Ground-Water Conditions in the Vicinity of Lake Mead Base Las Vegas Valley, Nevada

By OMAR J. LOELTZ

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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By Omar J. Loeltz

ABSTRACT

The principal source of ground water for the Lake Mead Base well field is precipitation in the Las Vegas drainage basin northwest of the well field. The amount of water moving through the area is small. Locally, the chemical quality of the water is unsatisfactory for most uses. The present supply of water of satisfactory chemical quality from two of four wells probably can be maintained, if pumpage from these wells is not increased significantly.

Additional ground-water supplies of satisfactory chemical quality probably can be developed west of the present well field.

INTRODUCTION

In April 1955, at the request of the Department of Defense, the U.S. Geological Survey began an investigation of ground-water conditions in the vicinity of Lake Mead Base, Las Vegas Valley, Nev. The chemical quality of the water from two of four wells supplying the base had deteriorated to the point where it was wholly unsatisfactory for use. The study was made to determine the cause of the deterioration and to provide data that might be helpful in maintaining a satisfactory supply for the base.

As part of the study, all known pertinent geologic and hydrologic data for the area were assembled and studied. During the investigation, considerable additional data were collected and studied. These data were obtained from pumping tests in the area, current-meter and conductivity surveys, and chemical analyses of water samples from wells.

The results of the investigation were made available to the Department of Defense upon completion of the study. On the basis of the 1955 study, a well was drilled in the summer of 1961 to augment the water supply of Lake Mead Base (R. J. Houghton, oral communication, 1962). The well is 2,000 feet west of well 4 and is pumped at the rate of 130 gpm (gallons per minute). The chemical quality of the water is more suitable for use on the base than the chemical quality of the water from any of the other wells. No significant change in chemical quality or yield of the water from wells 2, 3, and 4 has been noted.

Data on file at Lake Mead Base were used extensively in the present study of the wells and water supply. Useful data also were obtained from a study by Maxey and Jameson (1948) and from a guidebook to the geology of Utah (Intermountain Association of Petroleum Geologists, 1952). In this report wells are given the same numbers used by the defense agencies for designating wells on their respective bases.

GEOGRAPHY

LOCATION

The area described in this report is in the eastern part of Las Vegas Valley (see fig. 1). The area studied most intensively is near the eastern edge of the valley between Nellis Air Force Base and Lake Mead Base, about 10 miles northeast of Las Vegas, where the well field for Lake Mead Base is located.

TOPOGRAPHIC FEATURES

Las Vegas Valley trends northwestward about 50 miles and is as much as 20 miles wide. The Spring Mountains, which have a maximum altitude of 11,910 feet, border the west side of the valley. The southern parts of the Pintwater, Desert, Sheep, and Las Vegas Ranges form the northeastern boundary. Frenchman and Sunrise Mountains and a group of unnamed low hills border the east side of the valley. The River Mountains and the McCullough Range form the southeastern boundary.

The relief of the mountains ranges from a few thousand feet to about 10,000 feet. The mountains are rugged and commonly rise abruptly above the alluvial apron that separates them from the basin lowlands. Large alluvial fans extend far out from the Spring Mountains. The alluvial fans on the east side of the valley are small. The fans merge into the basin lowlands, which are nearly flat and slope southeastward.

Drainage is southeastward to the Colorado River (east of the area shown in fig. 1) through Las Vegas Wash. There are no perennial streams in the area. Runoff ordinarily infiltrates into the ground high on the alluvial fans. After intense summer storms, however, the runoff may be sufficient for short periods of time to flow onto the floor of the valley. Occasionally the runoff causes extensive damage to railroads, roads, and urban areas.

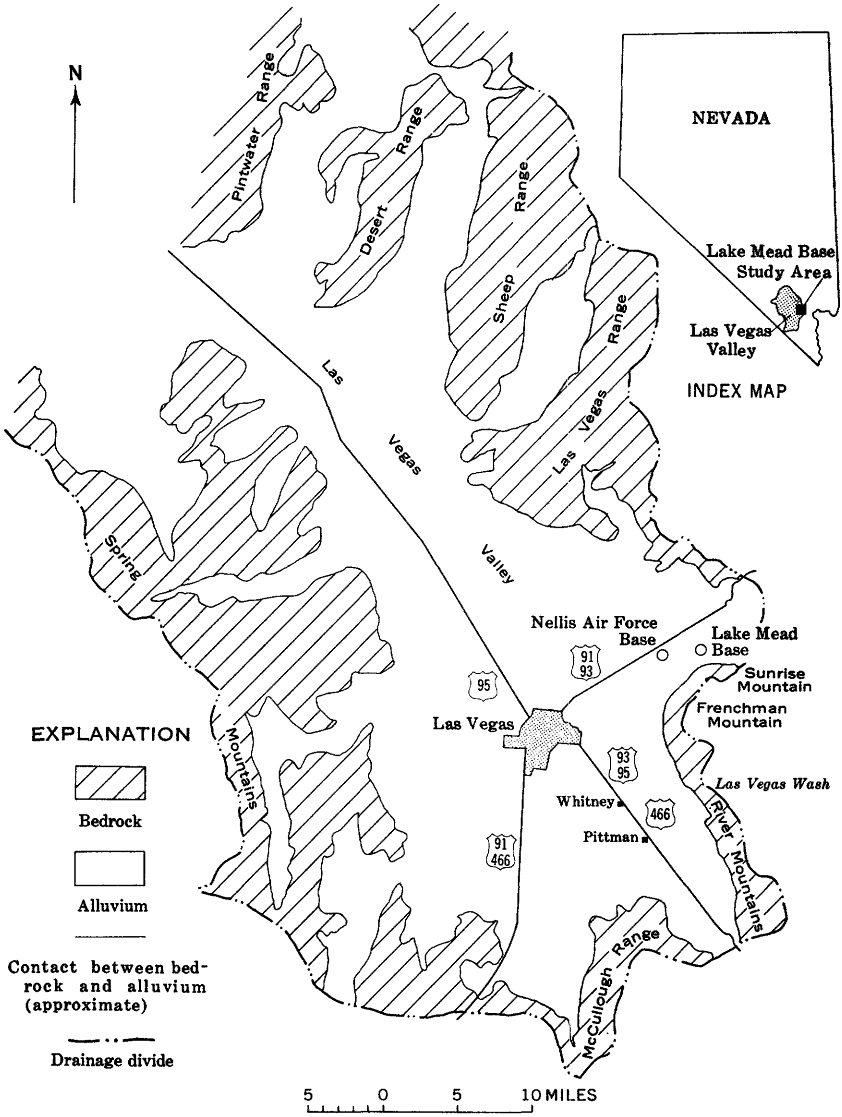

FIGURE 1.—Sketch map of Las Vegas Valley, Clark County, Nev.

CLIMATE

The climate is arid. Relative humidity is low, the percentage of sunshine is high, and the daily and seasonal range in temperature is large. Strong winds are common throughout the year.

GEOLOGY

The mountains generally are composed of consolidated sedimentary and igneous rocks of Precambrian, Paleozoic, Mesozoic, and early Tertiary age. Rocks of Precambrian age are exposed only at the base of Frenchman Mountain. The structure of the consolidated rocks is exceedingly complex because of numerous thrust, lateral, and normal faults. The alluvial apron and the valley fill are composed mostly of unconsolidated deposits of Miocene(?), Pliocene, Pleistocene, and Recent age.

Except for the Sultan and the Monte Cristo Limestones of middle Paleozoic age, the older rocks of the mountains generally are barriers to the movement of ground water. The Sultan and the Monte Cristo Limestones locally transmit large quantities of water through solution channels formed mainly along faults and joints. These rocks are exposed in Frenchman Mountain, and they probably are in contact with saturated alluvium east of Nellis Air Force Base.

The alluvial apron is composed largely of poorly sorted gravel, sand, silt, and clay. However, some of the alluvial fans that extend far out from the mountains contain clean gravel strata on their higher slopes. Most of these fans emerge from canyons in the Spring Mountains and are the principal areas of recharge to the ground-water reservoir of Las Vegas Valley.

The valley fill consists, to an unknown depth, of deposits of gravel, sand, silt, and clay. Most of the water developed to date has been from strata less than 700 feet deep. At greater depths the deposits tend to be finer grained and may be consolidated.

GROUND WATER

RECHARGE

The source of recharge to the ground-water reservoir of Las Vegas Valley is within the drainage basin. Precipitation in the Spring Mountains is the major source of the recharge, although some recharge results from the infiltration of precipitation and resulting runoff on the lower ranges.

The aquifers in the Nellis Air Force Base area are recharged principally from precipitation on the alluvial fans at the south end of the Las Vegas Range, although part of the recharge may be derived from precipitation in the Spring Mountains.

Probably the only significant source of recharge to the aquifers in the Lake Mead Base area is precipitation on the southern part of the Las Vegas Range. Thus, most of the ground-water recharge to the respective well fields is from a common source, precipitation on the southern part of the Las Vegas Range and the alluvial fans that border it.

MOVEMENT AND DISCHARGE

Ground water in Las Vegas Valley moves from the Spring Mountains and other recharge areas toward pumped and flowing wells and toward springs and areas of evapotranspiration, principally near and east of Las Vegas.

In the vicinity of Las Vegas, artesian water moves generally eastward toward Frenchman Mountain and then southward along the east side of the valley toward Las Vegas Wash.

Data for the area near Lake Mead Base and Nellis Air Force Base are insufficient for accurate mapping of the direction of ground-water movement, but it is inferred to be southeastward beneath the military bases toward Frenchman Mountain. (See fig. 2.)

Whether some or all of the ground water in the Lake Mead Base area moves southeastward into Frenchman Mountain is not known. The possibility of movement into the mountain is recognized because the contours on the piezometric surface, although insufficiently controlled, infer such movement, and the nature and structure of the rocks do not preclude movement of water through them. As was pointed out in the discussion on the geology of the valley, the Sultan and Monte Cristo Limestones, both exceptions to the general rule that the rocks of the mountains are barriers to the movement of ground water, are probably in the zone of saturation in the Lake Mead Base area. Furthermore, the rocks into which the water may be moving have been extensively faulted, a condition that might allow the transmission of water in otherwise nearly impermeable rocks. The fact that no large springs or large areas of evapotranspiration are known to result from the southeastward movement of water through Frenchman Mountain does not preclude such movement, because the amount of water involved (see p. Q10) probably is very small.

CHEMICAL QUALITY OF THE WATER

Much of Las Vegas Valley yields water suitable for most domestic uses and for irrigation. In general, ground water in the northern and central parts of the valley has a low dissolved-solids content. For example, near Las Vegas the dissolved-solids content generally is about 300 ppm (parts per million). In the southern part of Las Vegas Valley, however, much of the ground water is so highly mineralized that it is unsatisfactory for domestic and irrigation use. For example, in the vicinity of Whitney and Pittman the concentration of dissolved solids commonly is several thousand parts per million.

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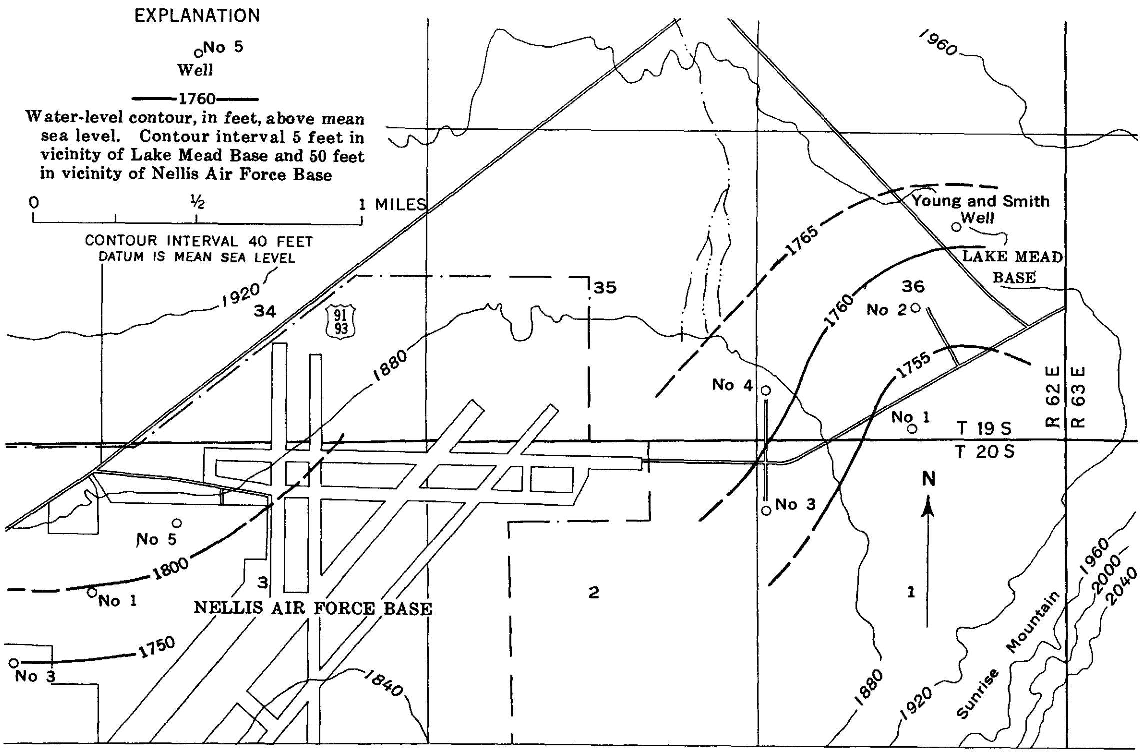

Base adapted from U.S. Army, Corps of Engineers, map dated October 1953

Hydrology by O. J. Loeltz, 1955

FIGURE 2.—Map of Lake Mead Base area, Las Vegas Valley, Nev., showing water-table contours and location of wells.

A notable exception to the rule that water in the central part of the valley commonly has a low dissolved-solids content is the water in wells 1 and 2 at Lake Mead Base. The dissolved-solids content of the water of well 1, on Mar. 2, 1955, after the well had not been used for months, was 1,810 ppm. The dissolved-solids content of the water of well 2, on the same date, was 1,170 ppm. These values are in marked contrast to those of the water of the other two wells on the base (about 500 ppm) and to those of the water of the wells supplying Nellis Air Force Base (250 to 500 ppm). The water from wells 1 and 2 was used during 1953 and 1954 to supply the needs of Lake Mead Base. It is reported that the water was unsatisfactory in many respects, especially for evaporative coolers and for the hot-water system. In 1955, wells 3 and 4 supplied water for the base, and wells 1 and 2 were virtually unused.

INVESTIGATIONAL PROCEDURES AND CONCLUSIONS

PIEZOMETRIC SURFACE

In an effort to determine the direction of ground-water movement in the vicinity of Lake Mead Base, contour lines of the piezometric surface in that area were drawn (fig. 2). (Meinzer (1923) defined the piezometric surface as an imaginary surface that everywhere coincides with the static level of the water in the aquifer.) In this study, the nonpumping levels of water in the wells in the spring of 1955 were considered to be points on the piezometric surface. The position and shape of the surface at other points were inferred from these few known points, and contour lines were drawn to show the position and shape of the piezometric surface as of that time.

The position of the contour lines on figure 2 is considered tentative because of inadequate and conflicting water-level data. If some of the data collected previous to the investigation had been used, the contour lines in the vicinity of the well field of Lake Mead Base would have been almost at right angles to those shown in figure 2. The altitude of the water level in well 1 in March 1952 reportedly was 1,768 feet. At the time of the investigation, April 1955, the altitude of the water level was 1,754 feet. The altitude of the water level in well 2 in March 1952, according to the same source, was 1,765 feet. During the present study, the altitude was 1,762 feet. The altitude of the water level in the Young and Smith well, which is about half a mile northeast of well 2, was 1,794 feet in January 1953, if the depth to water as given in the driller's log is correct. In April 1955, the altitude of the water level was 1,762 feet.

In contrast to these declines, the available data indicate a substantial rise in water levels in wells 3 and 4 since the date of their completion in late 1953. Reportedly, the altitude of the water level in well 3 in December 1953 was 1,734 feet. During the present study, the altitude of the water level was 1,758 feet. The same source indicates that the altitude of the water level in well 4 in December 1953 was 1,739 feet. During the present study the altitude of the water level was 1,761 feet.

Because the methods used to collect data prior to the present study and the circumstances under which those data were collected are not fully known, the following statements are based largely on data obtained and verified during the present study in which depths to water were measured with a steel tape.

The contour lines (fig. 2) suggest that the main source of the ground water beneath the Lake Mead Base well field is the precipitation and runoff that infiltrates into the alluvial fans at the southern end of the Las Vegas Range (fig. 1). A negligible amount also may be derived from precipitation on the hills and mountains north and east of the base. Because of the gypsiferous nature of some of the rocks comprising these hills and mountains, such water may be highly mineralized. Whether the water passing beneath the well field moves southeastward into Frenchman Mountain or is deflected southward along the base of the mountain is not known. In any event, the source of the water of low dissolved-solids content appears to be northwest of the well field.

ATTITUDE OF PRINCIPAL AQUIFERS

Electric logs are available for wells 1 to 4. The logs indicate that the principal aquifers dip eastward 500 feet per mile and more. At well 3, the principal aquifers are about 150 feet lower than at well 4; at well 2 they are more than 500 feet lower; at well 1 they are about 300 feet lower. Because the alluvium slopes southwestward in the vicinity of the well field, the depth to the principal aquifers increases rapidly eastward. The main aquifers, which to date have been tapped by the Lake Mead Base wells, therefore, probably lie at shallower depths westward from wells 3 and 4.

PUMPING TESTS

To obtain estimates of the coefficients of transmissibility and storage, wells 2 and 4 were pumped at constant rates at different times, and the effects of such pumping on the water levels in the pumped wells and the other wells in the well field were noted.

Beginning at 9:23 a.m. on April 18, 1955, well 4 was pumped at a nearly constant rate of 130 gpm for 30 hours. Although none of the wells had been pumped for 24 hours before the test, the wells were recovering from the effects of earlier pumping. The rate of recovery in well 4 was considerably less than 0.1 foot per hour at the time the pumping test began. Based on the drawdown and subsequent recovery data, the coefficient of transmissibility was computed to be somewhat less than 1,500 gpd (gallons per day) per ft. Periodic measurements were made in wells 1, 2, and 3 to the nearest hundreth of a foot, and the Young and Smith well was equipped with a recording gage. Effects of the pumping could be identified only in well 3, and these effects, a marked change in the previously established pattern of recovery of water levels in well 3, were noted about 7 hours after beginning of pumping of well 4. By extrapolating the recovery curve for well 3, it is estimated that pumping well 4 for 30 hours retarded the normal rate of recovery of well 3 by more than 1 foot.

That interference effects were noted in well 3 indicates that some of the strata common to both wells contain confined (artesian) water, because under unconfined (water-table) conditions the effects of the pumping would have been too small to be measurable. The coefficient of storage, 3.6×10^{-5}, computed on the basis of interference effects in well 3, also indicates artesian conditions. However, the value obtained may be considerably in error, because the coefficient of transmissibility for aquifers tapped by well 3, computed from the intereference data, is about 20,000 gpd per ft, or about 20 times larger than a much more reliable determination of the coefficient of transmissibility made from data obtained when well 3 itself was pumped. (See p. Q10.) The coefficient of transmissibility computed from interference data will exceed the true value if either well taps aquifers that are not common to both or if, because of the duration of this particular pumping test and the distance between wells, either well taps strata containing unconfined water. One of these conditions, perhaps both, probably exists, hence, the value of the coefficient of transmissibility as determined by interference effects very likely is too high.

The lack of measurable interference effects in wells 1 and 2 and in the Young and Smith well indicates that these wells have little, if any, artesian hydraulic connection with well 4. The test does not eliminate the possibility that the wells are connected hydraulically with well 4 by a water-table aquifer. Under water-table conditions, pumping at 100 gpm might be continued for 30 days or more before interference effects of 0.01 foot or more between wells 2,000 feet apart would occur.

Well 2 was pumped at a constant rate of about 140 gpm for 20 hours, beginning at 12:08 p.m. on April 20, 1955. The computed coefficient of transmissibility was about 800 gpd per ft. Because no interference with other wells could be detected as a result of the pumping, a value for the coefficient of storage could not be obtained.

The hydraulic continuity under artesian conditions, if any, is evidently poorer between wells 1 and 2 than it is between wells 3 and 4. However, as noted earlier, all the wells still may be hydraulically connected under unconfined conditions. The foregoing tests show that interference effects between wells spaced 2,000 feet apart are negligible for the rates of pumping and the pumping schedules that have been used on the base in the past.

Well 3 was pumped for 1 hour at 195 gpm, beginning at 10:06 a.m. on April 21, 1955. The coefficient of transmissibility was computed to be about 1,000 gpd per ft.

The low coefficients of transmissibility of the aquifers tapped by the Lake Mead Base wells indicate that it is not possible to obtain yields of more than a few gallons per minute per foot of drawdown from these wells.

To estimate the amount of water moving through the area under natural conditions, pumping tests also were made on all the Nellis Air Force Base wells for which the required data could be obtained. In the Lake Mead Base well field, the coefficient of transmissibility was estimated to be 1,000 gpd per ft. In the vicinity of Nellis Air Force Base, the coefficient of transmissibility was estimated to be 5,000 gpd per ft. The general hydraulic gradient toward Lake Mead Base is about 30 feet per mile, and that toward Nellis Air Force Base is about 40 feet per mile. Thus, in the vicinity of the Lake Mead Base well field, only about 30,000 gpd moves across each mile-wide section normal to the direction of ground-water movement, and in the Nellis Air Force Base area the quantity is about 200,000 gpd. Although these estimates show only the general order of magnitude of the quantity of water that is moving through the saturated deposits beneath the two bases, they indicate that the quantity is small and that the demand for water can easily equal or exceed the amount of water naturally passing through a given area.

The peak demand at Lake Mead Base in 1961 exceeded 100,000 gpd. The yearly demand averaged about 85,000 gpd, and a substantial increase in demand is anticipated. The natural movement of water through that part of the well field from which ground-water withdrawals were being made, a strip about half a mile wide, was only about 10,000 gpd. To continue to meet the demands of the base indefinitely, water will have to be diverted to the well field. This diversion can be accomplished by continuing withdrawals to meet the demands of the base, provided the demands do not greatly exceed several hundred thousand gallons per day. Under this practice, water will be taken from ground water in storage and water levels will continue to decline. As the practice is continued, however, more of the water that is diverted to the well field from storage will be derived from an ever increasing volume of sedimentary deposits, probably principally from deposits of Las Vegas Valley lying west of the well field, and consequently water levels will decline at a slower rate for a given withdrawal. Although the total decline, including the general decline of water levels anticipated for Las Vegas Valley, may be substantial, it will hardly in the forseeable future reach the several hundred feet that would be required to deplete the supply to the well field to the point where the field would be incapable of meeting demands of the base.

CHEMICAL ANALYSES

The records to date indicate that, except for wells 1 and 2, the water from wells in the Lake Mead Base and Nellis Air Force Base well fields is only moderately mineralized.

The hardness (as $CaCO_3$) of the water from well 3 is about 300 ppm, about 100 ppm higher than the hardness of the water from well 4 and from the wells supplying Nellis Air Force Base. The dissolved-solids content of water from wells 3 and 4 is about 500 ppm, or several hundreds parts per million higher than that of most of the water used at Nellis Air Force Base. The higher dissolved-solids content in the ground water of the Lake Mead Base well field probably is due partly to the slower movement of water in the vicinity of Lake Mead Base and partly to the mineralogy of the sedimentary strata. The valley fill in the vicinity of the Lake Mead Base well field probably contains a large amount of gypsum because the hills and mountains north and east of the well field from which at least part of the fill was derived contain gypsum. Ground water moving through the valley fill dissolves some of the gypsum and becomes highly mineralized.

There is no evidence that withdrawals have caused a significant deterioration of the quality of the water yielded by most of the wells of Lake Mead Base and Nellis Air Force Base. Water from Nellis Air Force Base well 1 in the SE¼SE¼NE¼ sec. 4, T. 20 S., R. 62 E., probably has been analyzed over the longest period of time. On May 5, 1941, the hardness was 220 ppm, and the dissolved-solids content was 255 ppm. On November 28, 1954, the hardness was 105 ppm, and the dissolved-solids content was 263 ppm. Other analyses between these dates likewise indicate no significant change.

Water from well 1 of Lake Mead Base, however, not only is highly mineralized, but the degree of mineralization changes with the amount of water pumped from the well. For example, the dissolved-solids content reportedly decreased from 1,310 to 861 ppm in a 1-week period in March 1952. A later analysis on November 30, 1953, after the well had been pumped for almost 6 months, showed that the dissolved-solids content had decreased only slightly, from 861 to 851 ppm, but that the hardness of the water had increased from 357 to 422 ppm.

On March 2, 1955, after well 1 had been idle for several months, a sample of water collected from it at the end of a 1-hour period of pumping at about 225 gpm had a hardness of 1,210 ppm and dissolved-solids content of almost 1,900 ppm. Even higher concentrations were noted at the beginning of the pumping period. A sample, collected 6 minutes after pumping began, had a hardness of 1,590 ppm, and; the specific conductance indicated a dissolved-solids content of more than 2,300 ppm. Measurements of the conductivity of samples collected during the period of pumping indicated that the conductivity, and hence the dissolved-solids content, decreased only slightly during the last 30 minutes of pumping. How much more the mineralization might have been reduced by continued pumping is not known, but it seems unlikely that the dissolved-solids content could have been lowered to the point where it approached that of the water from wells 3 and 4. The constituents principally responsible for increase in the dissolved-solids content are calcium, magnesium, and sulfate.

The results of chemical analyses of typical samples of water obtained during this investigation are shown in the following table.

Chemical analyses of water samples from Lake Mead Base wells, Las Vegas Valley, Clark County, Nev.

[Analyses by U.S. Geol. Survey. Chemical constituents in parts per million]

Well No	1	2	3	4
Salt Lake City laboratory No	13958	14220	13960	14219
Date of collection	3-2-55	4-21-55	3-2-55	4-19-55
Pumping period ... hours	1	19	1	30
Pumping rate ... gpm	250	140	220	130
Temperature ... °F	80	84	77	82
Silica (SiO_2)	77	81	70	40
Iron (Fe) [total]	.14	.32	.06	.1
Manganese (Mn)	.03	.04	.02	.0
Calcium (Ca)	190	106	47	41
Magnesium (Mg)	172	75	43	23
Sodium (Na)	102	86	46	90
Potassium (K)	9.5	11	4.5	8.1
Bicarbonate (HCO_3)	134	142	198	187
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	1,150	549	171	172
Chloride (Cl)	55	43	39	48
Fluoride (F)	1.8	1.9	1.3	1.5
Nitrate (NO_3)	1.6	9.9	2	1.9
Dissolved solids:				
Total ... ppm	1,810	1,030	522	518
Residue on evaporation at 180° C ... do	1,990	1,050	544	510
Hardness:				
As $CaCO_3$ ... do	1,180	573	294	197
Noncarbonate ... do	1,070	456	132	44
Specific conductance ... micromhos at 25° C	2,180	1,330	748	786
pH	7.6	7.4	7.6	7.4
Color	5	5	5	5

EXPLORATION OF WELL 1

In addition to the 1-hour pumping test on March 2, 1955, during which changes in temperature and chemical constituents of water from well 1 were observed, two other tests were made to obtain additional information as to the quality and quantity of the water yielded by different strata.

On June 30, 1955, after the well had been idle for months, the conductivity of the water in the well versus depth was determined by a conductivity apparatus lowered into the well. The survey showed an increase in the conductivity of the water to a depth of about 300 feet below the top of the casing, after which little change in conductivity was noted. (See fig. 3.) A survey by means of a deep-well current meter indicated that, if there was movement from strata below a depth of 680 feet to higher strata, such movement was too slow to be detected by the current meter. The meter probably would have detected movements as small as a gallon or two per minute, because a gasket of rubber belting attached to the meter tube presumably forced virtually all the water in the casing to pass through the 3-inch-diameter tube in which the meter was housed. The sensitivity of the meter to vertical movement was lessened considerably at depths above 600 feet, because the casing diameter changed from 10 to 14 inches at 600 feet. Nevertheless, any substantial movement in the 14-inch casing probably would have been detected.

On July 1, 1955, from 7:30 a.m. to 9:20 a.m., water from wells 3 and 4 was introduced into well 1 at a rate of about 210 gpm. At 9:10 a.m., a conductivity survey showed a rather uniform low conductivity at all depths above 1,040 feet, and indicated that all the water in the well above that point had been displaced by the mixture of water from wells 3 and 4. At 9:22 a.m., a survey was started from the bottom of the well to the top of the water. Four other surveys were made shortly thereafter. The results of all the surveys are shown in figure 3. From the surveys one can infer that water in strata at depths of 300, 350, 850, and 910 feet probably has a higher head than water in other strata, because the strata having higher heads more likely would be the first to redischarge the highly mineralized water into the wells after recharge operations were stopped. The additional downward movement shown from strata in the region of 350 feet to strata at least 450 feet deep indicates that aquifers containing water under less head are at or below that depth. One might also infer that strata below a depth of 920 feet contain water whose head is lower than the head immediately above a depth of 920 feet.

On September 9, 1955, well 1, which had been idle since the surveys in July, was started and a conductivity survey was made while the

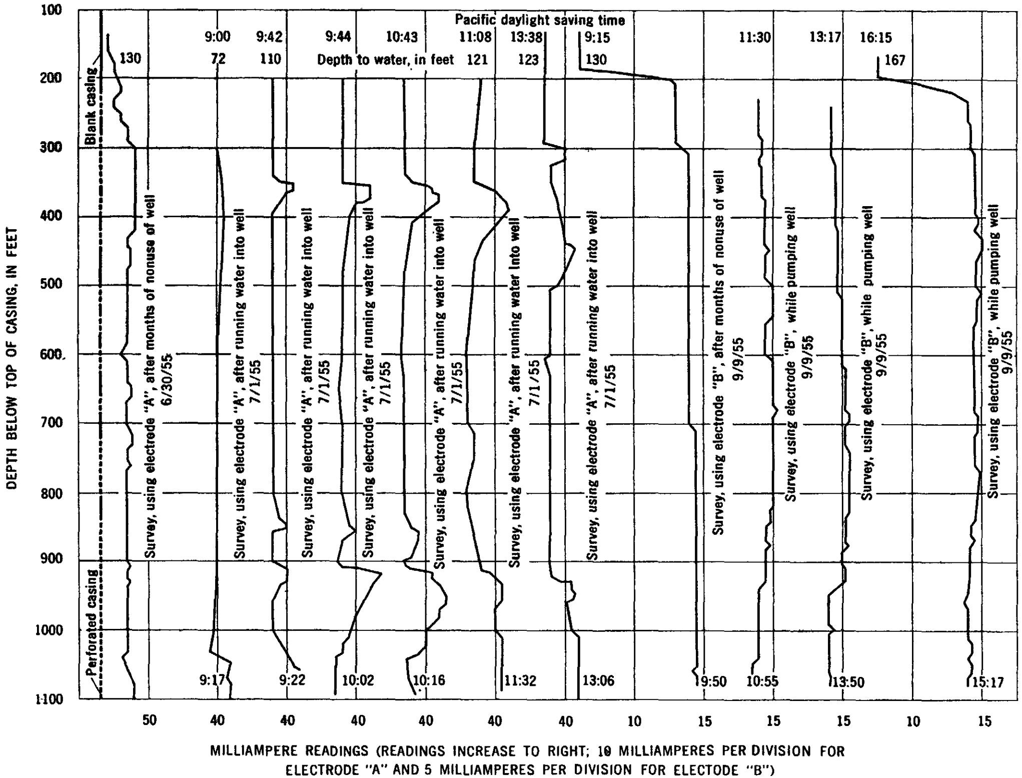

FIGURE 3.—Conductivity curves for well 1, Lake Mead Base, Las Vegas Valley, Nev.

well was being pumped. The bottom of the suction pipe was 220 feet below the top of the casing, or about 90 feet below the nonpumping level. The well was pumped at about 80 gpm from 9:57 a.m. to 12:45 p.m., then at about 150 gpm to 12:53 p.m., at which time the water level had lowered to the bottom of the suction pipe, and then at about 110 gpm until the completion of the survey at 5 p.m. At 10:15 a.m., the conductivity of the water being pumped was 3,200 micromhos at 25° C., the temperature of the water was 72° F. At 10:42 a.m., these characteristics were 3,080 and 73°, respectively; at 12:40 p.m., they were 2,990 and 77°; at 2 p.m., 2,970 and 77.5°; and at 3:17 p.m., 2,850 and 78°. The readings of the milliammeter at various depths below the top of the casing are shown in figure 3.

The data obtained on September 9, 1955, indicate that the dissolved-solids content above 200 feet was only about half the dissolved-solids content below that depth. The data indicate also that strata at about 920 feet are contributing water that is more highly mineralized than that from the lower strata. The concentration of dissolved solids does not appear to decrease significantly at any point between the depths of 500 and 920 feet, the region in which the highest concentrations occur; hence, it seems unlikely that water of satisfactory chemical quality can be obtained at reasonable rates from this section.

Although the water in the casing below 920 feet is of somewhat better chemical quality, the dissolved-solids content is not sufficiently less to offer any encouragement for obtaining a satisfactory supply from that section of the well either.

On the basis of milliampere readings, the dissolved-solids content of the best quality of water in the well is about half that of the water pumped from depths in excess of 250 feet. However, the fact that a sample of the water that was being used on the base at the time of the survey showed a reading of only about 4 milliamperes, or slightly more than half the reading obtained from the best quality of water in well 1, indicates that even this lower concentration may still be high.

The relative volumes of water from aquifers above 220 feet (the depth of the bottom of the suction pipe) and from aquifers below this depth, based on a milliampere reading of 7 for the water above 220 feet, 14 for the water below 220 feet, and 11 for the water discharged by the pump, are two-sevenths for the water above 220 feet and five-sevenths for the water below 220 feet.

As a result of the exploratory work done on well 1, it cannot be stated positively that water of satisfactory chemical quality cannot be developed at the site, though it almost certainly would be impractical to do so.

Because the chemical quality of the water deteriorates with nonuse of the well, it is inferred that one or more strata contain highly mineralized water at heads higher than the heads in strata containing water having a lower dissolved-solids content. When the well is not used, the highly mineralized water flows into the well and out again into the strata containing the water of lower mineralization under lesser head and thus contaminates these strata. When the well is pumped, the strata that received the highly mineralized water will, of course, yield the highly mineralized water back to the well before yielding the water of lower mineralization.

The length of pumping time and rate of pumping that will be necessary to cause aquifers to yield the true quality of the water they contain are dependent on the preceding length of nonpumping time and the rate of leakage under nonpumping conditions. The opportune time to determine the true chemical quality of the water in the various strata in a well in which leakage from one strata to another is taking place is immediately upon its completion.

In well 1, months of continuous pumping to waste at a rate of 100 gpm or so may be required to flush the aquifers that have been contaminated as a result of nonuse of the well. Whether this would be a justifiable procedure is questionable, because of a lack of evidence that strata penetrated by the well contain a sufficient quantity of water of satisfactory chemical quality or that they contain any satisfactory water at all.

SUMMARY

The findings of the study may be summarized as follows:

1. The principal source of the water in the Lake Mead Base well field is precipitation in the Las Vegas Valley drainage basin northwest of the well field.
2. The ground water is moving southeastward.
3. The amount of water passing through the area under natural conditions is small.
4. The principal aquifers in the well field probably dip eastward 500 feet per mile or more.
5. There is no conclusive evidence that withdrawals to date have caused a marked lowering of water levels.
6. By lowering the water levels, sufficient additional water can be diverted to the area from the main supply of Las Vegas Valley or obtained from storage to take care of the foreseeable needs of the base.

7. Wells having specific capacities in excess of a few gallons per minute per foot of drawdown are not likely to be developed in the immediate area of the base.
8. Interference effects between existing wells are too small to be measured or are insignificant under the present pumping schedules.
9. There is a good probability that all the wells are hydraulically connected; therefore, continued pumping from wells 3 and 4 at sufficiently high rates eventually may cause the more highly mineralized water in wells 1 and 2 to enter wells 3 and 4.
10. As yet, there has been no significant deterioration in the chemical quality of the water from wells 3 and 4.
11. The mineralization of the water from wells 1 and 2 increases during periods of nonuse.
12. Calcium, magnesium, and sulfate are the principal constituents of the highly mineralized water.
13. It does not appear practical to attempt to obtain a satisfactory supply of water from well 1.
14. Additional data relative to pumpage, water levels, and changes in chemical quality of the water are needed for more accurate future evaluation of the geologic and hydrologic factors that control the occurrence, movement, and chemical quality of the ground water.

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