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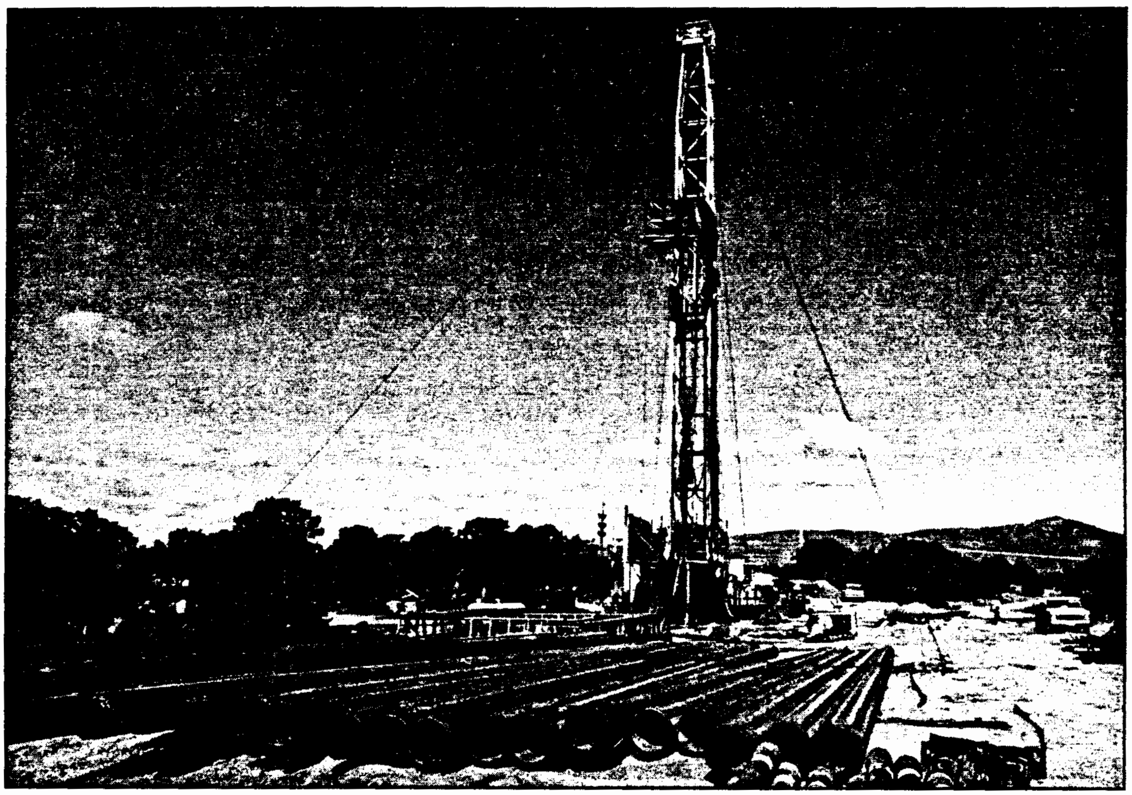

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HYDROLOGIC CHARACTERISTICS OF THE MAIN AQUIFER IN THE LOS ALAMOS AREA: DEVELOPMENT OF GROUND WATER SUPPLIES

by

W. D. Purtymun

ABSTRACT

Deep wells completed into the main aquifer have furnished 40.5×10^9 gal. of water for the Los Alamos National Laboratory and for the communities of Los Alamos and White Rock from 1947 through 1982. The main aquifer is within the siltstones and sandstones of the Tesuque Formation along the Rio Grande, and it rises westward into the lower part of the Puye Conglomerate beneath the central and western part of the Pajarito Plateau. The Laboratory and communities of Los Alamos and White Rock are located on the Pajarito Plateau.

Supply, test, and stock wells have been used to collect hydrologic data from the aquifer beneath the Pajarito Plateau and to the east along the Rio Grande. Hydrologic characteristics of springs along the Rio Grande, which are in the discharge area from the main aquifer, are included to supplement the data from the wells. Hydrologic characteristics of the aquifer determined from tests and observations are the saturated thickness, pumping or production rates of the wells, drawdown, specific capacity, field coefficient of permeability, transmissivity, rate of water movement in the aquifer, production from wells and fields, water-level trends of the aquifer, rates of water-level decline, and production per foot of water-level decline.

Chemical quality of water in the aquifer varies according to the formations yielding water to the wells. Based on hydrologic characteristics of existing wells, suggested locations for four additional wells were made in areas to develop high-yield low-drawdown (1000-gpm/100-ft) supply wells. These locations are recommended in long-range planning for future water supply as the demand for water increases at the Laboratory and in the communities. A well to replace well G-4 in the Guaje Field is recommended to offset declining production in the field.

I. INTRODUCTION

The Los Alamos National Laboratory and the communities of Los Alamos and White Rock are supplied by water pumped from deep wells in three well fields located in Los Alamos Canyon, in Guaje Canyon, and on the Pajarito Plateau. Production from these wells is from the main aquifer of the Los Alamos area. The main aquifer is the only aquifer that is capable of municipal and industrial supply. In addition to the 18 supply wells that penetrate into the main aquifer, 10 test wells and 2 stock wells in the Los Alamos area are completed into the main aquifer.

A. Purpose and Scope

Hydrologic data have been collected from 1947 through 1982 from supply and test wells. The data have been collected and published to ensure a continuing historical record to provide guidance for water management resources and long-range planning for the water supply sytem.[1-14] The purpose of this report is to evaluate this hydrologic data and to describe the hydrology of the main aquifer to provide support for long-range planning of locations for additional wells.

B. Geography

The facilities of the Los Alamos National Laboratory and the communities of Los Alamos and White Rock are located on the Pajarito Plateau. The Pajarito Plateau forms an apron 8 to 16 miles wide and 30 to 40 miles long around the eastern flanks of the Sierra de los Valles (Fig. 1). The surface of the plateau slopes gently eastward from an altitude of about 7800 ft along the

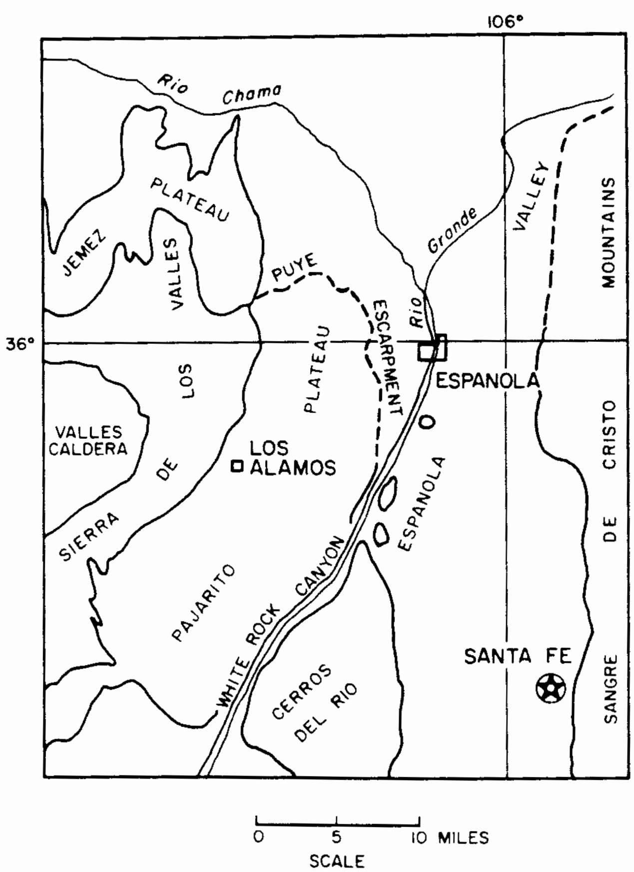

Fig. 1. Topographic features in the Los Alamos area.

flanks of the mountains to about 6200 ft along the eastern edge, where it terminates along the Puye Escarpment and White Rock Canyon. The plateau is drained by southeast- and eastward-trending streams that have cut deep canyons into the surface of the plateau.

The Rio Grande lies to the east of the plateau. It drops from an altitude of about 5500 ft at Otowi (mouth of Los Alamos Canyon) to about 5360 ft at the junction with Frijoles Canyon. North of Otowi the Rio Grande lies in a broad valley, whereas to the south it is confined in a deep narrow canyon (White Rock Canyon).

The mountain peaks of the Sierra de Los Valles rise to an altitude of about 11 500 ft near the head of Santa Clara Canyon and to an altitude of 10 200 ft near the head of Frijoles Canyon. The crest of the north/south-trending range of peaks and ridges forms a surface water divide. Streams originating on the eastern slopes and Pajarito Plateau flow directly into the Rio Grande. Streams on the western slopes follow a more circuitous course and enter the Rio Grande 75 miles to the south.

The climate and vegetation change westward from the Rio Grande to the crest of the Sierra de Los Valles, along with the change in altitude. The average precipitation increases from about 10 in. along the Rio Grande to as much as 30 in. along the crest of the mountains. The average annual precipitation on the plateau is about 18 in. About 70% of the precipitation occurs in July and August during summer thundershowers.

C. Definitions of Terms

A few of the hydrologic terms are defined for the convenience of the reader.

- Aquifer. A body of rocks or formations that contains sufficient permeable material to conduct ground water and to yield economically significant quantities of water to wells or springs.
- Saturated Thickness. The zone of complete saturation, which includes permeable and relatively impermeable rock units.
- Pumping or Production Rate. Reported in gallons per minute (gpm).
- Drawdown. The distance the water level in a well is lowered by pumping (ft).
- Specific Capacity. The rate of discharge of a water well per unit of drawdown (gpm/ft).
- Transmissivity. The rate at which water in an aquifer is transmitted through a unit width of the aquifer under unit hydraulic gradient (gpd/ft).

- Field Coefficient of Permeability. The rate of flow of water in gallons per day through 1 sq ft under a hydraulic gradient of 100% at prevailing temperature in the aquifer (gpd/ft^2).
- Rate of Movement in the Aquifer. Derived from the equation V = PI/p, where P = field coefficient of permeability in gpd/ft^2 (converted to ft^3), I = hydraulic gradient, and p = per cent porosity of saturated thickness ranging from 15% for fine sediments to 20% for sandstones and conglomerates.
- Production. Reported in gallons (gal.).

II. GEOLOGY

Drainage areas or streams that head on the flanks of the mountains are cut into the rocks of the Tschicoma Formation. Canyons on the Pajarito Plateau are cut into and are underlain by the Bandelier Tuff. Along the eastern edge of the plateau, the channel is cut through the Puye Conglomerate into the Tesuque Formation, which floors the valley north of Otowi on the Rio Grande and forms the lower canyon walls along the Rio Grande in White Rock Canyon (Fig. 1). The basaltic rocks of Chino Mesa are in places interbedded in the sediments of the Puye Conglomerate.

The rock units described, from oldest to youngest, are the Tesuque Formation, Puye Conglomerate, and basaltic rock of Chino Mesa of the Santa Fe Group; the Tschicoma Formation and Bandelier Tuff of the volcanic rocks of the Jemez Mountains; and alluvium and soil of recent age. The generalized geology, stratigraphy, and structure are presented as a basis for understanding hydrology of the main aquifer. Detailed geology can be found in Refs. 15-19. The geologic nomenclature used in this report is from Griggs.[17]

The generalized stratigraphic relations are shown on the geologic cross-section through the Pajarito Plateau, Fig. 2. A diagrammatic section correlation of rock units between supply and test wells is shown in Fig. 3.

A. Santa Fe Group

The Santa Fe Group, in ascending order, consists of the Tesuque Formation, Puye Conglomerate, and basaltic rocks of Chino Mesa (Fig. 2).

The Tesuque Formation is the oldest geologic formation to be considered in this report. It consists of a poorly to moderately cemented light-pink siltstone, silty sandstone, and a few lenses of pebbly conglomerate and clay. The sand-sized particles are dominantly quartz and feldspar; minor amounts of biotite, muscovite, and magnetite are also present. Rock fragments are rhyolite, gneiss, schist, limestone, and quartzite. Basalt flows are interbedded with the sediments of the Tesuque Formation. They generally are about 50 ft thick and contain interflow breccias of sediments.

The Tesuque Formation crops out along the Rio Grande and in lower Los Alamos and Guaje Canyons and underlies the Pajarito Plateau (Fig. 2).

Many individual beds in this formation are permeable and, where saturated, will yield water to a well. Some of the beds are relatively impermeable, and they restrict vertical and lateral movement of water within the formation. Beneath the Pajarito Plateau, coarse volcanic rock fragments of latite, basalt, rhyolite, tuff, and pumice predominate in the upper 1000 ft of the Tesuque Formation. These coarse sediments yield larger amounts of water to wells than do the finer sediments that predominate in the formation farther to the east along the Rio Grande.

The interbedded basalt flows in the Tesuque Formation may be fairly dense; when thin, they may be highly jointed and yield large amounts of water. Sediments of the interflow breccias between basalt flows are coarse and should yield water readily.

The Puye Conglomerate overlies the Tesuque Formation and consists of poorly to well-cemented detritus, which ranges in size from clay to large boulders (Fig. 2). The rocks that compose the conglomerate are latite, quartz latite, dacite, rhyolite, basalt, and pumice. Lenses and tongues of silt, clay, or pumice are common. The basal bed of the conglomerate is a slightly consolidated channel-fill deposit distinctive in composition, consisting of pegmatite gravel and boulders of quartzite, granite, gneiss, schist, and fragments of basalt and limestone.

The Puye Conglomerate crops out along the Rio Grande and thickens westward beneath the Pajarito Plateau. Along the western edge of the plateau, it interfingers in the subsurface with flow rocks of the Tschicoma Formation (Fig. 2). The Puye Conglomerate is highly permeable and, when saturated, it yields large amounts of water to wells.

The basaltic rocks of Chino Mesa consist of a series of basalt flows and interflow breccias. Individual flows generally are less than 50 ft thick; however, a series of flows may form a single thick-basalt unit. Interflow breccias of broken fragments of basalt and sediments may occur between individual flows.

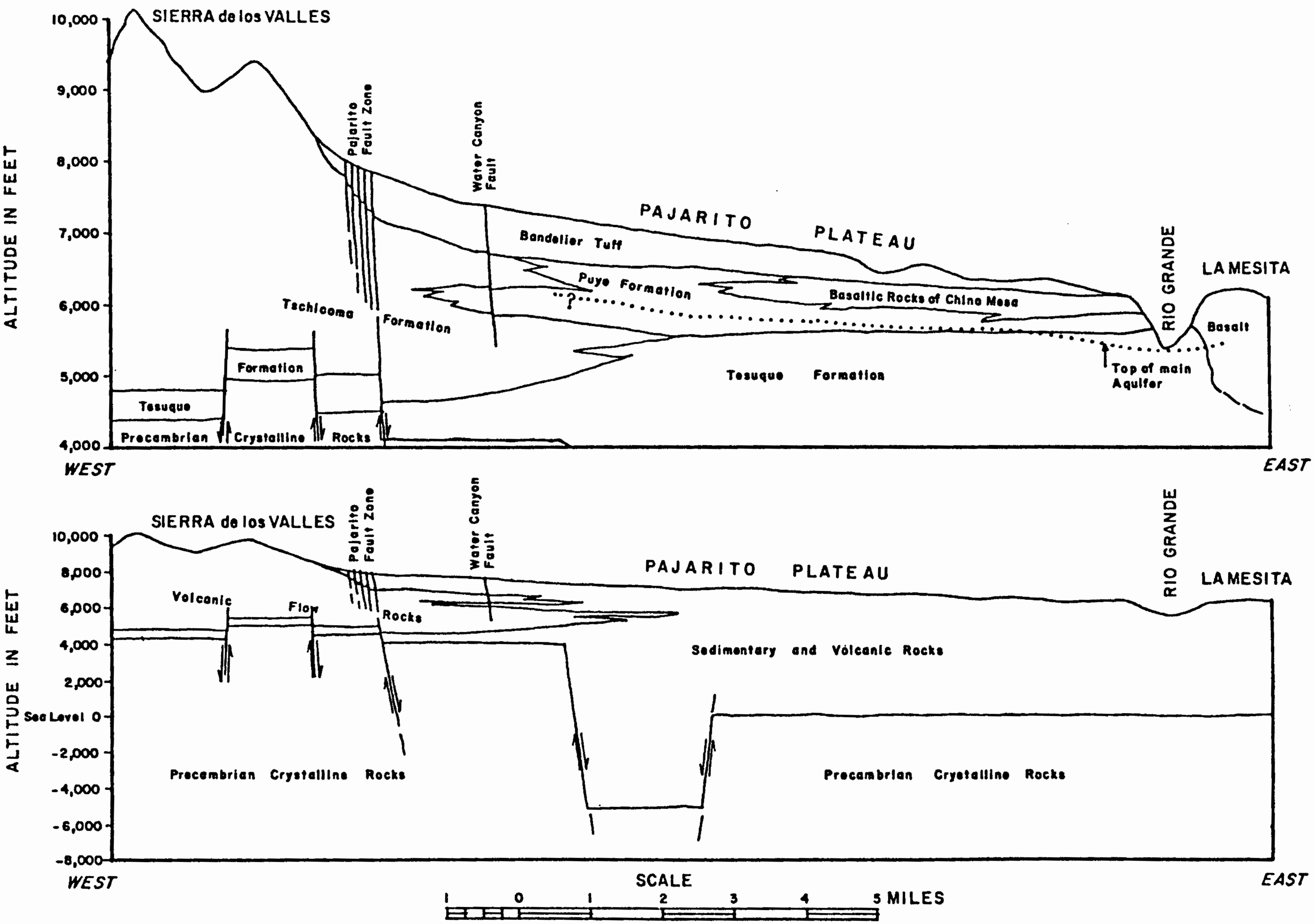

Fig. 2. Geologic section showing stratigraphy and structure from the Sierra de los Valles across the Pajarito Plateau to the Rio Grande.

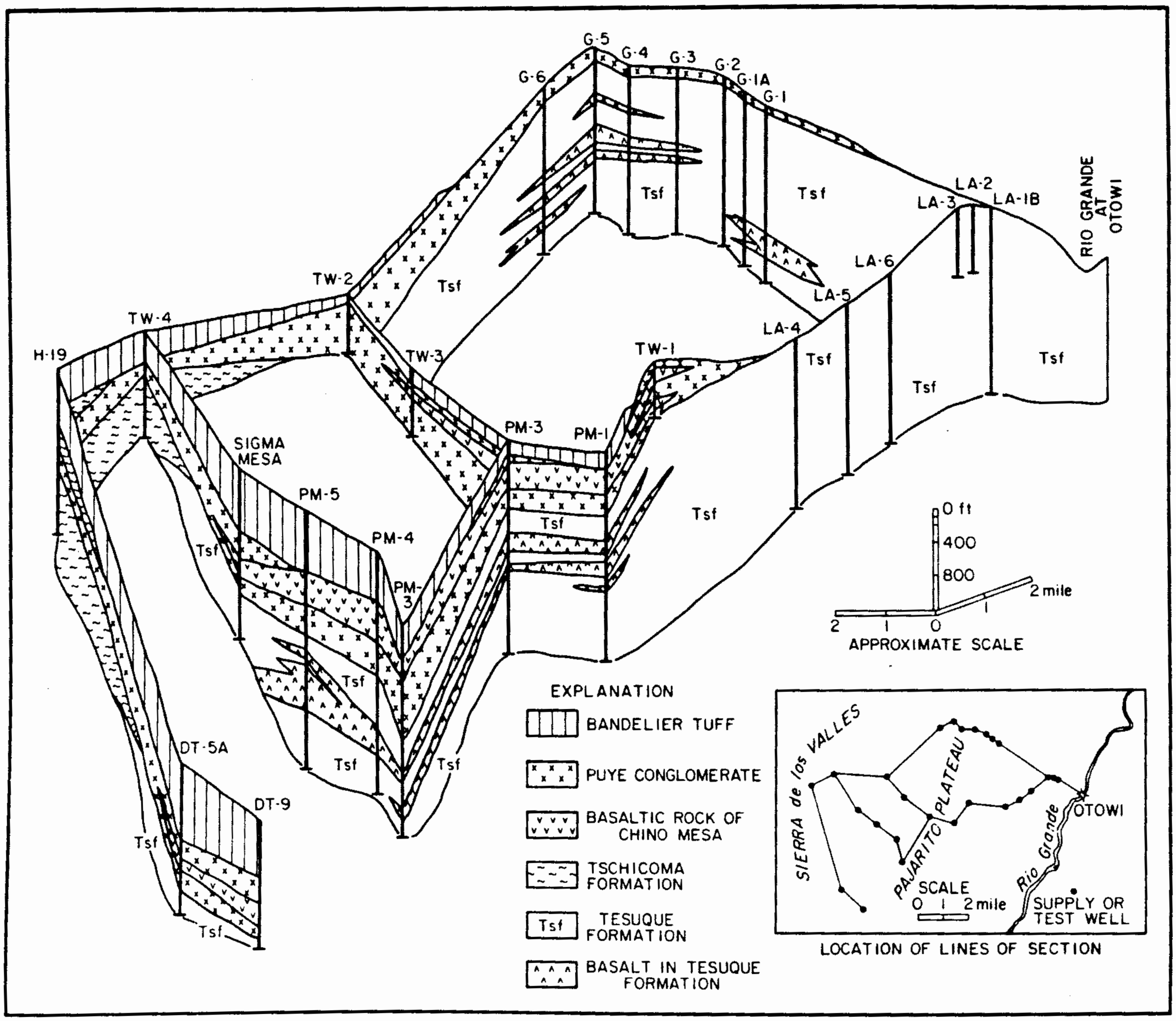

Fig. 3. Diagrammatic section of geologic units in the Los Alamos area.

A thick section of these rocks crops out along the Rio Grande in White Rock Canyon south of Los Alamos Canyon. The rocks thin westward beneath the Pajarito Plateau, where they interfinger in the subsurface with sediments of the Puye Conglomerate.

The basalt flows were extruded from centers east of the Rio Grande, and they flowed north, northwest, and west across the present course of the river. They form the eastern edge of a north/south-trending basin beneath the central part of the Pajarito Plateau (Fig. 3). The basin is filled with conglomerate that interfingers with the basalt; deposition of the conglomerate and emplacement of the basalts were contemporaneous. Thick sections of basalt into the subsurface and along the eastern margin of the Pajarito Plateau occur where the flows filled topographic lows in the Puye Conglomerate.

Thin basalt flows, separated by interflow breccias beneath the central part of the Pajarito Plateau, are permeable and when saturated, will yield water readily. Open joints and cavities in thick-basalt flows also yield water; however, along the Rio Grande (White Rock Canyon), steepening of the contours on the surface of the main aquifer indicates that thick-basalt flows form a barrier to movement of ground water (Fig. 4).

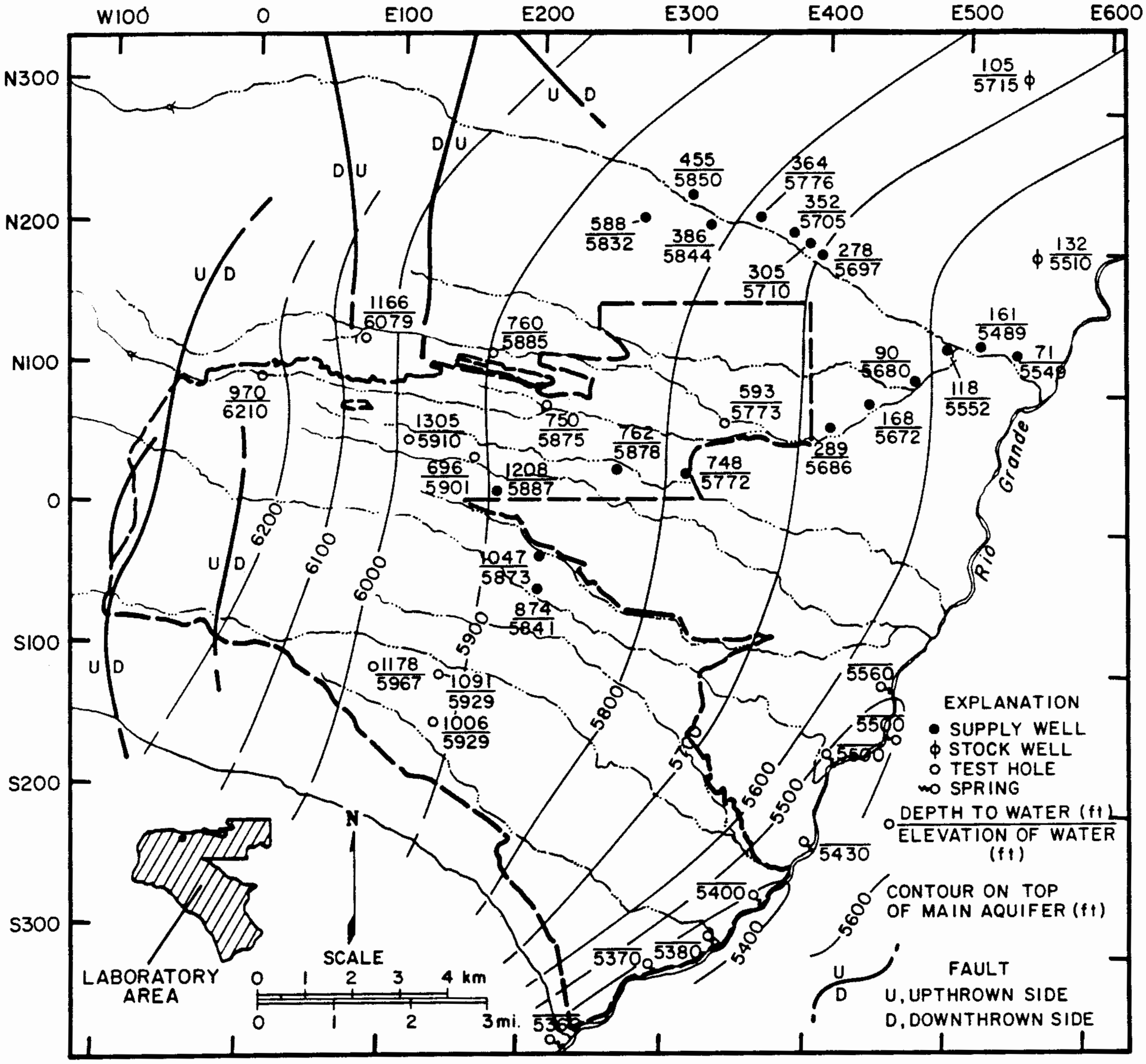

Fig. 4. Generalized contours on the surface of the main aquifer.

B. Volcanic Rocks of the Jemez Mountains

Volcanic rocks of the Jemez Mountains, along the eastern flanks of the Sierra de los Valles and on the Pajarito Plateau, consist of the Tschicoma Formation and the younger Bandelier Tuff (Fig. 2).

The Tschicoma Formation consists of flow and pyroclastic rocks composed of latite, quartz latite, dacite, and andesite. Interflow breccias of broken fragments of flow rocks and sediments occur between flows.

The Tschicoma Formation forms the Sierra de los Valles west of the Pajarito Plateau and is present in the subsurface beneath the western part of the plateau, where it interfingers with the Puye Conglomerate (Figs. 2 and 3).

The Tschicoma Formation has low permeability and thus retards and restricts the movement of ground water. Open joints and interflow breccias within the formation, which could yield appreciable amounts of water, are limited.

The Bandelier Tuff consists of a series of ash fall and ash flow tuff that is light grained and rhyolitic. The tuff contains quartz and sanidine crystals, pumice, and small fragments of other igneous rock in a matrix of fine ash shards.

The tuff overlies the older rocks and forms the surface of the Pajarito Plateau. The thickness ranges from about 1000 ft along the western margin of the plateau, where it laps onto the Tschicoma Formation, to less than 50 ft along the Rio Grande, where it overlies the Puye Conglomerate or the basaltic rocks of Chino Mesa (Fig. 2).

The tuff is above the main ground-water body and only in areas on the flanks of the Sierra de los Valles does it contain small amounts of perched water, which discharges from springs.

C. Alluvium and Soil

Alluvium from the Sierra de los Valles and the Pajarito Plateau has been deposited in the canyons of the plateau. Near the heads of the canyons, bedrock commonly is exposed in the lower parts, but farther down the canyons, alluvium may be several hundred feet wide and as much as 80 ft thick.

Alluvial deposits in the canyons heading on the flanks of the Sierra de los Valles contain cobbles and boulders with accompanying clay, silt, sand, and gravel derived from the Tschicoma Formation and Bandelier Tuff. Deposits in the canyons heading on the Pajarito Plateau contain clay, silt, sand, and gravel derived from the Bandelier Tuff. The alluvium contains some water in the larger canyons; however, the amount is insufficient for water supply.

Clayey soil derived from weathering of the Bandelier Tuff covers most of the fingerlike mesas of the Pajarito Plateau.

D. Structure

The Rio Grande depression is a structurally low area that constitutes the valley through which the Rio Grande flows.[20] The Pajarito Plateau is part of the depression, although it forms a topographic high area along the western margin of the valley.

The most prominent structural features of the Pajarito Plateau is the Pajarito fault zone, which trends northward along the western edge of the plateau. It is a part of the complex fault system that formed the Rio Grande depression. The fault zone consists of normal faults that are downthrown to the east and that displace rocks of the Bandelier Tuff, Puye Conglomerate, and Tschicoma Formation (Fig. 2). The displacement, estimated from the fault scarp, is from 400 to 500 ft. The amount of displacement decreases northward where, at a point north of Los Alamos, all visible traces of the fault disappear. The movement along the fault zone has been in small increments, which began before the deposition of the Bandelier Tuff and continued into post-Bandelier time. The displacement of the older rocks is greater than the displacement of the younger rocks. The major fault in this zone extends into and displaces the Precambrian rocks.

North of Los Alamos and east of the Pajarito fault zone, two normal faults cut the Bandelier Tuff, the Puye Formation, and the Tschicoma Formation. These faults, downthrown to the west, form a graben between them and the Pajarito fault zone. They are a part of the fault system that formed the Rio Grande depression.

Beneath the central part of the Pajarito Plateau, a north-trending depositional basin is formed in the Tesuque Formation. The basin is filled with volcanic debris of the Puye Conglomerate, overlain by the Bandelier Tuff. The eastern edge of the basin is formed by thick flows of basalt from Chino Mesa, 5 to 10 miles west of the Rio Grande (Fig. 2).

A gravity survey indicated that the deepest part of the Rio Grande depression (top of the Precambrian rocks) is in a north-trending trough near the center of the plateau. The bottom of this sediment-filled trough lies about 5000 ft below sea level (Fig. 2).[21]

III. MAIN AQUIFER OF THE LOS ALAMOS AREA

The main aquifer of the Los Alamos area is the only aquifer capable of municipal and industrial water supply. The upper surface of the main aquifer rises westward from the Rio Grande through the Tesuque Formation into the lower part of the Puye Conglomerate, beneath the central and western parts of the plateau (Fig. 2).[22] The water in the aquifer moves from the major recharge area in the Valles Caldera eastward toward the Rio Grande, where a part is discharged into the river through seeps and springs (Fig. 4).

The major recharge area for the aquifer is the intermountain basin formed by the Valles Caldera. The upper parts of the sediments in the basin are lacustrine deposits of clay, sand, and gravels, which are underlain by volcanic debris resulting from collapse of the caldera.[23] The sediments and volcanics in the basin are highly permeable and are saturated. The saturated "basin fill" recharges the main aquifer in sediments of the

Tesuque Formation. Minor amounts of recharge may occur in the deep canyons containing perennial streams on the flanks of the mountains. The intermittent streams in the canyon, which are cut into the plateau, add little, if any, recharge to the main aquifer.

Radiometric methods to date the age of the water in the main aquifer (time in transit from recharge to discharge) have been made using tritium and carbon-14. Tritium concentrations in water from wells from the Los Alamos and Guaje well fields have been less than 0.5 tritium units. Based on a natural occurrence of eight tritium units in precipitation (before hydrogen bomb tests), the age of the water in the aquifer in the two well fields is greater than 50 yr. Carbon-14 analyses of water from a well in the Pajarito Field at the eastern edge of the well have indicated that the age of water in the main aquifer is about 1400 yr. The radiometric age of water in the main aquifer indicates a slow rate of movement from the recharge area in the Valles Caldera.

The gradient on the surface aquifer, beneath the Sierra de los Valles and the western part of the Pajarito Plateau in the Los Alamos area, is about 120 ft per mile in the Tschicoma Formation interbedded with the Puye Conglomerate. As water in the aquifer moves into the more permeable sediments of the Puye Conglomerate in the central part of the plateau, the gradient increases to 60 to 80 ft per mile. The gradient decreases to 80 to 100 ft per mile along the eastern edge of the plateau as the water in the aquifer moves into the less permeable sediments of the Tesuque Formation (Fig. 4). The depth to the aquifer ranges from about 1200 ft along the western edge of the plateau, decreasing to about 600 ft along the eastern edge.

The Rio Grande is the principal area for ground water discharges from the main aquifer. A gain in streamflow in the Rio Grande in a 26-mile reach from the gaging stations at Otowi to Cochiti was computed at about 25 cfs.[24] Further investigation indicated that the river gained flow from Otowi to the mouth of the Frijoles Canyon, a distance of about 11.5 miles. Below Frijoles Canyon the Rio Grande is a losing stream.[25] Water from the river is lost to underlying sediments. It is estimated that the 11.5-mile reach of the canyon below Otowi receives a discharge from the main aquifer of 4300 to 5500 acre-feet annually.[26]

The main aquifer extends to the south into Bandelier National Monument. The movement of water in the Monument trends more the south than east, as in the Los Alamos area. The depth to water along the western edge of the Pajarito Plateau in the Monument ranges from 1000 to about 1200 ft, with a gradient of 60 to 80 ft per mile. The Rio Grande above the mouth of Frijoles Canyon is a gaining stream, whereas below Frijoles Canyon the Rio Grande is a losing stream. Thus, the surface of the aquifer north of Frijoles Canyon is slightly above the river level, but the surface of the aquifer to the south is at an elevation below the river level.[25]

The main aquifer extends to the north of Los Alamos beneath the Pajarito Plateau around the northwestern flanks of the Sierra de los Valles. Water movement is to the east and northeast in the Puye Conglomerate and the Tesuque Formation beneath the Pajarito Plateau and within the Tesuque Formation in the Española Valley.

The thickness of the main aquifer is unknown; however, the Rio Grande depression contains over 15 000 ft of volcanic rocks and sediments that overlie the Precambrian crystalline rocks.[21] These volcanic rocks and sediments are potential aquifer.

The volcanic rocks and sediments that fill the depression are apparently saturated. Water quality will deteriorate at increased depth. Most of the wells in the depression yield fresh [less than 1000 mg/ℓ total dissolved solids (TDS)] to slightly saline water (1000 to 3000 mg/ℓ TDS).[27] The deepest well in the Los Alamos area penetrated about 2250 ft of sediments in the depression. The TDS concentrations from this well are about 500 mg/ℓ. It is estimated that the water in the depression will be fresh to a depth of 6000 to 7000 ft before the TDS will exceed 1000 mg/ℓ. Thus, the main aquifer in the area has a saturated thickness of at least 6000 ft before chemical quality may restrict the use of the aquifer for municipal and industrial supply.

A. Supply, Test, and Stock Wells

The Los Alamos Field is composed of five producing wells (LA-1B, 2, 3, 4, and 5). One well (LA-6) is on standby to be used only in case of an emergency because the water contains excessive amounts of arsenic. The field was constructed in 1946 and 1948. One well (LA-1B) was added to the field in 1960 (Fig. 5).

The Guaje Field is composed of seven wells. The field was constructed in 1950 and 1951. Well G-1A was added to the field in 1954 and well G-6 was added in 1964.

The Pajarito Field is composed of wells PM-1, 2, and 3, which were constructed in 1965 and 1966; well PM-4, added to the system in 1982; and well PM-5, completed in 1982 but not added to the system until late 1983.

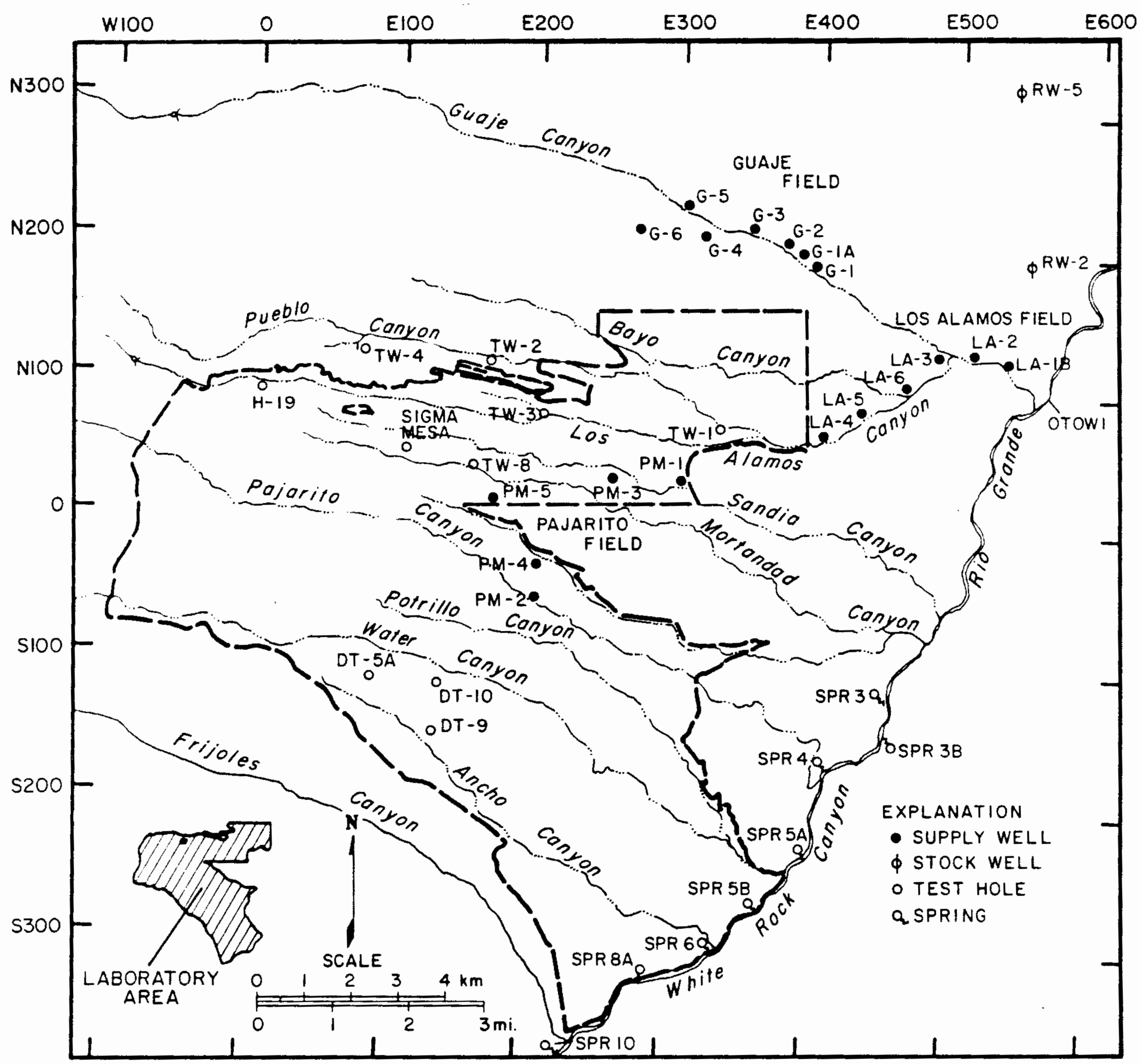

Fig. 5. Location of supply, test, and stock wells and springs in the Los Alamos area.

Construction and hydrologic data for the individual supply wells are presented in Appendix A.

Test wells TW-1, 2, 3, 4, and H-19 were drilled in 1949 through 1950 to determine the geologic and hydrologic characteristics of formations underlying the Pajarito Plateau. Test wells TW-1, 2, 3, and 4 are cased and are used as part of a well net that monitors the main aquifer.[28] Test well H-19 was abandoned uncased.

Test wells DT-5A, DT-9, and DT-10 were drilled in 1960 to evaluate the geologic and hydrologic conditions of a test site.[29] Test well TW-8 was drilled in 1960 to determine the geologic and hydrologic condition beneath a canyon disposal area for treated liquid low-level radioactive effluents.[30] Sigma Mesa was a test hole drilled in 1979 to determine geologic and hydrologic conditions related to possible development of geothermal energy for use at the Laboratory. The hole was scheduled for a depth of 10 000 to 12 000 ft; however, construction problems (lost circulation) terminated the hole at a depth of 2292 ft.

Two stock wells, equipped with windmills located on San Ildefonso Pueblo, were drilled in 1954 and 1955.

Nothing is known about hydrologic characteristics of the main aquifer, except for original water levels and chemical quality.

Construction and hydrologic data for the individual test and stock wells are presented in Appendix B.

Eight springs in White Rock Canyon were used in construction of the contours on the surface of the main aquifer and aid in interpretation of chemical quality of water in the main aquifer.[25] Hydrologic data for the springs are presented in Appendix C.

B. Production and Water-Level Fluctuations

Water from the wells in the Los Alamos Field is lifted vertically about 1800 ft through four booster stations into storage in the Laboratory and community areas. The water from the Guaje Field is lifted vertically about 1500 ft through four booster stations into storage. In the Pajarito Field, wells PM-1 and PM-3 supply the community of White Rock. The water is produced from the wells to storage. Wells PM-2, 4, and 5 can be used to supply White Rock, or their output can be lifted about 800 ft vertically into the Laboratory or community area through two booster stations.

The total production from well in the three wells fields from 1947 through 1982 has been 40 496 × 10^6 gal. (Table I). Production from three test wells in the southern area of the Laboratory (DT-5A, DT-9, and DT-10) was measured during testing after completion in 1960.

The main aquifer beneath the western and central part of the Pajarito is under water table conditions, whereas along the eastern margin and Rio Grande it is under artesian conditions.[26] In 1946 a number of test holes were drilled along the Rio Grande, north of Otowi and in the lower part of Los Alamos Canyon, to determine if a water supply could be developed in this area.[31] Three test holes along the Rio Grande drilled to a depth of 475 to 495 ft were artesian, as were the four test holes ranging in depth from 375 to 475 ft in lower Los Alamos Canyon.[31]

Supply wells LA-1 (abandoned and replaced by LA-1B), LA-2, and LA-3, which were completed in late 1946 and 1947 and cased to a depth of 870 ft, also were artesian and flowed when completed.[32] Pumpage soon reduced the artesian pressure, and water levels were below the well head. Other wells in Los Alamos Field (LA-4, -5, and -6) probably encountered semiartesian conditions, as did some of the wells in Guaje Canyon (G-1, G-1A, and G-2) and in the Pajarito Field (PM-1 and -3).

The hydrostatic pressures increased with depth. In 1960 the water levels in the lower part of the Los Alamos Field (LA-1, -2, and -3) ranged from 13 to 76 ft below the well head. Well LA-1B, 150 ft northeast of abandoned well LA-1, was drilled to a depth of 2256 ft and was cased and gravel packed to 1750 ft. The well began flowing during development. The well flow increased to about 100 gpm. The well was shut in and pressures measured over a 30-day period. Shut-in pressure was 13 psi, which is equal to a head of water 34 ft above the land surface.[26] Pumpage in the first month reduced the artesian pressure so that the water levels were below land surface. If the well is not pumped for several months, the water level rises in the well; several times in the last 20 yr, the well flowed for short periods of time before artesian pressures were reduced by pumpage.

Months of heavy production generally occur in June, July, and August and months of light production are in December, January, and February. The differences in demand for periods of heavy-to-light production (summer to winter) are mainly due to the use of water for lawn and yard irrigation. As a result, the water levels in the wells fluctuate with production. The highest water level occurs during the winter and lowest water level occurs during the summer.

1. Los Alamos Field. The wells in the Los Alamos Field produced 14 503 × 10^6 gal. of water from 1947 through 1982. This pumpage was 36% of the total pumpage from the three well fields (Table I).

Water levels in the individual wells have generally declined in response to the pumpage. The water-level declines from 1950 through 1982 in wells LA-2, -3, -4, -5, and -6 have ranged from 7 ft in LA-6 to 72 ft in LA-2. The water-level decline in well LA-1B from 1960 through 1982 has been 64 ft. In general, the largest amount of water-level decline has occurred in the lower part of the field (LA-1B, -2, and -3) and the least amount of decline in the upper part of the field (LA-4, -5, and -6). The average decline in the lower part of the field has been 52 ft from 1950 through 1982, whereas the lower field has produced 35% of the water from the field. The average water-level decline in the upper part of the field has been 21 ft from 1950 through 1982, whereas the upper field has produced 65% of the water from the field (Table I).

TABLE I

PRODUCTION FROM THE LOS ALAMOS, GUAJE, AND PAJARITO WELL FIELDS 1947-82

	Pumpage (10^6 gal.)	Percentage of Field	Percentage of Total
Los Alamos Field			
Well LA-1[a]	154	1	<1
Well LA-1B	1964	14	5
Well LA-2	1305	9	3
Well LA-3	1644	11	4
Well LA-4	3503	24	9
Well LA-5	3049	21	8
Well LA-6[b]	2884	20	7
Total	14 503	100	~36
Guaje Field			
Well G-1	2402	16	6
Well G-1A	2937	20	7
Well G-2	2520	17	6
Well G-3	2040	13	5
Well G-4	1217	8	3
Well G-5	2790	19	7
Well G-6	1077	7	3
Total	14 983	100	37
Pajarito Field			
Well PM-1	1593	14	4
Well PM-2	5863	53	14
Well PM-3	3478	32	9
Well PM-4	76	1	<1
Well PM-5	---	---	---
Total	11 010	100	~27
Total	40 496	---	~100

[a]Production 1946 to 1952 and 1955 to 1956 (well abandoned).

[b]Production from 1948 to 1976, well on standby production, pumped to wastes 1977 to 1982.

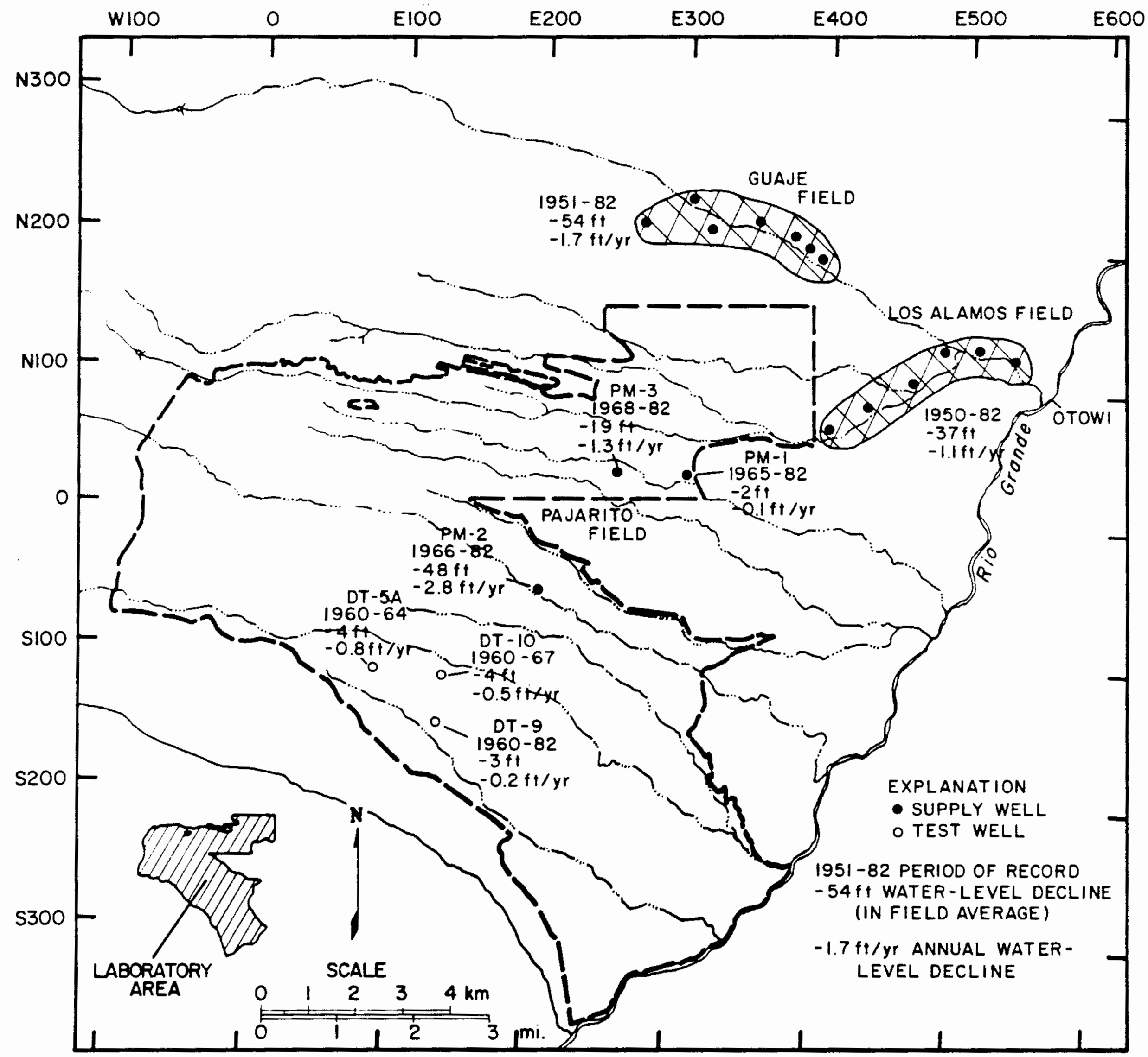

Fig. 6. Water-level declines in well fields and supply and test wells.

The average water-level decline in the Los Alamos Field from 1950 through 1982 has been 37 ft, with an average annual rate of decline of 1.1 ft/yr (Fig. 6). Production of 14 503 × 10^6 gal. and a water-level decline of 37 ft equal the production of 392 × 10^6 gal. of water per foot of water-level decline in the field (Fig. 7).

2. Guaje Field. The wells in the Guaje Field produced 14 983 × 10^6 gal. of water from 1951 through 1982. This pumpage was 37% of the total pumpage from the three well fields (Table I).

Water levels in the individual wells have responded to the amount of pumpage resulting in a general decline. Water-level declines from 1951 through 1982 in wells G-1, -1A, -2, -3, -4, and -5 have ranged from 29 to 93 ft. The water level in well G-6 from 1964 through 1982 has been 7 ft. The largest decline has been in the lower part of the field (G-1, -1A, -2, and -3), where production has been the greatest. The average decline has been about 75 ft, whereas about 66% of the total production from the field has been from these wells. The average decline in the upper field (G-4, -5, and -6) has been about 26 ft,

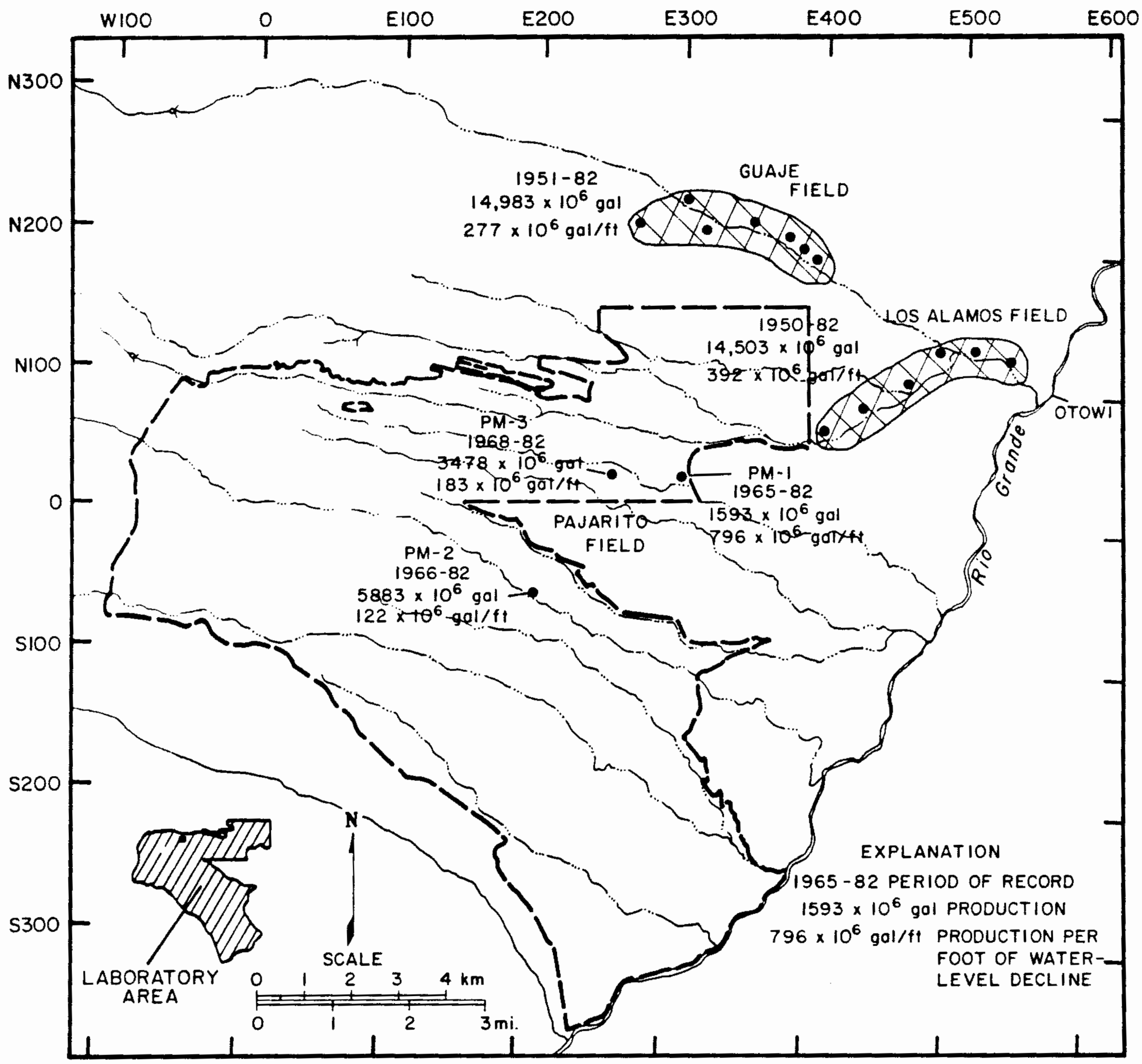

Fig. 7. Water-level declines related to production from well fields and supply wells.

while 34% of the total production has been from these wells.

The larger amount of production from the lower field is based on greater pumping rates. The declines are as anticipated for amount of pumpage and are not considered significant.

The average water-level decline in the Guaje Field for the period 1951 through 1982 has been 54 ft with an average annual rate of decline of 1.7 ft/yr (Fig. 6). The production of 14 983 × 10^6 gal. and a water-level decline of 54 ft equal the production of 277 × 10^6 gal. of water per foot of water-level decline in the field (Fig. 7).

3. Pajarito Field. The well in the Pajarito Field produced 11 010 × 10^6 gal. for the period 1965 through 1982. The pumpage was mainly from PM-1, -2, and -3, because production from PM-4 began in July 1982 and construction of the transmission system of PM-5 has not yet been completed. The pumpage from the field was 27% of the total pumpage from the three well fields (Table I). The water levels in the individual wells respond to the amount of pumpage, resulting in a general water-level decline.

The water level in well PM-1 declined 2 ft from 1965 through 1982 or at a rate of about 0.1 ft/yr (Fig. 6). The pumpage during this period was about 1593×10^6 gal. or 14% of the field total (Fig. 6 and Table I). The water level declined during production of 796×10^6 gal./ft for the period 1965 through 1982. As the well PM-1 was pumped, the well continued to develop while allowing new water-bearing beds to contribute to the pumpage from the well. This is evident in the specific capacity, which increased each year from 15 gpm/ft in 1965 to 27 gpm/ft in 1982. This has resulted in the highest ratio in these wells of production to total water-level decline (Fig. 7).

The water level in well PM-2 declined 48 ft from 1966 through 1982, at a rate of 2.8 ft/yr (Fig. 6). The pumpage during this period was 5863×10^6 gal., or about 53% of the field total. This is a high-yield well with a pumping rate of about 1400 gpm.

In the 18 years that well PM-2 was in operation, it produced 14% of the total production from all three well fields (Table I). The production during the period 1966 through 1982 was 5863×10^6 gal. with a water-level decline of 42 ft. This equals the production of 122×10^6 gal./ft of water-level decline (Fig. 7). Specific capacities varied slightly at about 23 gpm/ft but showed no significant trends for the period 1966 through 1982. There was little indication from the specific capacity that there was any further development of the well after it was placed in service.

The water level in well PM-3 declined 19 ft from 1968 through 1982, at a rate of 1.3 ft/yr (Fig. 6). The pumpage during this period was 3478×10^6 gal. or about 32% of the field total (Table I).

PM-3 is a high-yield well with a pumping rate of 1400 gpm. In 15 yr of service, it has produced 9% of the total water produced at Los Alamos from 1947 through 1982 (Table I). The specific capacity of the well has increased from 48 gpm/ft in 1968 to about 61 gpm/ft in 1982. Based on specific capacity and production rates, this is the best well in the system. The water level has declined during production of 183×10^6 gal./ft during the period 1968 through 1982 (Fig. 7).

Well PM-4 was completed in 1982 and was placed in production in July. The well produced 76×10^6 gal. for the remaining 6 months of 1982. Water level, nonpumping and pumping, rose slightly as the well developed while it was pumped. The pumping cleaned out the drilling mud and fine silts, clays, and sands that were left in the gravel pack and water-bearing formations when the well was drilled. The specific capacity increased from 30.0 gpm/ft to 36.8 gpm/ft from July to December. It is also a high-yield well with a pumping rate of 1470 gpm and a high specific capacity. Based on production rates and specific capacity, this is the second best well in the system.

Well PM-5 was completed in 1982 and has not been equipped or connected to the system. Tests of the well indicate that the pump will be rated at about 1225 gpm, which will result in a drawdown of about 144 ft, with a specific capacity of about 8.5 gpm/ft of drawdown. The well will probably develop with pumpage when put into production, resulting in a smaller drawdown and a greater specific capacity.

4. Test Wells. Test well DT-5A was pumped for a 24-h period for testing early in 1960. The amount of water produced was about 0.1×10^6 gal. The water level recovered after the test and showed no effect of the pumpage. During the period 1960 through 1964 after the test, the well was not equipped with a pump. During this period the water level declined about 4 ft or at a rate of 0.8 ft/yr (Fig. 6). The decline is under normal conditions (lack of recharge), not as the result of pumpage.

The test well DT-5A was equipped with a pump in 1970. Since that time, the well has produced about 0.3×10^6 gal. for collection of samples for chemical and radiochemical analyses. The well is pumped twice a year at about 5 gpm for about 2 days before sampling. The amount of water removed from the aquifer is small, and if any decline occurred from pumpage, it would be insignificant and immeasurable from one pumping period to the next (6 months later).

Test well DT-9 was pumped for a 24-h period early in 1960. The amount of water produced was about 0.1×10^6 gal. The water levels recovered after that and showed no effect of the pumpage. During the period 1960 to 1982 after the test, the well was not equipped with a pump. Water was bailed out for sample collection. No more than 500 gal. have been removed from the well since 1960. The small amount of water removed from the well would not result in significant water-level changes in the aquifer.

The well DT-9 is 0.75 mile south of well DT-10 and 1.25 miles southeast of well DT-5A, so that the small amount of water pumped from these wells will not affect the water level of well DT-9 (Fig. 2). Well DT-9 was equipped with a water stage recorder from 1960 to 1968 and 1970 to 1982. A continuous water-level record was obtained from the recorder. Water-level data were compiled into average annual measurements to illustrate

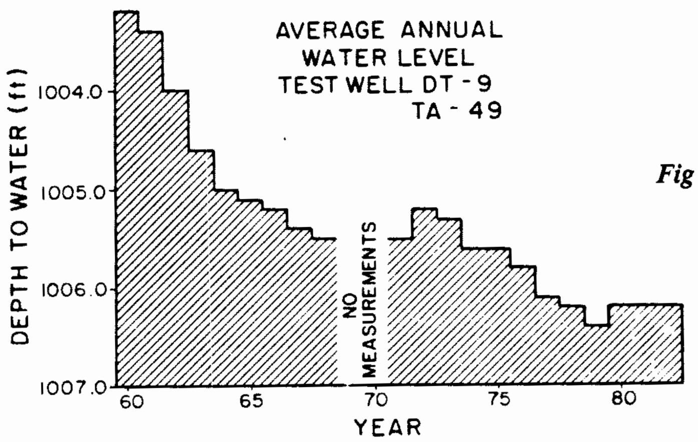

Fig 8. Average annual water levels in Test Well DT-9, 1960 to 1968 and 1971 to 1982.

water-level trends over a period of 22 yr. This reflects normal water-level fluctuations and trends for the region. The water level in the well declined from 1003 ft to 1006 ft from 1960 through 1982 (or at an average rate of about 0.1 ft/yr) (Fig. 8). The most rapid decline occurred from 1960 to 1968,when the decline was 2.3 ft or about 0.3 ft/yr (Fig. 8). The annual average water level rose 0.3 ft from 1971 to 1972, then declined 1.2 ft to 1979. Since 1979 the water level has remained about the same. The fluctuation of water levels reflects normal regional water-level trends. The decline in water levels shows deficient recharge, with only one period (1971) of recharge exceeding the normal discharge of the aquifer in White Rock Canyon.

The well and records from the water stage recorder were used in a special study, "Air Volume and Energy Transfer Through Test Holes and Atmospheric Pressure Effects on the Main Aquifer."[33] The main aquifer is very sensitive to atmospheric pressure changes, earth shocks, and probable earth tide effects. These effects (water-level fluctuation) were monitored by a continuous water stage record on well DT-9.

The possible earth tide effects are recorded by minor water-level fluctuations in which the gravitational pull of the moon elongates and compresses the aquifer. These effects, estimated from records by eliminating atmospheric effects, range from 0.01 to 0.03 ft of water-level fluctuation.

Water-level fluctuations are also recorded from earth shocks. In general, these are the result of strong earth motion. Records of the Alaskan earthquake of 1964 caused a water-level fluctuation of more than 1 ft in well DT-9. Small fluctuations have occurred, generally less than 0.10 ft, which are attributed to major earthquakes in Mexico or Central America. These water-level fluctuations are caused by expansion and compaction of the aquifer by surface waves of the earthquake.[33]

Test holes or wells in the Bandelier Tuff and Puye Conglomerate transfer air to and from the tuff and conglomerate in response to changes in atmospheric pressure. Test holes tend to "blow air" during barometric lows and to "suck air" during barometric highs. The air is transferred to and from the unsaturated zone above the main aquifer. The changes in atmospheric pressure also cause water-level fluctuations. During a storm in December 1967, a fluctuation of over 0.6 ft was recorded. Minor changes in atmospheric pressure also cause water-level fluctuations.

During a special study, October 10 through 14, 1964, four cycles of pressure changes were correlated with four cycles of water-level fluctuations. Increased atmospheric pressure caused water-level declines, and a decrease in pressure caused the water level to rise. The changes in water level, atmospheric pressure, and rates of air transfer from the test holes were correlated.[33]

The barometric efficiency of the aquifer can be expressed in terms of a column of water. The ratio of water-level changes to pressure changes expresses the barometric efficiency of the aquifer. During the four cycles of water-level and atmospheric pressure changes, the barometric efficiency of the aquifer ranged from 51 to 88%. The smaller pressure changes with smaller volumes of air transferred resulted in greater barometric efficiency.

The aquifer penetrated by DT-9 is not homogeneous but is made up of three different formations (conglomerate, basalts, and sandstones) with three different transmissibilities and probably three different pressure heads (water pressures in each unit). The variations in barometric efficiency are the result of the combined different pressures within each formation.[33]

Test well DT-10 was equipped with a pump for a 24-h period for testing in early 1960. The amount of water produced was about 0.1×10^6 gal. The water level recovered after the test and showed no measurable effect of the pumping. During the period 1960 to 1967, the water level declined about 4 ft or at an annual rate of 0.5 ft/yr. The well was not equipped with a pump during this period. Water-level decline was normal, not from pumpage, but because of lack of recharge to the aquifer.

It was not until 1979 that well DT-10 was equipped with a pump. The well is pumped twice a year at a rate of about 6 gpm for a period of 4 h. The amount of water produced during the past 4 yr is small (0.02×10^6 gal.). Any resulting water decline caused by pumpage would be too small to measure from one pumping period to the next pumping period.

Test well TW-8 was bailed for testing in December 1960. The amount of water removed during the test was about 2.0×10^3 gal. Recovery to the original water level was completed 8 min after the bailing ended.[33] The water-level decline from 1960 to 1965 was about 1 ft or about 0.2 ft/yr. This is a normal water-level decline.

In 1972 a pump was installed on TW-8. The well is pumped at about 6 gpm for a 2-h period twice a year. Thus, since 1972 about 0.03×10^6 gal. of water have been pumped from the well for collection of samples.

C. Hydrologic Characteristics

Hydrologic characteristics, pumping rates, specific capacities, transmissivities, and field coefficients of permeability were determined during aquifer tests or during periods of production from the wells or test holes (Fig. 9). The rock type or formation that forms the aquifer determines the hydrologic characteristics of the particular well or test hole (Table II). Wells in the Los Alamos and Guaje Fields are complete in the Tesuque Formations. Basalt flow occurs in the Tesuque Formation within the Guaje Field but is absent in the Los Alamos Field. Test well TW-4 is complete in the Tschicoma Formation. Supply wells in the Pajarito Field and test wells DT-5A, DT-9, and DT-10 are complete in the Puye Conglomerate and Tesuque Formation. Test wells TW-1, -2, -3, and -8 are complete in the Puye Conglomerate. Various thicknesses of saturation and different amounts of fines, such as silts, clays, and very fine sands in the various rock types, result in different hydrologic characteristics.

1. Tesuque Formation. The wells in the Los Alamos Field are completed in the fine sediments of the Tesuque Formation. The sediments contain no interbedded basalts (Fig. 3). The saturated thicknesses penetrated by the wells range from 709 to 1700 ft with an average of 1350 ft. At an average pumping rate of 365 gpm, the average specific capacity is 4.5 gpm/ft of drawdown, an average drawdown of 91 ft. Based on production characteristics of the well field, a drawdown of >125 ft results in excessive sand produced with water, which shortens the life of the pumps.

The field coefficient of permeability ranges from 3.0 to 9.3 gpd/ft^2 with an average of 5.6 gpd/ft^2. Transmissivity of the aquifer ranges from 2.5×10^3 to 15.7×10^3 gpd/ft with an average 8.4×10^3 gpd/ft (Fig. 9). The rate of movement of water in the aquifer, based on hydrologic characteristics and gradient on the top of the main aquifer in the Los Alamos Field, is estimated at 20 ft/yr within the upper 1350 ft of the aquifer (Fig. 10).

2. Tesuque Formation with Interbedded Basalts. All wells in the Guaje Well Field penetrated the sediments with interbedded basalts, except one well, G-2 (Fig. 3). The saturated thickness of the aquifer ranged from 942 to 1722 ft with an average of 1410 ft. At an average pumping rate of 376 gpm, the average specific capacity was 5.8 gpm/ft of drawdown or an average drawdown of 65 ft.

The field coefficient of permeability ranged from 5.3 to 11.3 gpd/ft^2 with an average of 8.2 gpd/ft^2. The average transmissivity of the aquifer in the Guaje Field is 11.6×10^3 gpd/ft.

The rate of movement of water in the upper 1410 ft of the aquifer of sediments and basalts in the Guaje Field is estimated at 35 ft/yr (Fig. 10).

3. Tschicoma Formation. Test well TW-4 was completed into a brecciated zone within the Tschicoma Formation. The saturated thickness was about 40 ft, and the specific capacity was low at 0.6 gpm/ft during a pumping rate of 2.8 gpm. The transmissivity low was at 0.75×10^3 gpd/ft and the field coefficient of permeability averaged 19 gpd/ft^2. The rate of movement of water in the 40 ft of the aquifer in the brecciated zone is estimated at 50 ft/yr (Fig. 10).

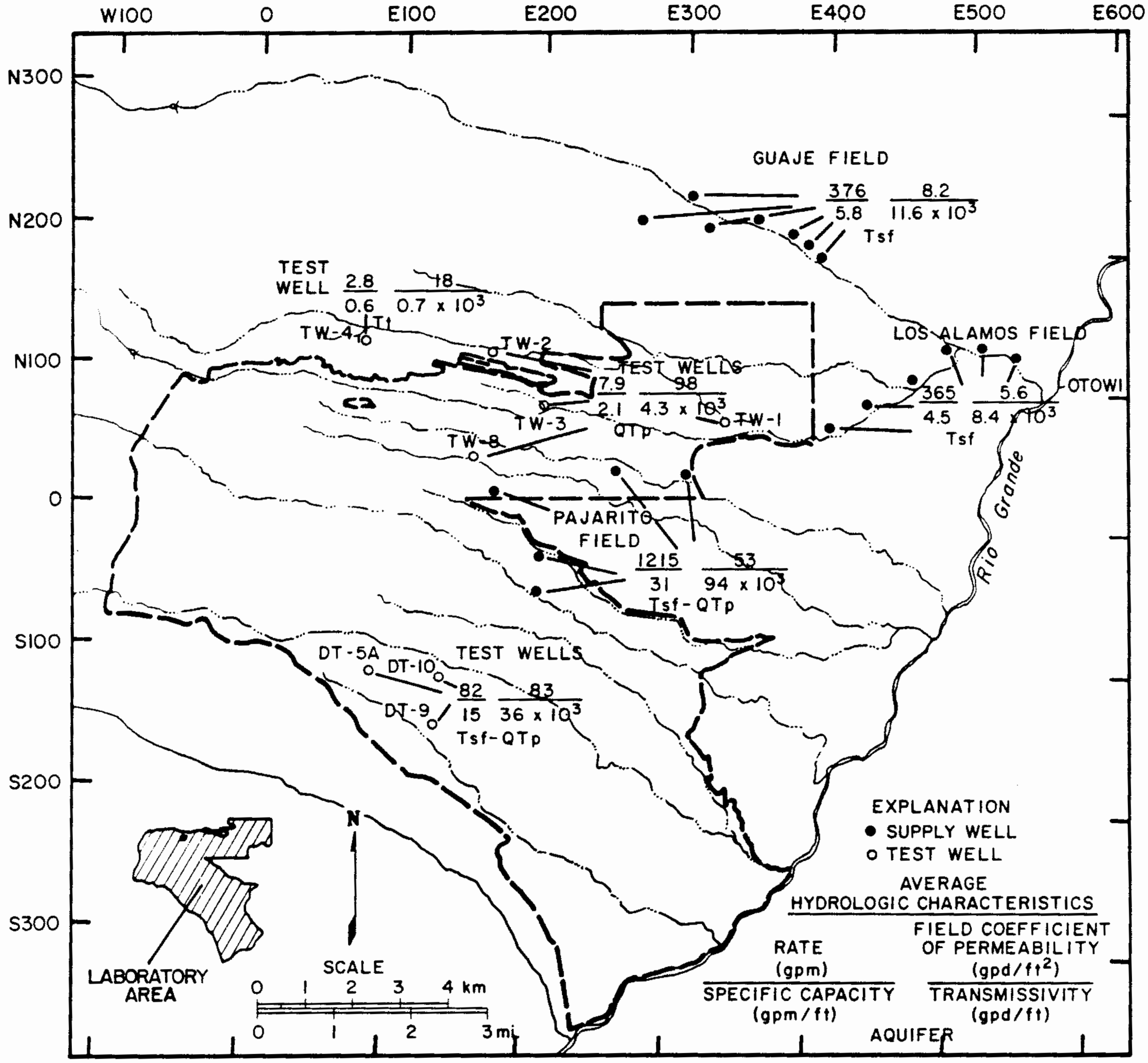

Fig. 9. Hydrologic characteristics of the main aquifer.

Test well H-19 encountered water in the lower part of the Puye Conglomerate underlain by a massive flow of Tschicoma Formation would yield very little water to the well. Tests indicated that the saturated section of the Tschicoma Formation (joints and brecciated zone between the flows) was relatively impermeable and was not a source of water supply.[17]

4. Tesuque Formation and Puye Conglomerate. The well in the Pajarito Field and test wells DT-5A, DT-9, and DT-10 penetrated the main aquifer in the lower part of the Puye Conglomerate and the Tesuque Formation. The Pajarito Field and test wells are located on the Pajarito Plateau. Beneath the plateau, the Tesuque Formation contains interbedded basalt flows.

The saturated thickness of the Puye Conglomerate in the Pajarito Field ranged from 50 to 535 ft with an average thickness of 270 ft, although the saturated thickness of the underlying Tesuque Formation ranged from 890 to 1700 ft with an average thickness of 1470 ft. At an average pumping rate of 1215 gpm, the average specific capacity is 31 gpm/ft of drawdown or an average drawdown of 40 ft (Fig. 9).

The field coefficient of permeability of the combined Puye Conglomerate and Tesuque Formation is 53 gpd/ft^2 with an average transmissivity of 94×10^3 gpd/ft.

TABLE II

AVERAGE HYDROLOGIC CHARACTERISTICS OF THE MAIN AQUIFER IN THE LOS ALAMOS AREA

	Saturated Thickness (ft)	Rate (gpm)	Specific Capacity (gpm/ft)	Field Coefficient of Permeability (gpd/ft^2)	Transmissivity (10^3 gpd/ft)
Los Alamos Field (Tesuque Formation)	1350	365	4.5	5.6	8.4
Guaje Field (Tesuque Formation and interbedded basalt)	1410	376	5.8	8.2	11.6
Pajarito Field (Tesuque Formation and Puye Conglomerate)	1740	1215	31	53	94
Test Hole TW-4 (Tschicoma Formation)	40	2.8	0.6	18	0.7
Test Holes DT-5A, -9, and -10 (Tesuque Formation and Puye Conglomerate)	490	82	15	83	36
Test Holes TW-1, -2, -3, and 8 (Puye Conglomerate)	60	7.9	2.1	98	4.3

Rate of movement of water in the combined thickness of 1740 ft of Puye Conglomerate and Tesuque Formation is 95 ft/yr (Fig. 10).

The saturated thickness of the Puye Conglomerate in the three test wells (DT-5A, -9, and -10) ranged from 310 to 355 ft with an average of 340 ft. The saturated underlying Tesuque Formation ranged from 15 to 290 ft with an average of 150 ft. At a pumping rate of 82 gpm, the average specific capacity was 15 gpm/ft of drawdown or about 5.5 ft of drawdown (Fig. 9).

The average field coefficient of permeability of the Puye Conglomerate and Tesuque Formation penetrated by the test holes was 83 gpd/ft^2, where the average transmissivity was 36×10^3 gpd/ft. The rate of movement of water in the 490 ft of aquifer penetrated by the test hole was 345 ft/yr (Fig. 10).

5. Puye Conglomerate. Test wells on the plateau that are complete within the main aquifer in the Puye Conglomerate are TW-1, -2, -3, and -8 (Fig. 3). The saturated thickness of the conglomerate ranges from 29 to 97 ft with an average of 60 ft. At an average pumping rate of 7.9 gpm, the specific capacity is 2.0 gpm/ft of drawdown or an average drawdown of 17 ft. The average field coefficient of permeability is about 98 gpd/ft^2 with an average transmissivity of 4.3×10^3 gpd/ft (Fig. 9). The rate of movement of water in the Puye Conglomerate with an average thickness of 60 ft is about 250 ft/yr (Fig. 10).

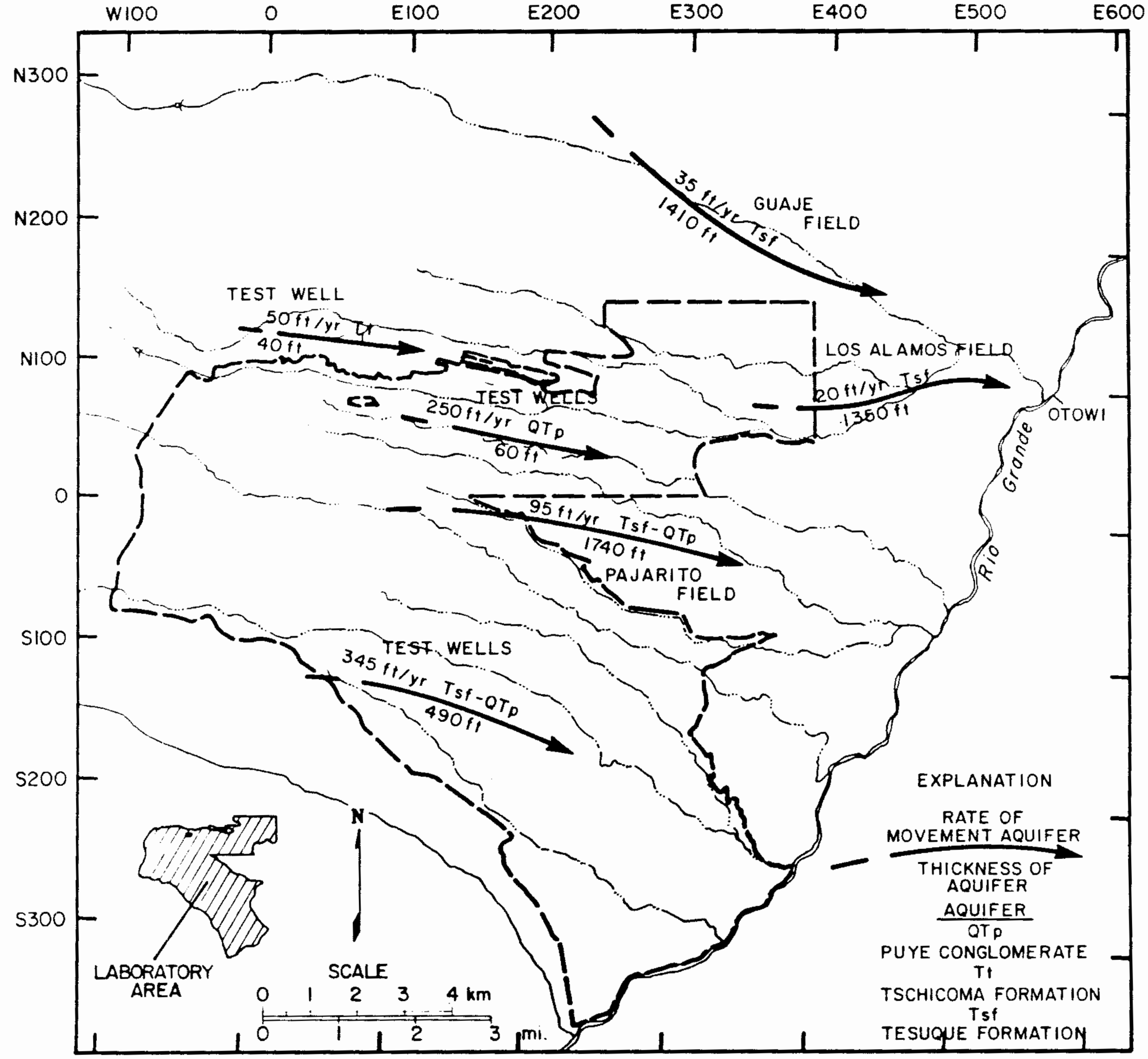

Fig. 10. Rate of movement of water in the main aquifer.

D. Quality of Water

The quality of water is monitored from the supply well to determine if the water meets the Federal primary, secondary, and radiochemical standards for municipal supplies.[34,35] The water is collected at the well heads after a period of pumping so that the water sampled represents what is in the aquifer adjacent to the well. Quality of water from a well depends on the depth of well, the lithology of the aquifer, and yields from individual beds within the aquifer. The quality of water from the individual wells varies because of local aquifer conditions within the same aquifer.

Primary drinking water standards relate directly to the safety of drinking water supplies.[34] Ten primary standards are compared with maximum concentrations from the wells (Table III), whereas detailed analyses from individual wells are presented in Appendix D (Table III). The maximum concentrations from wells are within the standards with the exception of fluoride of 2.6 mg/ℓ

TABLE III

CHEMICAL AND RADIOCHEMICAL QUALITY OF WATER FROM SUPPLY WELLS

Chemical	Units	Maximum Concentration Supply Well	Standards
Chemical Standards[a]			
Primary			
Ag	mg/ℓ	<0.0005	0.05
As	mg/ℓ	0.048	0.05
Ba	mg/ℓ	0.09	1.0
Cd	mg/ℓ	<0.001	0.01
Cr	mg/ℓ	0.022	0.05
F	mg/ℓ	2.6	2.0
Hg	mg/ℓ	<0.0002	0.002
NO_3	mg/ℓ	7.6	45
Pb	mg/ℓ	0.005	0.05
Se	mg/ℓ	<0.003	0.01
Chemical Standards[b]			
Secondary			
Cl	mg/ℓ	16	250
Cu	mg/ℓ	0.013	1.0
Fe	mg/ℓ	0.325	0.3
Mn	mg/ℓ	0.008	0.05
SO_4	mg/ℓ	27	250
Zn	mg/ℓ	0.12	5.0
TDS	mg/ℓ	408	500
pH	---	8.1	6.5 - 8.5
Radiochemical Standards[a]			
^{137}Cs	10^{-9} μCi/mℓ	40 ± 60	200
^{238}Pu	10^{-9} μCi/mℓ	0.018 ± 0.024	7.5
^{239}Pu	10^{-9} μCi/mℓ	0.010 ± 0.010	7.5
Gross Alpha	10^{-9} μCi/mℓ	11 ± 6.0	15
^{3}H	10^{-6} μCi/mℓ	4.2 ± 0.6	20
Total U	10^{-9} μg/ℓ	7.0 ± 1.4	1800

[a]Reference 34.
[b]Reference 35.

from well LA-1B in the Los Alamos Field. Mixing water with that from other wells in the field reduces the fluoride concentrations to acceptable limits within the distribution system.

Secondary standards are not related to the safety of drinking water but, instead, refer to the aesthetic quality.[35] Listed are eight constituents from the wells that are below the secondary standards (Table III). Secondary constituents from individual wells are listed in Appendix E.

Radiochemical standards relate to the safety of drinking water.[34] Radioactivity in the water from the wells occurs naturally in the aquifer. Gross alpha activity from the water from well PM-4 ($20 \pm 8.0 \times 10^{-9}$ μCi/mℓ) is above the standard (15×10^{-9} μCi/mℓ). Further analyses indicated gross alpha was $0.0 \pm 0.8 \times 10^{-9}$ μCi/mℓ. Analyses were performed for ^{226}Ra. It was 0.03×10^{-9} μCi/mℓ, much less than the 5×10^{-9} μCi/mℓ drinking water standard. The high gross alpha reported initially probably reflects contamination of the sample after collection. All other radioactive concentrations were below the standards (Table III). Radiochemical analyses from individual wells are listed in Appendix F.

Water from well LA-6, Los Alamos Field, is not used for municipal supply because the arsenic concentration in the water exceeds the primary standards. The water cannot be mixed with other water from the well field to reduce the arsenic concentrations in the distribution system to a level below the standards.[36]

Routine analyses determine whether water quality deteriorates with continued production. Some of these analyses, along with some of the primary and secondary constituents, are used to discuss the quality of water from the well fields, supply wells, and test wells (Fig. 11).

1. Los Alamos Field. Predominate chemical constituents in water from the Los Alamos Field are sodium-bicarbonate (Fig. 12). The water from the well field is very soft with total hardness ranging from 16 to 28 mg/ℓ. (Hardness classification: soft, 1 to 60 mg/ℓ; moderately hard, 61 to 120 mg/ℓ; hard, 121 to 180 mg/ℓ; and very hard, >180 mg/ℓ.)[37]

The TDS range from 70 to 514 mg/ℓ. The high 514 mg/ℓ occurs in water from well LA-1B. The maximum concentration of chloride is about 15 mg/ℓ, but fluorides range from 0.4 to 2.5 mg/ℓ. Dilution in the distribution system reduces the fluoride from well LA-1B (2.5 mg/ℓ) to levels below the standards for municipal use.

The arsenic-bearing water at well LA-6 is from a deep source and is circulated upward through a permeable fault zone that crosses or lies adjacent to the well. The high arsenic concentration in water from the well (range 0.141 to 0.203 mg/ℓ) precludes using this water for the municipal supply. It was calculated that the arsenic level from the well would have to be at a concentration of 0.100 mg/ℓ or less, at a pumping rate of 300 gpm, in order to dilute it enough by pumpage from the other wells in the field to lower it to an acceptable level in the distribution system.[36]

2. Guaje Field. Water from wells in the upper part of the Guaje Field (G-5 and -6) is a calcium bicarbonate type changing downgradient to a calcium sodium bicarbonate type at well G-4 to a sodium bicarbonate water in the lower part of the well field (G-1, -1A, -2, and -3). The transition from one type of water to another in the field is probably because the basalts in the upper part of the field yield more water than those in the lower field (Fig. 12). The water from the field is soft, with hardness ranging from 24 to 54 mg/ℓ. The hardness of the water decreases from the upper part of the field into the lower part of the field. The TDS range from 134 to 220 mg/ℓ. The chloride concentrations in water from the wells are about 2 mg/ℓ, but fluoride concentrations are 0.8 mg/ℓ or less.

3. Pajarito Field. Water from wells PM-1 and -3 contains calcium bicarbonate. As a result, the water is hard, with a hardness of about 90 mg/ℓ. The well penetrated a thickness of saturated basalt in the sediments of the Tesuque Formation, which may have caused the high concentration of calcium and magnesium resulting in the hard water. The general chemical quality of the water from the two wells is similar, with TDS of 212 and 216 mg/ℓ in PM-1 and -3, respectively. Chlorides are 4 and 10 mg/ℓ and fluorides are about 0.4 mg/ℓ in water from each well.

The water from wells PM-2, -4, and -5 is similar in quality, being a sodium bicarbonate water (Fig. 12). The water is soft, ranging from 36 to 52 mg/ℓ, but the TDS range from 140 to 211 mg/ℓ. Chlorides are low at 9 mg/ℓ or less; fluorides are 0.3 mg/ℓ.

4. Test Wells. Water from TW-1, -2, and -3 is a calcium bicarbonate water. The water quality is not exactly the same at each of the wells. Water from TW-1

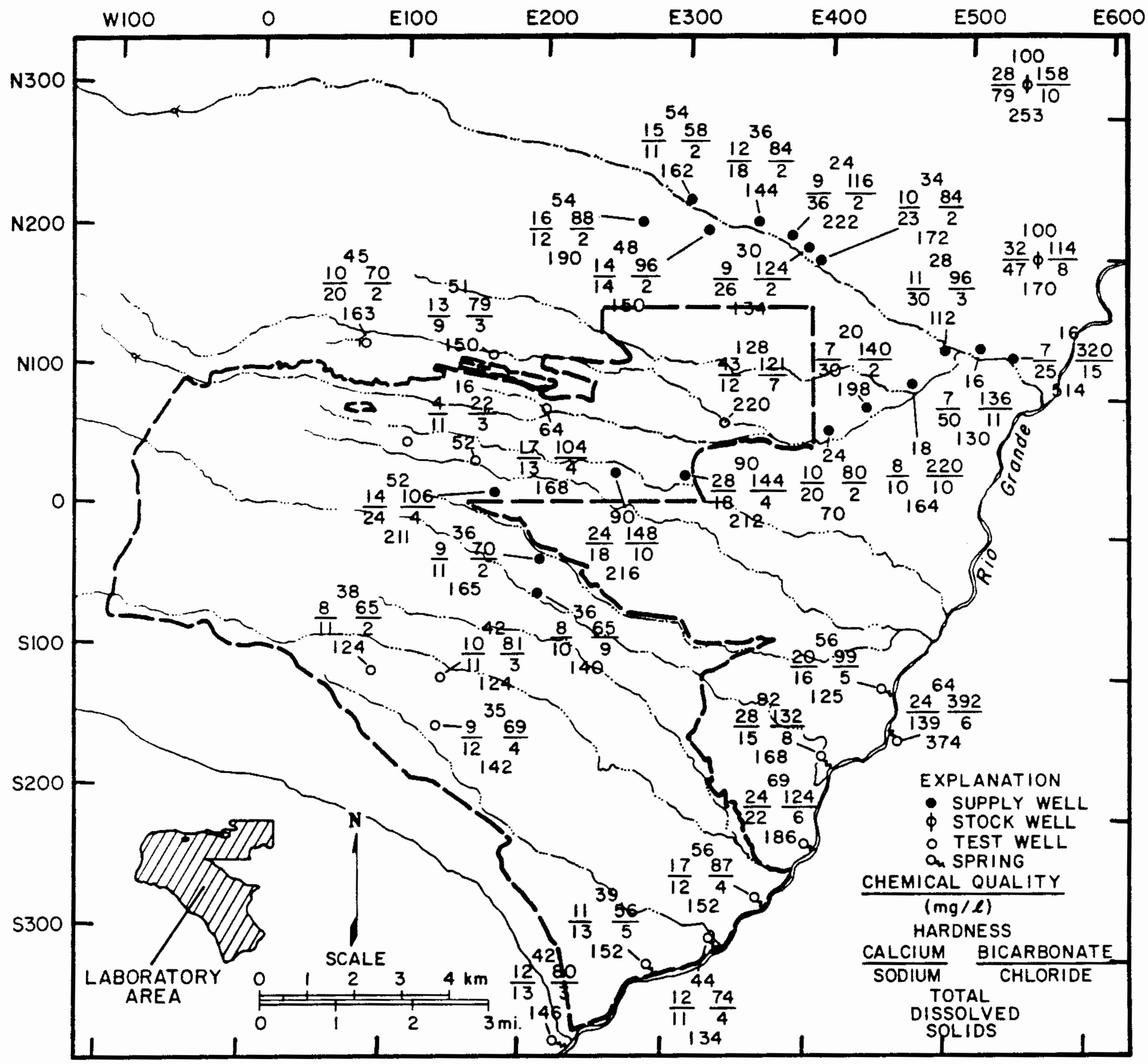

Fig. 11. Chemical quality of water from supply, test, and stock wells.

is hard at 128 mg/ℓ, and TDS are 220 mg/ℓ, where chloride is 7 mg/ℓ and fluoride is 0.4 mg/ℓ. Water from TW-2 is soft at 51 mg/ℓ, and TDS are 150 mg/ℓ, where chloride is 3 mg/ℓ and fluoride is 0.5 mg/ℓ. Water from TW-3 is moderately hard at 64 mg/ℓ, and TDS are 168 mg/ℓ, where chloride is 4 mg/ℓ and fluoride is 0.4 mg/ℓ.

Water from TW-4 and -8 is a sodium bicarbonate water, which is different in chemical quality (Fig. 12). Water from TW-4 is soft at 45 mg/ℓ with TDS of 163 mg/ℓ. The chlorides are about 2 mg/ℓ, where fluorides are <0.4 mg/ℓ. Water from TW-8 is soft at 16 mg/ℓ with TDS of 52 mg/ℓ. Chlorides are about 3 mg/ℓ, where fluorides are 0.2 mg/ℓ.

Water from DT-5A, -9, and -10 is of a sodium bicarbonate type. The quality of water is quite similar from all three test wells. The water is soft, ranging from 35 to 42 mg/ℓ. The concentrations of TDS range from 124 to 142 mg/ℓ with chloride concentrations of 4 mg/ℓ or less and fluoride of 0.3 mg/ℓ or less.

5. Stock Wells. Water from the stock wells RW-2 and -5 is similar in chemical quality and is a sodium

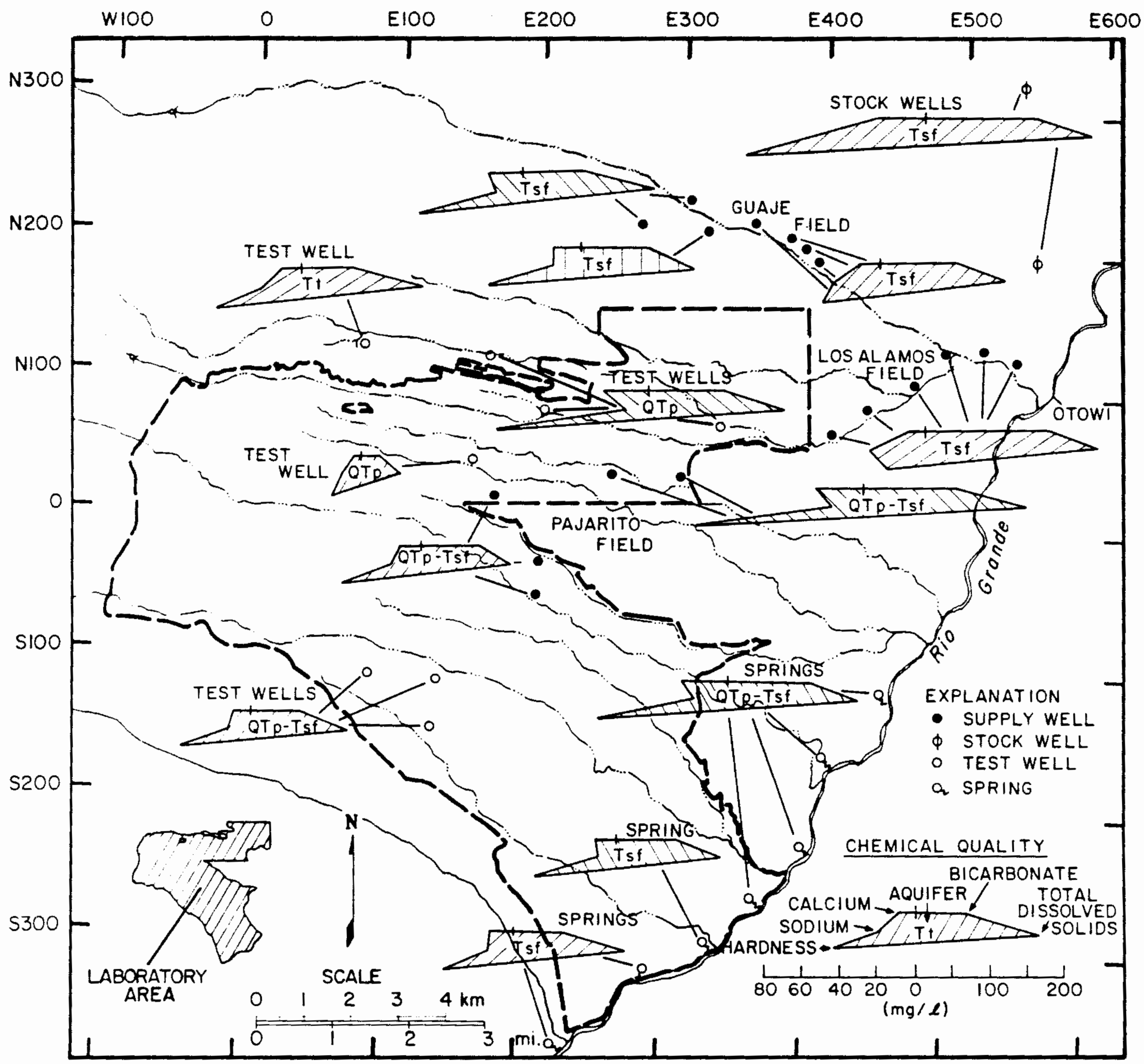

Fig. 12. Graphic comparison of chemical constituents in water from supply, test, and stock wells.

bicarbonate type water (Fig. 12). There is a large amount of calcium and magnesium in the water, which results in a moderately hard water with a hardness of 100 mg/ℓ. The TDS are 170 and 253 mg/ℓ, where chlorides are 10 mg/ℓ or less. The fluoride concentrations are 0.2 mg/ℓ or less.

6. Springs. The quality of water from the springs varies; however, it is combined in four groups for the purpose of this report. The springs discharge from the main aquifer.

The water from Spring 3B is a sodium bicarbonate type with TDS of about 610 mg/ℓ. The water is moderately hard at 64 mg/ℓ, where chlorides are 6 mg/ℓ and fluorides are 0.6 mg/ℓ. The spring discharges from basalts in the Tesuque Formation along a fault or dike. The quality of water is different from that of any other spring in this area of White Rock Canyon.

The quality of water from the spring changes from a calcium bicarbonate to a sodium bicarbonate water south between Spring 5A to Spring 8A in White Rock

Canyon (Fig. 12). The spring discharge is from the main aquifer.

Water from Springs 3, -4, -5A, and -5B is of the calcium bicarbonate type, and water quality varies. Water from Spring 3 is soft with a hardness of 56 mg/ℓ; the TDS are 125 mg/ℓ, where chlorides are 5 mg/ℓ and fluorides are 0.4 mg/ℓ. Water from Spring 4 is moderately hard at 92 mg/ℓ; the TDS are 168 mg/ℓ, where chlorides are 8 mg/ℓ and fluorides are 0.5 mg/ℓ. Water from Spring 5A is moderately hard at 69 mg/ℓ; the TDS are 186 mg/ℓ, where chlorides are 6 mg/ℓ and fluorides are 0.3 mg/ℓ. Water from Spring 5B is soft at 56 mg/ℓ; the TDS are 152 mg/ℓ, where chlorides are 4 mg/ℓ and fluorides are 0.5 mg/ℓ.

The water from Spring 6 is transitional from a calcium bicarbonate water to a sodium bicarbonate water (Fig. 12). The concentrations of calcium and sodium are almost equal at 12 mg/ℓ and 11 mg/ℓ, respectively. The water is soft at 44 mg/ℓ, where the TDS are 134 mg/ℓ. The chlorides are low at 4 mg/ℓ, as are the fluorides at 0.3 mg/ℓ.

Water from Springs 8A and 10 is a sodium bicarbonate water. The water chemical quality from these springs is similar. The water is soft with hardnesses of 39 and 42 mg/ℓ, respectively. The TDS of water from Spring 8A are 152 mg/ℓ and those from Spring 10 are 146 mg/ℓ. The chloride concentrations are 5 mg/ℓ or less, and fluoride concentrations are 0.4 mg/ℓ.

IV. DEVELOPMENT OF ADDITIONAL WATER SUPPLY

The main aquifer extends from the Rio Grande westward beneath the Pajarito Plateau and rises stratigraphically through the Tesuque Formation into the lower part of the Puye Conglomerate. The Puye Conglomerate becomes an important part of the main aquifer. The conglomerate attains its greatest thickness in the north/south-trending basin beneath the central part of the plateau. The coarse volcanic debris within the conglomerate yields water readily to wells and, in part, allows the development of high-yield, low-drawdown wells in this area. The Tesuque Formation beneath the Pajarito Plateau is saturated and is the main source of water supply for municipal and industrial use. The sediments of the Tesuque Formation become coarser westward from the Rio Grande; the upper bed becomes younger with the westward dip. This coarse sediment aids in the development of high-yield wells in this area.[38]

The locations of future wells in this area must be chosen carefully, because wells placed too far west will encounter flow rock of the Tschicoma Formation, which does not yield water readily. Wells placed too far to the east encounter vast thicknesses of basalt, which will not only constitute difficult drilling but may also not yield water readily (Fig. 2).[39]

A. Los Alamos Field

The Los Alamos Field is composed of five producing wells in lower Los Alamos Canyon (Fig. 5). The well and two booster stations and transmission lines are on San Ildefonso Pueblo land. The combined production rate from the field in 1982 was about 2050 gpm,[13] and the booster stations are equipped to handle 2300 gpm. Thus, to reach full capacity of the system an additional 250 gpm could be developed.

The Los Alamos Field was developed in 1946 through 1948, but one well (LA-1B) was added in 1960. Of the six original wells in the field, only four (LA-2, -3, -4, and -5) are still in use. Well LA-1 was abandoned when its yield declined, owing to partial filling of the well with fine sand and sediments. Well LA-6 is on standby for emergency use only because arsenic concentrations in the water are above standards for municipal use. Of the four original wells (1946-1948) in service, the combined pumping rate has declined from 1935 gpm in 1950 to 1562 gpm in 1982. The specific capacity has also declined from 4.3 gpm/ft to 2.5 gpm/ft indicating that over the past 30 yr, some wells have deteriorated. Screen openings are corroded and gravel pack material is filled with fine sand, silts, or clay. To ensure continued production from the field, future plans should include additional wells to offset production decline in the older wells.

The present location of the field is on Pueblo land in an area where only low- to moderate-yield wells (300 to 500 gpm) can be developed. The present spacing between wells in the Los Alamos field restricts any future well locations in that field, because any closer spacing would result in interference between wells, thus causing rapid water-level decline in this section of the field.

Location and development of additional wells for the Los Alamos Field should be west of the present field in lower Pueblo Canyon (Fig. 13). This is in an area where high yield and low drawdown (1000 gpm with less than 100 ft of drawdown) can be developed. In this area, the lower part of the Puye Conglomerate is saturated and the coarser sediments in the upper part of the Tesuque Formation are within the main aquifer. Two wells could be developed in this area that could use the existing Los Alamos Field transmission and booster system (Fig. 13). Combined production rates from the two wells should be at least 2000 gpm or about the output of the five presently producing wells in the field.

The anticipated geologic section of wells drilled in the lower Pueblo Canyon area is presented in Table IV. The pilot hole should be at least 2500 ft deep. This would allow about 1800 ft of saturated thickness for development of the well.

The water quality should be similar to that of supply well PM-1. The water will probably have a hardness of about 90 mg/ℓ, a TDS concentration of 212 mg/ℓ, and chloride and fluoride concentrations of 4 mg/ℓ and 0.3 mg/ℓ, respectively.

TABLE IV

ANTICIPATED GEOLOGIC LOG OF A SUPPLY WELL IN LOWER PUEBLO CANYON

Elevation: 6400 to 6600 ft above sea-level datum
Depth of Pilot Hole: 2500 ft
Hydrologic Data:
 Depth to water: 600 to 750 ft
 Yield: Estimated 1000 gpm
 Drawdown: Estimated 100 ft or less
 Aquifer: Puye Conglomerate and Tesuque Formation

Stratigraphic Unit	Thickness (ft)	Depth (ft)
Alluvium		
Gravel and boulders	20	20
Puye Conglomerate		
Conglomerate	60	80
Basaltic rocks of Chino Mesa		
Basalts and interflow breccia, may contain perched water, at a depth of 210 to 260 ft	205	285
Puye Conglomerate		
Conglomerate	165	450
Basaltic rocks of Chino Mesa		
Basalts and interflow breccias	100	550
Puye Conglomerate		
Conglomerate	250	800
Tesuque Formation		
Siltstone, sandstone, and conglomerate with occasional basalt flow in upper 1200 ft of formation	1700	2500

B. Guaje Field

The Guaje Field is composed of seven producing wells. The combined production of the field in 1982 was 2630 gpm. The booster stations and transmission lines can handle 2700 gpm; thus, to reach full capacity, an additional 70 gpm could be developed in the field.

The Guaje Field was developed in 1950 through 1951, with one well (G-1A) added in 1954 and another well (G-6) added in 1964. The five wells in the field in 1950 through 1951 had a combined production rate of 2387 gpm in 1952 and an average specific capacity of 7.9 gpm/ft. The pumping rate had declined to 1847 gpm, and the average specific capacity declined to 5.0 gpm/ft in 1982. The wells deteriorated because of age, corrosion of the screen openings, the well filling with sediments, gravel pack filled with fine sediments, and mainly, the damage to screen sections of the wells, especially wells G-4 and G-5.[6] The yield from the wells will continue to decline with time because of deterioration of the casing, screen, and gravel pack. To ensure continued production from the field and maximum use of existing booster and distribution systems, one replacement well should be considered and other wells should be rehabilitated.[11]

A replacement well should be considered, because at present, the spacing of existing wells in the Guaje Field is adequate with minor interference occurring when the wells are pumped. An additional well in the field would cause excessive drawdown because of the proximity of other wells. An additional well in the field should not be located northwest or west of the existing wells because of the outcrop of Tschicoma Formation in these areas. A well that is finished in or near the outcrop of Tschicoma would not yield an appreciable amount of water because the rocks are relatively impermeable and they form a barrier to east and southeast movement of ground water in the main aquifer. Land ownership will not permit locating a well southeast of well G-1 in Guaje Canyon (Fig. 5).

A replacement well should be considered for well G-4. Maximum yield from the well was 434 gpm with a specific capacity of 3.0 gpm/ft of drawdown in 1954. In 1982 the yield had declined to 297 gpm with a specific capacity of 1.5 gpm/ft of drawdown. At times, the well produces a lot of sand with the pumpage.

Well G-4 was completed at a depth of 1930 ft in 1951. In November 1953 the well was filled with sediments to about 1129 ft. Attempts to remove the sediments from the well were abandoned at a depth of 1486 ft because the bailer would stick and gravel pack was being bailed from the well. The presence of gravel pack indicated that the casing was ruptured. In October 1954 the well was opened to 1386 ft. About 110 ft of the 360 ft of screen buried below the 1380-ft level reduced the yield of the well because sediment continued to accumulate. In 1968 the well had filled with sediments to a depth of 765 ft. When sediments were being removed from the well, a large amount of gravel pack was present, so it was cleaned only to a depth of 798 ft. The well was filled with sediments to a depth of 750 ft in 1975. At this time, the sediments were cleaned out to a depth of 1750 ft. A video log of the hole was made with a television camera, which indicated minor breaks in the screen above the depth of 1230 ft with major breaks in sections of the screen below a depth of 1230 ft. A slotted liner was set from 1214 to 1750 ft; however, after the well was back in operation, pumpage sometimes contained a large amount of sand. In 1981 the hole was opened only to a depth of 1150 ft. Only 22 ft of sediments were cleaned out of the well because the bailer tended to stick in the well. Well G-4 should be replaced because of the damaged screen. The well will continue to deteriorate with sand accumulation until the yield will be insufficient to continue economical operation. It can be replaced with a well that should produce at least 500 gpm with less than 100 ft of drawdown.

The replacement well should be located at least 150 ft south of well G-4; however, a distance of 300 to 500 ft would be preferable because drilling would be less likely to affect the cavities caused by pumpage of sand from G-4. The pilot hole should be at least 2000 ft deep. This would allow a saturated section of about 1600 ft to develop the well. The stratigraphic section penetrated by the replacement well should be similar to those penetrated by well G-4 (Table V). The water quality should also be similar to that of well G-4. The TDS should be about 150 mg/ℓ, with soft water at 48 mg/ℓ. Chloride should be less than 5 mg/ℓ and fluorides should be about 0.2 mg/ℓ.

TABLE V

ANTICIPATED GEOLOGIC LOG OF A SUPPLY WELL NEAR WELL G-4 IN GUAJE CANYON

Elevation: 6230 ft above sea-level datum
Depth of Pilot Hole: 2000 ft
Hydrologic Data:
Depth To Water: 400 ft
Yield: Estimated 500 gpm
Drawdown: Estimated 100 ft or less
Aquifer: Tesuque Formation

Stratigraphic Unit	Thickness (ft)	Depth (ft)
Alluvium		
Gravels and boulders	15	15
Puye Conglomerate		
Conglomerate	105	120
Tesuque Formation		
Siltstone and sandstone	380	500
Basalt and interflow breccia	30	530
Siltstone and sandstone	330	860
Basalt and interflow breccia	75	935
Siltstone and sandstone	30	965
Basalt and interflow breccia	20	980
Siltstone and sandstone	130	1110
Basalt and interflow breccia	40	1150
Siltstone and sandstone	850	2000

Well G-3 had a pumping rate of 410 gpm and a specific capacity of 8.6 gpm/ft of drawdown in 1954. The pumping rate has declined to 240 gpm, with a specific capacity of 2.1 gpm/ft of drawdown in 1982. Television logs of the well indicate that the casing and screens are in good condition. The well should be rehabilitated by some method (acid, shock, jetting screens with high pressure, or swabbing) to try to increase the yield of the well.

Well G-5 is missing large sections of the screen below a depth of 700 ft. As the well continues to be a good producer with little drawdown (520 gpm with specific capacity of 9.5 gpm/ft), no attempt should be made to repair or rehabilitate the well. A replacement well should be considered in the future for this well if yield and specific capacity decline.

C. Pajarito Field

The Pajarito Field is composed of four producing wells. One well that was just completed should be added to the system in late 1983. The four wells can produce about 4800 gpm and when the fifth well is added to the system, the production should be about 6000 gpm. These wells are high-yield wells in an area capable of developing wells with pumping rates >1000 gpm. The development of additional wells in the field is not imminent; however, if additional wells are to be developed, locations should be in areas where high yield and low drawdown can be expected.

The Pajarito Field north and west of PM-2, -4, or -5 cannot be expanded and still remain in the area where high-yield wells can be developed. Also, space is unavailable in Sandia Canyon for additional wells, if space is maintained between wells to reduce interference or overlapping of drawdown. Adding wells in lower Pueblo Canyon has already been discussed.

The suggested location for additional wells in the Pajarito Field is to the southwest of well PM-2 (Fig. 13). The locations are chosen for maximum spacing between wells to minimize the interference between wells when they are pumping and to align the wells at right angles to the movement of ground water in the main aquifer, which is west to east.

One additional well could be located about 3500 ft southwest of PM-2 at an elevation of about 6850 ft, with a second well located about 7000 ft southwest of PM-2 at an elevation of about 6800 ft. The quality of water at these locations should be similar to that of PM-2. The TDS should be about 140 mg/ℓ with a chloride value of 9 mg/ℓ and fluoride value of 0.3 mg/ℓ. The water is soft with hardness of 36 mg/ℓ.

The pilot hole at these locations should be at least 2800 ft, which would result in a saturated section of about 1800 ft to develop a high-yield well. The anticipated geologic section at the two locations is shown in Table VI.

D. Drilling Conditions

Cable tool and rotary methods of drilling have been used to construct water supply wells in the Los Alamos area. The cable tool and rotary method has been used to drill the upper section of unsaturated material (alluvium, Bandelier Tuff, Puye Conglomerate, and Basaltic Rocks of Chino Mesa) above the main aquifer. Rotary drilling has been used to complete the well in the saturated sediments and volcanic rocks within the main aquifer, the lower part of the Puye Conglomerate, and the Tesuque Formation.

The alluvium or soil at most sites is thin. The alluvium (Guaje or Pueblo Canyons) may cover large, very hard boulders of latite, rhyolite, or quartz latite.

The Bandelier Tuff is a soft, friable, porous, and permeable rock. The drilling should progress easily. A thick section of tuff may cause major circulation problems if it is drilled with the rotary using drilling mud as a cutting carrier. Drilling by cable tool should cause no lost circulation problems; using air foam as a cutting carrier with the rotary should reduce the lost circulation problem and should allow the upper section of the hole to be cased above the main aquifer. The wall of the borehole in the Bandelier Tuff holds up well when it is drilled by either cable tool or rotary.

The Puye Conglomerate contains numerous latite, rhyolite, and quartz latite boulders that are quite hard. The formation is slightly consolidated to consolidated. Drilling will be slow, and in some cases, circulation of drilling fluid when using the rotary method may be difficult.

The basaltic rocks of Chino Mesa are hard and contain joints and small cavities. Drilling these rocks will be slow and difficult, and if rotary methods are used, circulation may be difficult to maintain. Using air foam as a cutting carrier through the basalts reduces the circulation problem. For completion of the well, it will probably be necessary to set a surface string of casing through these basalts. The pilot hole in basalts is likely to become crooked because when the hard rocks are drilled, the bits are deflected by joints and interflow breccias between flows of different hardnesses.

The Tesuque Formation of siltstones and sandstones is drilled easily by rotary methods using mud as a cuttings carrier. The interbedded basalts in the sediments are hard to drill and will, in most cases, cause problems in maintaining the circulation using a mud rotary. The formation is completely saturated at most of the locations (Guaje Canyon is the exception). If sufficient penetration of the aquifer is made and a high head of water can be maintained in the drill hole, reverse circulation using air down a drop line in the drill stem has been successful in maintaining circulation at depth in

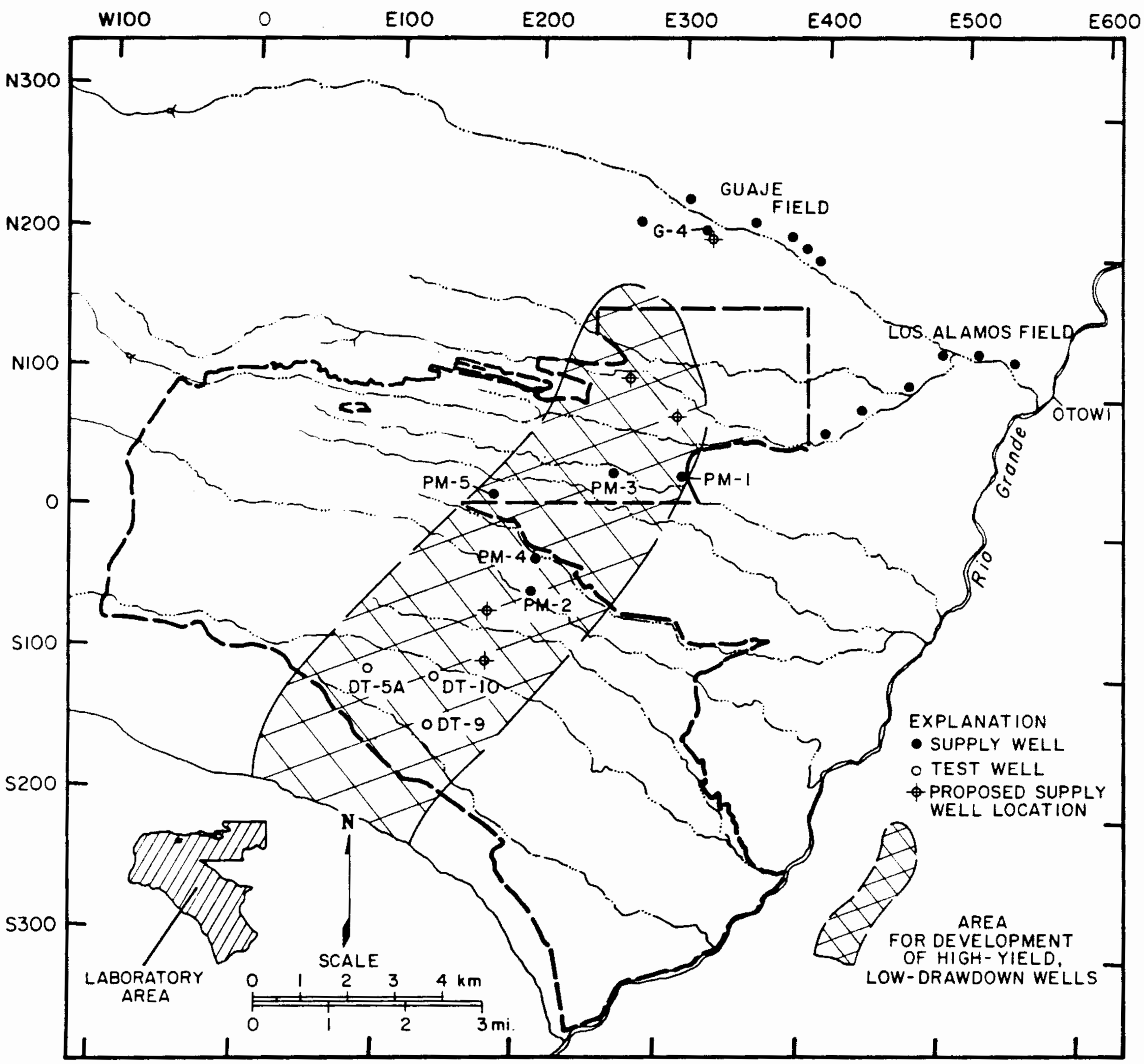

Fig. 13. Proposed locations for additional supply wells and area for development of high-yield, low-drawdown wells.

the Tesuque Formation when the sediments contain interbedded basalts.

E. Geology and Geophysical Logs

The depth at which a supply well will be completed is determined from geologic and geophysical logs. During drilling of the pilot hole, cuttings should be caught at 5-ft-depth intervals when using a cable tool or at 10-ft-depth intervals when using a rotary. Cuttings are then described by a geologist and a geologic log is prepared. The geologic log is used to correlate and compare rock units with hydrologic characteristics of geophysical logs.

Geophysical logs to be run in the pilot hole are (1) Compensated Neutron-Formation Density, (2) Dual Induction—SFL with Linear Correlation Log, (3) Micro-log, and (4) Temperature Log. These logs, along with the geologic log, will aid in determining the water-bearing

TABLE VI

ANTICIPATED GEOLOGIC LOG OF SUPPLY WELLS ON THE PAJARITO PLATEAU SOUTH OF WELL PM-2

Elevation: ~6850 ft
Depth of Pilot Hole: 2850 ft
Hydrologic Data:
Depth to Water: 950 ft
Yield: Estimated 1000 gpm
Drawdown: Estimated 100 ft or less
Aquifer: Puye Conglomerate and Tesuque Formation

Stratigraphic Unit	Thickness (ft)	Depth (ft)
Bandelier Tuff		
Ashflow tuff and pumice	650	650
Basaltic rocks of Chino Mesa		
Basalt and interflow breccia	350	1000
Puye Conglomerate		
Conglomerate	650	1650
Tesuque Formation		
Sandstone and conglomerate	400	2050
Basalt and interflow breccia	50	2100
Sandstone and siltstone	200	2300
Basalt and interflow breccia	100	2400
Siltstone and sandstone	450	2850

characteristics of the Puye Conglomerate and Tesuque Formation within the main aquifer.

F. Well Construction

Well construction should provide for a surface string of blank casing, adequately cemented, to seal out water encountered in the alluvium (Pueblo and Guaje Canyon). It will also be necessary to seal out, with casing, any water encountered above the main aquifer. Samples of water encountered above the main aquifer should be obtained for chemical and radiochemical analyses, where possible, if drilling with cable tool or air rotary.

Most of the water-bearing beds of the Tesuque Formation contain fine sediments so poorly consolidated that a gravel pack around the casing and screen section of the well will be required to reduce the entry of fine material into the well. Perforated pipe or screen should be placed through the entire saturated section of the well except in the upper 200 to 250 ft of the saturated section. The pump intake is usually set 200 to 250 ft below the top of the aquifer. Blank pipe should be set through this section to prevent "cavitation" of the pump bowls in order to obtain the maximum efficiency of the pump.

Two gage lines (2-in. i.d.) attached outside the casing should extend from the surface and enter the casing at 200 to 250 ft below the top of the main aquifer or near the top of the screen section. One gage line houses the air line and continuously monitors the water levels; the second gage line is used for the water-level measurement equipment or well-surveying instruments.

V. SUMMARY AND CONCLUSIONS

The main aquifer of the Los Alamos area is the only aquifer capable of municipal and industrial water supply. The main aquifer extends from the Rio Grande westward beneath the Pajarito Plateau and rises westward stratigraphically through the Tesuque Formation into the lower part of the Puye Conglomerate. The water in the aquifer moves eastward toward the Rio Grande, where it discharges through a series of springs and seeps. The depth of the main aquifer varies from about 1200 ft along the western margin of the plateau to about 600 ft at the confluence of Pueblo and Los Alamos Canyons. At the Rio Grande, some wells encountered water in the aquifer under artesian pressures. The main aquifer extends north and south of the Los Alamos area and is estimated to be over 6000 ft thick.

The Puye Conglomerate is highly permeable and, where it is saturated beneath the Pajarito Plateau, will yield large amounts of water to wells. The Tesuque Formation is composed of siltstones, sandstones, and some conglomerate. Many of the individual beds in the Tesuque Formation are highly permeable and, where saturated, will yield water to a well. Beneath the Pajarito Plateau, coarse volcanic rock fragments are in the upper 1000 ft of the Tesuque Formation, and they yield more water to wells than do the finer sediments, which predominate in the formation farther to the east along the Rio Grande.

In the Los Alamos area, 18 supply wells, 10 test wells, and 2 stock wells are supplied by the main aquifer. Hydrologic characteristics of the main aquifer were determined from some of these wells. The hydrologic characteristics reflect the permeability and thickness of the formations.

The Los Alamos Field is completed in siltstones and sandstones of the Tesuque Formation. With a saturated thickness of about 1350 ft, the average specific capacity is about 4.5 gpm/ft of drawdown at a pumping rate of 365 gpm. The average transmissivity is 8.4×10^3 gpd/ft with a field coefficient of permeability of 5.6 gpd/ft^2. The average rate of movement in the upper 1350 ft of aquifer in the Los Alamos Field is about 20 ft/yr. The production from the field in 1947 to 1982 has been 14.5×10^9 gal. or about 36% of the total water pumped for use at Los Alamos. This has resulted in an average water-level decline in the field of 37 ft or about 1.1 ft/yr. The average production per foot of water-level decline has been 392×10^6 gal./ft.

The Guaje Field is completed in siltstones and sandstones with some interbedded basalt flows and breccias of the Tesuque Formation. The average saturated thickness of 1410 ft has an average specific capacity of 5.8 gpm/ft of drawdown at a pumping rate of 376 gpm. The average transmissivity is 11.6×10^3 gpd/ft with a field coefficient of permeability of 8.2 gpd/ft^2. The average rate of movement is about 35 ft/yr. The production in 1951 through 1982 from the field has been 14.9×10^9 gal. or about 37% of total water pumped for use at Los Alamos. This has resulted in an average water-level decline in the field of 54 ft or about 1.7 ft/yr. The average production per foot of water-level decline has been 277×10^6 gal./ft.

The Pajarito Field is completed in siltstones, sandstones, and conglomerates that are interbedded with basalt and basalt breccias of the Puye Conglomerate and Tesuque Formation. The lower part of the Puye Conglomerate is also saturated within the field. The average saturated thickness of 1740 ft has an average specific capacity of 31 gpm/ft of drawdown at a pumping rate of 1215 gpm. The average transmissivity is 94×10^3 gpd/ft with an average field coefficient of permeability of 53 gpd/ft^2. The average rate of movement in the 1740 ft of Puye Conglomerate and Tesuque Formation is 95 ft/yr. Production from the field from 1965 to 1982 has been 11.0×10^9 gal. or about 27% of the total water pumped at Los Alamos.

There are five wells in the field, but most of the production has been from three wells: PM-1, -2, and -3. Well PM-4 was placed in service in July 1982, and well PM-5 was completed but had not been connected to the transmission line by the end of 1982. The production from well PM-1 has been about 1.6×10^9 gal. from 1965 to 1982 resulting in a water-level decline of 2 ft. The average production per foot of water-level decline has been 796×10^6 gal./ft. The production from well PM-2 has been 5.9×10^9 gal. from 1966 to 1982. This well has produced the most water of the individual wells (14% of the total water pumped at Los Alamos in 1950 through 1982). The water level declined 48 ft from 1966 to 1982 or about 2.8 ft/yr. The average production per foot of water-level decline has been 122×10^9 gal./ft. The production of well PM-3 has been 3.5×10^9 gal. from 1968 to 1982. This has resulted in a water-level decline of 19 ft with an average production of 183×10^6 gal./ft of drawdown.

Test well TW-4 is completed into a brecciated zone in the Tschicoma Formation. At a pumping rate of 2.8 gpm, the specific capacity is 0.6 gpm/ft of drawdown. The 40-ft zone of saturation has a transmissivity of 0.7×10^3 gpd/ft and a field coefficient of permeability of 18 gpd/ft^2. The rate of movement in the brecciated zone is about 50 ft/yr.

Test wells DT-5A, -9, and -10 penetrated a saturated thickness of 345 ft at the Tesuque Formation and lower part of the Puye Conglomerate. The test well had an average specific capacity of 15 gpm/ft of drawdown at a pumping rate of 82 gpm. The average transmissivity is 36×10^3 gpd/ft with an average field coefficient of permeability of 83 gpd/ft^2. The amount of pumpage from these test wells is low, thereby causing no significant change in water levels; however, water-level decline in well DT-5A from 1960 to 1964 was 4 ft and in well DT-10 it was 4 ft from 1960 to 1967. At well DT-9, the average annual water levels were recorded from 1960 to 1968 and 1970 to 1982. The most rapid decline occurred from 1960 to 1968, about 2.3 ft. The water level rose about 0.3 ft from 1971 to 1972, then declined about 1.2 ft to 1979. Since 1979 the water level has remained about the same. The water-level declines reflect decreases in recharge resulting in natural water-level declines.

Test Wells TW-1, -2, -3, and -8 penetrated a 60-ft saturated section in the lower part of the Puye Conglomerate. At a pumping rate of 8 gpm, the average specific capacity is 2.1 gpm/ft of drawdown. The average transmissivity is 4.3×10^3 gpd/ft with an average field coefficient of permeability of 98 gpd/ft^2. The average rate of water movement in the 60-ft saturated section of the aquifer is about 250 ft/yr.

Based on hydrologic characteristics of the wells, high-yield and low-drawdown (1000 gpm/100 ft) wells can be developed near the center of the Pajarito Plateau in a northeast-trending zone. Two high-yield and low-drawdown wells can be developed in lower Pueblo Canyon as replacement wells or wells to supplement production from the Los Alamos Field. Two high-yield and low-drawdown wells can be located on the Pajarito Plateau southwest of well PM-2 to supplement the production from the Pajarito Field to meet future increased demand.

A replacement well for well G-4 in the Guaje Field should be considered to offset decline in production in the field as well efficiency declines in the field. The well could be constructed to produce 500 gpm with less than 100 ft of drawdown.

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APPENDIX A

CONSTRUCTION AND HYDROLOGIC DATA FOR WELLS IN LOS ALAMOS, GUAJE, AND PAJARITO FIELDS

	Los Alamos Field						
	LA-1[a]	LA-1B	LA-2	LA-3	LA-4	LA-5	LA-6
Date of Completion (yr)	1946	1960	1946	1947	1948	1948	1948
Elevation of LSD (ft)	5625	5620	5650	5670	5975	5840	5770
Construction							
Depth drilled (ft)	1001	2256	882	910	2019	2084	7030
Depth completed (ft)	870	1750	870	870	1965	1750	1790
Diameter (in.) [b]	10	12 (650 ft) 10	10	10	12 (754 ft) 10	12 (630 ft) 10	12 (597 ft) 10
Water Levels							
Date	1982	1982	1982	1982	1981	1982	1982
Depth below LSD (ft)	40	71	161	118	289	168	90
Elevation (ft)	5585	5549	5489	5552	5686	5672	5680
Water-Level Fluctuations							
Period	1950-1982	1960-1982	1950-1982	1950-1982	1950-1981	1950-1982	1950-1982
Change (ft)	−79	−64	−72	−21	−11	−45	−7
Annual rate (ft/yr)	−2.4	−2.8	−2.2	−0.6	−0.3	−1.4	−0.2
Aquifer							
Formation	Tsf	Tsf	Tsf	Tsf	Tsf	Tsf	Tsf
Saturated thickness (ft)	830	1679	709	752	1676	1582	1700
Yield							
Date	1950	1982	1982	1982	1981	1982	1981
Rate (gpm)	366	486	269	247	579	467	580
Drawdown (ft)	293	109	187	128	104	136	57
Specific capacity (gpm/ft)	0.8	4.5	1.4	1.9	5.6	3.4	10.2
Transmissivity (gpd/ft)	--	15 700	2500	2500	9600	4800	15 500
Field coefficient of permeability (gpd/ft^2)	---	9.3	3.5	3.3	5.7	3.0	9.1
Production							
Period (yr)	1947-1956	1960-1982	1947-1982	1948-1982	1948-1982	1948-1982	1948-1975
Pumpage (10^6 gal.)	353	1964	1305	1644	3503	3049	2884

APPENDIX A (cont)

	Los Alamos Field						
	LA-1[a]	LA-1B	LA-2	LA-3	LA-4	LA-5	LA-6
Quality of Water							
Date	1952	2-28-80	2-28-80	2-28-0	2-28-80	2-28-80	2-28-80
Chemical (mg/ℓ)							
SiO_2	29	40	26	24	30	36	26
Ca	7	7	7	1	10	7	8
Mg	1	0.4	0.2	0.2	0.2	0.2	0.2
Na	80	25	50	30	20	30	10
CO_3	0	0	0	0	0	0	0
HCO_3	177	320	136	96	80	140	220
SO_4	20	37	13	7	3	5	22
Cl	18	15	11	3	2	2	10
F	1.3	2.5	1.2	0.5	0.4	0.9	1.6
NO_3	1.8	2.3	2.5	2.4	2.0	2.3	2.3
TDS	---	514	130	112	70	198	364
Hardness	22	16	16	28	24	20	18
Specific conductance (μmho)	385	330	270	550	200	200	300
pH	---	8.4	8.5	8.4	8.5	8.7	8.7
Radiochemical							
Total uranium (μg/ℓ)	---	5.7 ± 1.2	4.5 ± 1.0	3.5 ± 0.8	0.9 ± 0.8	4.8 ± 0.8	3.1 ± 0.8
Temperature (°F)	63	83	75	67	83	77	84

APPENDIX A (cont)

	Guaje Field						
	G-1	G-1A	G-2	G-3	G-4	G-5	G-6
Date of Completion (yr)	1950	1954	1951	1951	1951	1951	1964
Elevation of LSD (ft)	5975	6015	6055	6140	6230	6305	6420
Construction							
Depth drilled (ft)	2100	2071	2006	1996	2002	1997	2005
Depth completed (ft)	2000	1519	1996	1792	1930	1840	1530
Diameter (in.)[b]	10 (490 ft) 10	12 (8663 ft) 10	12 (8600 ft) 10	12 (8695 ft) 10	12 (8720 ft) 10	12 (8739 ft) 10	12
Water Levels							
Depth below LSD (ft)	278	305	352	364	386	455	588
Elevation (ft)	5697	5710	5703	5776	5844	5850	5832
Water-Level Fluctuations							
Period (yr)	1951-1982	1955-1982	1951-1982	1951-1982	1951-1982	1951-1982	1964-1982
Change (ft)	−83	−40	−93	−83	−29	−41	−7
Annual rate (ft/yr)	−2.6	−1.4	−2.9	−2.6	−0.9	−1.3	−0.4
Aquifer							
Formation	Tsf	Tsf	Tsf	Tsf	Tsf	Tsf	Tsf
Saturated thickness (ft)	1722	1214	1644	1428	1544	1385	942
Yield							
Date	1982	1982	1982	1982	1982	1982	1982
Rate (gpm)	313	505	476	239	297	522	281
Drawdown (ft)	165	42	47	112	192	55	81
Specific capacity (gpm/ft)	1.9	12.0	10.1	2.1	1.5	9.5	3.5
Transmissivity (gpd/ft)	12 000	11 000	15 000	7500	17 500	12 000	6300
Coefficient of permeability (gpd/ft^2)	7.0	9.1	9.1	5.3	11.3	8.7	6.7
Production							
Period (yr)	1950-1982	1954-1982	1951-1982	1951-1982	1951-1982	1951-1982	1952-1982
Pumpage (10^6 gal.)	2386	2921	2504	2084	1202	2774	1062

APPENDIX A (cont)

	Guaje Field						
	G-1	G-1A	G-2	G-3	G-4	G-5	G-6
Quality of water							
Date	2-28-80	2-28-80	2-28-80	2-28-80	2-28-80	2-28-80	2-24-80
Chemical (mg/ℓ)							
SiO_2	86	78	78	54	52	64	70
Ca	10	9	9	12	14	15	16
Mg	0.5	0.5	0.6	1.5	2.5	3.7	3.6
Na	23	26	36	18	14	11	12
CO_3	0	0	0	0	0	0	0
HCO_3	84	124	116	84	96	88	88
SO_4	4	4	4	4	3	4	3
Cl	2	2	2	2	2	2	2
F	0.5	0.5	0.8	0.3	0.2	0.2	0.2
NO_3	2.1	2.1	1.9	2.5	2.7	2.9	1.8
TDS	172	134	222	144	150	162	190
Hardness	34	30	24	36	48	54	54
Specific conductance (μmho)	130	200	200	300	160	130	200
pH	8.3	8.4	8.5	8.3	8.2	8.2	7.9
Radiochemical							
Total uranium (μg/ℓ)	1.0 + 0.8	0.7 + 0.8	0.9 + 0.8	0.8 + 0.8	1.0 + 0.8	0.8 + 0.8	2.4 + 0.8
Temperature (°F)	78	84	85	82	79	78	83

APPENDIX A (cont)

	Pajarito Field				
	PM-1	PM-2	PM-3	PM-4	PM-5
Date of Completion	1965	1965	1966	1981	1982
Elevation of LSD (ft)	6520	6715	6640	6920	7095
Construction					
Depth drilled (ft)	2501	2600	2552	2920	3120
Depth completed (ft)	2499	2300	2552	2875	3093
Diameter (in.)[b]	12	14	14	16	16
Water Levels					
Date	1982	1982	1982	1982	1982
Depth below LSD (ft)	748	874	762	1047	1208
Elevation (ft)	5772	5841	5878	5873	5887
Water-Level Fluctuations					
Period (yr)	1965-1982	1966-1982	1968-1982	1981-1982	---
Change (ft)	−2	−48	−19	5	---
Annual rate (ft/yr)	−0.1	−2.8	−1.3	---	---
Aquifer					
Formation	QTp-Tsf	QTp-Tsf	QTp-Tsf	QTp-Tsf	QTp-Tsf
Saturated thickness (ft)	1751	1426	1790	1828	1885
Yield					
Date	1982	1982	1982	1982	1982
Rate (gpm)	589	1386	1402	1473	1225
Drawdown (ft)	22	60	23	40	144
Specific capacity (gpm/ft)	26.8	23.1	60.9	36.8	8.5
Transmissivity (gpd/ft)	55 000	40 000	320 000	44 000	10 000
Field coefficient of permeability (gpd/ft^2)	31	28	179	24	5.3
Production					
Period (yr)	1965-1982	1966-1982	1968-1982	1982	---
Pumpage (10^6 gal.)	1593	5863	3478	76	---
Quality of Water					
Date	3-18-81	3-18-81	3-18-81	8-3-81	8-4-81
Chemical (mg/ℓ)					
SiO_2	77	81	88	87	86
Ca	28	8	24	9	14
Mg	6.9	3.1	8.4	3	4
Na	18	10	18	11	24
CO_3	0	0	0	0	0
HCO_3	144	65	148	70	106
SO_4	5	3	7	4	10
Cl	4	9	10	2	4
F	0.3	0.3	0.4	0.3	0.3
NO_3	2.0	<0.1	1.8	2	8
TDS	212	140	216	165	211
Hard	90	36	90	36	52
Specific conductance (µmho)	260	130	250	120	190
pH	8.0	7.8	8.3	8.2	8.2
Radiochemical					
Total uranium (µg/ℓ)	2.4 ± 0.8	0.0 ± 0.8	1.0 ± 0.8	0.8 ± 0.8	2.2 ± 0.4
Temperature (°F)	71	69	71	69	73

[a]Well was abandoned in 1956; data were not used in the average hydrologic characteristics. It is located 150 ft SW of well LA-1B.

[b]Wells have two different diameter sizes of casing; i.e., 12 (650 ft) 10 reads: 12-in. diameter to 650 ft, then 10-in. diameter to completed depth of well.

Note: QTp = Puye Conglomerate; Tsf = Tesuque Formation.

APPENDIX B

CONSTRUCTION AND HYDROLOGIC DATA FOR TEST AND STOCK WELLS

	Test Wells				
	TW-1	TW-2	TW-3	TW-4	TW-5A
Date of Completion	1950	1949	1949	1950	1960
Elevation of LSD (ft)	6370	6645	6625	7245	7145
Construction					
Depth drilled (ft)	642	789	815	1205	1821
Depth completed (ft)	642	789	815	1205	1821
Diameter (in.)	8	8	10	6	8
Water levels					
Date	1951	1951	1951	1951	1964
Depth below LSD (ft)	593	760	750	1166	1178
Elevation (ft)	5773	5885	5875	6079	5967
Water-Level Fluctuations					
Period	---	---	---	---	1960-1964
Changes (ft)	---	---	---	---	–4
Annual rate (ft/yr)	---	---	---	---	–0.8
Aquifer					
Formations	QTp	QTp	QTp	Tt	QTp-Tsf
Saturated thickness (ft)	49	29	65	39	643
Yield					
Date	1951	1951	1951	1951	1960
Rate (gpm)	2.4	6.7	6.6	2.8	81
Drawdown (ft)	38.9	7.5	15.0	4.8	14.2
Specific capacity (gpm/ft)	<0.1	1.0	0.5	0.6	5.7
Transmissivity (gpd/ft)	200	7000	7800	750	11 000
Field coefficient of permeability (gpd/ft^2)	4	241	120	19	17
Quality of Water					
Date	2-28-81	9-17-81	3-31-81	6-8-65	9-16-81
Chemical (mg/ℓ)					
SiO_2	49	79	84	---	72
Ca	43	13	17	10	8
Mg	7.7	3.8	6.0	5	2.5
Na	12	9	13	20	11
CO_3	0	0	0	0	0
HCO_3	121	79	104	70	65
SO_4	3	3	3	---	1
Cl	7	3	4	2	2
F	0.4	0.5	0.4	<0.4	0.2
NO_3	2.4	6.2	4.1	0.4	3.9
TDS	220	150	168	163	124
Hardness	128	51	64	45	38
Specific conductance (μmho)	320	150	190	150	120
pH	8.0	8.0	7.9	7.9	7.9
Radiochemical					
Total uranium (μg/ℓ)	6.1 ± 1.2	0.1 ± 0.8	0.7 ± 0.8	0.5 ± 0.5	0.0 ± 0.8
Temperature (°F)	70	71	74	70	70

APPENDIX B (cont)

	Test Wells					Stock Wells	
	TW-8	DT-9	DT-10	Sigma Mesa	H-19	RW-2	RW-5
Date of Completion	1960	1960	1960	1979	1949	1954	1955
Elevation of LSD (ft)	6870	6935	7020	7215	7180	5642	5820
Construction							
Depth drilled (ft)	1065	1501	1409	2292	2000	161	132
Depth completed (ft)	1065	1501	1408	---	2000 [a]	161	132
Diameter (in.)	8	12	12	---	---	---	---
Water Levels							
Date	1965	1982	1967	1979	1949	1954	1955
Depth below LSD (ft)	969	1006	1091	1305.[b]	970	132	105
Elevation (ft)	5901	5929	5929	5910	6210	5510	5715
Water-Level Fluctuations							
Period	1960-1965	1960-1982	1960-1967	---	---	---	---
Change (ft)	−1	−3	−4	---	---	---	---
Annual rate (ft/yr)	−0.2	−0.2	−0.5	---	---	---	---
Aquifer							
Formations	QTp	QTp-Tsf	QTp-Tsf	QTp-Tsf	Tt-QTp	Tsf	Tsf
Saturated thickness (ft)	97	498	324	987	1030	---	---
Yield							
Date	1960	1960	1960	---	---	---	---
Rate (gpm)	16	88	78	---	---	---	---
Drawdown (ft)	8.0	4.0	4.9	---	---	---	---
Specific capacity (gpm/ft)	2	22	16	---	---	---	---
Transmissivity (gpd/ft)	2400	61 000	36 100	---	---	---	---
Field coefficient of permeability (gpd/ft^2)	25	122	111	---	---	---	---
Quality of Water							
Date	4-6-81	4-10-81	4-2-81	---	---	12-7-67	12-7-67
Chemical (mg/ℓ)							
SiO_2	50	72	58	---	---	---	---
Ca	4	9	10	---	---	32	28
Mg	0.9	3.1	3.5	---	---	5	7
Na	11	12	11	---	---	47	79
CO_3	7	0	0	---	---	0	0
HCO_3	22	69	81	---	---	114	158
SO_4	<1	2	1	---	---	---	---
Cl	3	4	3	---	---	8	10
F	0.2	<0.2	0.3	---	---	0.1	0.2
NO_3	4.4	4.3	<0.4	---	---	0.9	3.1
TDS	52	142	124	---	---	170	253
Hardness	16	35	42	---	---	100	100
Specific conductance (μmho)	90	150	130	---	---	200	270
pH	9.8	8.0	8.3	---	---	8.1	7.6
Radiochemical							
Total uranium (μg/ℓ)	0.0 ± 0.8	0.8 ± 0.8	0.8 ± 0.8	---	---	1.8 ± 0.4	2.3 ± 0.8
Temperature (°F)	67	70	67	---	---	67	66

[a]Hole abandoned.

[b]Water level interpreted from geophysical logs.

Note: Tsf = Tesuque Formation; QTp = Puye Conglomerate; and Tt = Tschicoma Formation.

APPENDIX C

HYDROLOGIC DATA FOR SPRINGS IN WHITE ROCK CANYON

	Spring 3	Spring 3B	Spring 4	Spring 5A	Spring 5B	Spring 6	Spring 8A	Spring 10
Elevation of LSD (ft)	5560	5500	5500	5430	5400	5380	5370	5360
Aquifer	QTp	Tsf	QTp	Tsf	Tsf	Tsf	Tsf	Tsf
Discharge at Rio Grande (gpm)	20	30	80	30	10	60	30	20
Quality of Water								
Date	10-13-81	10-13-81	10-13-81	10-13-81	10-14-81	10-14-81	10-14-81	10-15-81
Chemical (mg/ℓ)								
SiO_2	52	46	60	60	64	74	75	69
Ca	20	24	28	24	17	12	11	12
Mg	1.6	2.0	5.7	2.7	4.4	3.6	2.8	3.2
Na	16	139	15	22	12	11	13	13
CO_3	0	0	0	0	0	0	0	0
HCO_3	99	392	132	124	87	74	56	80
SO_4	4	4	6	7	2	2	3	3
Cl	5	6	8	6	4	4	5	4
F	0.4	0.6	0.5	0.3	0.5	0.3	0.4	0.4
NO_3	2.6	8.4	<0.4	1.7	2.0	<0.4	<0.4	1.7
TDS	125	374	168	186	152	134	152	146
Hardness	56	64	92	69	56	44	39	42
Specific conductance (μmho)	210	610	220	240	150	140	130	120
pH	8.1	7.5	7.0	7.4	7.4	7.0	9.0	7.8
Radiochemical								
Total uranium (μg/ℓ)	2.3 ± 0.8	19 ± 4.0	1.5 ± 0.8	2.2 ± 0.8	1.9 ± 0.8	1.0 ± 0.8	1.7 ± 0.8	1.7 ± 0.8
Temperature (°F)	72	68	66	70	61	73	72	66

Note: Tsf = Tesuque Formation and QTp = Puye Conglomerate.

APPENDIX D

CHEMICAL QUALITY OF WATER FROM MUNICIPAL SUPPLY AND DISTRIBUTION

	Primary Chemical Quality Required for Municipal Use (Concentrations in mg/ℓ)									
	Ag	As	Ba	Cd	Cr	F	Hg	NO_3	Pb	Se
Los Alamos Field										
Well LA-1B	<0.0005	0.039	0.06	<0.001	0.022	2.6	<0.0002	1.2	<0.003	<0.003
Well LA-2	<0.0005	0.013	0.09	<0.001	0.020	1.9	<0.0002	1.8	<0.003	<0.003
Well LA-3	<0.0005	0.009	0.06	<0.001	0.010	0.7	<0.0002	1.7	<0.003	<0.003
Well LA-5	<0.0005	0.032	0.07	<0.001	0.010	1.0	<0.0002	1.4	<0.003	<0.003
Guaje Field										
Well G-1	<0.0005	<0.005	0.06	<0.001	0.008	0.4	<0.0002	1.2	<0.003	<0.003
Well G-1A	<0.0005	0.009	0.04	<0.001	0.006	0.5	<0.0002	1.2	<0.003	<0.003
Well G-2	<0.0005	0.048	0.03	<0.001	0.011	1.0	<0.0002	0.9	<0.003	<0.003
Well G-3	<0.0005	0.018	0.02	<0.001	0.005	0.4	<0.0002	1.0	0.004	<0.003
Well G-4	<0.0005	<0.005	0.02	<0.001	0.004	0.3	<0.0002	1.5	<0.003	<0.003
Well G-5	<0.0005	<0.005	0.02	<0.001	0.002	0.3	<0.0002	3.0	<0.003	<0.003
Well G-6	<0.0005	<0.005	0.02	<0.001	0.005	0.3	<0.0002	0.6	<0.003	<0.003
Pajarito Field										
Well PM-1	<0.0005	<0.005	0.09	<0.001	0.010	0.3	<0.0002	1.1	<0.003	<0.003
Well PM-2	<0.0005	<0.005	0.02	<0.001	0.004	0.2	<0.0002	0.4	<0.003	<0.003
Well PM-3	<0.0005	<0.005	0.05	<0.001	0.003	0.3	<0.0002	0.7	0.005	<0.003
Well PM-4	<0.0005	<0.005	0.04	<0.001	0.006	0.3	<0.0002	7.6	<0.003	<0.003
Well PM-5	<0.0005	<0.005	0.04	<0.001	0.002	0.4	<0.0002	3.0	<0.003	<0.003
Los Alamos Well LA-6	<0.0005	0.185		<0.001	0.014	2.3	<0.0002	0.4	0.006	<0.003
USEPA Maximum Contaminant Level	0.05	0.05	1.0	0.01	0.05	2.0	0.002	45	0.05	0.01

APPENDIX E

SECONDARY CHEMICAL QUALITY FOR MUNICIPAL USE
(concentrations in mg/ℓ)

	Cl	Cu	Fe	Mn	SO_4	Zn	TDS	pH
Los Alamos Field								
Well LA-1B	16	0.003	0.028	<0.002	27	<0.01	408	7.9
Well LA-2	16	0.006	0.100	0.008	12	<0.01	204	8.5
Well LA-3	4	<0.002	0.007	<0.002	5	<0.01	162	8.3
Well LA-5	2	<0.002	<0.005	<0.002	3	<0.01	170	8.6
Guaje Field								
Well G-1	3	0.003	0.007	0.010	<2	0.02	162	7.9
Well G-1A	3	0.013	0.006	<0.002	<2	0.02	152	8.3
Well G-2	3	<0.002	0.010	<0.002	2	<0.01	168	8.3
Well G-3	3	0.010	0.018	<0.002	<2	0.12	120	8.3
Well G-4	3	0.012	0.062	0.002	3	0.09	126	8.2
Well G-5	3	<0.002	0.012	0.002	4	<0.01	160	8.3
Well G-6	3	<0.002	<0.005	<0.002	2	<0.01	134	7.6
Pajarito Field								
Well PM-1	6	<0.002	<0.005	<0.002	2	<0.01	188	7.6
Well PM-2	2	0.003	<0.005	<0.002	2	0.04	134	8.0
Well PM-3	8	0.001	<0.005	<0.002	3	0.01	203	8.0
Well PM-4	2	<0.002	0.020	0.003	4	<0.01	169	8.2
Well PM-5	3	<0.002	0.050	0.005	10	<0.01	211	8.2
Water Canyon								
Gallery	<1	<0.002	0.325	<0.002	2	0.02	114	7.5
Los Alamos Well LA-6	4	0.011	0.908	<0.002	2	0.07	222	8.6
Secondary Standards	250	1.0	0.3	0.05	250	5.0	500	6.5 - 8.5

APPENDIX F

RADIOCHEMICAL QUALITY OF WATER FROM MUNICIPAL SUPPLY AND DISTRIBUTION

Station	1982 Date	Radiochemical						
		^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}Pu (10^{-9} μCi/mℓ)	Gross Alpha (10^{-} μCi/mℓ)	Gross Beta (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)
Los Alamos Field								
Well LA-1B	3-30	−50 ± 80	−0.004 ± 0.014	−0.004 ± 0.012	11 ± 6.0	6.4 ± 2.4	---	5.0 ± 1.0
Well LA-2	3-30	19 ± 40	0.009 ± 0.020	−0.019 ± 0.000	9.0 ± 4.0	4.1 ± 1.8	0.3 ± 0.6	3.9 ± 0.8
Well LA-3	3-30	−80 ± 40	0.004 ± 0.012	−0.012 ± 0.008	1.5 ± 1.4	6.5 ± 2.0	1.2 ± 0.6	4.6 ± 1.0
Well LA-5	3-30	−10 ± 34	−0.005 ± 0.010	−0.010 ± 0.010	3.3 ± 2.0	3.8 ± 1.8	0.9 ± 0.6	7.0 ± 1.4
Guaje Field								
Well G-1	3-30	40 ± 60	−0.006 ± 0.012	−0.012 ± 0.012	0.1 ± 1.2	2.4 ± 1.6	3.4 ± 0.6	0.9 ± 0.8
Well G-1A	3-30	−2 ± 80	0.007 ± 0.030	−0.007 ± 0.020	0.3 ± 1.0	28 ± 6.0	1.8 ± 0.6	1.0 ± 0.8
Well G-2	3-30	−7 ± 38	0.005 ± 0.016	−0.014 ± 0.012	0.8 ± 1.2	0.8 ± 1.4	0.3 ± 0.6	0.9 ± 0.8
Well G-3	3-30	−40 ± 40	0.004 ± 0.014	−0.013 ± 0.000	1.0 ± 1.2	2.1 ± 1.6	4.1 ± 0.6	1.6 ± 0.8
Well G-4	3-30	40 ± 60	0.014 ± 0.038	0.010 ± 0.600	1.1 ± 1.2	1.2 ± 1.4	0.2 ± 0.6	1.0 ± 0.8
Well G-5	3-30	−40 ± 80	−0.005 ± 0.000	−0.016 ± 0.010	1.0 ± 1.0	3.8 ± 1.6	0.7 ± 0.6	1.3 ± 0.4
Well G-6	3-30	19 ± 40	0.009 ± 0.026	−0.009 ± 0.038	5.9 ± 2.4	7.7 ± 2.2	0.8 ± 0.6	1.7 ± 0.8
Pajarito Field								
Well PM-1	3-30	−50 ± 40	−0.010 ± 0.020	−0.050 ± 0.100	0.7 ± 1.4	8.1 ± 2.4	0.5 ± 0.6	1.8 ± 0.8
Well PM-2	3-30	20 ± 40	0.010 ± 0.040	−0.020 ± 0.040	1.1 ± 1.2	1.9 ± 1.6	0.3 ± 0.6	0.0 ± 0.8
Well PM-3	3-30	30 ± 20	−0.014 ± 0.014	−0.005 ± 0.014	1.0 ± 1.4	13 ± 3.2	4.2 ± 0.6	1.6 ± 0.8
Well PM-4	8-3	10 ± 48	0.012 ± 0.020	−0.012 ± 0.034	0.0 ± 0.8	18 ± 4.0	0.5 ± 0.6	0.8 ± 0.8
Well PM-5	8-4	36 ± 34	0.018 ± 0.024	0.004 ± 0.024	3.9 ± 2.2	3.2 ± 1.6	0.4 ± 0.6	2.2 ± 0.4
Los Alamos Field								
Well LA-6	3-30	−30 ± 40	−0.005 ± 0.000	−0.015 ± 0.030	2.9 ± 2.2	4.0 ± 1.8	0.5 ± 0.6	3.8 ± 0.8

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