Ground-Water Quality and Geochemistry of Las Vegas Valley, Clark County, Nevada, 1981-83: Implementation of a Monitoring Network

By Michael D. Dettinger

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CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to metric (International System) units by using the following factors:

Multiply	*By*	*To obtain*
Acres	4,047	Square meters (m^2)
Acres	0.4047	Square hectometers (hm^2)
Acre-feet (acre-ft)	1,233	Cubic meters (m^3)
Acre-feet per year (acre-ft/yr)	0.001233	Cubic hectometers per year (hm^3/yr)
Feet (ft)	0.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi^2)	2.590	Square kilometers (km^2)

For temperature, degree Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)] + 32.

ALTITUDE DATUM

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), which is derived from a general adjustment of the first-order leveling networks of both the United States and Canada.

GROUND-WATER QUALITY AND GEOCHEMISTRY OF LAS VEGAS VALLEY, CLARK COUNTY, NEVADA, 1981-83: IMPLEMENTATION OF A MONITORING NETWORK

By Michael D. Dettinger

ABSTRACT

As a result of rapid urban growth in Las Vegas Valley, rates of water use and wastewater disposal have grown rapidly during the last 25 years. Concern has developed over the potential water-quality effects of this growth. The deep percolation of wastewater and irrigation return flow (much of which originates as imported water from Lake Mead), along with severe overdraft conditions in the principal aquifers of the valley, could combine to pose a long-term threat to ground-water quality.

The quantitative investigations of ground-water quality and geochemical conditions in the valley necessary to address these concerns would include the establishment of data-collection networks on a valley-wide scale that differ substantially from existing networks. The valley-wide networks would have a uniform areal distribution of sampling sites, would sample from all major depth zones, and would entail repeated sampling from each site. With these criteria in mind, 40 wells were chosen for inclusion in a demonstration monitoring network. In developing this network, water samples were collected from 56 wells for determination of as many as 34 water-quality characteristics.

Ground water in the northern half of the valley generally contains 200 to 400 milligrams per liter of dissolved solids, and is dominated by calcium, magnesium, and bicarbonate ions, reflecting a chemical equilibrium between the ground water and the dominantly carbonate rocks in the aquifers of this area. The intermediate to deep ground water in the southern half of the valley is of poorer quality (containing 700 to 1,500 milligrams per liter of dissolved solids) and is dominated by calcium, magnesium, sulfate, and bicarbonate ions, reflecting the occurrence of other rock types including evaporite minerals among the still-dominant carbonate rocks in the aquifers of this part of the valley. The poorest quality ground water in the valley is generally in the lowland parts of the valley in the first few feet beneath the water table, where dissolved-solids concentrations range from 2,000 to more than 7,000 milligrams per liter, and probably reflects the effects of evaporite dissolution, secondary recharge, and evapotranspiration. The most common water-quality constraint on potential ground-water use is the high salinity. No evidence of large-scale contamination of deep ground water was found in this study.

INTRODUCTION

The City of Las Vegas and the other cities in Las Vegas Valley have grown severalfold in the past 25 years. This growth rate has been reflected in rapidly increasing rates of water use and wastewater disposal within the boundaries of the valley. Concern over the potential water-quality effects of urban growth in the valley has been intensified by recognition of a trend of increasing concentrations of nitrate in primary supply wells of the Las Vegas Valley Water District (LVVWD), the largest water-supply agency in the valley.[1] This trend probably is related to interactions between (1) deep percolation of wastewater and irrigation (lawn-watering) return flow to the water table in much of the valley and (2) severe overdraft conditions in the principal aquifers of the valley, which result in downward leakage of poor-quality ground water from the water table to the deeper aquifers.

The study reported herein is a step toward addressing these concerns, and was made by the U.S. Geological Survey in cooperation with the Clark County Department of Comprehensive Planning and Las Vegas Valley Water District between 1981 and 1983.

Purpose and Scope

The purpose of this study was to design and implement a network to monitor ground-water quality, consisting of a manageable number of sampling sites. This network was intended to serve as a demonstration network which, if maintained over a period of years, could provide a time series of water-quality data that could be used to detect slowly developing and large-scale water-quality problems. The network was also intended to generate geochemical data which, along with historical data, could provide a basis for quantitative investigations and evaluations of ground-water quality and geochemical conditions in the valley as a whole. Funding and laboratory capabilities constrained the network to approximately 40 to 50 sampling sites, to be sampled semiannually or annually. Constituents to be determined were largely restricted to those regularly analyzed at the LVVWD laboratory in Boulder City, Nev. This report describes the design of the network and the results obtained during its implementation in 1981-83.

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[1] The increasing nitrate concentrations were indicated by analyses of 45 water samples collected from 14 district water-supply wells (analyses made by the Las Vegas Valley Water District laboratory in Boulder City, Nev.). The samples were collected and analyzed between October 1976 and November 1980, and appear to show a quadrupling of nitrate concentrations during that period [from a median of 0.14 mg/L (milligrams per liter) as nitrogen in 1976 to a median of 0.60 mg/L in 1980]. The concentrations are low relative to drinking-water standards, but the rise suggested a need for further data collection.

The investigation described in this report was limited to the floor of Las Vegas Valley--the area in which most urban development has taken place (figure 1). Areas in the surrounding mountains, such as Kyle Canyon in the Spring Mountains, were not included. The investigation was also limited to identifying valley-scale water-quality conditions rather than attempting to locate or document more local problems. In particular, the Henderson area (with several industrial waste-disposal sites that are listed as "Uncontrolled Hazardous Waste Sites" by the U.S. Environmental Protection Agency; Van Denburgh and others, 1982, page 3) was not addressed in the network design, because it is a special problem in a relatively localized setting near the ground-water outlet of the valley. Numerous agencies are currently monitoring water quality in the Henderson area, and the massive efforts that would be required to materially add to those programs would have been outside the scope of this study.

Previous Investigations

The present investigation was built on the results of a number of valley-wide evaluations of ground-water quality in Las Vegas Valley. Early investigations such as those of Carpenter (1915), Hardman and Miller (1934), and Miller and others (1953) were concerned primarily with establishing the utility of the native ground water in the valley for irrigation and domestic use. Maxey and Jameson (1948) presented the first explanations of the variations of water quality and temperature in Las Vegas Valley. Those explanations are necessarily simplistic but, within the scope of what the authors were trying to accomplish, have withstood the test of time. Maxey and Jameson also presented a useful summary of data for samples collected prior to their study period and added analyses performed during the early 1940's. Malmberg (1965) presents historical data and data collected during the 1950's. His brief discussion of ground-water quality conditions in the valley follows closely the conclusions of Maxey and Jameson. A detailed investigation of the relation between surficial geology--in particular, the secondary mineralogy of the surficial deposits--and the quality of shallow ground water in Las Vegas Valley was made by Dinger (1977). This study shows the relation between the secondary deposits of gypsum in the lower (southeast) end of the valley and the natural degradation of water quality there. Kauffman (1978) presents a detailed description of water quality in the first 300 feet of the basin-fill material in Las Vegas Valley. Much of the work is descriptive, but the report discusses in some detail the relation between land use, water use, wastewater disposal, and ground-water quality in the valley. Weaver (1982) interpreted analyses of ground-water chemistry from 32 wells that tap the principal aquifers, and concluded that chemical variations reflect (1) mineralogic variations in the aquifer materials and (2) different sources of recharge.

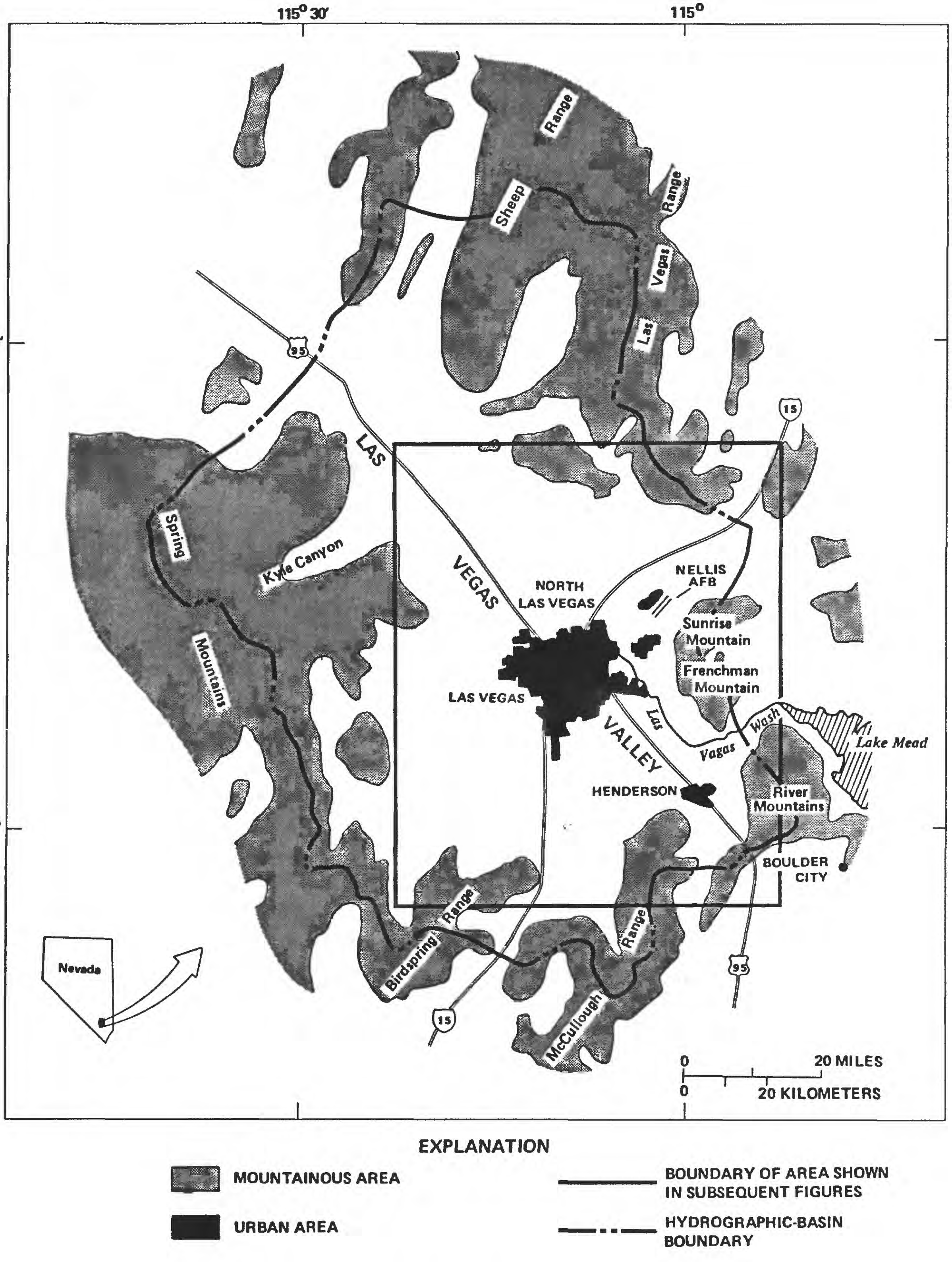


FIGURE 1.--Location and general features of Las Vegas Valley.

Many studies dealing with more local water-quality issues that have been done in Las Vegas Valley add to understanding of the valley as a whole. Most notable among these local studies are an investigation (Patt and Hess, 1976; Hess and Patt, 1977) of elevated nitrate concentrations in a part of the northwest corner of the valley, the work of Loeltz (1963) in the Lake Mead Base area in the northeast corner of the valley, and the many studies in the Henderson-Pittman area at the southeast corner of the valley. Studies in the Henderson-Pittman area for the most part have dealt either with the transport of industrial wastes in the ground water near the Henderson industrial facilities (Westphal and Nork, 1972; Geraghty & Miller, Inc., 1980) or with the control of salinity in Las Vegas Wash, which drains the ground water of this area to Lake Mead (French and Woessner, 1981; U.S. Bureau of Reclamation, 1982).

This investigation builds directly on the work reported by Van Denburgh and others (1982), which consisted of designing an "ideal" network for monitoring ground-water quality in Las Vegas Valley. One spring and 185 wells were proposed as candidate sites for inclusion in the network. Forty-five water-quality characteristics were suggested for monitoring; and suggestions were made on the most useful, efficient storage of network analytical results.

Existing Networks

Three major continuing efforts at monitoring ground-water quality were identified during this study. These networks were maintained by (1) the Desert Research Institute of the University of Nevada system in Las Vegas and the U.S. Bureau of Reclamation, (2) the Las Vegas Valley Water District, and (3) the Clark County Health District.

The monitoring programs of the Desert Research Institute and Bureau of Reclamation have been primarily project oriented. Although the wells constructed for these programs are located in all parts of the valley, most are concentrated in the southeast corner of the valley. This concentration of wells is a consequence of the continuing interest in water-quality conditions in and around Las Vegas Wash (Arthur Tuma, U.S. Bureau of Reclamation, oral communication, 1982). Concentrations of major constituents and values for standard physical properties are determined for most of the samples collected at the sites monitored by these two organizations.

Las Vegas Valley Water District has been sampling and analyzing water from the many sources and delivery points within the District and the neighboring City of North Las Vegas. This monitoring program was designed to meet the sampling requirements dictated by the U.S. Safe Drinking Water Act (U.S. Environmental Protection Agency, 1976; 1977), and in 1980 included 184 sampling sites at wells and assorted delivery points around Las Vegas, North Las Vegas, Henderson, Boulder City (outside the valley itself), and Nellis Air Force Base (Gustino, 1980). More recently, the large-scale monitoring program was altered to meet requirements of the Safe Drinking Water Act at delivery points rather than at the source wells. District wells that are in current use (1983) are sampled as part of a separate District investigation that is designed to identify any trends of increasing nitrate and dissolved solids concentrations. This program involves major-chemistry and physical-property determinations, and the wells sampled are, as a rule, those that have been pumped in the normal course of supply-system operation (David Rexing, Southern Nevada Water System, oral communications, 1983).

Nevada State law requires that water taken from newly constructed wells in Las Vegas Valley be analyzed to determine if it meets U.S. Public Health Service water-quality standards. The samples are delivered to the Nevada Health Division laboratory, and chemical determinations are made of principal constituents, selected physical properties (for example, color and turbidity), and nitrate, fluoride, arsenic, iron, and manganese. Samples are collected only once at most sites and, when a second sample is collected, it is usually analyzed only for a particular constituent that is believed to be present at concentrations that exceed health standards.

The network demonstrated in this study is designed to have three characteristics that are not all contained in any one of the above networks. These characteristics are:

- Uniform areal distribution of sampling sites.
- Sampling of all of the major aquifer depth zones.
- Repeated sampling at all network sites to allow identification of temporal trends.

Acknowledgments

Appreciation is extended to local residents and businesses for permitting access to and pumping of their wells for sampling required during this study. The Las Vegas Valley Water District, City of North Las Vegas, Nellis Air Force Base, Desert Research Institute, and Clark County Department of Recreation also provided access to and information concerning the construction of their wells that are included in the network. Laboratory analyses for major ions, filterable residue, and selected trace elements were performed by the Las Vegas Valley Water District laboratory in Boulder City, Nev. Other laboratory analyses were performed by the Geological Survey Central Laboratory, Lakewood, Colo.

Location System for Wells

In all tables, figures, and text of this report, wells are identified by site numbers as defined in table 1. The wells are further identified in tables 1 and 2 in terms of local well numbers and U.S. Geological Survey site ID numbers.

The local well numbers in tables 1 and 2 are based on the rectangular subdivision of public lands, referenced to the Mount Diablo base line and meridian. A complete designation of a well location consists of: (1) the township number south of the base line; (2) the range number east of the meridian; (3) the section number; (4) letters designating the quarter section, quarter-quarter section, and so on (the letters "A," "B," "C," and "D" indicate northeast, northwest, southwest, and southeast quarters, respectively); and (5) a sequence number that distinguishes between wells that lie in the same tract within the section. For example, well S21 E60 11ADB1 is the first recorded in the NW¼SE¼NE¼ of section 11, T. 21 S., R. 60 E. (Township and range numbers are shown along the margins of maps within this report.)

The Geological Survey site-identification (ID) numbers in tables 1 and 2 are based on the grid system of latitude and longitude, and indicate the geographic location of each site. The ID consists of 15 digits: The first 6 digits denote the degrees, minutes, and seconds of latitude; the next 7 digits denote the degrees, minutes, and seconds of longitude; and the final 2 digits are sequence numbers that distinguish among wells within a 1-second tract. The sequence number assures that the site ID is unique for each site.

GENERAL FEATURES OF THE STUDY AREA

Major features of the geology, hydrology, and water chemistry of Las Vegas Valley that significantly affect the design of a water-quality monitoring network are described in the following sections. More detailed information is given by Malmberg (1965) and Maxey and Jameson (1948).

Location and Physiography

The Las Vegas Valley hydrologic basin comprises 1,564 mi^2 of Clark County in southeastern Nevada. Figure 1 shows the locations and configurations of the principal features of the area that are related to this study. A metropolitan area, including the cities of Las Vegas and North Las Vegas, lies in the center of the valley. The area is bordered on the west by the Spring Mountains, rising to altitudes of just under 12,000 feet above sea level; on the north by the Sheep and Las Vegas Ranges, rising to more than 8,000 feet; on the east by Frenchman and Sunrise Mountains, rising to less than 4,000 feet; and to the south by the McCullough Range and River Mountains, also rising to less than 4,000 feet. The altitude of the valley floor ranges from 2,400 feet in the west to 1,600 feet in the southeast corner at Las Vegas Wash; the center and most heavily populated part of the valley is about 2,000 feet above sea level. Las Vegas Wash carries surface and ground water from the valley to Lake Mead on the Colorado River.

Geologic Setting

Large coalescing alluvial fans have formed at the base of the mountains and descend to the valley floor over distances of up to 10 miles. The mineralogic composition of these fans depends on the mountains from which they derived. The Spring Mountains and Sheep and Las Vegas Ranges are composed primarily of Paleozoic and Mesozoic carbonate and clastic rocks (Plume, 1984, pages 6-7); hence, the massive fan deposits on the west and north sides of the valley comprise predominantly cemented and uncemented calcareous clasts (Dinger, 1977, pages 134-136). The Frenchman and Sunrise Mountain area east of Las Vegas is underlain by a mix of Paleozoic carbonate rock and Miocene deposits comprising interbedded limestones, gypsum beds, sandstones, and lava flows (Plume, 1984, page 7). Consequently, the smaller fan deposits on the east side of the valley consist predominantly of calcareous and gypsiferous clasts (Dinger, 1977, pages 145-148). The McCullough Range and River Mountains are composed of volcanic rocks of late Tertiary age (Plume, 1984, page 7). The small fan deposits at the south end of the valley are dominated by volcanic clasts (Dinger, 1977, page 137).

The distal ends of the fans merge smoothly into the basin lowlands, which are underlain primarily by heterogeneous Quaternary deposits ranging in thickness from 0 to 1,000 feet. Underlying the alluvial-fan and basin-lowland deposits are older (Pliocene and Miocene) basin-fill deposits, including the calcareous and gypsiferous Muddy Creek Formation, which toward the center of the valley is from 3,000 to 4,000 feet thick. The basin-fill deposits are generally present as interbedded and interfingering sequences of gravel, sand, silt, and clay of complex and variable structure (Plume, 1984, pages 7-10).

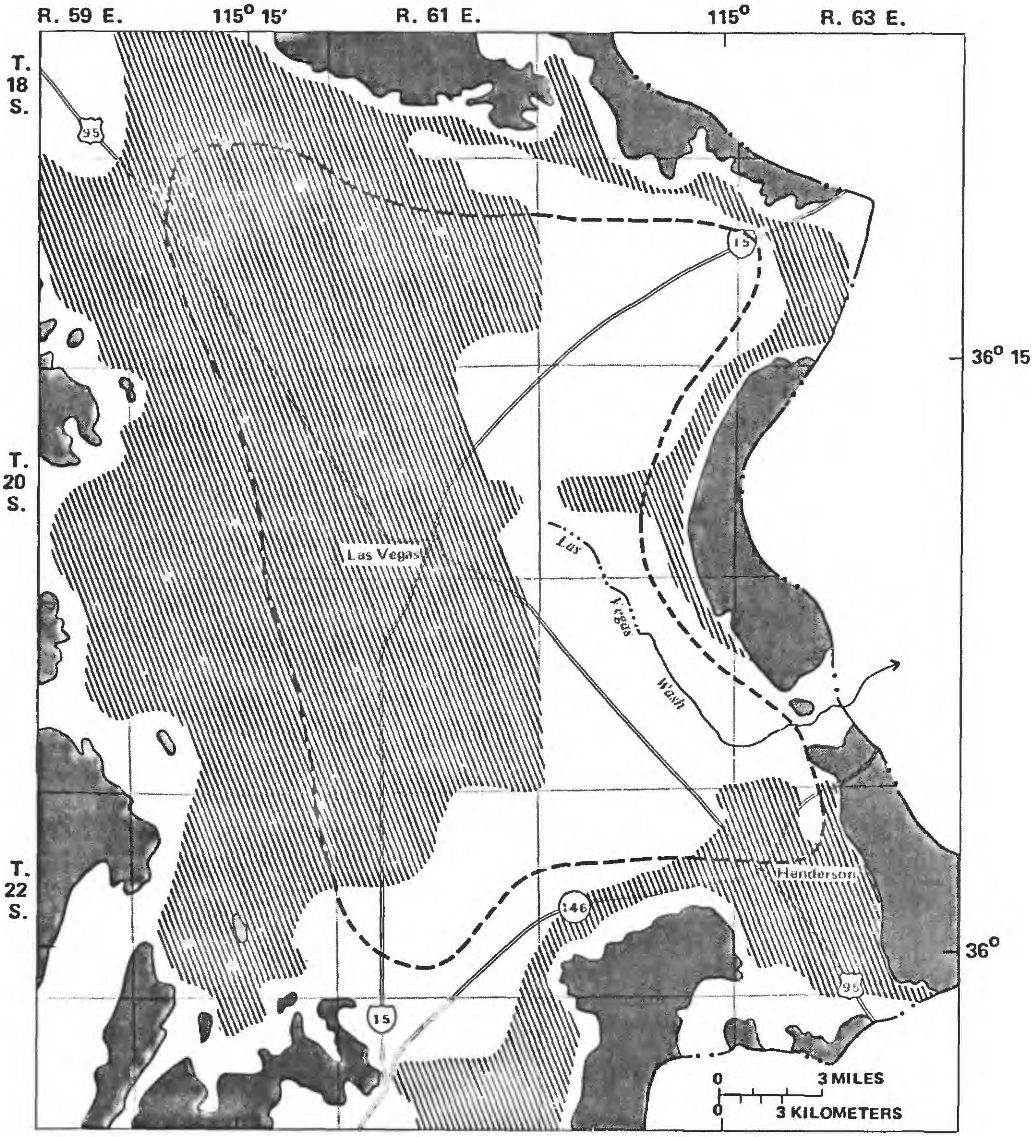
The basin-fill deposits in the northern and central parts of the valley are composed primarily of carbonate materials, whereas the southern and eastern basin-fill deposits contain carbonate materials, gypsum, and igneous rocks (Maxey and Jameson, 1948, page 110).

Geohydrologic Setting

The ground-water system of Las Vegas Valley has been described as an alluvial reservoir, as much as 5,000 feet thick, contained within a basin formed by surrounding and underlying consolidated rocks (Plume, 1984, page 22). The hydrogeology of the valley has been discussed in terms of four units: (1) a shallow zone that consists of the water table and the first 30 feet of saturated deposits; (2) a "near-surface reservoir" (Malmberg, 1965, page 24) that is composed of as much as approximately 200 feet of fine-grained deposits; (3) the principal aquifers that are composed of thick beds of coarse- and intermediate-grained deposits, to a depth greater than 1,000 feet below land surface; and (4) the untapped deep zone of basin-fill sediments that is below most of the deepest production wells (Harrill, 1976, pages 9-11). (See schematic hydrogeologic section in figure 2.) The water-bearing basin-fill deposits are most permeable and productive on the west side of the valley and are relatively impermeable in the central and eastern portions of the valley. The mostly fine grained near-surface reservoir does not extend beneath the entire basin-fill reservoir, but it does extend beneath most of the valley floor. Figure 2 shows the boundaries of this reservoir and the general area of downward vertical hydraulic gradients in 1980. Ground water in this reservoir occurs under both confined and unconfined conditions; the condition depends on the presence or absence of caliche and other local confining beds (Malmberg, 1965, page 65). Where the ground water is unconfined, the water table tends to parallel the land surface. Over most of its extent, the reservoir acts as a semiconfining layer for the principal aquifers. At the margins of the near-surface reservoir, horizons of caliche also can act as local confining layers (Harrill, 1976, page 47). Outside these margins, near the edges of the basin fill, the principal aquifers are virtually unconfined.

One of the characteristics of these hydrogeologic units is that they vary in depth, thickness, and hydrologic impact throughout the valley. Thus, a single meaningful range of depths that correspond to these units over the study area cannot be defined. Differentiation between the units at any particular site is difficult. For these reasons, Van Denburgh and others (1982, page 7) defined the following arbitrary depth zones for discussions of monitoring wells in Las Vegas Valley: a shallow zone (less than 30 feet below the static water table), an intermediate zone (from 30 to 200 feet below the water table), and a deep zone (more than 200 feet below the water table). The shallow zone corresponds to the zone from 0 to 30 feet below the water table. The intermediate zone generally corresponds to the near-surface reservoir. The deep zone generally corresponds to the principal aquifers. Both of these sets of depth-zone designations are used in this report; the geohydrologic units are used in discussion of general geohydrologic conditions, whereas the depth zones for monitoring wells are used in discussions of particular wells and of specific results of this study.

Natural ground-water recharge to the principal aquifers is primarily by runoff from snowmelt and precipitation in the northern part of the Spring Mountains (figure 1). Precipitation in the other mountains bordering the valley contributes lesser volumes of recharge, and precipitation on the lowland parts of the valley probably contributes negligible amounts (Malmberg, 1965, pages 37-38). Under natural conditions, between 25,000 and 35,000 acre-ft/yr were recharged to the aquifers (Harrill, 1976, page 50). The near-surface reservoir was recharged primarily by upward leakage from the principal aquifers and by infiltration of flow from artesian springs (and later from artesian wells) associated with the principal aquifers (Malmberg, 1965, page 68).



EXPLANATION

☐ BASIN FILL

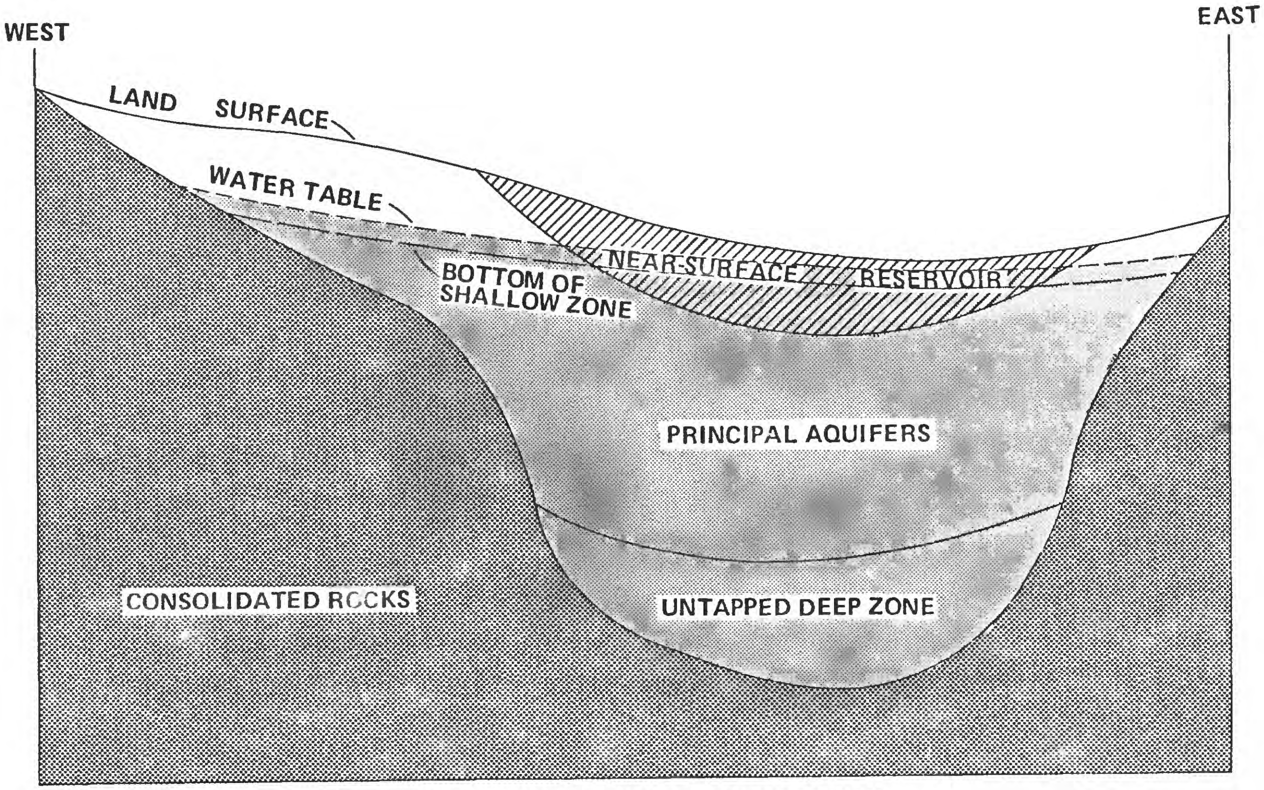
■ CONSOLIDATED ROCKS

—··— BASIN BOUNDARY

▨ AREA WHERE DIRECTION OF VERTICAL HYDRAULIC GRADIENT WAS DOWNWARD FROM THE WATER TABLE IN 1980— Number based on the available data in central part of valley and on figure 1 of Van Denburgh and others (1982)

— — — APPROXIMATE BOUNDARY OF NEAR-SURFACE RESERVOIR—From Harrill, 1976, figure 4

FIGURE 2.--Hydrogeologic setting.



SCHEMATIC HYDROGEOLOGIC SECTION
Vertical scale greatly exaggerated

FIGURE 2.--Continued.

Under natural conditions, ground water in the principal aquifers moved down the valley from the recharge areas in the northwest quadrant of the valley toward the east-central part, where natural discharge dominated in the basin lowlands. Ground water in the principal aquifers was under sufficient pressure to leak upward into the near-surface reservoir and then discharge through transpiration or evaporation from the water table or near springs and seeps. A small part of the ground water that flows through the system is believed to leak through the consolidated rock under Frenchman Mountain in the northeast corner of the valley (Harrill, 1976, page 50). Under natural conditions, Las Vegas Wash was dry except during periods of floods (Malmberg, 1965, page 80).

Geochemical Setting

The natural geochemistry of the ground water of Las Vegas Valley is not unlike that of many valleys in Nevada in the ways that it reflects the influence of the geology and hydrology of the valley. The mineralogy of the sediments through which ground water has flowed plays a significant role in the chemical composition of that water. Other external factors that determine the chemical composition of ground water are the amount of recharge feeding the flow, the length of the flowpath along which the water has passed, and the extent to which evaporative losses have concentrated the constituents in the water. Mineral equilibria place limits on the aqueous chemistry that, in part, determine the concentrations of key constituents in the ground water.

The result in Las Vegas Valley is that the large quantities of ground water flowing down the valley from the northwest toward discharge areas in the eastern and southeastern parts reflect the chemistry and hydrology of the northern Spring Mountains and Sheep Range. The quality of the water is good, having low concentrations of most ions except bicarbonate. This is due primarily to the scarcity of easily dissolved minerals in the high-altitude areas of the recharge area (Malmberg, 1965, page 100). The bicarbonate, along with calcium and magnesium, reflect a moderate supersaturation with respect to minerals of the predominantly carbonate rocks and sediments in the mountains and the northwestern alluvial parts of Las Vegas Valley (Weaver, 1982, page 76).

Ground water in the southern and eastern parts of the basin-fill reservoir, on the other hand, moves through consolidated rocks and basin-fill sediments that comprise a more varied mix of lithologies and mineralogies, including volcanic rocks and gypsum, as well as other evaporites. The ground water there has dissolved significant quantities of gypsum and other evaporites from the mountain blocks and basin fill. As a result, salinities are significantly higher and the overall chemistry of the ground water is different from that in the northern half of the valley, as a result of the conflicting influences of (1) carbonate equilibria, which control the major cations--calcium and magnesium--and bicarbonate, and (2) the persistent input of chloride, sulfate, calcium, and magnesium that results from the dissolution of evaporite minerals (Malmberg, 1965, page 101). Recharge from the predominantly volcanic McCullough Range south of the valley floor may serve to dilute ground water as it flows east toward Las Vegas Wash (Weaver, 1982, page 117).

A more dramatic chemical change occurs in the water-table zone in response to evaporation and transpiration in the lowest parts of the valley. These processes increase the concentration of most of the constituents in the ground water by removing dilute water and leaving the dissolved solids behind. Unless a constituent is involved in a chemical-equilibrium reaction that requires it to precipitate from the ground-water solution in response to this concentrating process, its concentration in the ground water rises dramatically. The constituents that have precipitated from the solution because of evaporative processes during one season may be redissolved during another season when less concentrated water flows through the precipitate. Thus, the quality of ground water from the water-table zone is generally poor, with salinities that are almost always higher than those in the underlying aquifers (Kaufman, 1978, page 2; Dinger, 1977, page 125).

Human Effect on the Hydrologic System

The history of population and water demands in Las Vegas Valley has been one of large scale and, at times, rapid growth. The first permanent non-native settlers in Las Vegas Valley were Mormon missionaries who built a fort in the valley in 1855, after which ranching gradually took hold (Patt, 1978, page 8). By 1912, many wells had been constructed in the valley to supplement artesian springs as a source of water for domestic and irrigation uses. The rate of ground-water withdrawals remained at about the same level (about 28,500 acre-ft/yr; Maxey and Jameson, 1948, pages 85 and 96) until 1941, when population and ground-water pumpage rates began to increase rapidly. By 1955, water use had increased to 57,000 acre-ft/yr. Between 1942, when water was first imported to the valley from Lake Mead, and 1955, the use of lake water was limited to the Henderson area, and the additional valley-wide demand was met by ground-water pumpage. In 1955, LVVWD began to purchase limited amounts of lake water from the Henderson industrial complex, for public use. Large imports from Lake Mead to the LVVWD distribution system were not practical until 1971, when the first phase of the Southern Nevada Water Project became operational. Since that time, imports of lake water have been able to compensate for growing water demands, and ground-water pumpage has remained at about 70,000 acre-ft/yr (Wood, 1979, page 22; URS Company and Converse Ward Davis Dixon, 1982, page 44; David S. Morgan, U.S. Geological Survey, oral communication, 1983), of which more than 5,000 acre-ft/yr is derived from the near-surface reservoir (Harrill, 1976, page 22). Lake Mead became the dominant source of water for the valley in 1975 (Wood, 1979, pages 23-32). Imports from the lake totaled 130,000 acre-ft in 1982 (David S. Morgan, U.S. Geological Survey, oral communication, 1983).

Harrill (1976, pages 23-43) delineated the primary hydrologic effects of water-resources development in the valley as: (1) Long-term declines in water levels (more than 200 feet in some places) in wells open to the principal aquifers in much of the valley, as a result of the long-term overdraft of these aquifers; (2) irreversible land subsidence of as much as 2 feet (locally) near the major pumping centers in the central part of the valley, owing to the same overdraft conditions and the consequent draining and compaction of fine-grained sediments at depth; (3) cessation of flow at the major springs in the central part of the valley, as a result of lowered potentiometric heads in the principal aquifers; (4) rising water table in much of the southeastern quadrant of the valley due to increased secondary recharge in heavily populated areas and the long-term lack of ground-water pumpage from this area; (5) perennial surface-water outflow from the valley through Las Vegas Wash (more than 80,000 acre-ft/yr by 1978), resulting from rising water levels in the southeastern quadrant of the valley and disposal of wastewater treatment plant effluents and industrial wasteflows to the wash; and (6) development of large-scale cones of depression of potentiometric heads in the principal aquifers around the major pumping centers in the valley. These cones of depression are deep enough that patterns of ground-water flow in the valley have been disrupted and a ground-water divide has developed beneath the central part of the valley. As a result, the horizontal hydraulic gradients that drive ground-water flow in the principal aquifers have been reversed along a line that extends roughly north and south through the center of the valley. In parts of the valley between this divide and the major pumping centers, where ground water under natural conditions flowed east and southeast toward natural discharge areas, the ground water now flows west toward the pumping centers. Upward hydraulic gradients, which forced ground water from the principal aquifers into the shallower zones under natural conditions, have also been reversed in areas of large drawdown.

Human Effect on Ground-Water Quality

The large-scale hydrologic impact of population growth--including the consequent increases in water use, importation of Lake Mead water, and wastewater disposal--may eventually have significant effects on ground-water quality in the valley.

The most common land uses in Las Vegas Valley are residential housing (the predominant use), resorts and commercial establishments, industry, public facilities, and several airports (URS Company and Converse Ward Davis Dixon, 1982, page 142). Agricultural uses constitute only a minor part of the total (Patt, 1978, pages 16-17). The generalized distribution of these land uses is shown in figure 3. The activities represented not only require water, but also generate wastewater that must be disposed of. The disposal of these wastes may be affecting the quality of ground water in the valley.

Pertinent aspects of the patterns of water use and wastewater disposal are shown in figure 4. The sources of the water used to support the various land uses are largely dependent on the location of the land and the volumes of water required. Lake Mead water is currently distributed for residential and commercial uses over most of the valley floor and has long been distributed for use in the southeast part of the valley (Roger Freeman, Las Vegas Valley Water District, oral communication, 1983). Water to serve the various residential and commercial uses is obtained primarily from water systems of the Las Vegas Valley Water District, the City of North Las Vegas, and the City of Henderson. The water supplied by both the Las Vegas Valley Water District and the City of North Las Vegas comprised about 60 percent lake water and 40 percent ground water from the principal aquifers in 1979 (URS Company and Converse Ward Davis Dixon, 1982, page 51). Residential and large industrial uses in the Henderson area rely wholly on lake water. Outside (and in some places, inside) the boundaries of the major purveyors (figure 4), water for domestic, industrial, and commercial uses is drawn from both "permit" and "nonpermit" wells. All wells in Las Vegas Valley except those producing water solely for domestic use are "permitted" wells that require a permit from the State Engineer before drilling or use (URS company and Converse Ward Davis Dixon, 1982, pages 79-80). Permit wells generally produce large volumes of water (greater than 1,800 gal/d), and most often tap the deep, productive principal aquifers. The nonpermit wells serve only domestic uses and relatively small volumes of near-surface reservoirs.

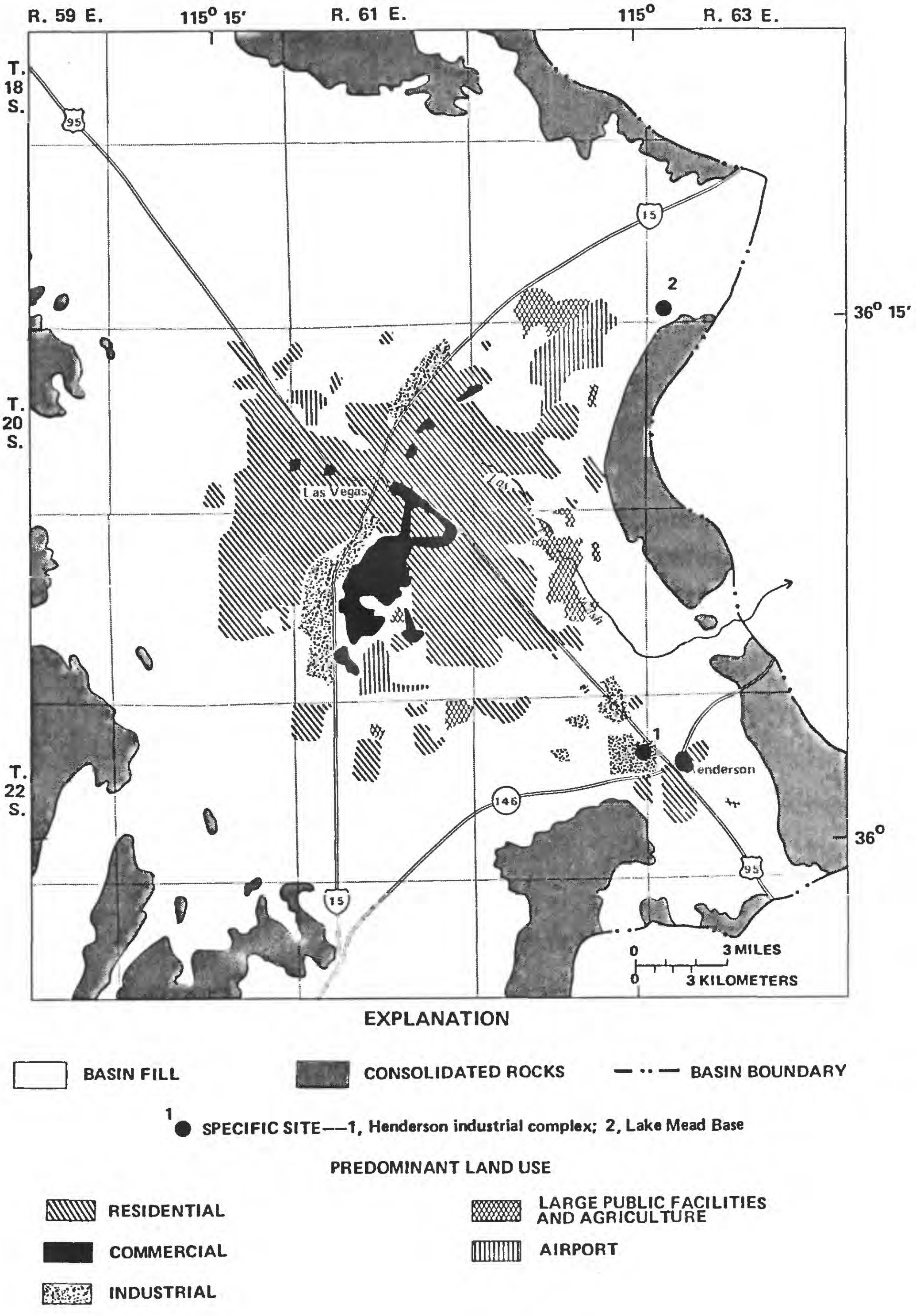


FIGURE 3.--Generalized land use, 1980 (modified from map by Clark County Department of Comprehensive Planning).

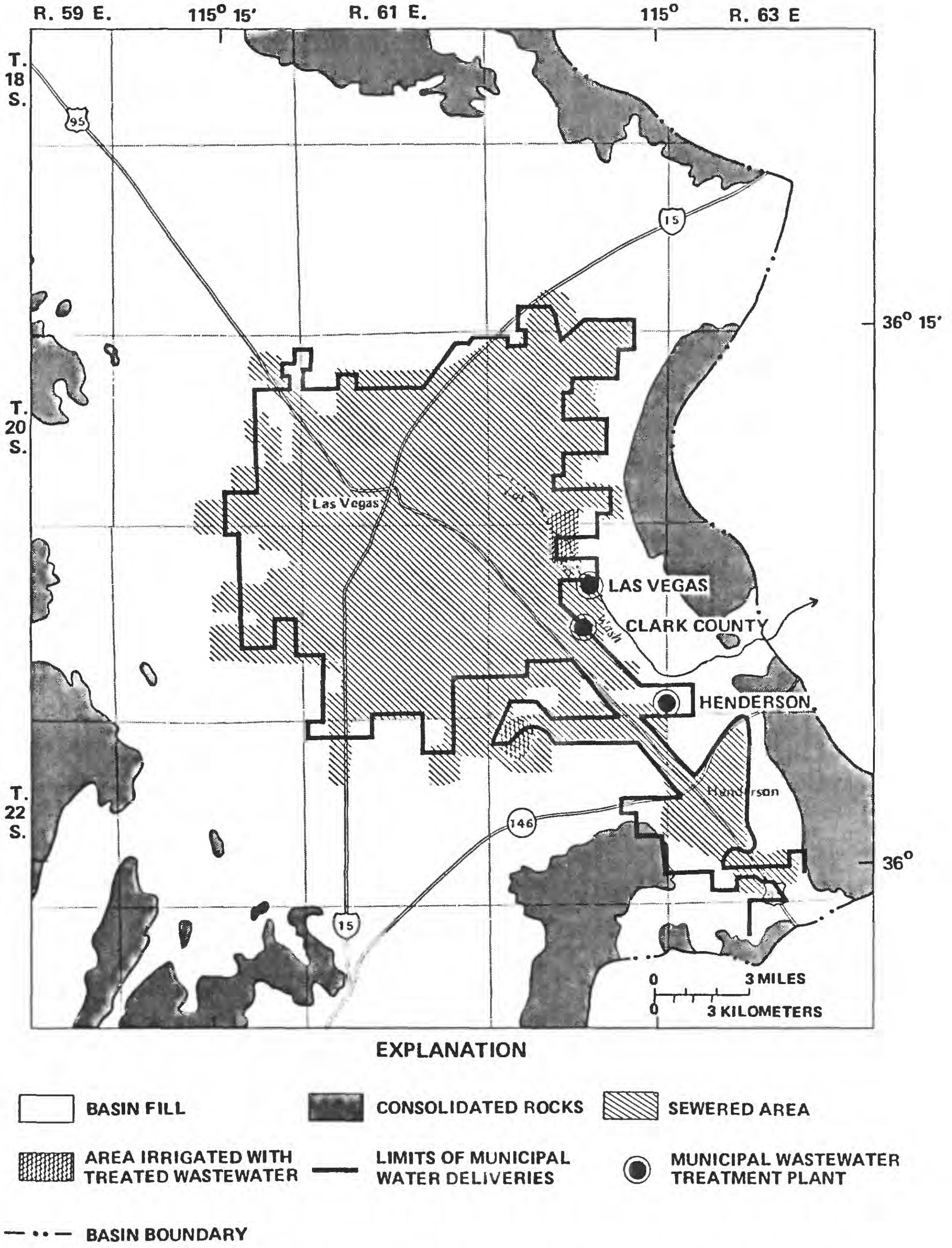


FIGURE 4.--Areas of municipal water deliveries, areas of wastewater reuse, extent of sewered areas, and location of municipal wastewater treatment plants, 1979. Information from URS Company and Converse Ward Davis Dixon (1983, table 32 and figure 15) and Clark County Department of Comprehensive Planning (1979, figure 2).

The types and ultimate dispositions of wastewater generated by the various land uses depend on the land-use type and location. Lawn irrigation in residential areas is generally inefficient and results in large amounts of secondary recharge to the water table and near-surface reservoir. Patt (1978, pages 17-22) found that residential lawn waterers were applying an average of about 13 ft/yr of water to their lawns, of which approximately 8 ft/yr percolated as recharge to the shallow ground water. Major irrigators, such as golf courses, are generally more efficient water users (Patt, 1978, pages 21-22) and these irrigators contribute relatively small rates of secondary recharge to the shallow ground water. The effect of secondary recharge from lawn irrigation on the quality of the shallow ground water may be to degrade the natural quality; this effect has not as yet been adequately quantified, however.

Water from indoor residential and commercial uses in most of the valley is sewered to the City of Las Vegas Sewage Treatment Plant, the Clark County Sanitation District Plant, or the City of Henderson Sewage Treatment Plant (figure 4). Most of the wastewater from small industries and some of the wastewater from the Henderson industrial facilities also is sewered to these plants. The wastewater treatment plants are on the east side of the valley, near Las Vegas Wash. About 7,900 acre-ft/yr of the effluent from two of the plants is recycled for use in irrigating several farms and golf courses and for use at two power plants near Las Vegas Wash (URS Company and Converse Ward Davis Dixon, 1982, page 73). The local effect of irrigation with recycled water on the underlying ground water is not known. The remainder of the effluent is discharged to Las Vegas Wash or to percolation ponds near the wash. A sewage treatment plant for Nellis Air Force Base disposed of the effluent to ponds northeast of upper Las Vegas Wash until 1971 (Patt, 1978, page 9), when the Clark County system assimilated the local sewer system. Some evidence of leachate from these ponds may be present in the high nitrate concentrations in water from one of the wells sampled in the present study (well 21 in table 1 and in figure 5).

Outside the boundaries of the sanitation districts (see figure 4), septic-tank leach fields are used to dispose of wastewater from indoor residential and commercial uses. The primary areas where septic-tank effluent may be entering the shallow ground-water system in significant quantities are along the western and northern margins of the valley floor. The overall ground-water system is particularly susceptible to the influence of secondary recharge at the western margin of the valley where the principal aquifers are unconfined and downward leakage of contaminants from the land surface to the principal aquifers is not impeded by aquitards of the near-surface reservoir. Certain areas within the sewer-system boundaries, such as in section 25, T. 21 S., R 61 E., were once unsewered (Patt, 1978, page 24) and may have contributed wastewater to the water table.

The concentration of dissolved solids in ground water at the water table within the near-surface reservoir in the lower parts of the valley was already high (roughly 3,000 mg/L) under natural conditions and, as a result of development in the valley, the quality may be (or may have been) affected by the large volumes of secondary recharge percolating to the water table. This secondary-recharge water generally has been degraded significantly by the water use from which it is draining and can contribute additional dissolved solids to the shallow ground water. Secondary recharge and rising water tables inundate previously unsaturated soils and sediments which may contain significant amounts of soluble minerals in the form of efflorescent crusts, evaporite deposits, and evaporite clasts. Dissolution of these minerals into the shallowest water can further degrade the quality of ground-water.

The better quality water in the principal aquifers also may be threatened by current hydrologic conditions. The reversal of vertical hydraulic gradients between the near-surface reservoir and the principal aquifers, resulting from the declining water levels in the principal aquifers and rising water levels in the shallow zones, is inducing downward leakage of water from shallow parts of the basin fill into the deeper parts. Because the quality of the shallow ground water is commonly poorer than that of the deeper water, the quality may be degraded at depth. The principal aquifers are most susceptible to degradation by mixing with shallow water around the margins of the valley where no confined layers impede downward movement and mixing. A lesser effect on the deeper, more productive zones might be the local release of poor quality water from compacting fine-grained sediments during the process of land subsidence (Alan H. Welch, U.S. Geological Survey, oral communication, 1983). This degradation would be most apparent in the concentrations of trace elements.

At the industrial complex in Henderson, wastewater historically has been disposed of in unlined ponds and ditches, in lined ponds, and directly into Las Vegas Wash. This practice made the complex the single largest source of secondary recharge in the valley for many years (Patt, 1978, pages 32-38). However, the practice has been discontinued in recent years. The practice, prior to being discontinued, contributed to the contamination of shallow ground water between the complex and Las Vegas Wash by industrial wastes such as organic compounds, heavy metals, and brines (Westphal and Nork, 1972; Geraghty and Miller, Inc., 1980). Other than this local problem area, no large-scale or major sources of ground-water contamination by industrial activities have been identified in the valley.

NETWORK FOR MONITORING GROUND-WATER QUALITY

A network of 40 wells open to various depth zones in various parts of the valley was designed for monitoring ground-water quality. In the course of designing this network, ground water from 56 wells were sampled. As many as 34 water-quality characteristics were determined for water from these sites. The network was designed within constraints on the number of samples that could be analyzed at the two laboratories employed, the variety of analyses that could be performed at the laboratories, and the number of sites that could be visited and sampled in a reasonable length of time. The network that was designed and the sites sampled are described in this section.

Site Selection

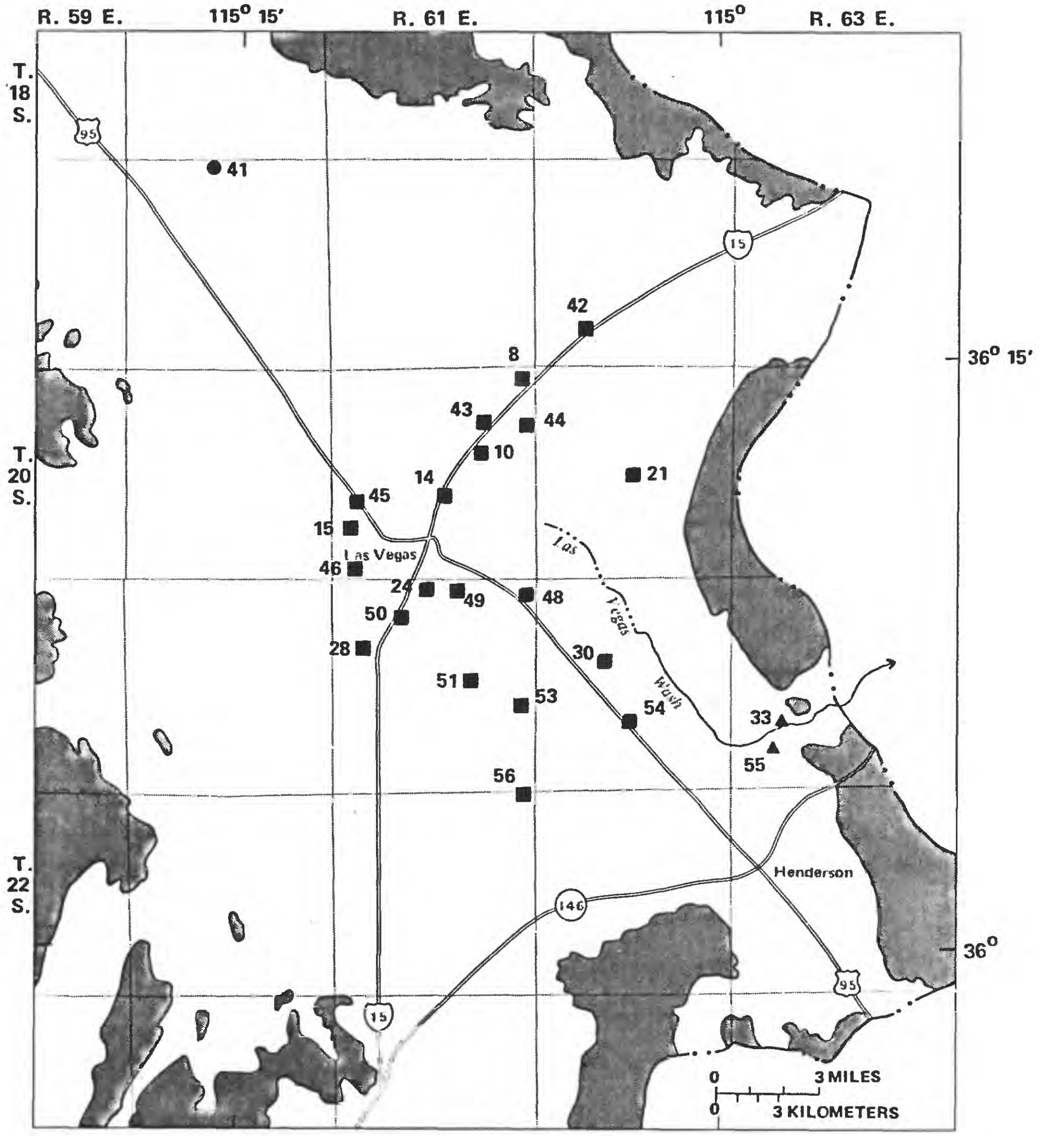
Of the 56 wells sampled as part of this project and the 40 wells chosen for inclusion in the final version of the network, most were chosen from among the 185 candidate wells proposed by Van Denburgh and others (1982, table 4). Some wells drilled by the U.S. Geological Survey as part of other, more recent studies in Las Vegas Valley were used in this network. A few additional wells were chosen to complete the network where candidate wells in certain areas were inaccessible or not suitable for this study.

For an initial sampling run, wells were chosen (1) on the basis of location and (2) in an effort to detail the water quality of ground water in the shallow zones immediately beneath the water table. This initial sampling run, made in October 1981, included 20 wells constructed by the U.S. Geological Survey which were designed to tap the water-table zone. Also during that run, three deeper wells were sampled. The locations of the wells sampled during this preliminary effort are shown in figure 5.

Sampling runs to develop experience and information for the design of a more complete water-quality network were made in May 1982 (locations in figure 6), and August 1982 (locations in figure 7). A final well, site 39 in table 1 and figure 8, was sampled in May 1983 to complete the 40-well network (existing network wells were not resampled at that time). The wells sampled and especially those included in the network were chosen to meet several criteria:

(1) Sites were chosen to give the best possible areal coverage and the best selection of the six combinations of depth zones shown in figures 6 and 7 and discussed earlier. Some of these sites represent the chemistry of specific depth zones, whereas others are representative of the quality of a mixture of waters from several depth zones in a given area. Wells that tap several depth zones can yield some useful geochemical data, but are most helpful in early identification of large-scale water-quality problems.

(2) Sites had to be accessible to meaningful sampling. This criterion restricted the network to wells that can be purged sufficiently in a practical length of time and to wells that are so configured that samples could be drawn from the well that are truly representative of the waters within the desired aquifer (or aquifers) at the chosen site.



EXPLANATION

☐ BASIN FILL

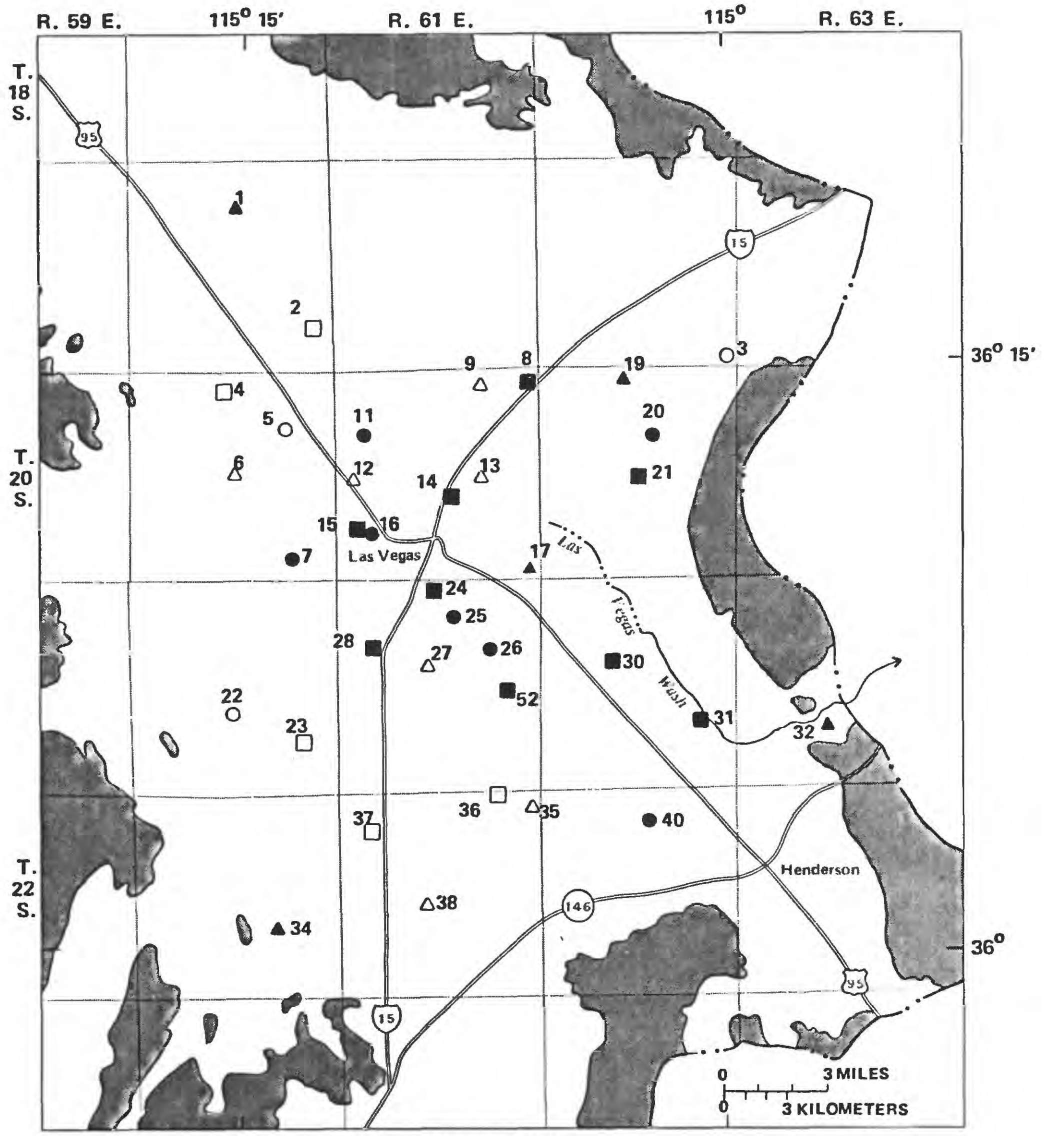
▨ CONSOLIDATED ROCKS

—··— BASIN BOUNDARY

DEPTH ZONES TAPPED BY SAMPLED WELLS (Site numbers in tables 1 and 2 are indicated)

21 ■ SHALLOW ZONE
55 ▲ INTERMEDIATE ZONE
41 ● DEEP ZONE

FIGURE 5.--*Wells sampled in October 1981.*



EXPLANATION

☐ BASIN FILL

▨ CONSOLIDATED ROCKS

—··— BASIN BOUNDARY

DEPTH ZONES TAPPED BY SAMPLED WELLS (Site numbers in tables 1 and 2 are indicated.)

8 ■ SHALLOW ZONE
4 □ SHALLOW AND INTERMEDIATE ZONES
1 ▲ INTERMEDIATE ZONE
38 △ INTERMEDIATE AND DEEP ZONES
7 ● DEEP ZONE
22 ○ ALL THREE ZONES

FIGURE 6.--Wells sampled in May 1982.

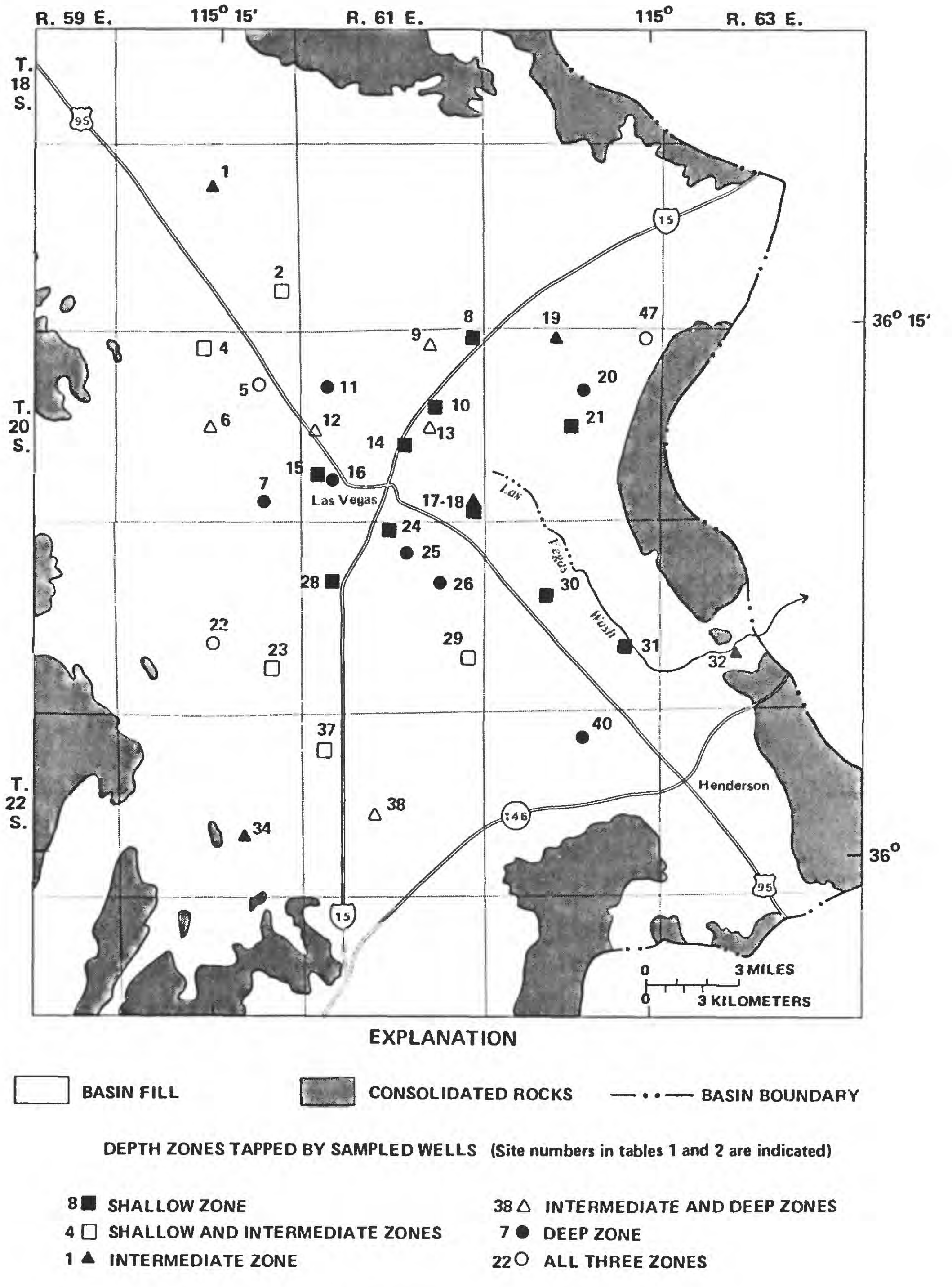


FIGURE 7.--Wells sampled in August 1982.

This criterion disqualified many municipal, industrial, and domestic wells that had no outlets or spigots between the well head and large storage tanks or chlorination facilities. Many unused wells and observation wells without pumps were disqualified because the large volumes of water that would need to be pumped from deep, large-diameter wells to properly purge old water made sampling impractical; others were disqualified because openings to the well casings were not large enough or were too inaccessible to allow the use of a pump or bailer. Of the 185 candidate wells listed by Van Denburgh and others (1982), 7 wells were outside the present study area, 61 were not practically accessible, and 66 wells were readily accessible; without extensive field inventories, the remaining 51 wells could not be judged in this respect.

(3) In selecting the sampling sites (particularly the shallow wells) attention was paid to nearby land uses that might influence water-quality conditions in the area. Attempts were made to select shallow wells up- and down-gradient from potential contaminant sources such as unsewered residential, golf course, and industrial areas. The industrial complex in Henderson was specifically excluded from consideration in the present network.

(4) Where practical without overemphasizing this criterion, pairs of wells of different depths in close geographic proximity were chosen for sampling. Over the long term, such pairs should help to delineate the geochemical and hydraulic continuity between the shallow ground water, which is most readily influenced by contamination, and the deeper ground water, upon which the municipalities depend.

The network in its final form included 40 wells, all of which were sampled at least once and most of which were sampled twice. The locations of the wells included in the final network as of May 1983 are shown in figure 8.

The following aquifer-depth zones were defined by Van Denburgh and others (1982, page 7): shallow zone (less than 30 feet below the water table), intermediate zone (from 30 to 200 feet below the water table), and deep zone (more than 200 feet below the water table). The 40 wells included in the final form of the network belong to the following combination of depth zones:

Producing interval	Number of wells
Shallow zone only	10
Shallow and intermediate zones	6
Intermediate zone only	6
Intermediate and deep zones	7
Deep zone only	8
All three zones	3

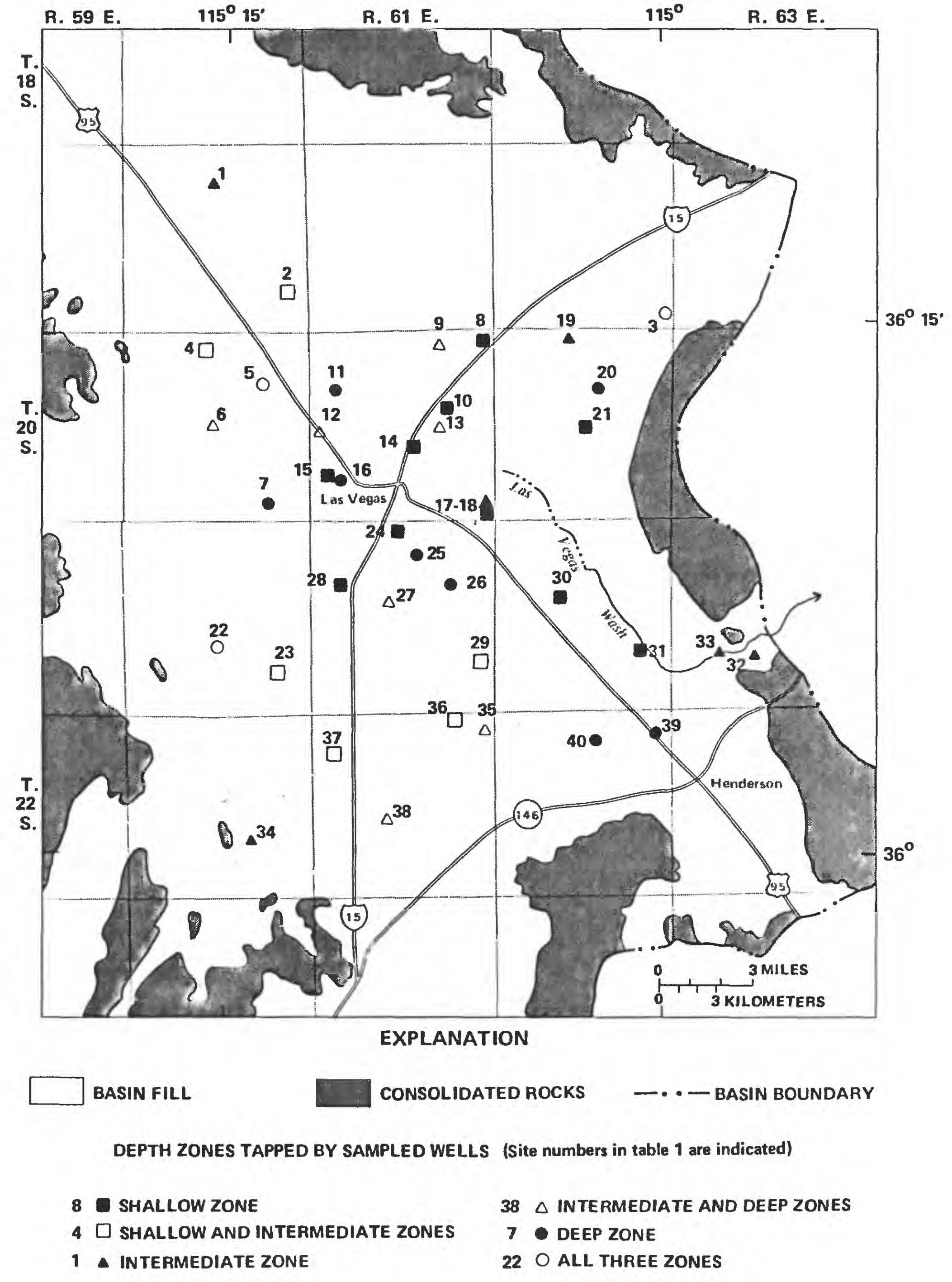


FIGURE 8.--Final network sampling sites, May 1983.

The wells were spaced fairly evenly through the valley. The distribution of wells open to the various depth zones were limited by the availability of properly constructed candidates at various points in the valley. For instance, wells open only to the shallow zone are not as common as other well types in the valley, especially in the far northwest part. As a result, no "shallow-only" wells were included in the network in this part of the valley. Similarly, wells open only to the deep zone are relatively uncommon outside the vicinity of the major pumping center west of the city; consequently, no "deep-only" wells were identified in the southwest and northwest corners of the valley. Generally, if the distinction between these depth zones is recognized as arbitrary, the distribution of wells chosen is probably adequate. If the number of wells that could be sampled were larger, then the distribution could be improved. For instance, a first step toward improving the network would be locating and sampling a deep well within T. 21 S., R. 62 E. (Figure 8).

Tables 1 and 2 list the characteristics of all wells sampled during this study, and figures 5 through 8 show their locations and depths. The differences between the wells sampled in May and August 1982 reflect problems encountered during the effort. For example, access to some wells was lost during one visit or the other, and the pumps at three of the wells were broken during the second round of samples. These kinds of difficulties have to be planned for in the design of a network; where possible, alternative sites should be available in the vicinity of key wells.

Water-Quality Characteristics Determined

The water-quality characteristics that were determined for waters from the various sites sampled may be grouped as follows:

Category	Place of determination
General properties	Field
Principal constituents	Laboratory[1]
Nutrients	Laboratory
Trace elements	Laboratory
Radiochemical indicators	Laboratory
Organics indicator	Laboratory

[1] Carbonate and bicarbonate determined in field.

TABLE 1.--*Data for wells chosen for inclusion in network*

Site no.: Number used to reference wells in text and figures 5-8, 10 and 15.
Local well number: Hydrographic area number (212) is omitted because all wells are in Las Vegas Valley.
Shallowest and deepest openings: Shallowest and deepest perforation or screen, as reported by driller.
Static water level: Most recent measurements available through January 1983. E, estimated; F, flowing.
Water use: D, domestic; I, irrigation; N, industrial or commercial; P, public supply; U, unused.
Depth-zone(s): 1, shallow zone only (less than 30 feet below water table); 2, shallow and intermediate zones; 3, intermediate zone only (30 to 200 feet below water table); 4, intermediate and deep zones; 5, deep zone only (more than 200 feet below water table); 6, all three zones. See section titled "Site selection" in text.
When sampled: 1, sampled during October 1981; 2, sampled during May 1982; 3, sampled during August 1982; 4, sampled during May 1983.

			Depth in feet below land surface		Static water level					
Site no.	Local well number	ID number	Total	Shallowest and deepest openings	Feet below land surface	Year	Water use	Usable pump	Depth zone(s)	When sampled
1	S19 E60 09DAD1	361840115153901	300	240 - 300	102	1981	D	Yes	3	2,3
2	S19 E60 25CCC1	361536115131301	275	60 - 275	142	1982	D	Yes	2	2,3
3	S19 E62 36CCB1	361445115001601	882	96 - 882	131	1982	P	Yes	6	2
4	S20 E60 04CAD1	361417115161301	500	285 - 500	344	1982	D	Yes	2	2,3
5	S20 E60 11CAA1	361303115140301	1,003	307 - 1,000	298	1981	P	Yes	6	2,3
6	S20 E60 21AAB1	361212115154201	975	500 - 893	445	1982	P	Yes	4	2,3
7	S20 E60 35DDBC1	360940115133701	1,013	330 - 986	340	1982	P	Yes	5	2,3
8	S20 E61 01ACCD1	361425115061501	84	80 - 84	62	1982	U	No	1	1,2,3
9	S20 E61 03DAD1	361418115081201	300	120 - 300	56	1982	P	Yes	4	2,3
10	S20 E61 14CCC1	361212115065901	46	43 - 46	28	1982	U	No	1	1,3
11	S20 E61 18ABBD2	361238115112102	1,000	506 - 1,000	209	1980	P	Yes	5	2,3
12	S20 E61 19BCC1	361140115121401	1,004	225 - 895	254	1982	P	Yes	4	2,3
13	S20 E61 22DCDB1	361110115082401	450	75 - 450	E40	1982	P	Yes	4	2,3
14	S20 E61 27BDAA1	361102115083601	15	11 - 15	11	1982	U	No	1	1,2,3
15	S20 E61 30ACC1	361053115120501	30	25 - 30	9	1982	U	No	1	1,2,3
16	S20 E61 30DDC1	361026115111401	902	560 - 878	191	1982	P	Yes	5	2,3
17	S20 E61 36DDD1	360933115055102	100	96 - 99	16	1982	U	No	3	2,3
18	S20 E61 36DDD2	360933115055101	40	36 - 39	13	1982	U	No	1	3
19	S20 E62 04BDCD1	361410115031101	200	110 - 190	67	1982	N	Yes	3	2,3
20	S20 E62 15BBA1	361233115021501	1,000	320 - 980	93	1982	I	Yes	5	2,3
21	S20 E62 21AAC1	361204115024901	95	91 - 95	84	1982	U	No	1	1,2,3
22	S21 E60 21DDD1	360605115154601	800	340 - 800	375	1981	N	Yes	6	2,3
23	S21 E60 35ADAB1	360444115132301	500	230 - 490	298	1981	D	Yes	2	2,3
24	S21 E61 04ABC1	360921115093601	17	13 - 17	9	1982	U	No	1	1,2,3
25	S21 E61 10BCAD1	360817115085701	1,000	517 - 964	E80	1982	I	Yes	5	2,3
26	S21 E61 14ACA1	360728115072901	750	580 - 740	29	1981	I	Yes	5	2,3
27	S21 E61 16CAB2	360719115095901	840	260 - 820	150	1982	I	Yes	4	3
28	S21 E61 17BADD1	360735115105201	45	41 - 45	23	1982	U	No	1	1,2,3
29	S21 E61 25BDA1	360542115065001	94	31 - 94	26	1981	D	Yes	2	3
30	S21 E62 17DAB1	360749115050801	11	7 - 11	8	1982	U	No	1	1,2,3
31	S21 E62 26DBA2	360529115010001	30	27 - 29	11	1982	U	No	1	2,3
32	S21 E63 28CAB1	360537114570501	75	-- --	30	1982	U	No	3	2,3
33	S21 E63 29BBB1	360832115060201	80	76 - 80	22	1982	U	No	3	1
34	S22 E60 27ABB1	360042115150501	554	470 - 550	432	1981	D	Yes	3	2,3
35	S22 E61 01CBA1	360349115064901	400	200 - 400	22	1978	I	Yes	4	2
36	S22 E61 02BBD2	360407115075602	180	60 - 180	40	1982	D	Yes	2	2
37	S22 E61 07BCB1	360307115112301	400	220 - 400	E285	1980	D	Yes	2	2,3
38	S22 E61 21CBD1	360102115100901	1,000	250 - 980	E144	1982	I	Yes	4	2,3
39	S22 E62 01CBC1	360343115003401	600	550 - 600	F	1982	U	Flows	5	4
40	S22 E62 04DCC1	360322115030801	780	430 - 690	F	1982	U	Flows	5	2,3

TABLE 2.--*Data for other wells sampled during the study*

Site no.: Number used to reference wells in text and figures 5-7, 10 and 15.
Local well number: Hydrographic area number (212) is omitted because all wells are in Las Vegas Valley.
Shallowest and deepest openings: Shallowest and deepest perforation or screen, as reported by driller.
Static water level: Most recent measurements available through January 1983.
Water use: I, irrigation; P, public supply; U, unused.
Depth-zone(s): 1, shallow zone only (less than 30 feet below water table); 3, intermediate zone only (30 to 200 feet below water table); 5, deep zone only (more than 200 feet below water table); 6, all three zones. See section titled "Site selection" in text.
When sampled: 1, sampled during October 1981; 2, sampled during May 1982.

			Depth in feet below land surface		Static water level					
Site no.	Local well number	ID number	Total	Shallowest and deepest openings	Feet below land surface	Year	Water use	Usable pump	Depth zone(s)	When sampled
41	S19 E60 04DAB1	361939115154801	780	— —	66	1982	I	Yes	5	1
42	S19 E62 32BBAA1	361542115042901	95	91 - 95	91	1982	U	No	1	1
43	S20 E61 11CDDC1	361305115073201	62	58 - 62	38	1982	U	No	1	1
44	S20 E61 12DBC1	361329115062301	77	73 - 77	54	1981	U	No	1	1
45	S20 E61 30ABB1	361117115114101	29	25 - 29	5	1981	U	No	1	1
46	S20 E61 31DCD1	360937115113401	18	14 - 18	11	1982	U	No	1	1
47	S20 E62 01BBCB1	361421115001601	1,026	96 - 1,026	131	1982	P	Yes	6	2
48	S21 E61 01ACCD1	360908115062901	23	19 - 23	8	1982	U	No	1	1
49	S21 E61 03AAAD1	360924115081101	15	11 - 15	8	1982	U	No	1	1
50	S21 E61 09BBBB1	360838115101801	25	21 - 25	13	1982	U	No	1	1
51	S21 E61 15DDDD1	360701115081301	24	21 - 24	17	1982	U	No	1	1
52	S21 E61 23DAB1	360625115070701	35	34 - 35	5	1982	U	No	1	2
53	S21 E61 24CAD1	360617115063801	24	20 - 24	13	1982	U	No	1	1
54	S21 E62 28AAB1	360548115024601	27	24 - 27	18	1982	U	No	1	1
55	S21 E63 29CCB1	360520114583801	105	— —	9	1981	U	No	3	1
56	S22 E61 01BAB1	360415115064101	37	33 - 37	26	1981	U	No	1	1

Table 3 presents the specific constituents and properties in these groups. Only the first three groups were determined on samples collected during October 1981. All six of the groups were determined on the samples of May 1982, and all except the radiochemical indicators were determined on the samples of August 1982. Nutrients, radiochemical, and organic-carbon determinations were not made on the single sample of May 1983.

The characteristics of primary geochemical interest are the principal constituents, trace elements, pH, and water temperature.

TABLE 3.--*Water-quality constituents and properties determined for demonstration-network samples, and water-quality standards*[1]

[Unless otherwise stated, all water-quality standards are Federal (U.S. Environmental Protection Agency, 1975, p. 59570-59571; 1976, p. 28404; 1977, p. 17146)]

Category	Constituent or property	Milligrams per liter, except as noted	
		Recommended or mandatory maximum or range for drinking water	Recommended maximum or range for irrigation
General	pH (units)	[a]6.5-8.5	4.5-9.0
	Specific conductance	--	--
	Water temperature	--	--
Principal constituents	Calcium (Ca)	--	(*b*)
	Magnesium (Mg)	[c]150	(*b*)
	Sodium (Na)	--	(*b*)
	Potassium (K)	--	--
	Bicarbonate and carbonate (HCO$_3$, CO$_3$)	--	--
	Sulfate (SO$_4$)	[c]500	--
	Chloride (Cl)	[c]400	--
	Fluoride (F)	[d]1.6	[e]15
	Silica (SiO$_2$)	--	--
	Dissolved solids residue on evaporation	[c]1,000	--
Nutrients	Nitrate (as N)	10	--
	Nitrite (as N)	--	--
	Orthophosphate (P)	--	--
Trace elements	Arsenic (As)	0.05	2
	Barium (Ba)	1	--
	Boron (B)	--	2
	Cadmium (Cd)	0.01	0.05
	Chromium (Cr)	0.05	1
	Copper (Cu)	[a]1	5
	Iron (Fe)	[c]0.6	20
	Lead (Pb)	0.05	10
	Manganese (Mn)	[c]0.1	10
	Mercury (Hg)	.002	--
	Nickel (Ni)	--	2
	Selenium (Se)	0.01	0.02
	Silver (Ag)	0.05	--
	Zinc (Zn)	[a]5	10

TABLE 3.--*Water-quality constituents and properties determined for demonstration-network samples, and water-quality standards*[1]--Continued

		Milligrams per liter, except as noted	
Category	Constituent or property	Recommended or mandatory maximum or range for drinking water	Recommended maximum or range for irrigation
Radiochemical indicators	Gross alpha (as U-natural)	15 pCi/L (equals 45 μg/L)	--
	Gross beta (as Cs-137)	--	--
	Gross beta (as Sr-90/Y-90)	(*f*)	--
Organics indicator	Total organic carbon (C)	--	--

---

[1] Modified from Nowlin (1986, table 3) and Van Denburgh and others (1982, table 1).

[a] Recommended concentration or range that should not be exceeded where suitable alternative supplies are available or can be made available.

[b] Criteria for concentrations of major cations in irrigation water are usually expressed in terms of the SAR (Sodium-adsorption ratio):

$$SAR = Na/\sqrt{(Ca + Mg)/2} ,$$

where concentrations are expressed in milliequivalents per liter.

[c] State of Nevada standard (Nevada Bureau of Consumer Health Protection Services, 1977, pages 8-9).

[d] Value for Las Vegas Valley, on basis of annual average of 26.0 °C for maximum daily air temperatures at Las Vegas office of National Weather Service, McCarran International Airport (published data from National Climatic Center, U.S. National Oceanic and Atmospheric Administration).

[e] Recommended maximum concentration for use during a 20-year period on neutral and alkaline, fine-textured soils (U.S. Environmental Protection Agency, 1972, pages 323-353).

[f] Beta radiation is of most concern when its emitter is the radioisotope strontium-90. A drinking-water standard of 8 pCi/L applies to this specific isotope (U.S. Environmental Protection Agency, 1976, page 28404).

Drinking-water standards that may be used to judge the quality of the sampled water are included in table 3. The standards for drinking water are generally the most restrictive of the water-quality standards. Recommended limits for irrigation-water quality, which are less restrictive, also are included in table 3. Standards and guidelines for other water uses, such as industrial cooling, construction, and steam generation, exist but are very site- and use-dependent. They are not listed in table 3, but are discussed in references such as "Quality Criteria for Water, 1986" (U.S. Environmental Protection Agency, 1986).

A commonly used measure of the general quality of water is the concentration of dissolved solids. Dissolved solids may be determined by summing the milligram-per-liter concentrations of the major ions, or by measuring residue on evaporation at 180 °C (Hem, 1985, pages 156-157). In this report, as in most previous work in Las Vegas Valley, residue on evaporation at 180 °C is the method used to determine dissolved-solids concentrations.

The nutrients determined generally may serve as indicators of problems related to sewage effluent, or, alternatively in Las Vegas Valley, may indicate the presence of naturally occurring, nitrate-rich evaporites (Hess and Patt, 1977, pages 29-33). Relative concentrations of various nitrogen and phosphorus species can provide clues to the oxidation state of the geochemical system and to the sources of natural and contaminating fluids (Hess and Patt, 1977, pages 17-19).

Several characteristics were chosen to serve as general indicators of a range of more specialized, undetermined contaminants. The radiochemical indicators and total organic carbon (TOC) were included for the purpose of determining the ambient, background levels of these characteristics. Such levels may be useful in long-term monitoring at both the valley-wide and local scales, in allowing preliminary delineation between contaminated and uncontaminated waters, or more exactly, by identifying water that deserves further analyses to determine the presence of contaminants. When a generalized indicator is observed at anomalously high concentrations in a ground-water sample, follow-up samples may be collected for more specific but more expensive determinations of the possible components of the indicator. For example, determination of concentrations of a suite of pesticides or solvents may be advisable if a high TOC concentration is encountered.

Sampling Procedures

To insure that the samples collected were representative of the ground water in the aquifers tapped by the wells, they were collected only after at least two well-casing volumes were purged from the wells. With the cooperation of well owners, wells were pumped for 3 to 4 hours prior to sample collection. This practice removed the standing water in the wells, the water that may have mixed therewith, and the water that had been in contact with the well casing for long periods of time. The standing water would have been away from its natural physiochemical setting since the previous pumping, and thus may have been altered significantly (Van Denburgh and others, 1982, page 14). Nearly all monitoring wells without pumps were purged with portable pumps for 40 to 80 minutes, until a total of three to five well volumes of water had been extracted. During the purging process, temperature and specific conductance were monitored regularly to verify the stabilization of these physical properties prior to sample collection.

Samples were obtained from the network wells either at spigots between the well head and storage tank at domestic, industrial, and municipal wells, or at the discharge hose from portable submersible pumps. All sample containers were thoroughly rinsed with water from the well immediately prior to sample collection. Samples for all properties and constituents except pH, radiochemistry, and TOC were filtered through field-rinsed 0.45-micrometer membrane filters immediately after collection. The samples for nutrient determinations were treated with mercuric chloride and chilled to less than 4 °C immediately after collection. TOC samples were also immediately chilled. Other samples were acidified or left untreated as required by the laboratories.

While the samples were being filtered and treated, the field determinations were made. Field determinations of dissolved carbonate and bicarbonate were made by the incremental titration method (Wood, 1981, pages 15-18, Method A) except during the October 1981 sampling run. The other field determinations also were made in accordance with methods described by Wood (1981).

Field determinations of the concentration of carbonate and bicarbonate were not made during the October 1981 sampling run; instead, laboratory determinations of alkalinity were made. Laboratory alkalinity and carbonate-bicarbonate as determined in the field are roughly comparable measures since laboratory alkalinity is, in most natural waters, a measure of the total concentration of the carbonate species--that is, carbonate ions, bicarbonate ions, and carbonic acid (Hem, 1970, page 152). Bicarbonate is the dominant carbonate species in the ground water of Las Vegas Valley, and thus with relatively little error, the bicarbonate concentration can be estimated by multiplying the laboratory alkalinity by the factor 1.22 (Hem, 1970, table 8).

Finally, the samples were labeled and stored until delivery to the appropriate laboratories.

During the May 1982 and August 1982 sampling runs, samples from eight wells selected at random from among the network sites were split and sent to both the U.S. Geological Survey and Las Vegas Valley Water District laboratories for duplicate analyses.

Results of the Water-Quality Determinations

The results of the several physical and chemical analyses of ground water from Las Vegas Valley made during the course of this study are presented in tables 4 and 5. These tables are organized in accord with the order of sites listed in tables 1 and 2 and the order of characteristics listed in table 3. The significance of these results is discussed in the next section.

GROUND-WATER QUALITY AND GEOCHEMISTRY, 1981-83

Laboratory and field determinations of chemical characteristics of ground-water samples made during the implementation of the network, consisting of relatively few samples during only a brief time period, are not in themselves sufficient to allow detailed interpretations of ground-water quality conditions in Las Vegas Valley or detailed assessments of the geochemical processes and trends that underlie the observed ground-water chemistry. The results of the analyses do, however, give an indication of the type of information that a continuing monitoring program could provide; in addition, they suggest the existence of certain potential problem areas in the valley.

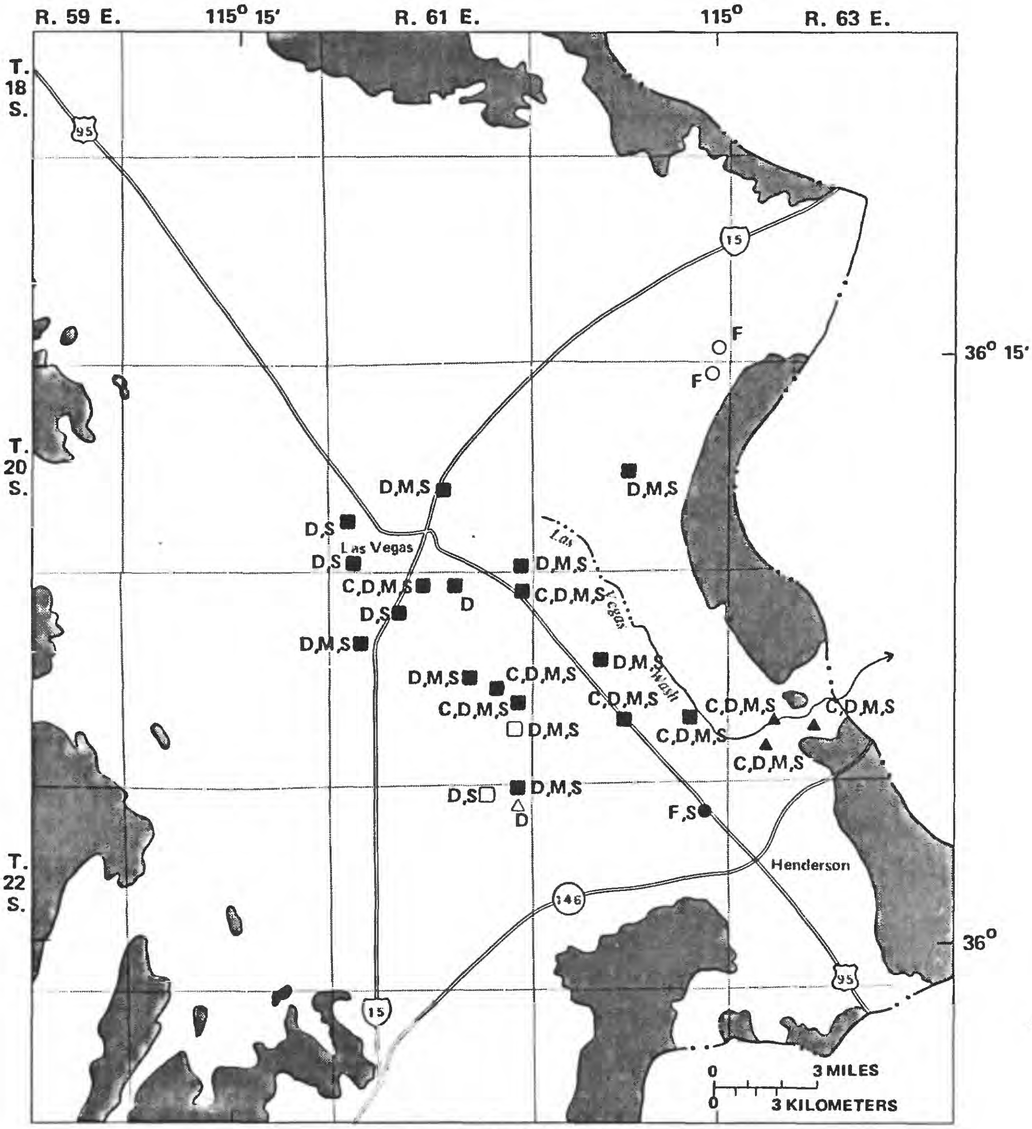
Water-Quality Conditions

The analytical results presented in tables 4 and 5 depict a wide range of ground-water quality in Las Vegas Valley. The quality ranges from good, in the deepest wells in the northwest quadrant of the valley where dissolved solids range from 200 to 400 mg/L, to very poor, in shallow wells tapping the water table in the center and southeast portions of the valley where dissolved solids range from 2,000 to more than 7,000 mg/L. Water extracted from near the water table was generally the poorest in quality everywhere in the valley, although along the north and west margins of the valley floor no chemical distinction between the quality of shallow and deep water could be made. Samples from intermediate and deep wells in the southern half of the valley were generally of poorer quality, with dissolved solids ranging from 700 to 1,500 mg/L, than the samples from the north and northwest.

The most common water-quality constraint on potential uses of ground water from Las Vegas Valley for drinking is a high dissolved-solids concentration. In wells tapping the shallow zone in the southeast end of the valley, the overall dissolved-solids content, along with the concentrations of sulfate and magnesium, commonly exceed drinking-water standards. In the lowest parts of the valley, especially along Las Vegas Wash, chloride levels also exceed the standard. The sites at which ground water was found to exceed drinking-water standards (table 3) are shown in figure 9. The deeper wells in these same areas generally yield water of much better quality.

The potential use of the ground water for irrigation would also be limited primarily by high salinity. A diagram showing the suitability of ground water for irrigation as determined during the implementation of the network is shown in figure 10. The sodium-adsorption ratio and specific conductance for each sample are plotted on this diagram, along with four fields of sodium hazard and four fields of salinity hazard. The sodium hazard of irrigation water arises when the water is sufficiently sodium-rich that the sodium replaces calcium and magnesium in clay minerals in the soil. Soils that have absorbed large amounts of sodium become less permeable as the clays expand, or become deflocculated, and the result may be decreased crop yields (Hem, 1970, page 330). Ten sites yielded water with more than a low sodium-hazard rating, and all of these were in the southeastern discharge area of the valley. High and very high salinity levels are much more common among the sites sampled. All the water with very high salinity-hazard ratings was from the shallow zone or from the extreme southeast corner of the valley.

Fluoride does not seem to follow the same areal pattern as the other principal constituents; instead, it exceeds the drinking-water standard primarily in the northeast corner of the valley (figure 9). The two neighboring wells at Lake Mead Base that were sampled (wells 3 and 47 in tables 1 and 2) yielded ground water that exceeded the standard, and water from nearby deep well 20 nearly exceeded it. Loeltz (1963, page Q12) had previously reported high fluoride concentrations in four wells at the Lake Mead Base, including the two sampled during this study. Deep well 39 and shallow well 31 yielded water with fluoride exceeding and nearly exceeding the drinking-water standard, respectively. The fluoride at all these sites is probably from naturally occurring minerals beneath the lower eastern parts of the valley. Fluoride in natural water is commonly derived from the calcium-flouride mineral fluorite, which can be present in both igneous and sedimentary rocks (Hem, 1970, page 177).



EXPLANATION

▢ BASIN FILL
■ CONSOLIDATED ROCKS
——··—— BASIN BOUNDARY

DEPTH ZONES TAPPED BY SAMPLED WELLS

- ■ SHALLOW ZONE
- ☐ SHALLOW AND INTERMEDIATE ZONES
- ▲ INTERMEDIATE ZONE
- △ INTERMEDIATE AND DEEP ZONES
- ● DEEP ZONE
- ○ ALL THREE ZONES

CONSTITUENTS FOR WHICH CONCENTRATIONS EXCEEDED STANDARDS
(standards, as listed in table 3, are indicated)

C CHLORIDE (400 milligrams per liter)
D DISSOLVED SOLIDS (1,000 milligrams per liter)
F FLUORIDE (1.6 milligrams per liter)
M MAGNESIUM (150 milligrams per liter)
S SULFATE (500 milligrams per liter)

FIGURE 9.--Sites where concentrations of principal constituents exceeded drinking-water standards, 1981-82.

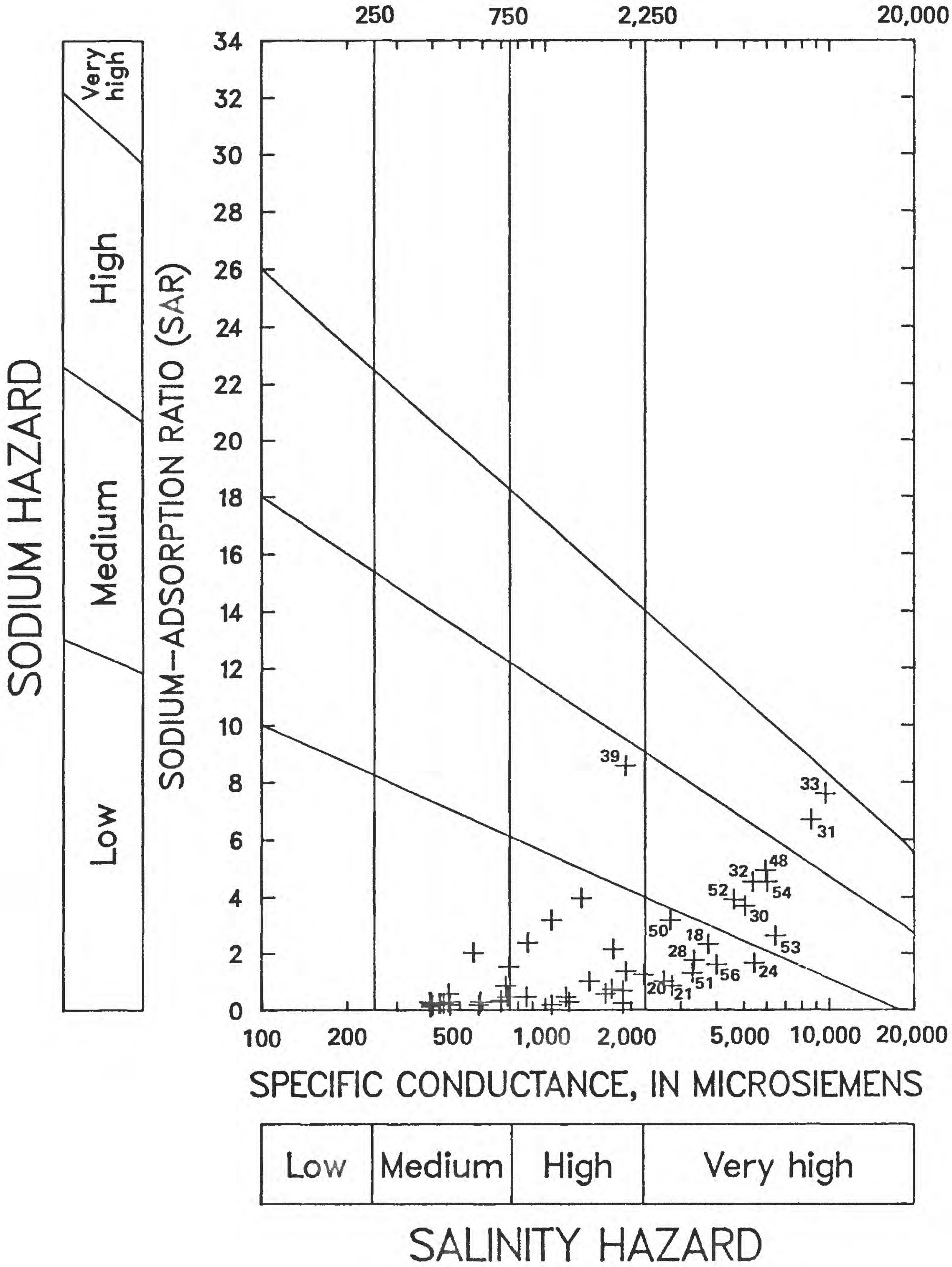


FIGURE 10.--Suitability of ground water for irrigation. Site numbers in table 1 are indicated for well water having medium or high sodium hazard, very high salinity hazard, or both. Plot for site number 55 (sodium-adsorption ratio, 32; specific conductance, 108,000 microsiemens) is not shown.

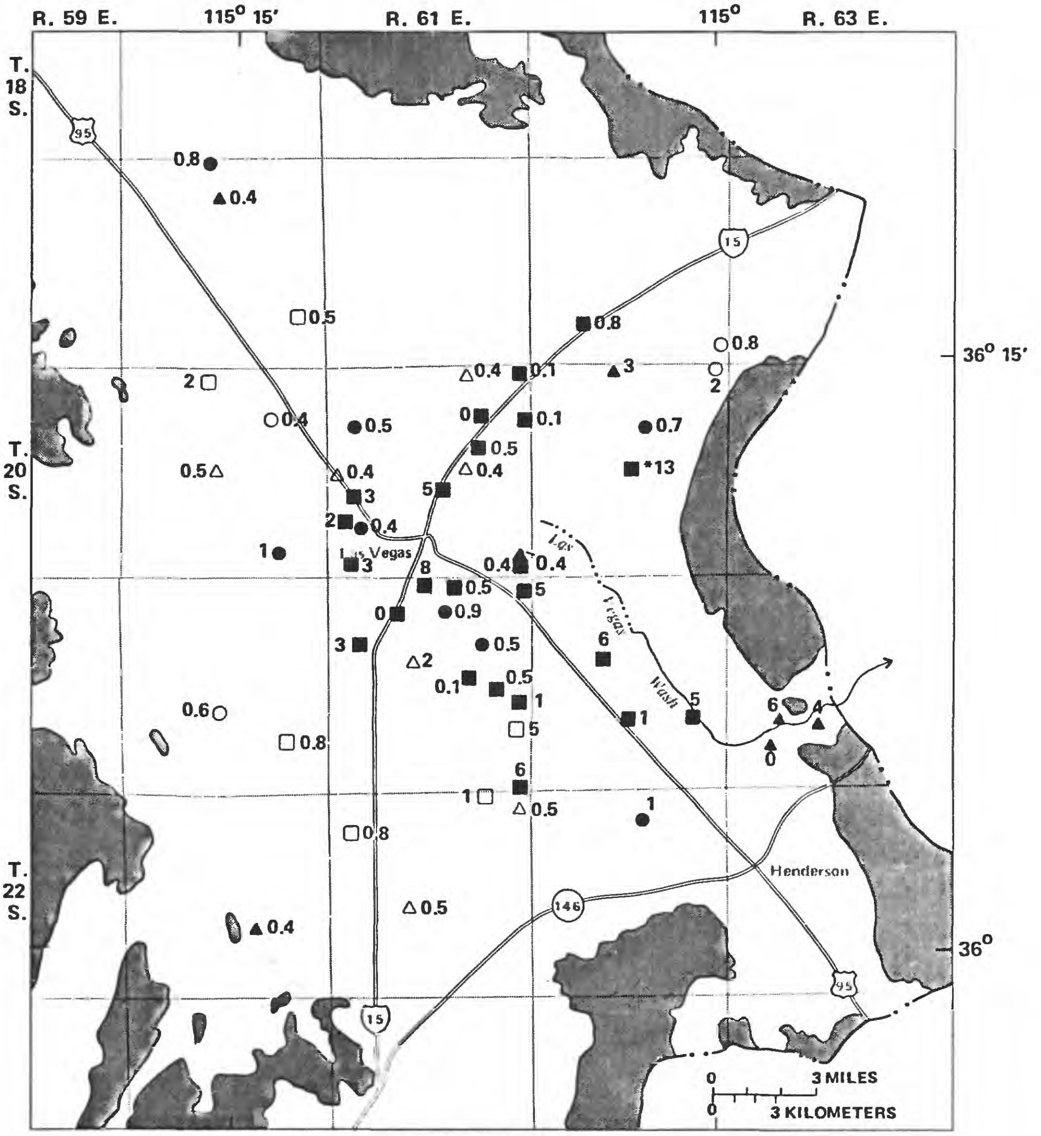
Nitrate concentrations in the shallow ground water of the valley are spatially quite variable and probably are strongly related to local disposal of wastewater, to lawn irrigation, and possibly to local uses of fertilizer in the developed areas at the center of the valley. The variability of nitrate in the well water sampled during this study is shown in figure 11. The highest and lowest concentrations were measured in water from wells tapping only the shallow zone. Nitrate concentrations at the sites sampled during the study ranged from below the detection limit at shallow well 43 in North Las Vegas, to 18 mg/L (expressed as nitrogen) at shallow well 21 south of Nellis Air Force Base. Generally, water from deep wells and from wells at the margins of the valley contained 0.4 to 1.6 mg/L of nitrate-nitrogen. The spatial variability of nitrate in the water from intermediate-depth and deep wells is somewhat less pronounced than in the shallow ground water, and no dominant large-scale geographic patterns are evident in the results of the current network. For instance, it would be difficult to argue that geographic variations in nitrate concentrations in water from the deep wells reflect nitrate concentrations in the shallow ground water. Nitrate concentrations seem to be related spatially to relatively local situations at present; no valley-wide pattern is evident in the results of the first-round sampling program conducted as part of this study.

Wells 5, 6, 12, and 16 are LVVWD supply wells sampled during this study (figure 8) and also sampled by the Water District laboratory between 1976 and 1980. A comparison of the results of nitrate determinations for these samples follows:

[Milligrams per liter]

Site No.	1976	1977	1978	1979	1980	This study, 1982
5	0.2	0.3	--	0.6	0.4	0.4
6	--	--	--	--	.8	.5
12	.3	--	0.5	--	--	.4
16	.1	--	--	--	.6	.4

The reported increase in nitrate concentrations in water from LVVWD wells during the period 1976-80, noted earlier, is apparent even in these few wells, but the most recent samples (1982) do not show a continuation of the trend. To adequately identify the long-term chemical trend (whether of rising, declining, or stable nitrate concentrations), a longer regime of periodic sampling is needed. Annual sampling, or even semiannual sampling, at network wells would provide the data necessary to identify trends in nitrate concentrations, as well as trends for other chemical constituents.



EXPLANATION

☐ BASIN FILL ▨ CONSOLIDATED ROCKS —··— BASIN BOUNDARY

DEPTH ZONES TAPPED BY SAMPLED WELLS
(Average nitrate concentrations, in milligrams per liter as nitrogen, are indicated)

3■ SHALLOW ZONE	0.4△ INTERMEDIATE AND DEEP ZONES
1☐ SHALLOW AND INTERMEDIATE ZONES	1● DEEP ZONE
4▲ INTERMEDIATE ZONE	0.6○ ALL THREE ZONES

* SITE AT WHICH NITRATE EXCEEDS DRINKING–WATER STANDARD (10 milligrams per liter)

FIGURE 11.--Nitrate concentrations.

The wells sampled in the current program are not sufficient in number to detail the spatial variability of nitrate concentrations, but they do strongly suggest the areal limits of shallow ground water that might serve as reservoirs of nitrate for the degradation of the deeper aquifers when head relations favor downward flow. Currently, most of the shallow water sampled contained between 1 and 6 mg/L of nitrogen. This implies that unless shallow conditions worsen, little immediate danger exists that mixing of shallow and deeper ground water will result in large areas of water exceeding the drinking standard (10 mg/L). However, the sources of nitrogen in the shallow zone are uncertain, and continued monitoring would be necessary (1) to verify that nitrogen concentrations in that zone are not increasing and (2) to help identify and quantify the sources of nitrogen. The primary advantage of a monitoring network such as the one described in this report, if it were continued, is that the large-scale growth of or recovery from a nitrate problem could be recognized.

The samples taken during this study gave no evidence of any large-scale or serious threats to water quality by trace elements. Arsenic, iron, manganese, and chromium were the only ones observed in concentrations greater than drinking-water standards in any of the wells sampled during the study. Nickel exceeded the recommended irrigation limit in the sample from shallow well 31 near Las Vegas Wash and was present at high concentration in the sample from nearby well 32 (figure 8 and table 1). Iron and manganese were present at concentrations exceeding standards in the August sample from intermediate-depth well 38 in the south-central part of the valley (table 1). The May sample from this well, however, was significantly different both physically and chemically from the August sample: the water temperature was 25.0 °C in May and 30.0 °C in August. The May sample contained trace elements in very low concentrations relative to the August sample. Additional analyses would be useful to determine which, if either, of the results reported for this site is the more representative of the ground water. An elevated arsenic concentration was encountered in water taken from deep well 39. All other samples exhibiting elevated trace-element concentrations were from unused observation wells which, except for well 32 at Las Vegas Wash, tapped only the shallow zone. The locations of wells from which water samples contained trace-element concentrations in excess of standards (table 3) are shown in figure 12.

Detectable levels of gross-beta radiation were reported for water from five sites in Las Vegas Valley; alpha radiation was present at a low but detectable level in the water from one site. These locations and the levels detected are shown in figure 13. None of the values are at or above the drinking-water standards. As noted in table 3, gross beta itself is not controlled by drinking-water standards. The determination is not a measure of any particular radioisotope; although reported relative to specific reference isotopes (strontium-90/yttrium-90 and caesium-137), it is not a direct measure thereof (Thatcher and others, 1977, page 29). The beta emitter strontium-90, for which the water-quality standard exists, is not a naturally occurring isotope; instead, it is generated in the nuclear reactions of fission and fusion (Matthess, 1982, page 141).

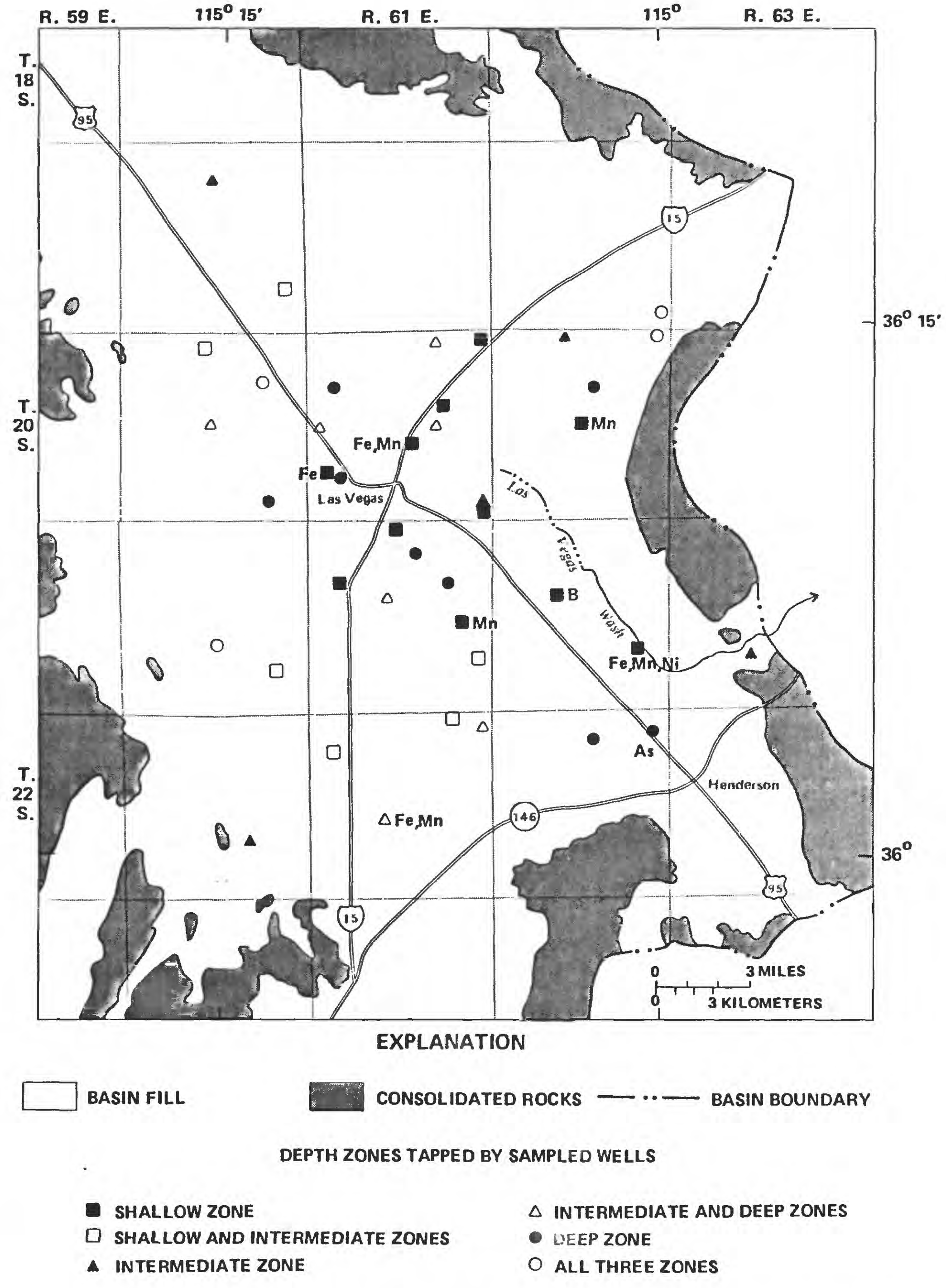
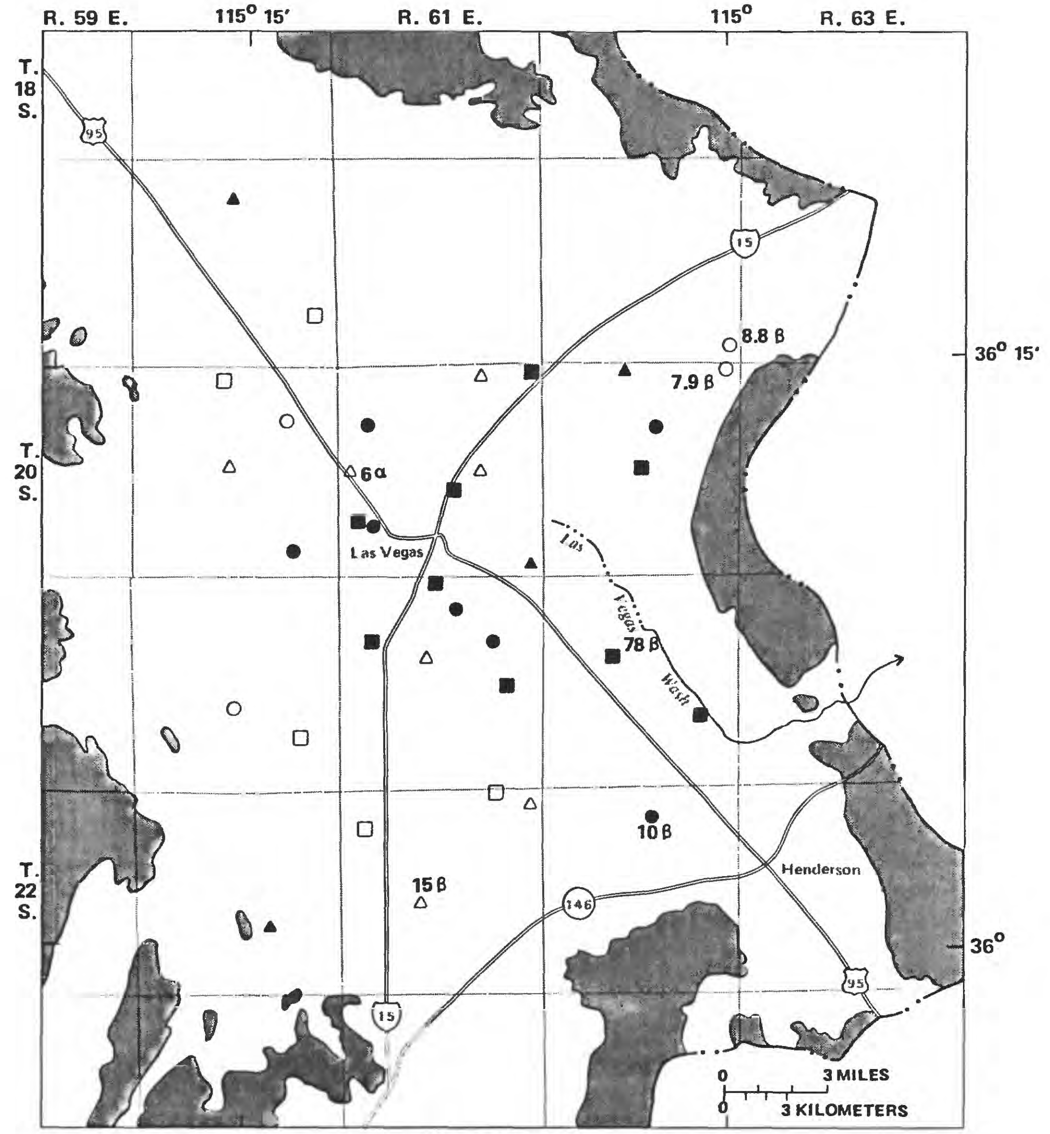


FIGURE 12.--Sites where trace-element concentrations were determined. Chemical symbols indicate constituents that exceed water-quality standards (table 3). For drinking water: As, arsenic (standard, 0.05 mg/L); Fe, iron (0.6 mg/L); Mn, manganese (0.1 mg/L). For irrigation water: B, boron (2 mg/L); Ni, nickel (2 mg/L).



EXPLANATION

☐ BASIN FILL

▨ CONSOLIDATED ROCKS

—··— BASIN BOUNDARY

DEPTH ZONES TAPPED BY SAMPLED WELLS

- ■ SHALLOW ZONE
- ☐ SHALLOW AND INTERMEDIATE ZONES
- ▲ INTERMEDIATE ZONE
- △ INTERMEDIATE AND DEEP ZONES
- ● DEEP ZONE
- ○ ALL THREE ZONES

FIGURE 13.--Sites where radiochemical activity was determined. Numbers indicate concentrations that exceeded the detection limits. Chemical symbols indicate form of radiochemical activity detected: α, gross alpha, in micrograms per liter as natural uranium; β, gross beta, in picocuries per liter as *strontium-90/yttrium-90*.

However, a common natural source of beta radiation in terrestrial settings is the isotope potassium-40, which is present in natural water at approximately 0.8 picocuries for each milligram per liter of dissolved potassium (Eisenbud, 1973, page 186). The beta radiation in the ground water of Las Vegas Valley is most easily explained as being derived from such natural isotopes, especially since four of the five wells in which it was detected are deep. Two of these wells are open to the shallow zone as well as the deeper aquifers, but the other two are not. Comparing the detected radiation levels with beta radiation expected from the potassium concentrations suggests that all of the detected radiation was due to the normal and natural concentrations of potassium-40.

Total organic carbon (TOC) is a semi-quantitative measurement of organic water quality in most ground-water applications (Malcolm and Leenheer, 1973). TOC can indicate the presence of a wide variety of organic compounds that may be derived from natural or artificial sources. No drinking-water standard exists for TOC. The parameter has been used effectively, however, in Las Vegas Valley and elsewhere as an inexpensive indicator of more specific organic contamination problems. For example, maps of TOC concentrations in the shallow ground water near the industrial complex at Henderson have been used frequently in studies of organic contamination in that area (for example, Geraghty and Miller, Inc., 1980, figure 9). Both the Nevada Division of Environmental Protection and the industries involved have used the 5-mg/L TOC line on these maps as an informal indicator of the areal extent of the contaminated ground water (LaVerne Rosse, Nevada Division of Environmental Protection, oral communication, 1982).

The results of the TOC determinations for the samples collected during the implementation of the network discussed herein are shown in figure 14. The TOC concentrations for water from the wells that tap only the shallow zone generally range from 3 to 10 mg/L of TOC (expressed as carbon), whereas water from the deeper wells contains 1 mg/L or less. Part of this difference may be due to the closer connection of the shallow ground water to the reservoir of organic matter in the soil zone. Locally, the elevated TOC may be due to contamination of the shallow ground water by sewage, irrigation return flow, and other wastewater. Finally, part of the difference also may be due to the greater abundance of sediment in water taken from the unused shallow monitoring wells. Such sediment definitely can influence the results of TOC determinations. To avoid this possible influence in the future, it would be useful to determine the dissolved-organic carbon concentration rather than TOC. On the other hand, the difference in TOC concentrations in waters from wells 18 and 17 (a shallow well and an intermediate-depth well, respectively, that are within 50 feet of each other in the east-central part of the valley) suggests that sediment is not the only difference between the TOC determinations for water from shallow and deep wells. Despite the fact that there was no observable difference in the amount of sediment in the two samples, the sample from the intermediate-depth well 17 contained only 10 percent as much TOC as the sample from the shallow well.

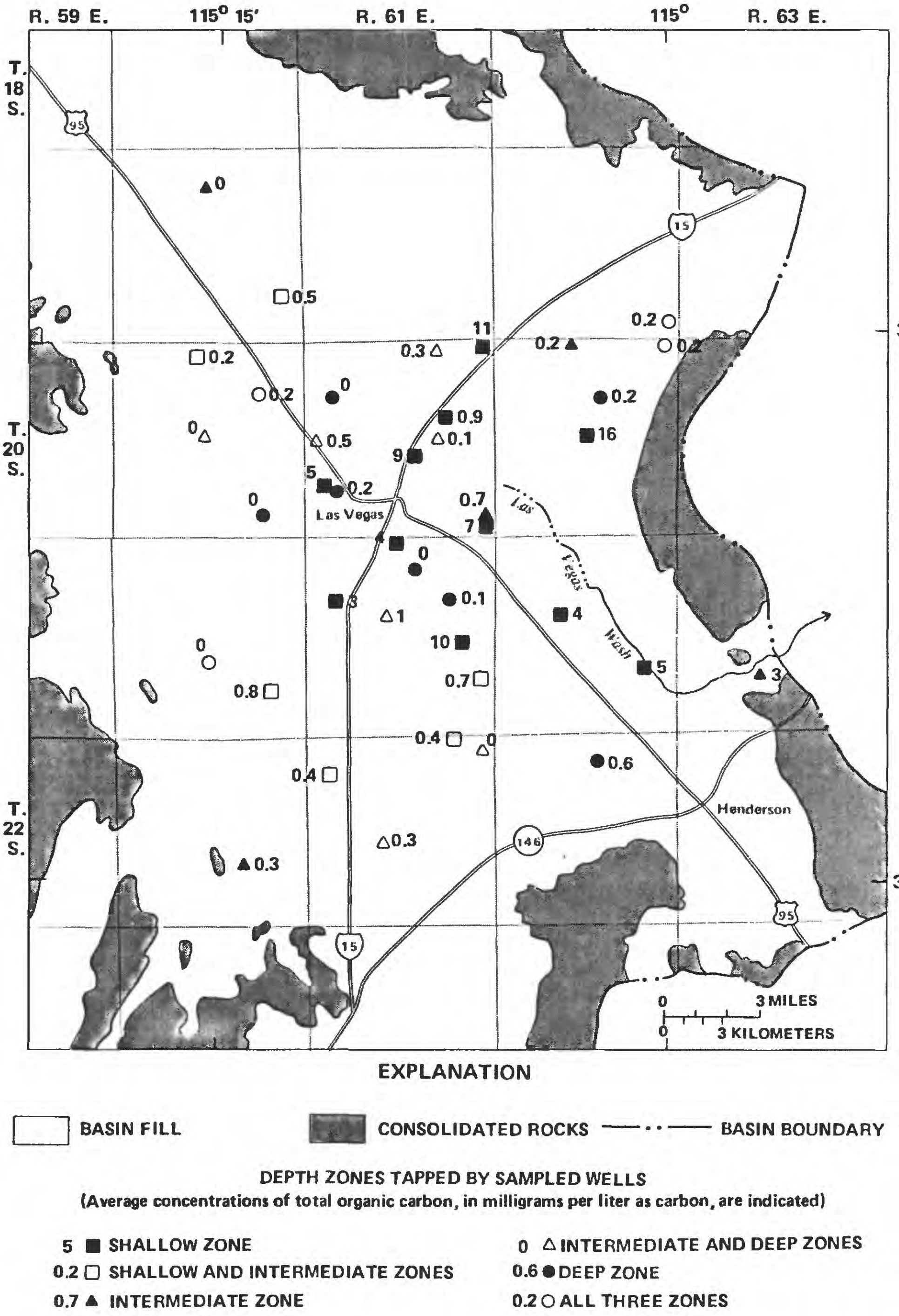


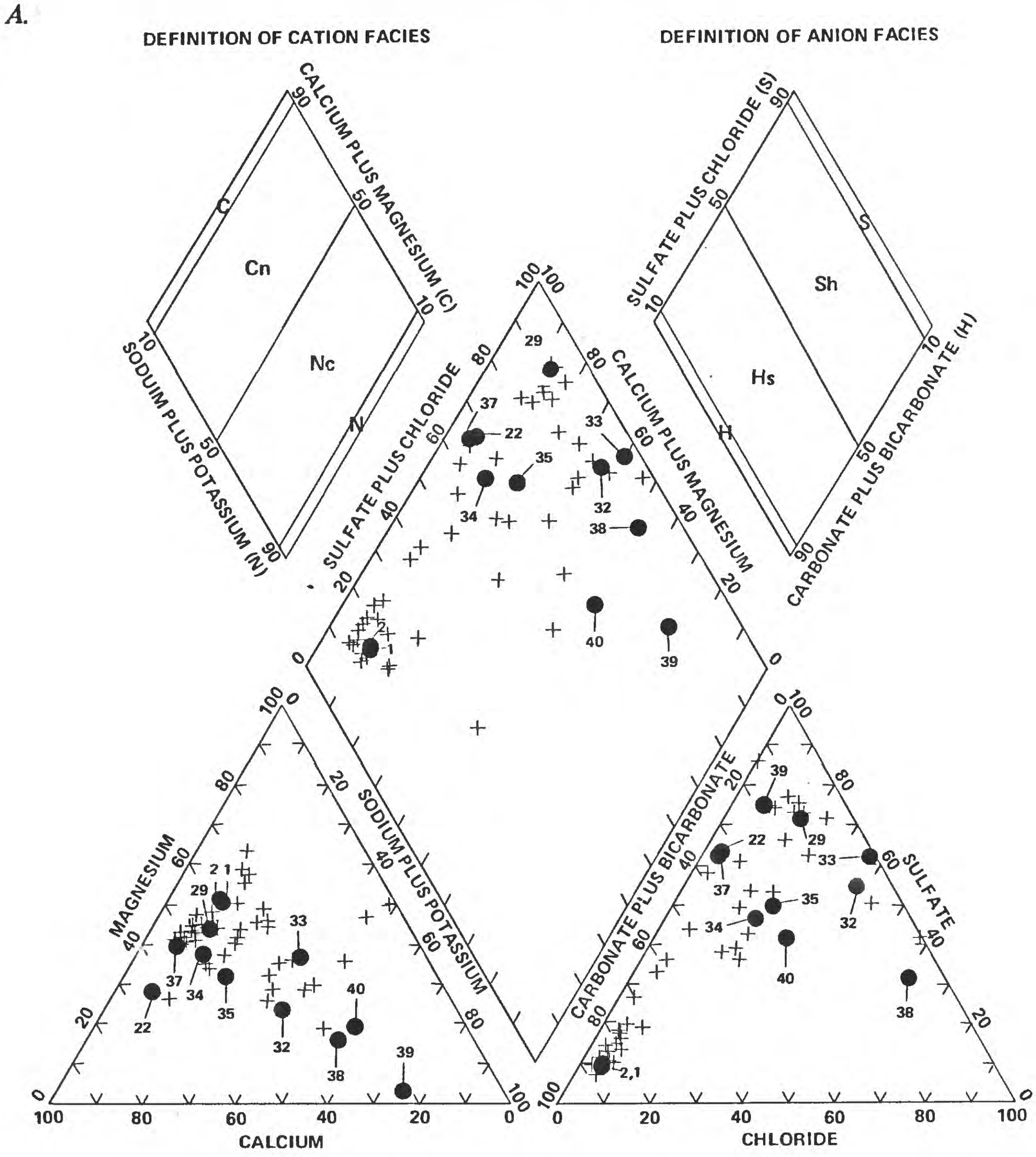
FIGURE 14.--Concentrations of total organic carbon.

If the nitrate and TOC in shallow wells (and eventually in deeper wells) are, in part, a result of human activities, then seasonal variations or long-term changes in concentration might be observable. Variations in the general chemistry of samples from well 14 may be an example of such temporal variation. Whether the contamination is a result of percolation of wastewater to the water table, or is due to leaching of naturally occurring contaminants in the unsaturated zone by the increasing volumes of secondary recharge, one would expect temporal variations in the rate at which contaminants are added to the shallow ground water. In fact, the nature of observed temporal variations might yield clues as to (1) whether the contaminants result from human influences and (2) the mechanisms and sources of contamination. It, therefore, would be useful to sample the network wells biannually--in the winter when lawn irrigation and fertilization are at a minimum and in the summer when they are most intensive. Annual sampling would provide less information but would be minimally adequate and would yield data to describe long-term accumulations or decreases in the concentrations of potential contaminants.

Geochemical Controls

A trilinear diagram (Hem, 1970, pages 268-270) showing the percentages of the principal cations and anions for each site on the basis of their average water chemistries is shown in figure 15A. The figure also shows the several hydrochemical facies, which are defined in terms of the following principal cation and anion groups: calcium plus magnesium, sodium plus potassium, sulfate plus chloride, and carbonate plus bicarbonate. The concept of hydrochemical facies is a means of summarizing the chemical nature of ground water (Back, 1961) and describes ground water in terms of its major chemical constituents. The geographic distribution of the facies as determined by the average water chemistry is shown in figure 15B.

Ground water that flows down the valley from the northern Spring Mountains and the Sheep Range generally is of good quality (see "Water-Quality Conditions") because of the near absence of evaporites in the carbonate rocks of the Spring Mountains and Sheep Range and among the basin-fill sediments in this part of the valley. The chemistry is in approximate equilibrium with the carbonate rocks of the Spring Mountains and Sheep Range, and with the carbonate-cemented carbonate-clast gravels of both the extensive alluvial-fan deposits and the coarse-grained basin-fill sediments. The water in the northern and western parts of the valley contains about 300 mg/L of dissolved solids dominated by calcium, magnesium, and bicarbonate, with only small amounts of sulfate. Throughout much of the valley, these equilibria result in bicarbonate concentrations between 100 and 300 mg/L. In the northwest, concentrations are in a narrow range of 200-230 mg/L. The water from wells 1 and 2 exemplifies the type of water in the northwest part of the valley (figure 8), and plots in the Hs-Cn quadrant of the trilinear diagram in figure 15A. The predominant cations, calcium and magnesium, are roughly equal, in milliequivalents, while bicarbonate is the predominant anion.



EXPLANATION

2 ● SITE MENTIONED BY NUMBER IN TEXT

+ OTHER SITES

FIGURE 15.--Chemical characterization of sampled well water and areal distribution of hydrochemical facies. *A*. Proportions of principal constituents. Percentages are based on milliequivalents per liter. Sites identified by number are listed in table 1. *B*. Areal distribution of hydrochemical facies. Facies symbols are defined in part *A* (diamond-shaped insets).

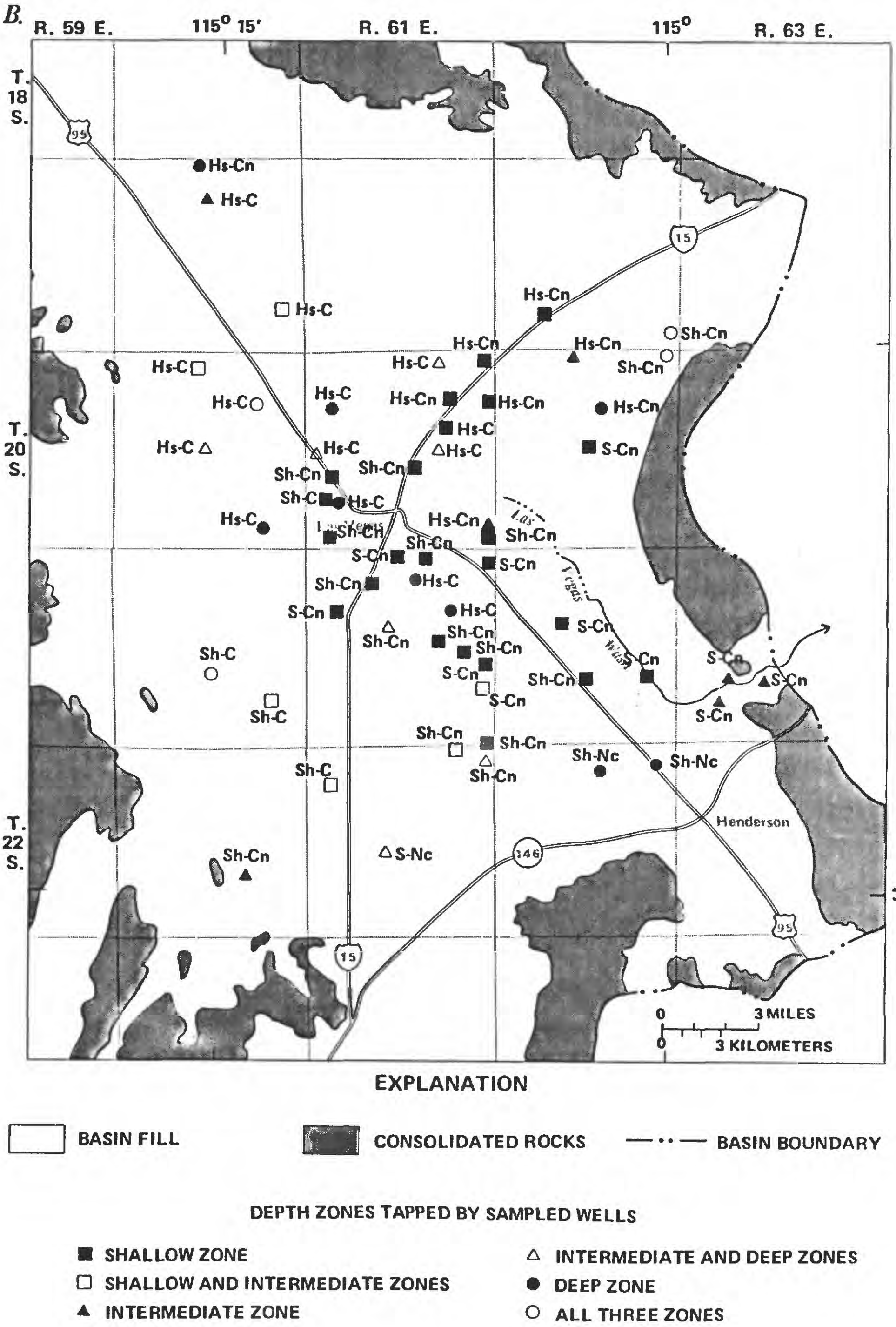


FIGURE 15.--Continued.

Ground water in the southwest corner of the valley is derived predominately from the southern Spring Mountains, with smaller amounts derived from the Birdspring Range (figure 1). Ground water from these sources shows the chemical influence of the clastic rocks of Permian to Jurassic age as well as the carbonate rocks that constitute much of the mountain block along this margin of the valley. The clastic rocks are sandstones, conglomerates, shale, and some limestone, and also include red beds and numerous gypsum beds (Plume, 1983, page 9). Ground water in this part of the valley reflects an equilibrium with carbonate rocks in the mountains and basin fill, but also contains more sulfate and chloride than the northern ground water. The water is dominated by calcium, magnesium, sulfate and bicarbonate. The water contains slightly more calcium than magnesium, and somewhat more sulfate than bicarbonate. Chloride is still a small fraction of the total concentration of anions in the water. The higher concentrations of sulfate and chloride in the water, in large part, are due to the mineralogy of the aquifer materials in this area (Kauffman, 1978, page 43). Samples from wells 22 and 37 are examples of the ground water in this corner of the valley (figure 8). The chemistry of the water from these wells plots near the top of the trilinear diagram in figure 15A (in the Sh-Cn quadrant).

The mountains along the southeastern and eastern borders of Las Vegas Valley contribute little recharge; thus, the ground water in the vicinity of these borders and beneath the lower parts of the valley floor does not directly reflect the chemistry of the nearby mountains as strongly as the water to the west. Instead, it tends to reflect (1) the interaction of ground-water inflow from the major recharge areas to the northwest (and to a lesser extent the southwest) with the mineralogy of the basin-fill materials in the southeast, (2) the concentrating effects of ground-water discharge by evaporation and transpiration, and (3) the mixing of limited recharge from nearby mountains with water from the other sources. Most of the water that flows into the southeastern and eastern parts of the valley has passed through several tens of miles of coarse-grained carbonate sediments, and the water has been near chemical equilibrium with the carbonate rocks for virtually the entire flowpath. When approaching the discharge area, it is perturbed from that equilibrium by the dissolution of evaporite minerals and by interaction with igneous-rock sediments in the basin-fill materials in this corner of the valley. The fan and basin-fill deposits derived from the nearby mountains are of mixed mineralogy and contribute dissolved solids to the ground water. In addition, lake and marsh deposits underlie the lower parts of the valley (Plume, 1984, page 9), and contain some evaporites. The resultant addition of ions such as sulfate and calcium leads to a pronounced degradation of water quality in the southeastern and eastern parts of the valley. Eventually, the concentrations reach levels that restrict further dissolution of various salts, and new equilibria are established for some ions. For example, chloride salts such as halite continue to dissolve when present throughout the valley; sulfate, on the other hand, reaches an equilibrium with calcium near Las Vegas Wash, which should prevent further dissolution of gypsum. The ground water in the southeastern part of the valley was reported to contain an average of about 1,000 mg/L sulfate, 200 mg/L chloride, 200 mg/L calcium, and 2,000 mg/L dissolved solids (Malmberg, 1965, page 100). Wells 29 and 32 in the present network yield examples of the water in this part of the valley (figure 8). This chemistry plots in the Sh-Cn quadrant of the trilinear diagram, with much more sulfate and chloride than bicarbonate and more sodium than in the water farther west.

The chemistry of samples from three deep wells in the southeast part of the valley may reflect recharge originating in the volcanic rocks of the McCullough Range or ranges farther south. Palmer and Cherry (1985, page 40) suggest that even in a carbonate-rich aquifer, ground water recharged through non-carbonate rocks will not contain as much bicarbonate and calcium as water recharged through carbonate rocks. Water from wells 38, 39, and 40 (figure 8) contains sodium in unusually high proportions compared to the other cations, and contains low (40-140 mg/L) concentrations of bicarbonate. Wells in other parts of the valley that contain such low concentrations of bicarbonate are better explained by the effects of dissolving evaporites, but water from the three southeastern wells does not contain significantly larger amounts of sulfate or chloride than surrounding bicarbonate-rich waters. Thus, this water probably derives from the mountain ranges to the south.

Dinger (1977, page 125) has suggested that the evaporites in Las Vegas Valley are more prevalent in the shallow zone and thus that mineral dissolution also is most intense in the shallow zone. Some mineral dissolution at all depths is evident, however, from the transformation of ground-water chemistry at all depths (Malmberg, 1965, pages 100-101). This transformation may be indicated in figure 15A by the hydrochemical facies changes among wells 34, 35, and 33 (figure 8). These three intermediate-depth wells, although not on a single flowpath, probably are progressively farther along their respective flowpaths. The water from the first two wells is dominated by calcium, magnesium, sulfate and bicarbonate ions, whereas water in the third well is dominated by sodium, magnesium, and calcium ions, with sulfate and chloride the dominant anions. Along this chemical evolution, there is a 10-fold increase of both sulfate and chloride in water from the first two wells and the third, and bicarbonate concentrations decrease in an eastward direction to about one-third of the westernmost concentration. This decrease is probably the result of the perturbation of the carbonate equilibrium caused by the large input of sulfate and calcium, that accompanies dissolution of gypsum and other evaporites. As these minerals dissolve, sulfate, sodium, and chloride concentrations increase, while calcium and bicarbonate from the water precipitate as calcite.

In the shallow zone, along with mineral dissolution, evapotranspiration of ground water increases the concentration of chemical constituents in discharge areas of the valley floor. This process degrades the quality and affects the chemistry of the ground water where the water table is within about 20-50 feet of land surface and in other areas where local recharge can evapotransport water and dissolved solids that have been concentrated by transpiration in the unsaturated zone down to the water table and shallow ground water. Dinger (1977, page 48) reported that the average concentrations for 35 samples of ground water from within 50 feet of land surface were 1,569 mg/L sulfate, 311 mg/L chloride, 303 mg/L calcium, and 2,824 mg/L dissolved solids. During this study, the average concentrations of samples from 18 wells that tap the shallow zone where the water table was within 50 feet of land surface were 1,500 mg/L sulfate, 310 mg/L chloride, 310 mg/L calcium, and 3,000 mg/L dissolved solids.

The chemical interactions among local recharge, upward leakage of water from the deeper aquifers, dissolution of evaporites and other mineral-water reactions, and the physical influence of evapotranspiration on shallow zone are not yet adequately understood. The effects of each process on water quality in the shallow zone requires further study. Moreover, the effect of secondary recharge of Lake Mead water (with its poorer quality) as opposed to locally derived water is even less adequately understood. These relations can be determined only through much more extensive interpretive geochemical studies including use of isotope methods, equilibrium modeling, and precise determinations of the minerals in the shallow basin fill.

The extent to which the poor-quality water in the shallow zone--whatever its source may be--interacts with the deeper ground-water systems is difficult to quantify. However, the upward vertical-flow gradients in 1982 in the southeastern corner of the valley (figure 2) and the low permeability of the near-surface reservoir are likely to limit downward transport of dissolved solids from the shallow zone there, unless the gradient is reversed in the future. For instance, table 4 shows that much better quality water is produced from the deeper wells of the following well pairs: Wells 17 (intermediate depth) and 18 (shallow), wells 13 (intermediate and deep) and 14 (shallow), and wells 35 (intermediate and deep) and 36 (shallow and intermediate).

Mixing of good-quality water with even small amounts of highly saline water might significantly degrade quality in productive aquifers in some areas of the valley. In the areas where flow is downward from the shallow zone, whether through well casings or as a result of the larger scale configuration of the flow system, mixing of poor-quality shallow water with good-quality deeper water might be expected.

SUMMARY

Concern over the current (1983) and future status of ground-water quality in Las Vegas Valley has grown in recent years in response to realizations that the intense development of the ground-water resource and the growing use of water from Lake Mead might lead to large-scale deterioration of the resource in the valley. Aquifer overdraft coupled with high rates of secondary recharge from domestic and other uses could tend to contaminate the near-surface reservoir and principal aquifers of the valley with poor-quality water from the shallow zone.

The present study was designed to begin the processes of data gathering and data analysis that are necessary to support quantitative assessments of the quality and geochemistry of the ground water of Las Vegas Valley. A monitoring network for ground-water quality was designed and implemented in the valley between October 1981 and May 1983. The objectives of the network were to demonstrate the types of chemical data needed to support future analysis and to select a practical number of representative wells that may be sampled periodically in the future.

In October 1981, ground-water samples were collected from 20 shallow observation wells and 3 deeper wells to expand the data base of quality of water in the shallow zone. Next, a total of 40 wells, open to various depths and evenly distributed over the valley floor, were chosen for sampling. Samples from as many of these wells as possible, plus other wells in the valley, were collected at the beginning and end of the summer of 1982. For the samples collected, determinations were made of selected physical properties and principal chemical constituents, trace elements, nutrients, radiochemical indicators, and total organic carbon. In May 1983, a well in the southeastern corner of the valley was added to the network and sampled.

The limitations of this monitoring network are considerable, and this initial sampling program does not add greatly to the body of historical data collected during other studies. The strength of the network implemented here is that the wells chosen are expected to be available for repeated sampling in the future and are expected to be representative for detecting changes in ground-water quality conditions throughout the valley. The water-quality network described in this report was designed, to the extent possible, to meet three monitoring needs that no single network presently in place in the valley is meeting:

- Uniform areal distribution of sampling sites valley-wide.
- Samples collected from all major depth zones (shallow, intermediate, and deep).
- Repeated sampling at each site, at least once a year and preferably twice.

A network with these attributes is necessary and desirable if future water-quality studies are to resolve developing and future water-quality problems. If the 40 sites chosen here (or an equivalent group of sites) can be reassessed, sampled, and augmented periodically, the time series of data necessary for future large-scale studies of developing ground-water problems in the valley can be gathered.

The results of this preliminary evaluation indicate that the ground water in the northern half of the valley generally contains 200 to 400 milligrams per liter dissolved solids, and is dominated by calcium, magnesium, and bicarbonate ions, with only small amounts of sulfate anions. The intermediate to deep ground water in the southern half of the valley is of poorer quality, containing 700 to 1,500 milligrams per liter dissolved solids and dominated by calcium, magnesium, sulfate, and bicarbonate ions, with more sodium and potassium ions than in ground water in the northern part of the area. The poorest quality ground water in the valley is generally in the lowland parts of the valley in the first few feet beneath the water table, where dissolved solids range from 2,000 to more than 7,000 milligrams per liter and where calcium, magnesium, sodium, sulfate, and chloride ions dominate. The most common water-quality constraint on potential ground-water use is the high salinity. The shallowest ground water and, to a lesser extent, the deeper ground water in the southern half of the valley are particularly likely to contain excessive concentrations of dissolved solids.

The chemical determinations made during the implementation of the network describe the large-scale variations in ground-water chemistry in the various parts of the basin-fill aquifers. In addition, the determinations suggest that the following are principal controls on ground-water chemistry: (1) equilibria with carbonate minerals (throughout the valley); (2) equilibria with other, less common minerals including evaporites (in the southern half and in shallow water); (3) source areas of natural recharge (in the southern half); and (4) secondary recharge and evapotranspiration (in the shallow parts of the ground-water system). No large-scale contamination of deep ground water was found in this short-term study; however, sampling of shallow wells suggests that the shallowest ground water is of much poorer quality than the deeper water. Mixing of shallow and deeper ground water could significantly degrade the quality in the principal aquifers of the valley.

HYDROGEOLOGIC DATA

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*

[Analyzing agencies: 80020, U.S. Geological Survey Central Laboratory, Denver, Colo.; 32017, Las Vegas Valley Water District, Boulder City, Nev., except for nutrient, radiochemical, and total organic determinations, which were made at the U.S. Geological Survey Central Laboratory. All field determinations of specific conductance, temperature, pH, bicarbonate, and carbonate were made by Nevada staff of the U.S. Geological Survey. Abbreviations: DEG C, degrees Celsius; FET-FLD, fixed-endpoint titration in field, MG/L, milligrams per liter; PCI/L, picocuries per liter; UG/L, micrograms per liter; US/CM, microsiemens per centimeter; --, data not available.]

SITE NUMBER	DATE OF SAMPLE	AGENCY ANALYZING SAMPLE (CODE NUMBER)	SPECIFIC CONDUCTANCE (US/CM)	WATER TEMPERATURE (DEG C)	pH, FIELD (STANDARD UNITS)	pH, LAB (STANDARD UNITS)	CALCIUM, DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	BICARBONATE FET-FLD (MG/L AS HCO3)
1	05-17-82	32017	419	20.5	7.7	--	27	25	8.0	1.9	230
	08-23-82	[a]80020	382	21.0	7.9	7.4	40	24	8.8	1.6	210
	08-23-82	32017	382	21.0	7.9	--	40	24	8.5	1.0	--
2	05-17-82	32017	407	21.5	7.5	--	28	26	6.9	2.0	200
	08-23-82	32017	375	20.5	7.8	--	39	24	7.0	2.0	200
3	05-21-82	32017	880	28.0	7.7	--	49	19	79	11	170
4	05-17-82	32017	435	22.0	7.5	--	39	26	4.7	1.4	220
	08-23-82	32017	440	25.5	7.6	--	58	26	5.0	1.0	230
5	05-20-82	32017	440	22.5	7.5	--	33	27	5.7	2.0	230
	08-26-82	32017	430	23.5	7.8	--	50	25	6.0	2.0	230
6	05-20-82	32017	460	24.0	7.4	--	37	27	5.4	2.6	230
	08-26-82	32017	460	24.0	7.6	--	50	25	5.2	2.0	220
7	05-20-82	32017	600	25.0	7.5	--	45	34	7.7	3.7	210
	08-26-82	32017	560	24.0	8.0	--	59	33	7.5	3.0	210
8	10-21-81	80020	670	21.0	--	7.6	30	44	11	4.7	--
	05-17-82	32017	600	23.5	7.8	--	37	42	10	4.2	290
	08-23-82	32017	520	25.0	7.5	--	33	41	11	3.0	310
9	05-21-82	32017	460	21.0	7.5	--	32	25	6.7	1.8	220
	08-27-82	[a]80020	420	23.0	7.6	7.7	48	24	7.8	1.3	220
	08-27-82	32017	420	23.0	7.6	--	49	25	7.5	1.0	--
10	10-22-81	80020	650	21.0	--	7.9	59	30	8.8	2.3	--
	08-24-82	32017	525	22.5	7.6	--	63	31	8.0	2.0	280
11	05-21-82	[a]80020	390	24.5	7.6	7.9	46	22	6.8	1.5	220
	05-21-82	32017	390	24.5	7.6	--	35	25	6.1	1.8	--
	08-27-82	32017	410	25.0	7.7	--	48	24	6.3	1.0	220
12	05-20-82	32017	440	23.5	7.4	--	36	25	5.6	2.3	240
	08-26-82	32017	430	23.0	7.6	--	50	24	5.6	2.0	230
13	05-21-82	32017	440	23.0	7.3	--	31	27	5.6	2.3	220
	08-27-82	32017	410	23.5	7.6	--	47	26	6.0	2.0	210
14	10-21-81	80020	2,570	22.5	--	6.9	170	170	130	24	--
	05-18-82	32017	2,140	24.0	7.0	--	180	170	120	17	470
	08-23-82	32017	1,140	32.0	7.1	--	100	70	55	17	410
15	10-21-81	80020	1,190	21.0	--	7.5	97	68	26	5.1	--
	05-17-82	32017	1,250	20.0	7.5	--	130	61	27	6.5	230
	08-24-82	32017	1,200	20.0	7.4	--	170	85	26	4.0	440

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	AGENCY ANALYZING SAMPLE (CODE NUMBER)	SPECIFIC CONDUCTANCE (US/CM)	WATER TEMPERATURE (DEG C)	pH, FIELD (STANDARD UNITS)	pH, LAB (STANDARD UNITS)	CALCIUM, DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	BICARBONATE FET-FLD (MG/L AS HCO3)
16	05-20-82	32017	440	24.5	7.5	--	36	26	5.5	3.2	230
	08-26-82	32017	445	25.0	7.6	--	51	25	5.6	2.0	230
17	05-19-82	32017	400	22.0	8.0	--	12	34	7.5	4.4	190
	08-25-82	32017	420	22.0	7.6	--	28	32	7.5	3.0	200
18	08-25-82	32017	3800	24.0	6.9	--	290	290	240	43	210
19	05-18-82	32017	700	28.0	7.4	--	27	44	29	3.7	280
	08-23-82	32017	763	29.0	7.5	--	54	44	34	3.0	300
20	05-21-82	32017	640	25.5	7.7	--	12	31	78	8.9	240
	08-27-82	32017	500	25.0	7.7	--	34	28	47	8.0	240
21	10-21-81	80020	3040	21.0	--	7.7	210	280	75	9.7	--
	05-22-82	32017	2760	23.0	7.6	--	82	82	--	--	160
	08-25-82	32017	2630	21.5	7.7	--	180	280	85	12	170
22	05-18-82	32017	1240	26.5	7.4	--	110	56	17	3.7	180
	08-24-82	32017	1220	26.5	7.3	--	180	29	15	3.0	190
23	05-20-82	32017	1080	26.0	7.4	--	96	49	12	4.5	210
	08-25-82	32017	1030	25.0	7.8	--	120	55	12	4.0	190
24	10-22-81	80020	5930	23.0	--	7.5	480	510	230	14	--
	05-17-82	32017	5510	22.0	6.9	--	480	430	200	50	390
	08-24-82	32017	4940	23.0	6.6	--	520	460	230	48	380
25	05-19-82	32017	730	22.5	7.1	--	49	38	11	3.8	230
	08-24-82	[a]80020	680	23.0	7.5	7.5	72	38	13	3.2	220
	08-24-82	32017	680	23.0	7.5	--	66	38	11	3.0	--
26	05-18-82	[a]80020	[b]469	23.0	7.3	7.6	48	25	7.9	2.8	200
	05-18-82	32017	--	23.0	7.3	--	31	28	7.5	3.2	--
	08-24-82	32017	465	23.0	7.6	--	48	27	7.4	3.0	210
27	05-19-82	32017	870	23.0	7.3	--	63	43	21	5.3	240
28	10-22-81	80020	3410	21.0	--	7.6	350	210	180	7.4	--
	05-17-82	32017	3360	25.0	7.3	--	340	200	120	8.1	180
	08-23-82	32017	3300	25.0	7.3	--	310	220	210	9.0	230
29	08-25-82	32017	2630	26.5	7.4	--	280	190	91	9.0	190
30	10-20-81	80020	5620	22.0	--	7.2	490	260	440	61	--
	05-18-82	[a]80020	5050	20.0	7.1	7.2	500	260	370	57	270
	05-18-82	32017	5050	20.0	7.1	--	500	--	--	--	--
	08-24-82	32017	4470	23.0	7.1	--	403	280	410	63	300

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	AGENCY ANALYZING SAMPLE (CODE NUMBER)	SPECIFIC CONDUCTANCE (US/CM)	WATER TEMPERATURE (DEG C)	pH, FIELD (STANDARD UNITS)	pH, LAB (STANDARD UNITS)	CALCIUM, DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	BICARBONATE FET-FLD (MG/L AS HCO3)
31	05-19-82	32017	9720	19.0	7.0	--	590	370	790	120	290
	08-25-82	32017	7600	21.0	7.0	--	590	370	890	120	290
32	05-19-82	[a]80020	5660	20.0	7.1	7.3	530	210	540	71	200
	05-19-82	32017	5660	20.0	7.1	--	580	--	--	84	--
	08-25-82	32017	5150	20.5	7.6	--	410	190	500	69	200
33	10-20-81	80020	9800	25.0	--	7.5	600	420	1000	69	--
34	05-20-82	32017	1140	27.0	7.3	--	81	50	29	5.4	210
	08-26-82	[a]80020	2070	27.0	6.9	7.5	120	56	31	4.9	200
	08-26-82	32017	2070	27.0	6.9	--	130	56	32	5.0	--
35	05-19-82	32017	1450	26.5	7.2	--	110	50	48	19	200
36	05-18-82	32017	1890	24.5	7.1	--	240	67	48	8.7	190
37	05-20-82	32017	1100	23.5	7.3	--	91	50	11	3.6	180
	08-26-82	32017	2700	24.5	7.4	--	140	59	14	3.0	180
38	05-14-82	32017	1480	25.0	7.7	--	120	45	62	8.9	190
	08-25-82	32017	1230	30.0	7.8	--	78	29	160	12	38
39	05-09-83	80020	1940	30.0	7.9	--	77	9.1	300	12	140
40	05-20-82	32017	1100	24.0	8.2	--	42	25	78	18	140
	08-22-82	32017	1040	25.5	8.2	--	46	22	140	14	140

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	ALKALINITY, LAB (MG/L AS CACO3)	SULFATE, DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C, DISSOLVED (MG/L)	NITROGEN NITRITE, DISSOLVED (MG/L AS N)	NITROGEN, NO2+NO3, DISSOLVED (MG/L AS N)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)
1	05-17-82	--	24	10	0.30	15	274	<0.020	0.26	0.080
	08-23-82	189	19	4.2	.30	18	260	<.020	.54	<.010
	08-23-82	--	12	5.0	.35	15	224	--	--	--
2	05-17-82	--	29	6.0	.24	20	306	<.020	.51	.010
	08-23-82	--	10	6.0	.36	16	212	<.020	.53	.040
3	05-21-82	--	160	52	2.8	51	497	<.020	.80	.020
4	05-17-82	--	39	6.0	.23	11	309	<.020	3.5	.020
	08-23-82	--	23	15	.24	14	260	<.020	.39	.020
5	05-20-82	--	28	8.0	.18	12	231	<.020	.37	.020
	08-26-82	--	26	6.0	.25	12	248	<.020	.38	.020
6	05-20-82	--	44	9.0	.26	11	269	<.020	.46	.010
	08-26-82	--	64	6.0	.28	11	252	<.020	.54	.020
7	05-20-82	--	130	11	.28	13	354	<.020	.84	.020
	08-26-82	--	100	7.5	.29	12	364	<.020	1.1	<.010
8	10-21-81	230	43	4.7	.80	64	321	--	.11	--
	05-17-82	--	41	14	.95	65	300	--	--	--
	08-23-82	--	25	3.0	.96	92	328	<.020	.13	.040
9	05-21-82	--	30	10	.25	13	249	<.020	.36	.010
	08-27-82	180	36	5.0	.20	17	340	<.020	.36	.010
	08-27-82	--	21	6.0	.26	13	240	--	--	--
10	10-22-81	220	63	7.5	.30	21	337	--	.60	--
	08-24-82	--	34	7.0	.34	18	324	<.020	.36	.020
11	05-21-82	190	33	3.5	.20	14	223	<.020	.30	.020
	05-21-82	--	27	6.0	.17	13	240	--	--	--
	08-27-82	--	24	4.0	.31	13	240	<.020	.63	.020
12	05-20-82	--	30	9.0	.30	13	229	<.020	.44	.010
	08-26-82	172	30	6.5	.31	12	236	<.020	.44	.010
13	05-21-82	--	36	13	.22	12	257	<.020	.40	.020
	08-27-82	--	39	9.0	.28	15	236	<.020	.43	<.010
14	10-21-81	470	740	170	.40	49	1,820	--	7.7	--
	05-18-82	--	860	140	.32	35	1,780	.030	4.2	.160
	08-23-82	--	120	252	.46	26	756	.030	2.0	.630
15	10-21-81	190	250	94	.20	24	726	--	1.7	--
	05-17-82	--	290	110	.20	21	680	<.020	1.7	.030
	08-24-82	--	250	130	.28	17	896	<.020	2.6	.040

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	ALKALINITY, LAB (MG/L AS CACO3)	SULFATE, DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C, DISSOLVED (MG/L)	NITROGEN NITRITE, DISSOLVED (MG/L AS N)	NITROGEN, NO2+NO3, DISSOLVED (MG/L AS N)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)
16	05-20-82	--	34	8.0	0.24	14	234	<0.020	0.42	0.020
	08-26-82	--	34	4.5	.31	12	260	<.020	.43	<.010
17	05-19-82	--	44	9.0	.45	21	226	.020	.33	.160
	08-25-82	--	43	8.5	.52	28	248	<.020	.51	.030
18	08-25-82	--	1500	3.7	.37	64	3300	<.020	.35	.020
19	05-18-82	--	91	27	.44	29	409	<.020	2.5	.020
	08-23-82	--	72	24	.50	27	468	<.020	3.4	.010
20	05-21-82	--	120	6.0	1.4	11	437	<.020	.60	.020
	08-27-82	--	72	9.5	1.4	31	420	<.020	.71	.010
21	10-21-81	130	1200	290	.80	67	2430	--	18	--
	05-22-82	--	2100	110	.72	71	--	.020	18	.030
	08-25-82	--	1200	230	.77	74	2360	.020	1.9	.090
22	05-18-82	--	410	19	.33	15	857	<.020	.62	.010
	08-24-82	--	340	14	.37	12	952	<.020	.58	.030
23	05-20-82	--	340	16	.32	11	769	<.020	.79	.010
	08-25-82	--	280	11	.41	11	776	<.020	.80	<.010
24	10-22-81	320	2800	480	.20	48	5160	--	14	--
	05-17-82	--	2700	230	.25	52	5140	<.020	9.8	.020
	08-24-82	--	3500	250	.37	50	5000	<.020	1.1	.030
25	05-19-82	--	140	17	--	15	429	<.020	.93	.010
	08-24-82	162	170	10	.20	16	472	<.020	.92	<.010
	08-24-82	--	130	14	.30	17	440	--	--	--
26	05-18-82	170	61	5.1	.30	17	260	<.020	.40	.030
	05-18-82	--	52	12	.34	18	--	--	--	--
	08-24-82	--	57	10	.35	14	256	<.020	.61	.010
27	05-19-82	--	220	23	.28	15	549	<.020	1.6	.010
28	10-22-81	150	1500	250	.30	15	2740	--	2.8	--
	05-17-82	--	1400	210	.31	16	2710	<.020	2.8	.020
	08-23-82	--	1600	240	.33	17	3000	.040	3.7	.020
29	08-25-82	--	1400	240	.36	19	2260	<.020	4.7	.020
30	10-20-81	230	2500	370	.50	61	4730	--	5.9	--
	05-18-82	230	2300	340	.50	54	4190	<.020	3.3	.030
	05-18-82	--	--	350	.56	62	3650	--	--	--
	08-24-82	--	2400	350	.59	54	4340	<.020	7.6	.010

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	ALKALINITY, LAB (MG/L AS CACO3)	SULFATE, DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C, DISSOLVED (MG/L)	NITROGEN NITRITE, DISSOLVED (MG/L AS N)	NITROGEN, NO2+NO3, DISSOLVED (MG/L AS N)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)
31	05-19-82	--	2500	1500	1.7	100	7200	<0.020	4.7	0.020
	08-25-82	--	2400	1500	1.5	7	6570	.020	5.4	.010
32	05-19-82	170	2000	750	1.2	58	4350	.020	7.8	.020
	05-19-82	--	1800	800	.8	75	4300	--	--	--
	08-25-82	--	1300	860	.94	9.8	3940	.020	.76	.010
33	10-20-81	49	3500	1500	.70	19	7460	--	5.6	--
34	05-20-82	--	270	87	.53	12	697	<.020	.38	.010
	08-26-82	173	300	84	.40	18	780	<.020	.44	<.010
	08-26-82	--	280	90	.51	19	800	--	--	--
35	05-19-82	--	360	110	.77	19	1000	<.020	.50	.010
36	05-18-82	--	900	66	.45	17	1410	<.020	1.3	.010
37	05-20-82	--	310	15	.32	12	723	<.020	.79	<.010
	08-26-82	--	370	13	.37	14	732	<.020	.79	.020
38	05-14-82	--	240	210	.66	21	849	<.020	1.0	.010
	08-25-82	--	170	230	.69	4.0	708	<.020	<.10	.010
39	05-09-83	--	690	59	1.7	47	--	--	--	--
40	05-20-82	--	230	94	.67	66	669	<.020	1.2	.010
	08-22-82	--	180	110	.75	66	664	<.020	1.2	.010

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	ARSENIC, DIS- SOLVED (UG/L AS AS)	BARIUM, DIS- SOLVED (UG/L AS BA)	BORON, DIS- SOLVED (UG/L AS B)	CADMIUM, DIS- SOLVED (UG/L AS CD)	CHRO- MIUM, DIS- SOLVED (UG/L AS CR)	COPPER, DIS- SOLVED (UG/L AS CU)	IRON, DIS- SOLVED (UG/L AS FE)	LEAD, DIS- SOLVED (UG/L AS PB)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)
1	05-17-82	1	130	250	<1	3	<25	12	<5	6
	08-23-82	1	130	40	<1	<1	4	7	2	2
	08-23-82	<1	<250	230	<1	<2	<20	3	<3	<2
2	05-17-82	1	140	180	<.1	2	<25	--	<5	2
	08-23-82	<1	<250	230	<1	3	<20	8	11	<2
3	05-21-82	31	<50	230	<.1	<2	<25	<10	<5	4
4	05-17-82	.6	60	220	<.1	<2	<25	<10	<5	1
	08-23-82	<1	<250	230	<1	<2	<20	3	<3	<2
5	05-20-82	1	70	170	<.1	<2	<25	<10	<5	1
	08-26-82	<1	<250	240	<1	<2	<20	<2	<3	<2
6	05-20-82	1	50	180	<.1	<2	<25	<10	<5	.6
	08-26-82	<1	<250	230	<1	<2	<20	<2	<3	<2
7	05-20-82	5	<50	260	3	<2	<25	14	<5	1
	08-26-82	<1	<250	260	<1	<2	<20	<2	<3	<2
8	10-21-81	--	--	--	--	--	--	--	--	--
	05-17-82	3	90	190	<.1	<2	<25	84	<5	12
	08-23-82	2	<250	190	<1	3	<20	480	12	50
9	05-21-82	2	70	200	<.1	<2	<25	<10	<5	.6
	08-27-82	2	100	40	<1	3	2	4	<1	1
	08-27-82	<1	<250	230	<1	<2	<20	6	<3	<2
10	10-22-81	--	--	--	--	--	--	--	--	--
	08-24-82	<1	<250	340	<1	<2	<20	28	<3	40
11	05-21-82	2	120	30	<3	<1	1	<9	<1	<3
	05-21-82	2	100	190	<.1	<2	<25	<10	<5	1
	08-27-82	<1	<250	230	<1	<2	<20	3	<3	<2
12	05-20-82	2	60	250	<.1	<2	<25	47	<5	2
	08-26-82	<1	<250	180	<1	<2	<20	<2	<3	<2
13	05-21-82	.8	80	280	<.1	<2	<25	<10	<5	.8
	08-27-82	<1	<250	310	<1	<2	<20	22	<3	<2
14	10-21-81	--	--	--	--	--	--	--	--	--
	05-18-82	3	<50	<250	<.1	<2	<25	<10	<5	68
	08-23-82	6	<250	280	<1	<2	20	640	36	180
15	10-21-81	--	--	--	--	--	--	--	--	--
	05-17-82	4	<50	370	<.1	<2	<25	11	<5	4
	08-24-82	8	250	390	1	2	20	2500	3	80

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	ARSENIC, DIS- SOLVED (UG/L AS AS)	BARIUM, DIS- SOLVED (UG/L AS BA)	BORON, DIS- SOLVED (UG/L AS B)	CADMIUM, DIS- SOLVED (UG/L AS CD)	CHRO- MIUM, DIS- SOLVED (UG/L AS CR)	COPPER, DIS- SOLVED (UG/L AS CU)	IRON, DIS- SOLVED (UG/L AS FE)	LEAD, DIS- SOLVED (UG/L AS PB)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)
16	05-20-82	2	60	210	1	<2	<25	<10	<5	14
	08-26-82	<1	<250	260	<1	2	<20	3	<3	<2
17	05-19-82	2	<50	200	<.1	<2	<25	12	<5	11
	08-25-82	<1	<250	190	<1	<2	<20	7	<3	6
18	08-25-82	<1	<250	440	<1	<2	<20	4600	40	27
19	05-18-82	4	90	200	1	<2	<25	<10	<5	2
	08-23-82	1	<250	290	<1	<2	<20	27	<3	3
20	05-21-82	15	80	260	<.1	<2	<25	<10	<5	2
	08-27-82	<1	<250	340	1	4	<20	4	<3	<2
21	10-21-81	--	--	--	--	--	--	--	--	--
	05-22-82	--	<50	340	1	<2	<20	16	<5	12
	08-25-82	3	<250	340	<1	3	<20	12	12	150
22	05-18-82	1	<50	270	<.1	<2	<25	23	<5	5
	08-24-82	<1	<250	340	<1	<2	<20	9	<3	<2
23	05-20-82	2	<50	260	<.1	<2	<25	25	<5	5
	08-25-82	<1	<250	270	<1	<2	<20	16	<3	8
24	10-22-81	--	--	--	--	--	--	--	--	--
	05-17-82	2	<50	600	1	<2	<25	19	5	20
	08-24-82	<1	<250	490	<1	<2	<20	32	5	6
25	05-19-82	2	<50	220	<.1	<2	25	15	<5	2
	08-24-82	1	46	90	<1	4	2	<3	1	<1
	08-24-82	<1	<250	230	<1	<2	<20	3	<3	<2
26	05-18-82	2	62	50	<3	2	1	<9	<1	<3
	05-18-82	2	60	230	<.1	<2	<25	<10	<5	1
	08-24-82	1	<250	480	<1	<2	<20	3	<3	<2
27	05-19-82	1	50	350	<.1	<2	<25	28	<5	7
28	10-22-81	--	--	--	--	--	--	--	--	--
	05-17-82	1	<50	<250	.3	<2	<25	15	<5	15
	08-23-82	1	<250	370	<1	<2	<20	23	46	60
29	08-25-82	<1	<250	180	<1	<2	<20	23	4	10
30	10-20-81	--	--	--	--	--	--	--	--	--
	05-18-82	10	<100	2600	<1	2	1	90	1	20
	05-18-82	6	<50	<250	<.1	<2	<25	16	<5	10
	08-24-82	2	<250	580	<1	<2	<20	300	48	14

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	ARSENIC, DIS-SOLVED (UG/L AS AS)	BARIUM, DIS-SOLVED (UG/L AS BA)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM, DIS-SOLVED (UG/L AS CD)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, DIS-SOLVED (UG/L AS PB)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)
31	05-19-82	30	<50	<250	<0.1	<2	<25	455	<5	110
	08-25-82	17	<250	630	<1	7	60	1000	32	60
32	05-19-82	34	<100	1300	<1	50	2	240	<1	200
	05-19-82	10	<50	<250	<.1	40	<25	460	<5	180
	08-25-82	8	<250	630	<1	30	<20	1400	7	290
33	10-20-81	--	--	--	--	--	--	--	--	--
34	05-20-82	1	<50	240	4	<2	<25	53	<5	0.6
	08-26-82	1	26	140	<1	<1	2	31	1	5
	08-26-82	<1	<250	310	<1	<2	<20	54	<3	11
35	05-19-82	11	<50	270	<.1	<2	<25	51	<5	7
36	05-18-82	7	<50	300	<.1	<2	<25	77	<5	5
37	05-20-82	2	<50	360	<.1	<2	<25	47	<5	--
	08-26-82	<1	<250	340	<1	<2	<20	69	<3	14
38	05-14-82	10	<50	330	<.1	<25	<25	49	<5	3
	08-25-82	<1	<250	300	<1	<2	<20	980	<3	130
39	05-09-83	350	16	1400	<1	--	<10	17	<10	35
40	05-20-82	18	<50	320	<.1	5	<25	960	<5	9
	08-22-82	8	<250	320	<1	7	<20	27	<3	3

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	MERCURY, DIS-SOLVED (UG/L AS HG)	NICKEL, DIS-SOLVED (UG/L AS NI)	SELE-NIUM, DIS-SOLVED (UG/L AS SE)	SILVER, DIS-SOLVED (UG/L AS AG)	ZINC, DIS-SOLVED (UG/L AS ZN)	GROSS ALPHA, DIS-SOLVED (UG/L AS U-NAT)	GROSS BETA, DIS-SOLVED (PCI/L AS CS-137)	GROSS BETA, DIS-SOLVED (PCI/L AS SR/Y-90)	CARBON, ORGANIC TOTAL (MG/L AS C)
1	05-17-82	<1.0	<20	<0.5	<12	160	<10	<6.2	<5.9	<0.10
	08-23-82	1.3	<1	1	<1	160	--	--	--	<.10
	08-23-82	--	<20	<2	<12	160	--	--	--	--
2	05-17-82	1.0	<20	<.5	<12	80	<10	<6.7	<6.4	<.10
	08-23-82	--	<20	<2	<12	120	--	--	--	1.0
3	05-21-82	1.0	<20	<.5	<12	110	<19	9.1	8.8	.20
4	05-17-82	1.0	<20	<.5	<12	130	<15	<7.1	<6.8	<.10
	08-23-82	--	<20	<2	<12	160	--	--	--	.30
5	05-20-82	1.0	<20	<.5	<12	10	<9.8	<5.1	<5.0	<.10
	08-26-82	--	<20	<2	<12	<50	--	--	--	.30
6	05-20-82	1.0	<20	<.5	<12	10	<11	<5.6	<5.4	<.10
	08-26-82	--	<20	<2	<12	<50	--	--	--	<.10
7	05-20-82	1.0	<20	<.5	<12	10	<11	<4.7	<4.5	<.10
	08-26-82	--	<20	<2	<12	<50	--	--	--	<.10
8	10-21-81	--	--	--	--	--	--	--	--	--
	05-17-82	1.0	<20	<.5	<12	50	<16	<9.3	<9.0	8.4
	08-23-82	--	<20	<2	<12	<50	--	--	--	13
9	05-21-82	1.0	<20	<.5	<12	10	<10	<6.6	<6.3	.60
	08-27-82	.4	<1	1	<1	9	--	--	--	<.10
	08-27-82	--	<20	<2	<12	<50	--	--	--	--
10	10-22-81	--	--	--	--	--	--	--	--	--
	08-24-82	--	20	<2	<12	<50	--	--	--	.90
11	05-21-82	<.1	<1	1	<1	<12	<8.8	<6.3	<6.0	<.10
	05-21-82	<1.0	<20	<.5	<12	5	--	--	--	--
	08-27-82	--	<20	<2	<12	<50	--	--	--	<.10
12	05-20-82	<1.0	<20	<.5	<12	10	18	<7.2	<6.8	<.10
	08-26-82	--	<20	<2	<12	<50	--	--	--	1.0
13	05-21-82	<.1	<20	<.5	<12	<250	<8.3	<3.4	<3.2	<.10
	08-27-82	--	30	<2	<12	<50	--	--	--	.20
14	10-21-81	--	--	--	--	--	--	--	--	--
	05-18-82	<1.0	<20	<.5	<12	40	<85	<39	<38	6.9
	08-23-82	--	40	<2	<12	<50	--	--	--	11
15	10-21-81	--	--	--	--	--	--	--	--	--
	05-17-82	1.0	<20	1	<12	20	<23	<17	<16	2.2
	08-24-82	--	40	2	12	50	--	--	--	7.5

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	MERCURY, DIS- SOLVED (UG/L AS HG)	NICKEL, DIS- SOLVED (UG/L AS NI)	SELE- NIUM, DIS- SOLVED (UG/L AS SE)	SILVER, DIS- SOLVED (UG/L AS AG)	ZINC, DIS- SOLVED (UG/L AS ZN)	GROSS ALPHA, DIS- SOLVED (UG/L AS U-NAT)	GROSS BETA, DIS- SOLVED (PCI/L AS CS-137)	GROSS BETA, DIS- SOLVED (PCI/L AS SR/ Y-90)	CARBON, ORGANIC TOTAL (MG/L AS C)
16	05-20-82	<1.0	<20	<0.5	<12	10	<11	<6.7	<6.4	0.50
	08-26-82	--	<20	<2	<12	<50	--	--	--	<.10
17	05-19-82	<1.0	<20	<.5	<12	4	<9.9	<6.4	<6.1	.60
	08-25-82	--	<20	<2	<12	<50	--	--	--	.90
18	08-25-82	--	160	<2	<12	<50	--	--	--	7.0
19	05-18-82	<1.0	<20	<.5	<12	80	<15	<8.2	<7.9	.10
	08-23-82	--	<20	<2	<12	120	--	--	--	.40
20	05-21-82	1.0	<20	<.5	<12	10	<16	<13	<12	<.10
	08-27-82	--	<20	<2	<12	<50	--	--	--	.30
21	10-21-81	--	--	--	--	--	--	--	--	--
	05-22-82	<1.0	--	<.5	<12	--	<55	<24	<23	13
	08-25-82	--	100	<2	<12	220	--	--	--	20
22	05-18-82	<1.0	<20	<.5	<12	40	<32	<16	<16	<.10
	08-24-82	--	40	<2	<12	80	--	--	--	<.10
23	05-20-82	<1.0	<20	<.5	<12	20	<19	<9.2	<8.8	1.0
	08-25-82	--	30	<2	<12	<50	--	--	--	.60
24	10-22-81	--	--	--	--	--	--	--	--	--
	05-17-82	1.0	<20	.5	<12	220	<200	<98	<94	3.6
	08-24-82	--	280	<2	<12	<50	--	--	--	3.6
25	05-19-82	1.0	<20	<.5	<12	10	<14	<6.2	<5.9	<.10
	08-24-82	.6	<1	2	<1	28	--	--	--	<.10
	08-24-82	--	<20	<2	<12	<50	--	--	--	--
26	05-18-82	<.1	<1	1	<1	12	<9.4	<5.6	<5.4	<.10
	05-18-82	<1.0	<20	<.5	<12	50	--	--	--	--
	08-24-82	--	<20	<2	12	<50	--	--	--	.30
27	05-19-82	<1.0	<20	<.5	<12	5	<20	<7.3	<6.9	1.1
28	10-22-81	--	--	--	--	--	--	--	--	--
	05-17-82	<1.0	<2	.6	<12	20	<79	<33	<31	3.1
	08-23-82	--	150	<2	<12	<50	--	--	--	3.7
29	08-25-82	--	110	<2	<12	90	--	--	--	.70
30	10-20-81	--	--	--	--	--	--	--	--	--
	05-18-82	.1	1	5	<1	20	<140	<81	78	3.9
	05-18-82	1.0	<20	<.5	<12	20	--	--	--	--
	08-24-82	--	200	<2	<12	<50	--	--	--	3.7

TABLE 4.--*Chemical and physical analyses of water from wells selected for inclusion in final network*--Continued

SITE NUMBER	DATE OF SAMPLE	MERCURY, DIS-SOLVED (UG/L AS HG)	NICKEL, DIS-SOLVED (UG/L AS NI)	SELE-NIUM, DIS-SOLVED (UG/L AS SE)	SILVER, DIS-SOLVED (UG/L AS AG)	ZINC, DIS-SOLVED (UG/L AS ZN)	GROSS ALPHA, DIS-SOLVED (UG/L AS U-NAT)	GROSS BETA, DIS-SOLVED (PCI/L AS CS-137)	GROSS BETA, DIS-SOLVED (PCI/L AS SR/Y-90)	CARBON, ORGANIC TOTAL (MG/L AS C)
31	05-19-82	1.0	<20	<0.5	<12	30	<230	<110	<110	5.1
	08-25-82	--	7000	<2	<12	140	--	--	--	5.9
32	05-19-82	.2	4	7	<1	30	<110	<55	<53	2.7
	05-19-82	<1.0	<20	.5	<12	10	--	--	--	--
	08-25-82	--	1100	<2	<12	100	--	--	--	2.6
33	10-20-81	--	--	--	--	--	--	--	--	--
34	05-20-82	1.0	<20	<.5	<12	1000	<22	<10	<9.6	<.10
	08-26-82	.5	<1	3	<1	420	--	--	--	.60
	08-26-82	--	70	<2	12	510	--	--	--	--
35	05-19-82	1.0	<20	<.5	<12	10	<29	<13	<13	<.10
36	05-18-82	--	<20	<.5	<12	100	<49	<25	<24	.90
37	05-20-82	<1.0	<20	<.5	<12	170	<20	<8.5	<8.2	--
	08-26-82	--	40	<2	<12	<50	--	--	--	.40
38	05-14-82	<1.0	<20	<.5	<12	20	<26	15	15	<.10
	08-25-82	--	50	<2	<12	<50	<16	<11	<11	.60
39	05-09-83	--	--	--	--	24	--	--	--	--
40	05-20-82	1.0	<20	<.5	<12	180	<18	10	10	.60
	08-22-82	--	80	<2	<12	<50	<18	11	10	--

[a] Duplicate sample, analyzed by both laboratories.

[b] Laboratory measurement of specific conductance.

TABLE 5.--*Chemical and physical analyses for water from other wells sampled during the study*

[Analyzing agencies: 80020, U.S. Geological Survey Central Laboratory, Denver, Colo.; 32017, Las Vegas Valley Water District, Boulder City, Nev., except for nutrient, radiochemical, and total organic determinations, which were made at the U.S.Geological Survey Central Laboratory. All field determinations of specific conductance, temperature, pH, bicarbonate, and carbonate were made by Nevada staff of the U.S. Geological Survey. Abbreviations: DEG C, degrees Celsius; FET-FLD, fixed-endpoint titration in field; MG/L, milligrams per liter; PCI/L, picocuries per liter; UG/L, micrograms per liter; US/CM, microsiemens per centimeter; --, data not available.]

SITE NUMBER	DATE OF SAMPLE	AGENCY ANALYZING SAMPLE (CODE NUMBER)	SPECIFIC CONDUCTANCE (US/CM)	WATER TEMPERATURE (DEG C)	pH, FIELD (STANDARD UNITS)	pH, LAB (STANDARD UNITS)	CALCIUM, DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	BICARBONATE FET-FLD (MG/L AS HCO3)
41	10-23-81	80020	395	23.0	--	8.0	37	27	11	3.1	--
42	10-22-81	80020	465	20.0	--	8.1	35	26	17	4.0	--
43	10-21-81	80020	555	23.5	--	8.1	46	25	14	13	--
44	10-21-81	80020	740	22.0	--	7.5	41	49	20	3.2	--
45	10-21-81	80020	1720	21.5	--	7.0	130	120	52	9.4	--
46	10-19-81	80020	2230	22.0	--	7.0	130	120	85	55	--
47	08-27-82	32017	750	25.0	7.7	--	62	44	65	8	200
48	10-20-81	80020	6000	25.0	--	7.1	370	320	530	28	--
49	10-19-81	80020	1750	22.0	--	7.2	130	67	120	22	--
50	10-22-81	80020	2780	21.0	--	7.9	170	140	230	14	--
51	10-19-81	80020	3320	24.5	--	7.5	420	200	130	28	--
52	05-18-82	32017	4620	22.5	7.1	--	42	170	250	78	810
53	10-20-81	80020	6480	22.0	--	7.4	610	410	340	20	--
54	10-20-81	80020	6030	23.0	--	7.0	570	240	520	55	--
55	10-23-81	80020	108000	22.5	--	7.3	200	7500	13000	12	--
56	10-20-81	80020	4090	19.5	--	6.6	480	220	170	23	--

SITE NUMBER	DATE OF SAMPLE	ALKALINITY LAB (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)
41	10-23-81	190	23	11	0.30	21	233	--	0.76	--
42	10-22-81	170	40	7.2	.70	24	268	--	.83	--
43	10-21-81	200	48	4.9	.50	21	286	--	<.09	--
44	10-21-81	250	76	10	.80	59	414	--	.15	--
45	10-21-81	220	560	60	.20	25	1220	--	3.2	--
46	10-19-81	330	570	120	.20	45	1440	--	3.0	--
47	08-27-82	--	170	51	1.8	77	528	<0.020	1.6	0.020
48	10-20-81	230	2400	420	.20	30	4780	--	5.1	--
49	10-19-81	190	480	130	.40	28	1130	--	.48	--
50	10-22-81	200	1000	170	.40	23	2050	--	<.09	--
51	10-19-81	250	1600	150	.70	48	2890	--	.11	--
52	05-18-82	--	1400	300	.31	400	2460	.270	.79	2.30
53	10-20-81	150	2900	650	.70	38	5400	--	1.2	--
54	10-20-81	430	2400	650	1.1	55	4970	--	1.3	--
55	10-23-81	200	23000	23000	.00	7.0	102000	--	<.09	--
56	10-20-81	210	1800	280	.60	30	3390	--	6.2	--

TABLE 5.--*Chemical and physical analyses for water from other wells sampled during the study*--Continued

SITE NUMBER	DATE OF SAMPLE	ARSENIC DISSOLVED (UG/L AS AS)	BARIUM, DISSOLVED (UG/L AS BA)	BORON, DISSOLVED (UG/L AS B)	CADMIUM DISSOLVED (UG/L AS CD)	CHROMIUM, DISSOLVED (UG/L AS CR)	COPPER, DISSOLVED (UG/L AS CU)	IRON, DISSOLVED (UG/L AS FE)	LEAD, DISSOLVED (UG/L AS PB)	MANGANESE, DISSOLVED (UG/L AS MN)
41	10-23-81	--	--	--	--	--	--	--	--	--
42	10-22-81	--	--	--	--	--	--	--	--	--
43	10-21-81	--	--	--	--	--	--	--	--	--
44	10-21-81	--	--	--	--	--	--	--	--	--
45	10-21-81	--	--	--	--	--	--	--	--	--
46	10-19-81	--	--	--	--	--	--	--	--	--
47	08-27-82	11	<250	280	<1	3	<20	23	<3	<2
48	10-20-81	--	--	--	--	--	--	--	--	--
49	10-19-81	--	--	--	--	--	--	--	--	--
50	10-22-81	--	--	--	--	--	--	--	--	--
51	10-19-81	--	--	--	--	--	--	--	--	--
52	05-18-82	2	80	<250	<0.1	<2	<25	56	<5	97
53	10-20-81	--	--	--	--	--	--	--	--	--
54	10-20-81	--	--	--	--	--	--	--	--	--
55	10-23-81	--	--	--	--	--	--	--	--	--
56	10-20-81	--	--	--	--	--	--	--	--	--

SITE NUMBER	DATE OF SAMPLE	MERCURY DISSOLVED (UG/L AS HG)	NICKEL, DISSOLVED (UG/L AS NI)	SELENIUM, DISSOLVED (UG/L AS SE)	SILVER, DISSOLVED (UG/L AS AG)	ZINC, DISSOLVED (UG/L AS ZN)	GROSS ALPHA, DISSOLVED (UG/L AS U-NAT)	GROSS BETA, DISSOLVED (PCI/L AS CS-137)	GROSS BETA, DISSOLVED (PCI/L AS SR/Y-90)	CARBON, ORGANIC TOTAL (MG/L AS C)
41	10-23-81	--	--	--	--	--	--	--	--	--
42	10-22-81	--	--	--	--	--	--	--	--	--
43	10-21-81	--	--	--	--	--	--	--	--	--
44	10-21-81	--	--	--	--	--	--	--	--	--
45	10-21-81	--	--	--	--	--	--	--	--	--
46	10-19-81	--	--	--	--	--	--	--	--	--
47	08-27-82	--	30	<3	<12	<50	<15	8.2	7.9	0.20
48	10-20-81	--	--	--	--	--	--	--	--	--
49	10-19-81	--	--	--	--	--	--	--	--	--
50	10-22-81	--	--	--	--	--	--	--	--	--
51	10-19-81	--	--	--	--	--	--	--	--	--
52	05-18-82	2.0	<20	2	<12	10	<98	<46	<44	9.7
53	10-20-81	--	--	--	--	--	--	--	--	--
54	10-20-81	--	--	--	--	--	--	--	--	--
55	10-23-81	--	--	--	--	--	--	--	--	--
56	10-20-81	--	--	--	--	--	--	--	--	--

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