213	—	—	—	—

Appendix (Cont)

Water Canyon Gallery

Year	Time (h)	Production (10^6 gal.)	Discharge Rate (gpm)
1947	8 760	84.0	159.8
1948	8 784	97.0	184.0
1949	8 760	92.0	175.0
1950	8 760	54.0	102.7
1951	8 760	39.0	74.2
1952	8 784	48.0	91.1
1953	8 760	39.0	74.2
1954	8 760	40.0	76.1
1955	8 760	33.0	62.8
1956	8 784	23.0	43.6
1957	8 760	40.0	76.1
1958	8 760	60.0	114.2
1959	8 760	54.0	102.7
1960	8 784	48.0	91.1
1961	8 760	54.0	102.7
1962	8 760	67.0	127.5
1963	8 760	51.0	97.0
1964	8 784	45.0	85.4
1965	8 760	72.0	137.0
1966	8 760	82.0	156.0
1967	8 760	56.0	106.5
1968	8 784	65.0	123.3
1969	8 760	80.0	152.2
1970	8 760	65.0	123.7
1971	8 760	37.0	70.4
1972	8 784	40.0	75.9
1973	8 760	49.0	93.2
1974	8 760	35.0	66.6
1975	8 760	42.0	79.9
1976	8 784	41.0	77.8
1977	8 760	57.0	108.4
1978	8 760	45.0	86.2
1979	8 760	44.0	83.7
1980	8 784	32.0	60.7
1981	8 760	45.5	86.6
1982	8 760	45.9	94.9
1983	8 760	38.2	72.7
1984	8 784	34.0	65.4
1985	8 760	36.6	69.6
1986	8 760	28.2	53.6
1987	8 760	34.2	65.1
1988	8 784	34.5	65.5
1989	8 760	23.0	43.8