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Evaluation of Yield and Water-Level Relations

by

R. L. Cushman*
W. D. Purtymun

*LASL Consultant. 5409 Frederick Drive, Cheyenne, Wyoming 82001

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

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EVALUATION OF YIELD AND WATER-LEVEL RELATIONS

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ABSTRACT

Yield and water relations in the Los Alamos supply wells were evaluated because of the increasing demand for water. Water-level declines were extrapolated for 10 yr, to 1983, on the basis of past records. On the basis of current pumpage, the extrapolations indicate that nonpumping water levels in individual wells will decline from 10 to 30 ft. Well characteristics were compiled to provide an individual history of each well, and recommendations for improving water production are presented.

I. INTRODUCTION

Sixteen wells in three fields were the main source of water for the Los Alamos Scientific Laboratory and the communities of Los Alamos and White Rock in 1973 (Fig. 1). The wells are completed into the main aquifer capable of municipal and industrial water supply. Cushman evaluated the 12 wells in use in 1961 and predicted water-level changes that might occur between 1960 and 1980 if selected pumping rates were used.[1] A new well (G-6) was added in 1964, two more (PM-1 and PM-2) were added in 1965, and one (PM-3) was added in 1966. The additional pumpage from these 4 wells reduced annual pumpage from the 12 wells in use in 1961. The pumpage and its effects on the ground-water reservoir were evaluated to plan for future increased water demand by the Laboratory and community. On the basis of past records of water level and pumpage, the water-level trends were extrapolated for 10 yr, to 1983. A history of physical change in each well was compiled, and recommendations for improving water production are presented.

Pumping and production statistics are available in publications by Purtymun and Herceg[2-5] for the years of record from 1947 through 1973. The tabulations include monthly average nonpumping and pumping water levels, monthly and yearly pumpage, monthly average specific capacity, monthly average pumping rates, and pumping time in hours per month.

The highest nonpumping water level and lowest pumping water level for each well were obtained from the weekly well-operations sheets for 1967 through 1973 which are kept by the Zia Company. These records were used to determine how well the average monthly high and low levels represented the highest and lowest annual levels.

II. PREDICTED WATER LEVELS EXTRAPOLATED TO 1983

The normal approach to predicting the response of an aquifer to stresses imposed

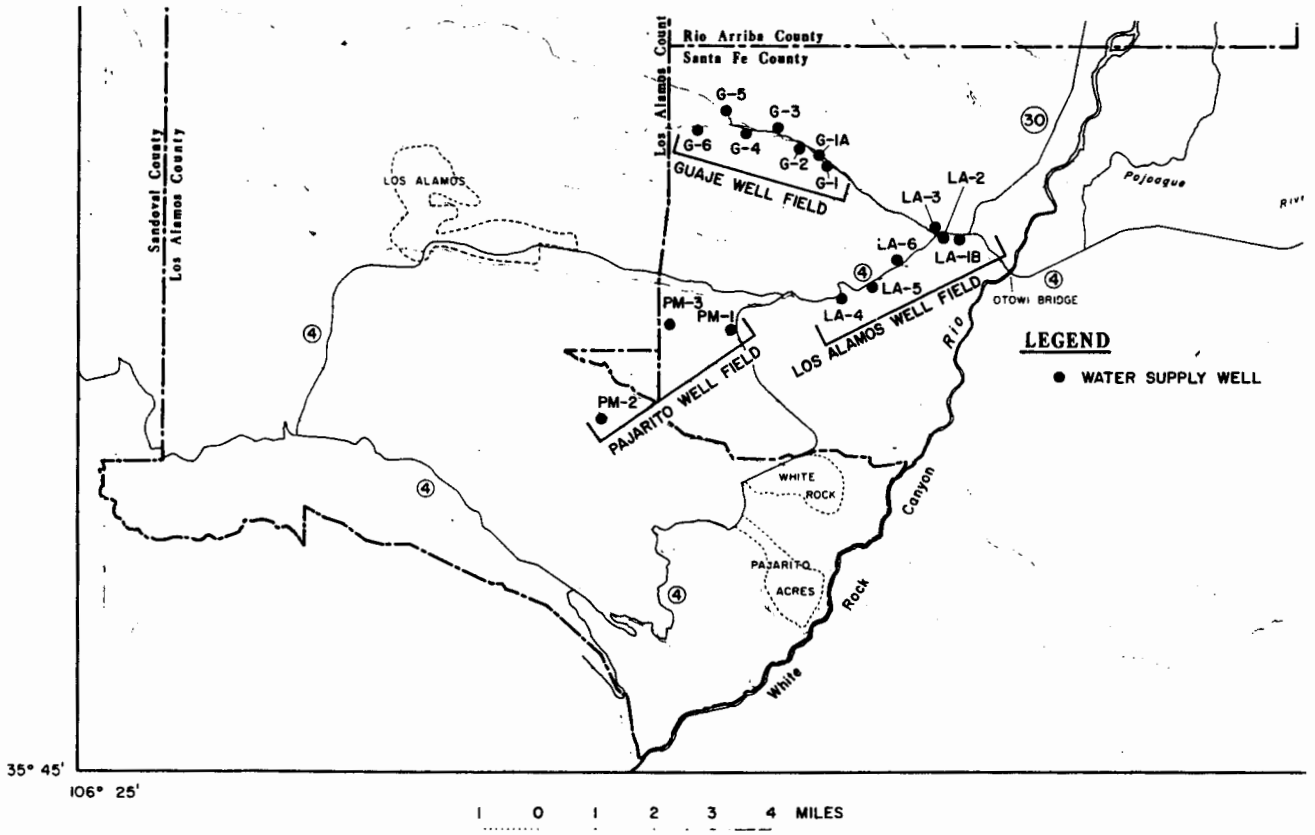

Fig. 1. Location of supply wells in the Los Alamos, Guaje, and Pajarito Fields.

by withdrawing water from wells would make use of formulas that require detailed data about the aquifer's water transmission and storage characteristics. Data about the magnitude of those characteristics and their variation from place to place in the aquifer are too sparse to permit computation of aquifer response to pumping of the Los Alamos supply wells.

A method that relies on extrapolation of the historical records of water-level changes and annual pumpage was adopted to predict water-level changes and optimum annual pumpage for the 10 yr from 1974 through 1983. Water-level changes caused by various pumpage volumes from each well were studied to determine the relationship that might best be used in predicting well operation for the next 10 yr. Nonpumping water levels were considered better than pumping levels for use in extrapolating water-level trends. The average annual pumpage was considered better than the instantaneous pumping rate (expressed in gpm) in relation to future pumping operations. The average annual pumpage and the water-level trends for 1964 through 1973 were given greater weight than those for previous years in determining the rates of water-level decline and pumpage for 1974 through 1983. The production potential of the wells and the water-level declines that can be expected between 1974 and 1983 are shown in Table I.

A. The Los Alamos Field

In 1973, the Los Alamos Field was composed of six wells in Los Alamos Canyon east of Los Alamos (Fig. 1). The wells are 870 to 1965 ft deep.

1. Supply Well LA-1B. Average annual pumpage in 1960 through 1973 was 91.8 million gal; annual pumpage ranged from 74.0

million gal in 1968 to 130.3 million in 1964. Average annual pumpage in 1964 through 1973 was 87.8 million gal. Average pumping rates ranged from 520 gpm in 1964 to 566 in 1972; the average was 559 gpm for the period of record and 551 for 1964 through 1973.

There has been a net decline of about 43 ft in the nonpumping level from 1960 through 1973, or about 3.1 ft/yr (Fig. 2). The well was artesian when completed, and the water level or head equalled a column of water about 30 ft above the land surface. The decline is attributed primarily to pumping of the well, but some is the result of interference by wells LA-2 and LA-3 (Fig. 1).

At an average annual pumpage of about 90 million gal, the nonpumping water level in 1983 will be about 15 ft lower than that in 1973 (Fig. 2). Judging by the relatively slow rate of water-level decline to date, greater annual pumpage seemingly would not cause an excessive rate of decline. The pumpage could be increased to 110 million gal if wells LA-2 and LA-3 were put on standby status. At this increased pumpage, the water level would drop about 25 ft by 1983.

2. Supply Well LA-2. Average annual pumpage was 35.6 million gal in the period of record, 1947 through 1973; annual pumpage ranged from 3.8 million gal in 1969 to 59.3 million in 1948. Average annual pumpage during 1964 through 1973 was 24.0 million gal. Average annual pumping rates ranged from 270 gpm in 1948 to 463 in 1957 and were 357 and 314 gpm for 1947 through 1973 and 1964 through 1973, respectively.

The nonpumping water level declined about 84 ft in the period of record, or an average of about 3.1 ft/yr. The water level was 2 ft above the land surface before pumping started in 1947. This decline amounts to about 10% of the well depth, so although it might be considered relatively small for a 27-yr period it is significant in terms of well depth.

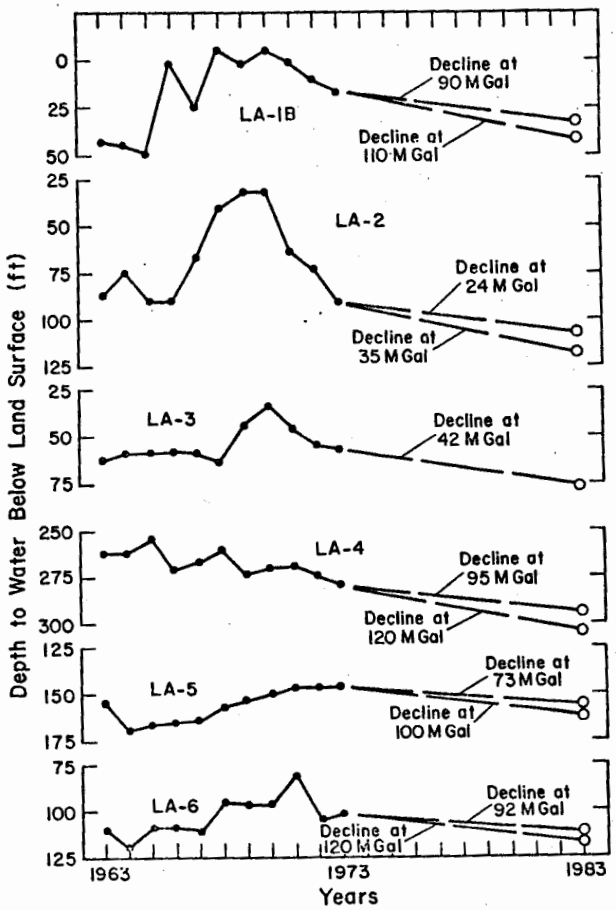

Fig. 2. Nonpumping water level (1963-1973) and projected declines (1974-1983) in supply wells in the Los Alamos Field.

If the average annual 24-million-gal pumpage is continued, the 1983 nonpumping water level will be about 15 ft lower than in 1973; if the 35-million-gal average is maintained, the level will be about 25 ft lower by 1983.

3. Supply Well LA-3. Average annual pumpage for the period of record, 1947 through 1973, was 43.1 million gal; annual pumpage ranged from 20.3 million gal in 1973 to 82.5 million in 1948. Average annual pumpage during 1964 through 1973 was 41.9 million gal. The average pumping rate for the period of record was 354 gpm; the annual average ranged from 294 gpm in 1960 to 462 in 1949.

The net decline in nonpumping water level was about 51 ft in 1947 through 1973. The water level was 2 ft below the land surface before pumping started in 1947. The decline is attributed primarily to pumping of the well and to interference by wells LA-2 and LA-1B (Fig. 1). A rise in nonpumping water level from 1968 to 1970 reflects decreased pumping in wells LA-2 and LA-1B.

If the average annual pumpage is maintained at about 42 million gal, the nonpumping water level in 1983 will be about 20 ft lower than the 1973 level. The annual pumpage should not exceed 42 million gal. To prevent excessive sand pumping, the pumping rate should be kept below 320 gpm.

4. Supply Well LA-4. Average annual pumpage for the period of record, 1948 through 1973, was 108.0 million gal; annual pumpage ranged from 37.5 million gal in 1949 to 173.6 million in 1951. Average annual pumpage during 1964 through 1973 was 95.0 million gal. The average annual pumping rate ranged from 454 gpm in 1948 to 665 in 1949; the average for the period of record, was 594 gpm, and that for 1964 through 1973 was 591.

The net decline in nonpumping water level has been about 88 ft from 1948 to 1973, or about 3.4 ft/yr. The water level before pumping started was 190 ft below the land surface. It is significant that the net decline in nonpumping water level from 1950 through 1973 was only 28 ft, or about 1.6 ft/yr. In 1969, when the well had not been pumped for 3 months, its water level was only 3 ft below the average 1950 nonpumping level. Water-level fluctuations in this well are caused primarily by pumping. The nearest well that would cause interference is LA-5 (Fig. 1).

If the average annual pumpage is maintained at about 95 million gal, the nonpumping water level in 1983 will be about 15 ft lower than in 1973. The well and aquifer can yield more than 95 million gal/yr. Increasing the pumping rate by about 150 gpm would increase the drawdown by about 20 ft. The well could be pumped longer at the same rate to yield greater annual pumpage. If the average annual pumpage is increased to 120 million gal, the nonpumping water level will drop about 25 ft by 1983.

5. Supply Well LA-5. The average annual pumpage in the period of record, 1948 through 1973, was 92.4 million gal; annual pumpage ranged from 50.5 million gal in 1965 to 187.4 million in 1951. The average annual pumpage in 1964 through 1973 was 72.7 million gal. The average annual pumping rate ranged from 460 gpm in 1973 to 575 in 1948; averages for 1948 through 1973 and 1964 through 1973 were 496 and 471 gpm, respectively.

There was a net decline of about 71 ft in the nonpumping water level in 1948 through 1973, or about 2.8 ft/yr. The prepumping level in 1948 was 75 ft below the land surface. The decline is attributed primarily to pumping of the well; interference from the two closest wells, LA-4 and LA-6, probably has been slight. In 1964 through 1973, the nonpumping water level rose because of reduced pumping of the well.

If the average annual pumpage of about 73 million gal is continued, the nonpumping water level in 1983 will be about 10 ft lower than in 1973. The well and aquifer can yield water at a higher pumping rate and annual pumpage than in 1964 through 1973. A pumping rate of about 500 gpm and an average annual pumpage of 100 million gal would not overextend the potential of the well and aquifer. Increasing the average annual pumpage to 100 million gal would lower the nonpumping water level about 15 ft by 1983.

6. Supply Well LA-6. Average annual pumpage in 1949 through 1973 was 110.1 million gal; annual pumpage ranged from 71.6 million gal in 1958 to 201.5 million in 1951. Average annual pumpage was 91.6

million gal in 1964 through 1973 and 81.4 million in 1967 through 1973. The average pumping rate for the period of record was 581 gpm; annual averages ranged from 543 gpm in 1964 to 652 in 1949. From 1964 through 1973, the average annual pumping rate ranged from 543 to 573 gpm.

The net decline in nonpumping water level was 75 to 85 ft in 1948 through 1973, or about 3 ft/yr. The depth to water was 20 ft before pumping started in 1948. The net decline between 1951 and 1973 was only 17 ft, or about 0.7 ft/yr. The nonpumping water level rose after 1966 when pumpage was reduced. The water-level decline is attributed primarily to pumping of the well and, to a small extent, to interference from other wells, the two closest being LA-5 and LA-3 (Fig. 1).

If the average annual pumpage of about 92 million gal is maintained at about 560 gpm in 1974 through 1983, the nonpumping water level will drop about 10 ft.

The well and aquifer can yield water at a higher pumping rate and annual pumpage without excessive water-level decline over the next 10 yr. If the pumping rate is increased to 700 gpm to yield an average annual pumpage of 120 million gal, the nonpumping water level will drop about 20 ft by 1983.

B. The Guaje Field

The Guaje Field is composed of seven wells in Guaje and Rendija Canyons east and northeast of Los Alamos (Fig. 1). The wells are 1520 to 2000 ft deep.

1. Supply Well G-1. Average annual pumpage from 1952 through 1973 was 82.6 million gal; annual pumpage ranged from 55.9 million gal in 1957 to 114.9 million in 1963. Average annual pumpage in 1964 through 1973 was 79.0 million gal. The average pumping rate for 1951 through 1973 was 478 gpm; annual averages ranged from 375 gpm in 1973 to 539 in 1951.

The net nonpumping water-level decline in the period of record, 1949 through 1973, was 73 ft, or about 3.2 ft/yr. The depth to water before pumping started in 1950 was 190 ft. The decline is attributed primarily to pumping of the well; however, wells G-1A and G-2, up the hydraulic gradient from well G-1, have created appreciable interference (Fig. 1). At equal distances, the interference created by a pumping well is greater downgradient than upgradient. The water level in well G-1 rose somewhat after 1964 when the annual pumpage was decreased.

If the average annual 79-million-gal pumpage is continued through the next 10 yr, the nonpumping water level will drop about 30 ft (Fig. 3). It is questionable whether the pumpage should be increased, because the well condition is in doubt. Condition of the well, rather than the aquifer, seems to be the dominant factor in planning future operation of this well.

2. Supply Well G-1A. Average annual pumpage from 1954 through 1973 was 111.0 million gal; annual pumpage ranged from 53.0 million gal in 1955 to 149.7 million in 1963. Average annual pumpage in 1964 through 1973 was 105.1 million gal. The average pumping rate for the period of record, 1954 through 1973, was 562 gpm; annual averages ranged from 531 gpm in 1973 to 587 in 1957.

The net decline in nonpumping water level in the period of record was 41 ft, or about 2.2 ft/yr. The depth to water before pumping started in 1954 was 250 ft. The decline is attributed primarily to pumping of the well; however, wells G-2 and, to a lesser extent, G-1 have caused interference. The net decline has been negligible since 1964 when pumpage was increased.

If the average annual pumpage of about 105 million gal is continued through the next 10 yr, the nonpumping water level will drop about 20 ft. The average pumping rate would be about 550 gpm. This rate probably should be reduced until the cause of sand pumping is determined and remedied. The gravel-pack level should be watched closely,

because a sudden drop in the level might indicate, or result in, collapse of the casing or screen.

3. Supply Well G-2. Average annual pumpage for 1952 through 1973 was 88.5 million gal; annual pumpage ranged from 62.8 million gal in 1970 to 105.7 million in 1963. Average annual pumpage in 1964 through 1973 was 78.1 million gal. The average pumping rate for the period of record, 1951 through 1973, was 446 gpm; annual averages ranged from 386 gpm in 1963 to 550 in 1952.

The net nonpumping water-level decline in the period of record was 74 ft, or about 3.4 ft/yr. The depth to water before pumping started in 1951 was 260 ft. Practically all the decline occurred before 1965; since then it has been small. The decline is attributed mostly to pumping of the well and to a lesser extent to interference from wells G-1A, G-1, and G-3. Decreased pumpage in this and nearby wells raised the water level in well G-2.

If the average 78-million-gal pumpage is continued through the next 10 yr, the nonpumping water level will drop about 15 ft. Annual pumpage can probably be increased in increments of 5 million gal/yr; 90 million gal is a suggested maximum.

4. Supply Well G-3. Average annual pumpage in 1952 through 1973 was 68.9 million gal; annual pumpage ranged from 47.3 million gal in 1973 to 87.9 million in 1956. Average annual pumpage in 1964 through 1973 was 59.6 million gal. The average pumping rate for the period of record was 361 gpm; annual averages ranged from 278 gpm in 1973 to 488 in 1955. The year 1951 was not considered, because the well was pumped less than 1 month.

The net nonpumping level decline in 1951 through 1973 was 49 ft, or about 2.2 ft/yr. The depth to water before pumping started in 1951 was 277 ft. The net decline from 1955 through 1973 was 25 ft, or about 1.4 ft/yr, attributed primarily to pumping of the well and to interference by

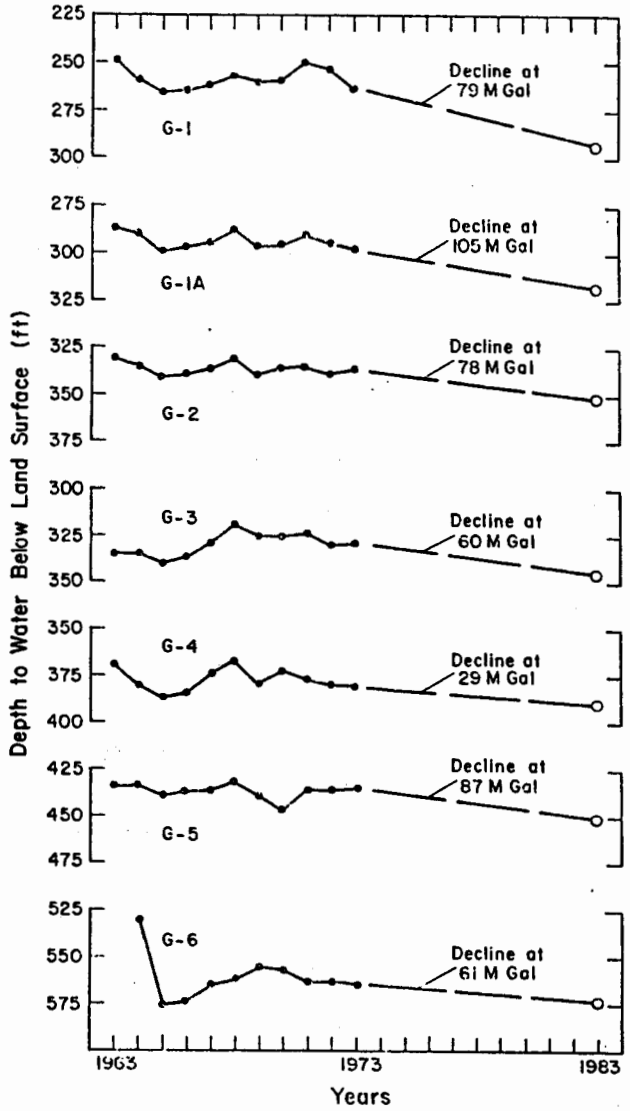

Fig. 3. Nonpumping water levels (1963-1973) and projected declines (1974-1983) in supply wells in the Guaje Field.

wells G-4 and G-2. A water-level rise after 1965 resulted from reduced pumpage of this and nearby wells.

Judging from past production and water-level trends, the well and aquifer can yield more than an average 60 million gal/yr, which would lower the nonpumping level about 15 ft between 1973 and 1983. If the well's specific capacity can be improved, the annual rate could be increased by increasing the pumping rate. Any attempted increase should be in increments

of 5 million gal/yr; an annual average of about 80 million might be optimum.

5. Supply Well G-4. Average annual pumpage in the period of record, 1951 through 1973, was 35.8 million gal; annual pumpage ranged from 7.7 million gal in 1970 to 58.8 million in 1954. Average annual pumpage in 1964 through 1973 was 29.3 million gal. The average pumping rate for the period of record was 270 gpm; annual averages ranged from 189 gpm in 1965 to 434 in 1954.

There has been a 36-ft net decline in the nonpumping water level between 1951 and 1973, or about 1.6 ft/yr. Between 1953 and 1973, the net decline was 8 ft, or about 0.4 ft/yr. The depth to water before pumping started in 1951 was 343 ft. The decline is attributed to pumping of the well and to some interference from wells G-5 and G-3.

If the average annual pumpage of about 29 million gal can be maintained through the next 10 yr, the nonpumping water level will drop about 10 ft.

6. Supply Well G-5. Average annual pumpage was 93.8 million gal in the period of record, 1951 through 1973; annual pumpage in 1966 through 1973 was 86.8 million gal. The average pumping rate for the period of record was 541 gpm; annual averages ranged from 436 gpm in 1953 to 581 in 1959 and have not exceeded 554 gpm for the last 8 yr.

There has been a 22-ft net decline in the nonpumping water level from 1951 through 1973, or about 1.0 ft/yr. The water level was 412 ft below the land surface before pumping started in 1951. The decline is the least of any well in the Guaje and Los Alamos fields.

If the average annual pumpage of about 87 million gal can be continued through the next 10 yr, the nonpumping water level will drop about 15 ft.

7. Supply Well G-6. Average annual pumpage for the period of record, 1964 through 1973, was 61.4 million gal; annual pumpage ranged from 42.8 million gal in 1971 to 92.2 million in 1966. The average pumping rate for the period of record was 356 gpm; annual averages ranged from 243 gpm in 1971 to 393 in 1967.

The prepumping water level in 1964 is uncertain; it was computed using data from the first pumping test. The computed level was 520 to 540 ft below the land surface, so an average of 530 ft was selected as a compromise.

There has been a 36-ft net decline in the nonpumping water level between 1964 and 1973, or about 3.8 ft/yr. The water level changes in the well are primarily the result of its pumping; the two closest wells, G-4 and G-5, and downgradient (Fig. 1).

If the average annual pumpage of about 61 million gal is continued through the next 10 yr, the nonpumping water level will drop about 10 ft.

C. The Pajarito Field

The Pajarito Field consists of three wells on the Pajarito Plateau southeast of Los Alamos. The wells are 2300 to 2550 ft deep.

1. Supply Well PM-1. Average annual pumpage for the period of record, 1965 through 1973, was 84.6 million gal; annual pumpage ranged from 46.5 million gal in 1973 to 111.0 million in 1967. The average pumping rate for the period of record was 596 gpm; annual averages ranged from 460 gpm in 1973 to 645 in 1967.

The nonpumping water level declined 10 ft during the period of record, or about 1.2 ft/yr. (Fig. 4). The 1965 prepumping water level was 722 ft below the land surface. The water-level changes result primarily from pumping the well, but pumping of PM-3 may be causing interference (Fig. 1).

If the average 85-million-gal annual pumpage is continued through the next 10 yr, the nonpumping water level will drop about 5 to 15 ft (Fig. 4).

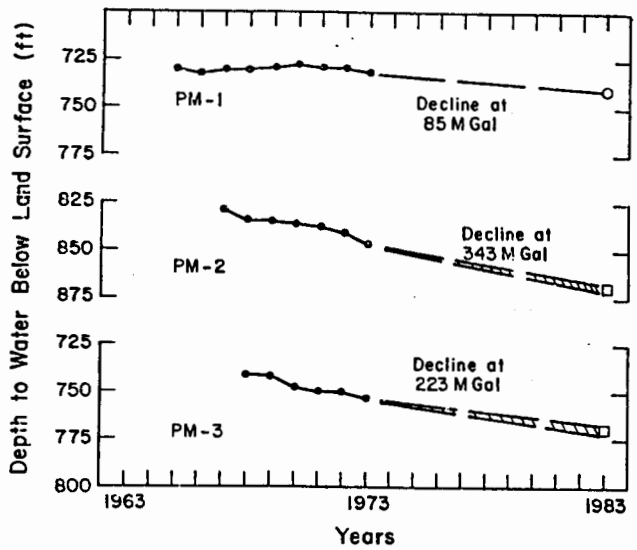

Fig. 4. Nonpumping water levels (1963-1973) and projected declines (1974-1983) in supply wells in the Pajarito Field.

2. Supply Well PM-2. Average annual pumpage in the period of record, 1966 through 1973, is 343.3 million gal, greatest of any Los Alamos supply well. Annual pumpage ranged from 279.9 million gal in 1969 to 385.3 in 1972. The average pumping rate for the period of record was 1405 gpm; annual averages ranged from 1388 gpm in 1973 to 1422 in 1966.

There has been a net 24-ft decline in the nonpumping water level in the period of record, or about 3.4 ft/yr. The water level before pumping started in 1966 was 823 ft below the land surface. The decline is attributed almost entirely to pumping of the well.

The estimated decline is based on a very short period of record. However, if the average annual pumpage continues at about 343 million gal, the nonpumping water level in 1983 could be 20 to 25 ft lower than in 1973.

3. Supply Well PM-3. Average annual pumpage in the period of record, 1968 through 1973, was 222.7 million gal, second greatest of any Los Alamos supply well. Annual pumpage ranged from 187.4 million gal in 1968 to 257.8 million in 1973. The average pumping rate for the period of record was 1318 gpm; the annual average ranged from 1300 gpm in 1971 to 1343 in 1968.

There has been a net decline of about 13 ft in the nonpumping water level during 1968 through 1973, or about 2.2 ft/yr. The water level before pumping started in 1968 was 740 ft below the land surface. The decline is attributed almost entirely to pumping of the well. The estimated decline is based on a very short period of record, but, if the annual pumpage continues at about 223 million gal, the nonpumping water level in 1983 could be 15 to 20 ft lower than that in 1973.

III. WELL HISTORY

The well history was prepared using Zia Company records and specific capacity. Specific capacity changes in each well were studied, together with the physical problems, to determine the factors that might have a large influence on future discharge-drawdown relations. A history of the physical changes in each well was compiled. The changes included breaking and/or collapsing of the casing and screen and whole or partial plugging of the well bore and screen by accumulated sediment drawn into the well from the aquifer. The frequency of pump repair necessitated by abrasion from discharge of fine-grained material carried into the well with the water was also noted in evaluating well conditions.

A. The Los Alamos Field

Well LA-1 was the first completed in the field, during 1946. The last well, LA-1B, completed in 1960, replaced LA-1 which was abandoned as its yield decreased because of sand problems. There are six operating supply wells in the field.

1. Supply Well LA-1B. The pump has not been pulled since it was installed in 1960. The cased depth of the well is 1750

ft; the pilot hole was drilled to 2256 ft. The bottom of the lowest screen is 56 ft above the bottom of the casing. If sediment is accumulating in the well, it would first fill the pilot hole and then fill 56 ft of casing to reach the bottom of the lowest screen. Indirect evidence indicates that some of the lower screens may be blocked. No large increase in sediment discharged with the water has been noted, so the casing and screens are apparently intact.

The well's specific capacity has decreased from about 6 gpm/ft in 1960 to about 4.5 in 1973. The decrease in saturated thickness of the aquifer has been too slight to be a major factor in the loss of specific capacity. More important factors are sediment accumulation in the well, accumulation of fine-grained aquifer material in the gravel pack, and mineral deposition in the screen openings. Which factor has the greatest influence cannot be determined until the interior of the well is examined.

2. Supply Well LA-2. Conditions inside this well have been examined at least four times since the permanent pump was installed in 1947. The well is cased to a depth of 870 ft, and it has been perforated through most of its depth. About 29 ft of sediment was removed in July 1962; cleaning on the latter date was to a depth of 880 ft, or 10 ft below the bottom of the casing. Measurements in December 1963 and March 1967 gave the well depth as 878 and 870 ft, respectively.

The specific capacity is the lowest of any supply well and it has fluctuated between 1 and 2 gpm/ft. The decreased specific capacity may result from the water level decline and interference from wells LA-1B and LA-3.

3. Supply Well LA-3. Accumulated sediment has been removed from this well twice. An unrecorded amount was removed in July 1959, and about 198 ft was removed in February 1961. The cased depth is 870 ft, and the 198 ft of sediment had covered about 10% of the screen. The well is a known sand-pumper, so considerable sediment must have accumulated in it since 1961.

The well's specific capacity is low, and has ranged from about 3.5 to about 1.5 gpm/ft. The decrease is attributed to sediment accumulation and interference from nearby wells. The water-level decline has had little effect on the specific capacity. Comparison in years when the water level differed by about 25 ft showed little change in specific capacity.

4. Supply Well LA-4. Conditions in this well have been observed twice since the permanent pump was installed in 1948. The depth was measured as 1962 ft in 1962 and 1964 ft in 1969. The cased depth is 1965 ft, but the pilot hole was drilled to 2015 ft. The pilot hole may have filled with sediment or have been obstructed by caving. The lack of sediment accumulation between 1962 and 1969 indicates that aquifer materials are not entering the well in large quantities.

The specific capacity of well LA-4 is the second greatest in the Los Alamos Canyon field. It has decreased from an 8.4-gpm/ft average in 1950 to 7.1 in 1973. The decrease has not been steady; it was greatest after 1969 when the specific capacity changed from 8.0 to 6.9 gpm/ft in 2 yr. The cause of this relatively large decrease is not known.

5. Supply Well LA-5. Conditions in this well have been observed only once since the permanent pump was installed in 1948. In 1962, the well depth was measured as 1970 ft. The well is cased to 1750 ft, but the pilot hole was drilled to 2024 ft. About 45 ft of pilot hole has filled in, but whether it is by caving or by sediment accumulation because of pumping is not known. Even if it is filled in by sediment, the rate of accumulation is low.

The specific capacity of well LA-5 decreased from about 4.8 gpm/ft in 1952 to about 3.0 in 1973. Probable causes do not include water-level decline or sediment accumulation. Accumulation of mineral deposits in the screen openings may be a factor. The well interior would have to be examined to determine.

6. Supply Well LA-6. Conditions in this well have been examined only once since the pump was installed in 1948. In January 1963, sediment was cleaned from the well between the 1775- and 1789-ft depths. The cased depth is 1790 ft, so 15 ft of sediment had accumulated.

The specific capacity of well LA-6 is the greatest of any well in the Los Alamos Canyon field. Before mid-1971, the specific capacity has 13 to 14 gpm/ft, but since October 1971 it has been more than 15 gpm/ft. The reason for this increase is not apparent.

B. The Guaje Field

Well G-1 was the first completed in the field, in 1950. The last was G-6, completed in 1964. There were seven operating supply wells in the field in 1973.

1. Supply Well G-1. Conditions in this well have been examined only once since the permanent pump was installed in 1950. The hole was drilled to a depth of 2020 ft. In February 1962, the well depth was measured as 1745 ft, so about 225 ft of sediment had accumulated in the cased part. The record does not indicate whether the sediment was removed. That depth of sediment would block about 75 ft of screen, or 15% of the total screen length. Assessing the effect of this sediment accumulation on potential productivity is impossible because the record does not show when the accumulation occurred. The steady decrease in the well's specific capacity may indicate an additional accumulation. The present well depth should be checked, and the casing and screen should be examined.

The well's specific capacity has decreased from about 7.2 to 3.0 gpm/ft. The interior of the well has not been inspected since 1962, so one can only speculate on the probable causes for the decrease. Sediment accumulation in the well and gravel pack and mineral deposition in the screen openings could be responsible. Another cause might be collapsed casing or screen partially blocking movement of water up through the well. The well depth should be measured, and the casing and screen should be examined.

2. Supply Well G-1A. Conditions in this well have been examined only once since the permanent pump was installed in 1954. In January 1974, sediment was cleaned from between the 1415-ft and 1519-ft depths; the well is cased to 1519 ft. Periodic sampling to determine whether sand is being discharged began about 1971. Recent samples seemingly indicate that the well is pumping more sand than before. Possibly a break developed in the casing or screen, and material from the aquifer is being drawn into the well with the water. The increased sand pumping has occurred within the past couple of years. If the quantity of sand now being pumped had been entering the well for many years, the pump would have given trouble long before 1974, but it has not been out of the hole since 1954. The casing and screen should be examined for breaks. Any break should be repaired before occurance of a collapse that would be more difficult to repair.

The well's specific capacity decreased from about 12 to less than 9 gpm/ft. The decrease may be related more to sediment accumulation than to a decline in water level, and some may result from interference by nearby wells.

3. Supply Well G-2. Conditions in this well have not been examined since the permanent pump was installed in 1951. This well should be given high priority

in a reconditioning program, to determine conditions of the well and pump.

The well's capacity has not changed appreciably during its years of operation. It has fluctuated between 11 and 12 gpm/ft. This fact can be considered as evidence that the well has not deteriorated seriously, but it does not mean that inspection is unnecessary.

4. Supply Well G-3. Conditions in this well have been examined only once since the permanent pump was installed in 1951. In April 1961, the well depth was measured as 1654 ft, 138 ft less than the cased depth of 1792 ft. Attempts to remove the sediment failed because the bailer could not pass a metallic object at a depth of 1657 ft. About 20 ft of screen is below that level.

The specific capacity has decreased from about 12.5 to about 3.5 gpm/ft. When the well depth was measured in 1961, only about 20 ft of screen was blocked by sediments, but the specific capacity had already decreased to about 5 gpm/ft; the water level had fallen about 49 ft. The evidence points to partial screen blocking, but the blockage may be fine-grained aquifer material that has been drawn into the gravel pack. Some blockage may be caused by deposition of minerals in the screen openings. Development work on the well seems desirable. The screens could be backflushed, and the pumping rate could be increased to draw any fine material through the pack into the well. The casing and screens should be examined before any development work.

5. Supply Well G-4. Conditions in this well have been examined several times since the permanent pump was installed in 1951. A November 1953 depth measurement showed that sediment had accumulated to the 1129-ft level, 836 ft above the bottom of the casing at 1965 ft. Cleaning attempts stopped at 1486 ft because the bailer stuck there. An October 1954 measurement indicated that sediment filled the well to the 1380-ft level. No attempt was made to clean the well, although one-third of the 360 ft of screen was blocked by the sediment. In 1955, the sediment was at the 832-ft level. In May 1966, sediment was cleaned from the 752- to 798-ft depths. Cleaning could not continue below the 798-ft level because of an apparent break in the casing which allowed the gravel pack to enter. Only 120 ft of screen is above that level.

The specific capacity ranged from about 4 to about 1.5 gpm/ft. The decrease is attributed to sediment accumulation in the well. The 4-gpm/ft specific capacity seems low for the well when it was completed and suggests that the well was not developed properly. Condition of the well, not the aquifer, will govern how much can be pumped at this site. It is recommended that a new well be drilled nearby and that well G-4 be abandoned.

6. Supply Well G-5. Conditions in this well have been examined three times since the permanent pump was installed in 1951. In November 1953, sediment was cleaned from the 1421- to 1436-ft depths; the cased depth is 1840 ft. During cleaning at the 1436-ft level, gravel entered the well from the gravel pack and work was stopped. About 125 ft of screen is below the 1436-ft level. In July 1958, a 4-in.-diam weight was lowered into the well to make a depth measurement, but it would not pass below the 673-ft level. It was concluded that the casing was broken and offset there. In March 1964, sediment was cleaned from the 663- to 673-ft depths. Approximately 300 ft of the 360 ft of screen is below the 673-ft level.

The well's specific capacity has ranged from about 12 to about 3.5 gpm/ft. The decrease is attributed to sediment accumulation and the offset in the casing.

An attempt should be made to open the well below the 673-ft level. A liner might be installed opposite the break in the casing. The aquifer will yield water faster than the well can be pumped in its present conditions.

The drawdown when the well is being pumped exposes about 50 ft of screen to air circulation. Intermittent exposure to air may hasten accumulation of minerals in the screen openings and lead to partial blockage. If the well can be cleaned and repaired, much more water can be pumped from it than at present. Conditions of the well, not the aquifer, governs water withdrawal at this site.

7. Supply Well G-6. Conditions in this well have been examined only once since the permanent pump was installed in 1964. In February 1972, sediment was removed from between the 1485-ft depth and the bottom of the casing at 1530 ft. The bailer actually entered the uncased pilot hole about 50 ft below the bottom of the casing. The wells should not be cleaned below the bottom of the cased section.

The specific capacity has fluctuated between 5.8 and 3.9 gpm/ft. The well is a sand producer, so, at present, the pumping rate should remain less than 420 gpm. Further development should involve intermittent backflushing and pumping to try to increase the specific capacity and yield.

C. The Pajarito Field

Well PM-1 was the first completed in the field, in 1965. The last was PM-3, completed in 1968. There are now three operating supply wells in the field.

1. Supply Well PM-1. Conditions in this well have been examined once since the permanent pump was installed in 1965. In January 1974, sediment was cleaned from between the 2000-ft level and the bottom of the casing at 2500 ft. The accumulation occurred during the in-service period. Accumulation of 500 ft of sediment in 7-1/2 yr is rapid, and indicates that the well should be examined. The gravel pack level should be checked frequently to see how rapidly it is settling. If rapid sediment accumulation persists and there are no breaks in the casing and screen to be repaired, the pumping rate may have to be reduced. Some further development of the well might be tried.

The specific capacity seems to be increasing; it ranged from about 14.5 gpm/ft in 1967 to about 24.4 in 1973. The higher value was for the year when pumping rates were lowest, and vice versa. The highest pumping rate seemingly exceeded the optimum rate for the well, at least for the well condition at the time. Knowledge of the sediment accumulation rate from year to year would have helped in interpreting the changes in specific capacity.

2. Supply Well PM-2. Conditions in this well have not been examined since the permanent pump was installed in 1966. There is no evidence that adverse conditions are developing.

The specific capacity ranged from about 28 to about 23 gpm/ft. Some of the decrease may be attributed to accumulation of sediment in the well. Fine-grained material may be entering the gravel pack and not passing on into the well.

3. Supply Well PM-3. Conditions in this well have not been examined since the permanent pump was installed in 1968. There is no indication that operation has caused adverse effects inside the well.

The specific capacity, about 55 gpm/ft, is the greatest of any Los Alamos supply well. There has been no significant change in specific capacity, an indication that conditions in the well are stable.

IV. RECOMMENDATIONS AND CONCLUSIONS

A. The Los Alamos Field

Wells in this field are not depleting water in the aquifer at an excessive rate. The annual pumpage could be increased above

400 million gal in increments of 20 million gal annually. The eventual total increase in pumpage would depend on the change in nonpumping water levels and on the reduction of the wells.

Wells LA-2 and LA-3 are the oldest operating wells in the water-supply system. They share a common cone of depression with LA-1B when in operation. Thus, pumpage from one well affects the yield and water levels in the other two. Wells LA-2 and LA-3 could be placed on standby status if their conditions deteriorate. Pumping of wells LA-1B, LA-4, LA-5 and LA-6 could be increased to make up the supply deficit from the field. This change would require higher capacity pumps in the four wells.

B. The Guaje Field

Wells in this field are not depleting water in the aquifer at an excessive rate. The present pumping rate is conservative in terms of the aquifer's potential yield. Well conditions are a greater factor in controlling yield than is the aquifer.

Problems with the wells are associated with construction, development, and maintenance. Construction seemingly did not cope with the fine-grained material in the aquifer. Well development was not adequate for the type of aquifer.

Except for wells G-2 and, possibly, G-6, wells in the Guaje Canyon Field are deteriorating from one or more of the following causes: breaking and/or collapsing of the casing and screen, sediment accumulation in the well, possible accumulation of fine-grained material in the gravel pack, and deposition of minerals in the screen openings. An orderly reconditioning program should be established.

A sand-pumping problem is apparent in well G-1A.

If a break has occurred, it should be fixed now. A break that is submerged in sediment is more difficult to repair than one exposed above the sediment accumulation. The inside of well G-2 should be surveyed before a large production increase is attempted. A replacement well should be drilled near well G-4 to take more advantage of the aquifer potential at that site. The blockage in well G-5 should be examined by a well expert to see whether the well can be opened. Additional development of well G-6 should be tried; the specific capacity seems to have been too low even when the well was first put into service.

C. The Pajarito Field

The three wells composing this field are, individually and collectively, the most prolific ground-water producers of the Los Alamos supply wells. Because they are good wells, there is a temptation to push them to greater yields. This temptation should be resisted until more data are available concerning the responses of the aquifer to present use and of the wells to present rates of discharge. It would be well to maintain the present average annual pumpage rates for another few years; no decrease seems necessary now.

D. General

The annual water demand in the Los Alamos area is being met by the present well system; however, the peak demand period is close to the capacity of the pumps. Prolonged shutdown of one of the best wells could cause a water shortage. At least two additional wells and a replacement for G-4 are needed to meet emergency situations and water demand.

Peak water demand is a prime factor in well-field design. Wells can operate longer hours to meet a long-term demand, but peak demand that exceeds the collective instantaneous capacities of the pumps can cause a crisis requiring abrupt shifts to water use on a priority basis. Instantaneous pumping capacity can be increased somewhat by measures suggested previously, but additional wells will be required for the future. Because drilling and equipping a well takes many months (equipment

and material supply shortages may prolong the time), plans should be made to add new wells to the system in the near future.

A systematic well reconditioning program should be initiated, and the pumping equipment and interior of the wells should be inspected routinely. Two of the Guaje Canyon wells require immediate reconditioning, and reconditioning of at least four other wells in the system should be considered.

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TABLE I

PRODUCTION POTENTIAL OF THE WELLS AND EXPECTED WATER-LEVEL DECLINE BETWEEN 1974 AND 1983

Well No.	Nonpumping Water Level 1973 (ft)	Nonpumping Water Level Net Decline 1974-1983 (ft)	Average Annual Pumpage 1974-1983 (Million Gal)	Average Instantaneous Discharge 1974-1983 (gpm)	Specific Capacity 1974-1983 (gpm/ft)
LA-1B	13	15	90	550	4
	13	25	110[a]	650	4
LA-2	82	15	24	315	1
	82	25	35[b]	315	1
LA-3	53	20	42	320	1
LA-4	278	15	95	590	7
	278	25	120[a]	740	7
LA-5	146	10	73	470	3
	146	15	100[a]	500	3
LA-6	95-105	10	92	560	13
	95-105	20	120[a]	700	13
G-1	263	30	79	430	3
G-1A	291	20	105	550	8
G-2	324	15	78	400	11
G-3	346	15	60	310	3
G-4	379	10	29	210	1
G-5	433	15	87	540	3
G-6	566	10	61	350	4
PM-1	732	10	85	600	22
PM-2	847	20-25	343	1400	21
PM-3	753	15-20	223	1300	50

[a]Probable potential.

[b]Production if 1947-1973 average is used.