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Quality of Ground Water Beneath Urban and Agricultural Lands in Las Vegas Valley and the Carson and Truckee River Basins, Nevada—Implications for Water Supply

Water-Resources Investigations Report 97-4259

Nevada Basin and Range Study Unit
National Water-Quality Assessment Program

By Michael S. Lico

ABSTRACT

As part of the U.S. Geological Survey's National Water-Quality Assessment Program, water-quality data were collected from wells in the Carson and Truckee River Basins and the Las Vegas area of Nevada during 1993-95. The data were evaluated to identify contaminants introduced to shallow water-table aquifers by land-use activities and to determine water-quality conditions in the underlying principal aquifers. Water samples were collected from shallow water-table wells and from deeper wells completed in the principal aquifers in the Carson Valley and Carson Desert agricultural areas, and in the Reno-Sparks and Las Vegas urban areas.

Results of chemical analyses indicate that the shallow water-table aquifers have a natural water quality that is highly variable. In headwater areas where precipitation is sufficient to produce ground-water recharge and surface runoff (Carson Valley and the Reno-Sparks area), concentrations of most dissolved constituents are lower than in the dryer basin areas (Carson Desert and Las Vegas area). Superimposed on this natural variability in water quality are the effects of land use, which are indicated by detections of manmade organic compounds [pesticides, volatile organic compounds (VOC's), methylene blue active substances (MBAS), and phenols] and of nitrate (from sewage or fertilizers).

Small concentrations of manmade organic compounds are present in many samples from principal aquifers, which indicate that some water from the shallow water-table aquifers is moving into the principal aquifers. Nonetheless, the principal aquifers generally are not contaminated to the point of endangerment to the human population using this resource.

Areas where the hydraulic gradient is downward due to natural conditions or ground-water pumping, or where no confining layers separate the shallow water-table and principal aquifers, are susceptible to contamination. Disturbance of confining layers also can increase the potential for contamination. Several mechanisms exist that could compromise the integrity of confining layers; these include subsidence and fissuring of the confining layer due to over-pumping of an aquifer, fracture or collapse of a well casing due to subsidence, improper well construction, and movement of water in abandoned or nonpumping wells. Another mechanism to move contaminants into principal aquifers is by artificial recharge of the aquifers with water containing contaminants.

INTRODUCTION

The Nevada Basin and Range (NVBR) study unit of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program is investigating the status of, trends in, and factors affecting water quality in the Carson and Truckee River Basins and Las Vegas Valley (fig. 1). One component of the NVBR NAWQA was to determine the quality of shallow ground water and examine relations of this quality to the overlying land use. Another component was to determine the quality of ground water in principal aquifers.

Ground water is an important source of water for municipalities and agriculture in the NVBR study area. One of the important issues facing the State of Nevada is its rapid urbanization and all the associated effects from this changing land use.

Rapid growth in the urban areas of Nevada makes it one of the fastest growing, most urbanized states in the Nation. Here, downtown Reno, the largest city in northern Nevada, is shown in March 1998.

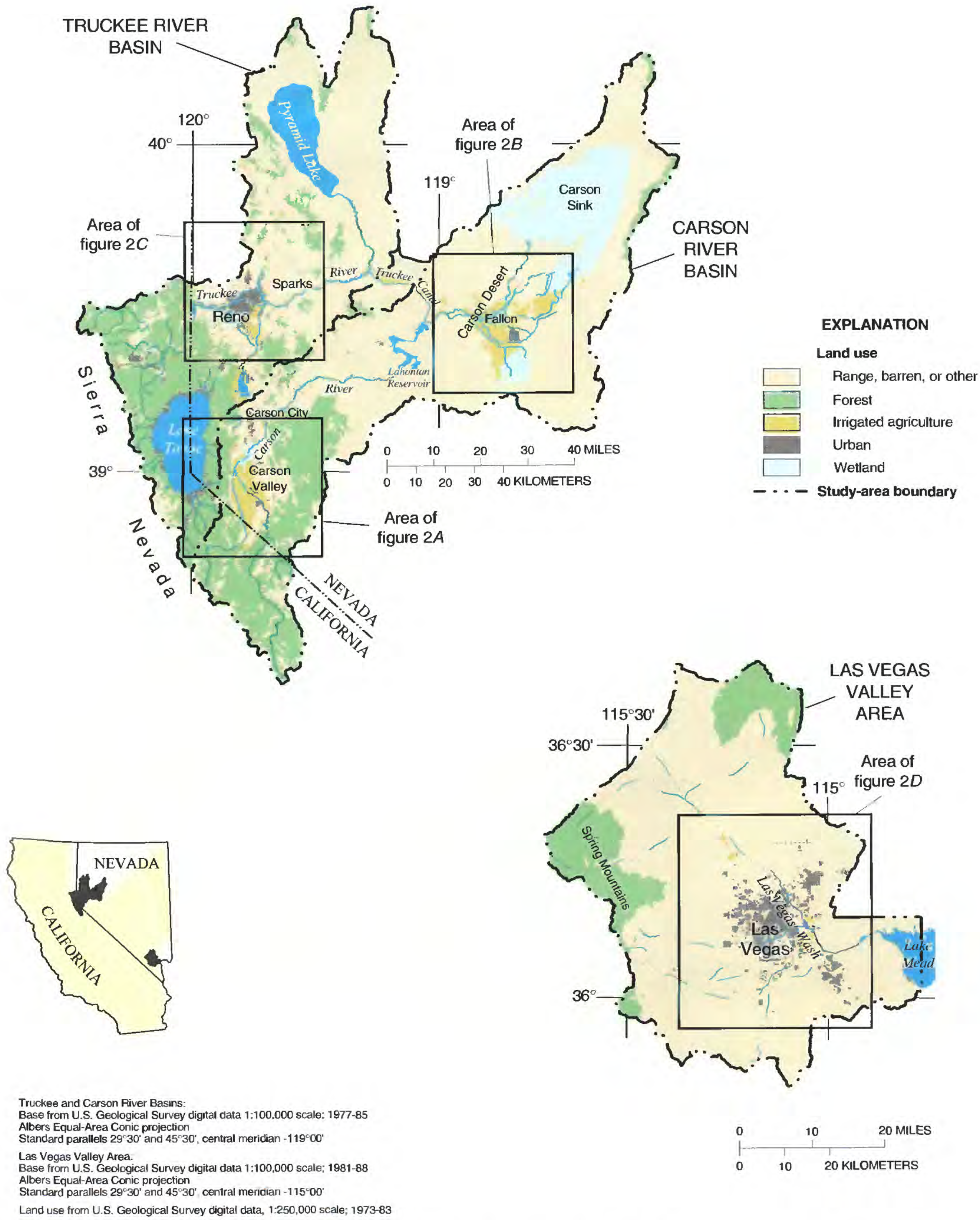


Figure 1. General physiographic features of the Nevada Basin and Range study unit, National Water-Quality Assessment Program.

Agricultural and range lands are being converted to urban uses at an increasing rate, especially in the Reno-Sparks and Las Vegas areas. Water-quality changes resulting from urban and agricultural activities could affect water supplies.

Purpose and Scope

The purpose of this report is to (1) characterize water quality of the shallow water-table aquifers; (2) determine if land use (from different human activities) has influenced water quality in the water-table aquifers; and (3) assess whether water in principal aquifers has been affected by the overlying shallow ground water.

This report evaluates ground water in parts of the Carson Valley and Carson Desert Hydrographic Areas[1] in the Carson River Basin, the Truckee Meadows Hydrographic Area in the Truckee River Basin, and the Las Vegas Valley Hydrographic Area in the Colorado River Basin. Ground-water-quality data were collected in these areas by NVBR personnel during 1993-95. In addition, major- and minor-element and isotope data from two previous studies, with adequately documented quality assurance, were used for comparisons in this report. One of these studies (Lico and others, 1987) investigated the geochemistry of arsenic in the Carson Desert (during 1984-86) and the other (Lico and Seiler, 1994; Welch, 1994; Whitney, 1994) was a pilot NAWQA study of the Carson River Basin (during 1987-90).

Description of Environmental Setting

The NVBR study area has climatic zones ranging from high-altitude alpine tundra to low-altitude desert. Typically, annual precipitation varies directly with altitude within the study area—the high mountains, including the Sierra Nevada and Spring Mountains, receive an average of more than 20 in., while the lower basin areas, including Carson Desert and Las Vegas Valley floor, receive less than 5 in. (Covay and others, 1996). Areas where precipitation is sufficient to produce ground-water recharge and surface runoff are termed "headwater areas" and areas where no significant natural recharge or runoff occurs are termed "basin areas" for the purposes of this report. A complete description of the climate, soils, vegetation, urbanization, and land and water use can be found in a recent report by Covay and others (1996).

Within the NVBR study area, urban and agricultural areas exist in headwater and basin settings. Water quality can depend on environmental setting as well as human activities. Thus, for this study, four distinct subareas were evaluated for their water quality: (1) a headwater agricultural area in Carson Valley; (2) a basin agricultural area in Carson Desert; (3) a headwater urban area (Reno-Sparks) in Truckee Meadows; and (4) a basin urban area (Las Vegas) in Las Vegas Valley.

Previous Studies

Many reports have been written describing the ground-water quality of the Carson and Truckee River Basins and the Las Vegas Valley including NVBR NAWQA reports by Covay and others (1996), Neal and Schuster (1996), Covay and Bevans (1997), and Kilroy and others (1997). Some other reports are, for the Carson River Basin, Glancy (1986), Morgan (1988), Sertic and others (1988), Welch and others (1989), Rowe and others (1991), Lico (1992), Thodal (1992, 1996), Lico and Seiler (1994), Welch (1994), Whitney (1994), Maurer and others (1996), and Mello (1996); for the Truckee River Basin, Cohen and Loeltz (1964), Van Denburgh and others (1973); and for the Las Vegas Valley, Dettinger (1987), Brothers and Katzer (1988), Emme and Prudic (1991), Hines and others (1993), and Thomas and others (1991).

Methods of Study

Wells in each of the four study-unit subareas were installed or selected to provide a representative sampling of the geographic area of interest. For the land-use surveys, several existing wells were used for sampling water quality. Where none existed, new wells were drilled with a hollow-stem auger using the methods described by Hardy and others (1989) and Lapham and others (1995). Care was taken to avoid selecting any wells that were previously installed by other investigators to monitor known contaminated areas of the aquifer.

Shallow wells in urban areas can indicate effects of land use on the quality of the water-table aquifer; Reno-Sparks urban area, November 1995.

For the study-unit surveys, only existing public-supply, domestic, or irrigation wells were used for water-quality sampling. As such, the study-unit surveys are evaluating the "in-use" resource, as opposed to the resource as a whole.

Water-quality samples were obtained from the wells using small-volume pumps or existing pumps installed in the well. For the land-use survey wells, either a stainless steel bladder pump or a teflon bailer was used to obtain the sample. All the study-unit survey wells had existing pumps from which the samples were obtained. Samples were collected and processed using NAWQA protocols developed by the U.S. Geological Survey. Details of these sampling procedures can be found in reports by Koterba and others (1995), Neal and Schuster (1996), and Covay and Bevans (1997).

Quality-assurance samples were collected to evaluate the accuracy and precision of concentrations of constituents measured in ground-water samples. These quality-assurance samples included

[1]Formal Hydrographic Areas in Nevada were delineated systematically by the U.S. Geological Survey and the Nevada Division of Water Resources in the late 1960's for scientific and administrative purposes (Rush, 1968; Cardinalli and others, 1968). The official Hydrographic Area names, numbers, and geographic boundaries continue to be used in U.S. Geological Survey reports and Nevada Division of Water Resources administrative activities.

blanks, replicates, and spikes that measure contamination, repeatability, and analyte recovery, respectively. Analytical results for the quality-assurance samples, which can be found in reports by Emett and others (1994, p. 583-588), Clary and others (1995, p. 710-717), and Bauer and others (1996, p. 666-668), indicate that the samples had no appreciable contamination, were reproducible, and had acceptable analyte recoveries.

Acknowledgments

The author expresses his sincere thanks to many people and organizations that helped in the different phases of this study. In the Las Vegas area, special thanks are extended to the Southern Nevada Water Authority, and in particular to Erin Cole, who allowed us to sample several of their wells and to install monitoring wells on their property. The City of Las Vegas and Clark County Parks and Recreation also allowed monitoring wells to be installed on their properties. The City of North Las Vegas, Clark County Parks and Recreation, Las Vegas Country Club, Las Vegas Hilton Country Club, Nellis Air Force Base, Sands Hotel Casino, Sheraton Desert Inn and Casino, Sky Harbor Airport, Tropicana Resort and Casino, and Andy Wheeler of Wheeler's Las Vegas RV all granted permission to sample their supply wells.

In the Carson River Basin, thanks are given to Genoa Lakes Golf Course, Mr. Peraldo, and Mr. Dodge who allowed monitoring wells to be installed on their properties. Also, the U.S. Geological Survey acknowledges the cooperation of the Incline Village and Indian Hills General Improvement Districts, the Towns of Gardnerville and Minden, the Minden-Gardnerville Sewer Improvement District, and several private well owners who graciously allowed sampling of their wells.

In the Truckee Meadows, the Washoe County Parks, School District, and Utilities Departments are recognized for their cooperation in this study. The Cities of Reno and Sparks and their respective Parks Departments assisted in obtaining permission for installing monitoring wells on their lands. A special thanks is extended to Robert Squires of Sierra Pacific Power Company who obtained permission from the power company and helped in siting locations for installing monitoring wells.

U.S. Geological Survey personnel who assisted in field and laboratory activities included Kip K. Allander, Glenda E. Brown, Scott R. Charlton, Ronald P. Collins, Charmaine D. Gunther, Arthur W. Johnson, Kathryn C. Kilroy, Edward G. Neal, R. Nyle Pennington, Michael M. Reddy, Armando R. Robledo, and Paul F. Schuster.

Ground water is used in parts of the study area for irrigation of alfalfa and pasture. Well in Carson Valley, November 1989. Photograph by James M. Thomas, U.S. Geological Survey.

QUALITY OF WATER IN SHALLOW WATER-TABLE AQUIFERS

For the purposes of this report, shallow ground water is defined as that which occurs in the upper part of the water-table aquifer. Depths to water in the study areas range from near land surface to about 60 ft below land surface. Wells completed in this part of the ground-water system would be expected to show the effects of human activities on the land surface, if those activities affect the ground-water quality. In many parts of the study area, water applied to the land surface, either in agricultural or urban areas, directly recharges the water table.

Agricultural Areas

Agriculture is an important land use in two areas of the NVBR NAWQA study unit, Carson Valley and Carson Desert. Both areas are within the Carson River Basin and differ in many characteristics. Carson Valley is in the headwater part of the Carson River Basin, receives more than 8 in/yr of precipitation, and has about 47,000 acres of irrigated agricultural land (Covay and others, 1996). Crops grown in Carson Valley are pasture, alfalfa, and some row crops (onion and garlic). Carson Desert is in the basin part of the Carson River Basin, receives less than 5 in/yr of precipitation, and has about 68,000 acres of irrigated agricultural land (Covay and others, 1996). The major crop grown in the Carson Desert is alfalfa, with lesser amounts of pasture and row crops (corn and melons). The major crops typically do not require heavy use of fertilizers or pesticides that could affect the ground-water quality.

A factor that may influence the quality of water in the shallow water-table aquifers beneath agricultural areas is the quality of the irrigation source water. Carson Valley agriculture is irrigated by surface-water diversions from the Carson River and ground-water pumpage. Estimates reported by Welch (1994) for agricultural ground-water use ranged from 7,400 to 22,000 acre-ft/yr and were dependent on snowpack storage of winter precipitation in the Sierra Nevada. Treated sewage effluent from the Lake Tahoe Basin is transported by pipelines to Carson Valley where it is used for irrigation during the growing season or stored in constructed wetlands during the winter. However, Carson Desert agriculture is irrigated solely by surface water provided by the Carson and Truckee (by way of the Truckee Canal) Rivers. Differences in the quality of these sources are reflected in that of the shallow ground water.

Natural processes also affect ground-water quality as the water moves "down-basin" in the Carson River Basin. Cooler temperatures during the growing season result in lower evapotranspiration rates in Carson Valley compared to those in Carson Desert. Pennington (1980) lists potential evapotranspiration rates of about 42 in/yr for Carson Valley and about 49 in/yr for Carson Desert. Active geothermal systems may have local effects on ground-water quality in Carson Valley and Carson Desert.

During April 1993 through March 1995, the median concentration of dissolved solids measured in monthly samples from the East Fork Carson River near Dresslerville (upstream from Carson Valley) was 199 mg/L, and the median concentration in the Carson River near Carson City (downstream from Carson Valley) was 210 mg/L. This apparent increase in concentration of dissolved solids may be attributed to drainage from agricultural lands. The median concentration of dissolved solids entering the Carson Desert (as measured downstream from Lahontan Reservoir) during 1978-89 was 216 mg/L (Lico and Seiler, 1994). Water delivered to Lahontan Reservoir by the Truckee Canal contains treated sewage effluent from the Reno-Sparks area.

Water in the shallow water-table aquifer in Carson Valley is a dilute calcium bicarbonate type, as indicated from an analysis of water samples from 34 monitoring wells (fig. 2*A*). The median dissolved-solids concentration was 355 mg/L (fig. 3*A*). The water contained high concentrations of manganese and radon (median concentrations of 118 μg/L and 1,025 pCi/L, respectively; figs. 3*D* and *G*). Manganese concentrations routinely exceeded the secondary maximum contaminant level (SMCL) of 50 μg/L set by the U.S. Environmental Protection Agency (USEPA; fig. 3*D*). Radon concentrations commonly exceeded the formerly proposed MCL of 300 pCi/L. The proposed radon MCL has been cancelled by USEPA. The natural geochemistry of this ground water is discussed in detail by Welch (1994). Aside from high manganese and radon concentrations, significant water-quality problems were not widespread in the shallow aquifer in Carson Valley, which generally is not used as a drinking-water source.

Water in the shallow water-table aquifer in the Carson Desert is a dilute sodium bicarbonate type, as indicated from an analysis of water samples from 42 wells (fig. 2*B*). Concentrations of dissolved solids, sulfate, arsenic, manganese, uranium, and radon were high in some ground-water samples. Median concentrations of dissolved solids (790 mg/L) and manganese (370 μg/L) exceeded the SMCL's of 500 mg/L and 50 μg/L, respectively (figs. 3*A* and *D*). Arsenic concentrations in shallow ground-water samples had a median concentration of 47 μg/L (fig. 3*E*), close to the primary maximum contaminant level (MCL) of 50 μg/L. The median uranium concentration (40 μg/L) in ground-water samples was twice that of the proposed MCL of 20 μg/L (fig. 3*F*). The natural processes that control the concentrations of these constituents are discussed in detail by Lico and Seiler (1994).

The quality of water in the shallow water-table aquifer in Carson Desert is marginal for consumption and irrigation and highly variable throughout the irrigated area. The shallow water-table aquifer is a primary drinking-water source for the residents in rural parts of the Carson Desert. Maurer and others (1996) estimated that as many as 4,500 wells withdraw water from the shallow aquifer.

Urban Areas

Two major urban areas are in the NVBR NAWQA study unit—Las Vegas and Reno-Sparks. Several characteristics are distinctly different between the two urban areas. The cities of Reno and Sparks, which are in the Truckee Meadows Hydrographic Area, have a climate with warm to hot summers and cold winters, with large daily temperature fluctuations. Annual precipitation in the Reno-Sparks area averaged more than 7 in. during the years 1981-91 (Covay and others, 1996). Las Vegas is in the Las Vegas Valley Hydrographic Area where hot summers and mild winters dominate. Annual precipitation at Las Vegas averaged less than 4 in. during 1981-91 (Covay and others, 1996). Both areas have many urban land uses, such as residential, commercial, industrial, and irrigated park areas. Use of fertilizers, pesticides, and other manmade organic compounds is common in urban areas and could affect ground-water quality.

Water applied to the land surface in these urban areas, mostly for turf irrigation, has many different sources. In the Reno-Sparks area, irrigation water is derived from surface (Truckee River) and ground-water sources. In the Las Vegas

Drains carry irrigation return flow to wetlands in Carson Desert, March 1995. Photograph by Ronald P. Collins, U.S. Geological Survey.

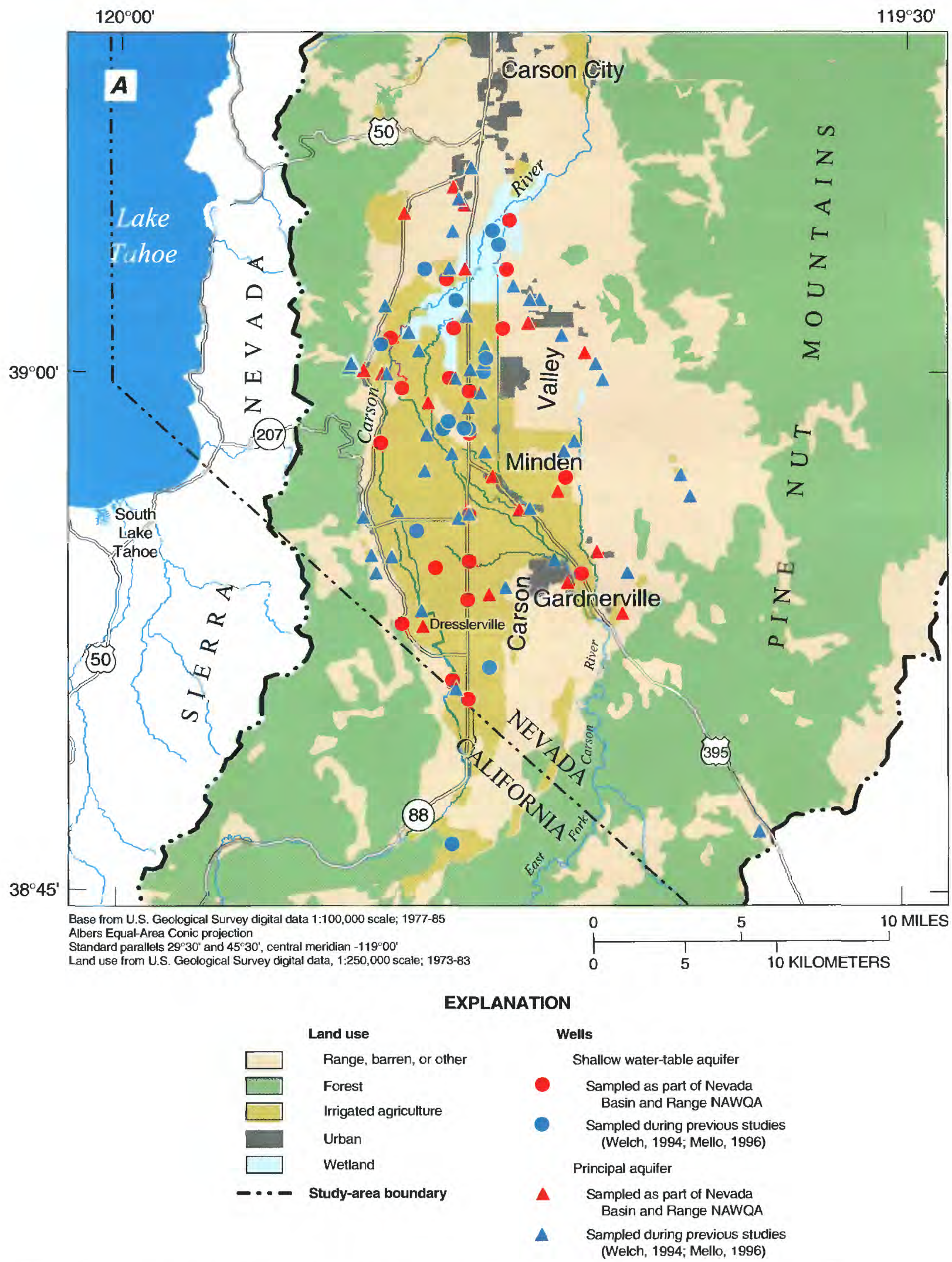
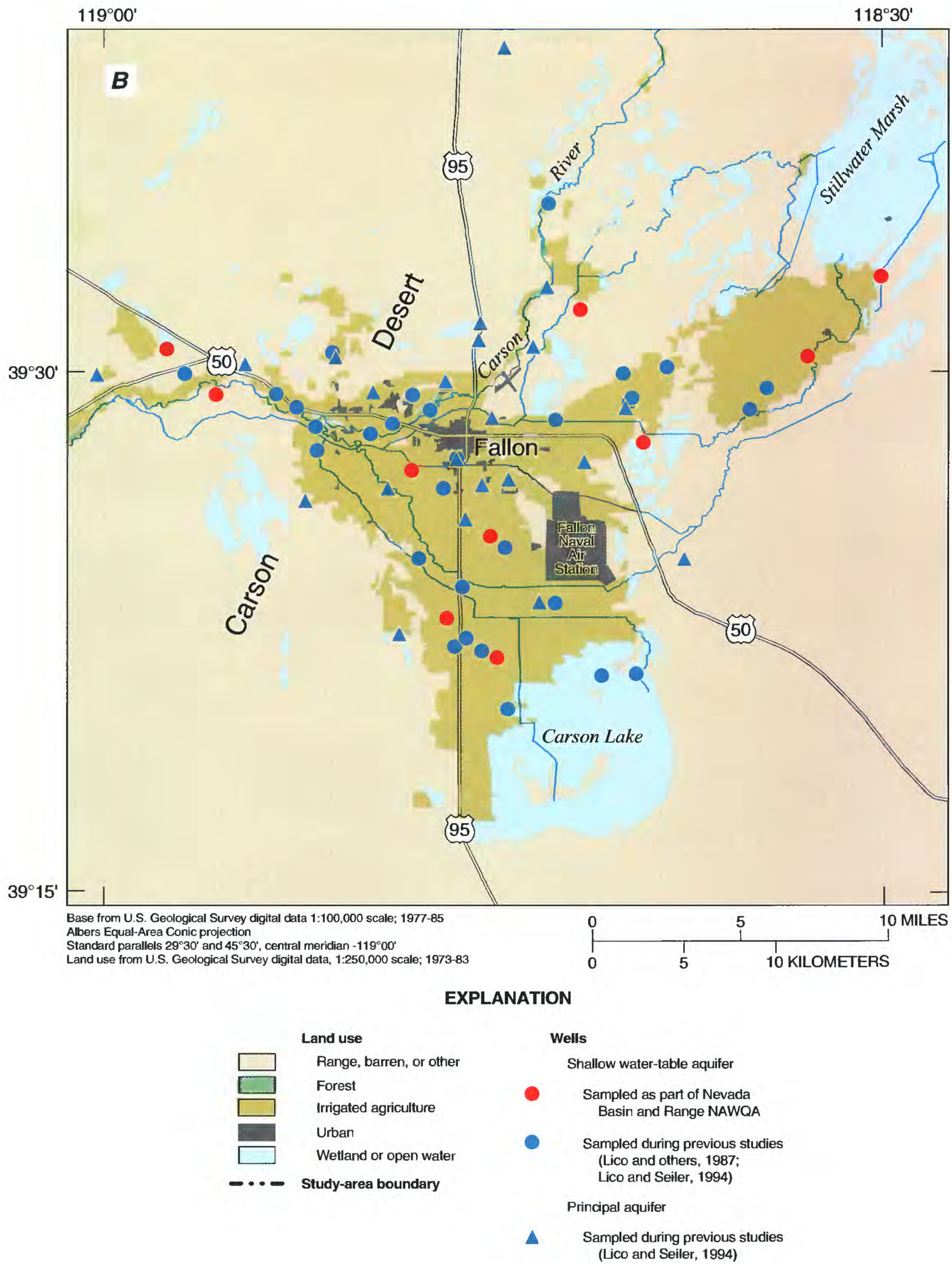


Figure 2. Locations of data-collection sites, hydrologic features, and land use in (*A*) Carson Valley, (*B*) Carson Desert, (*C*) Reno-Sparks area, and (*D*) Las Vegas area.



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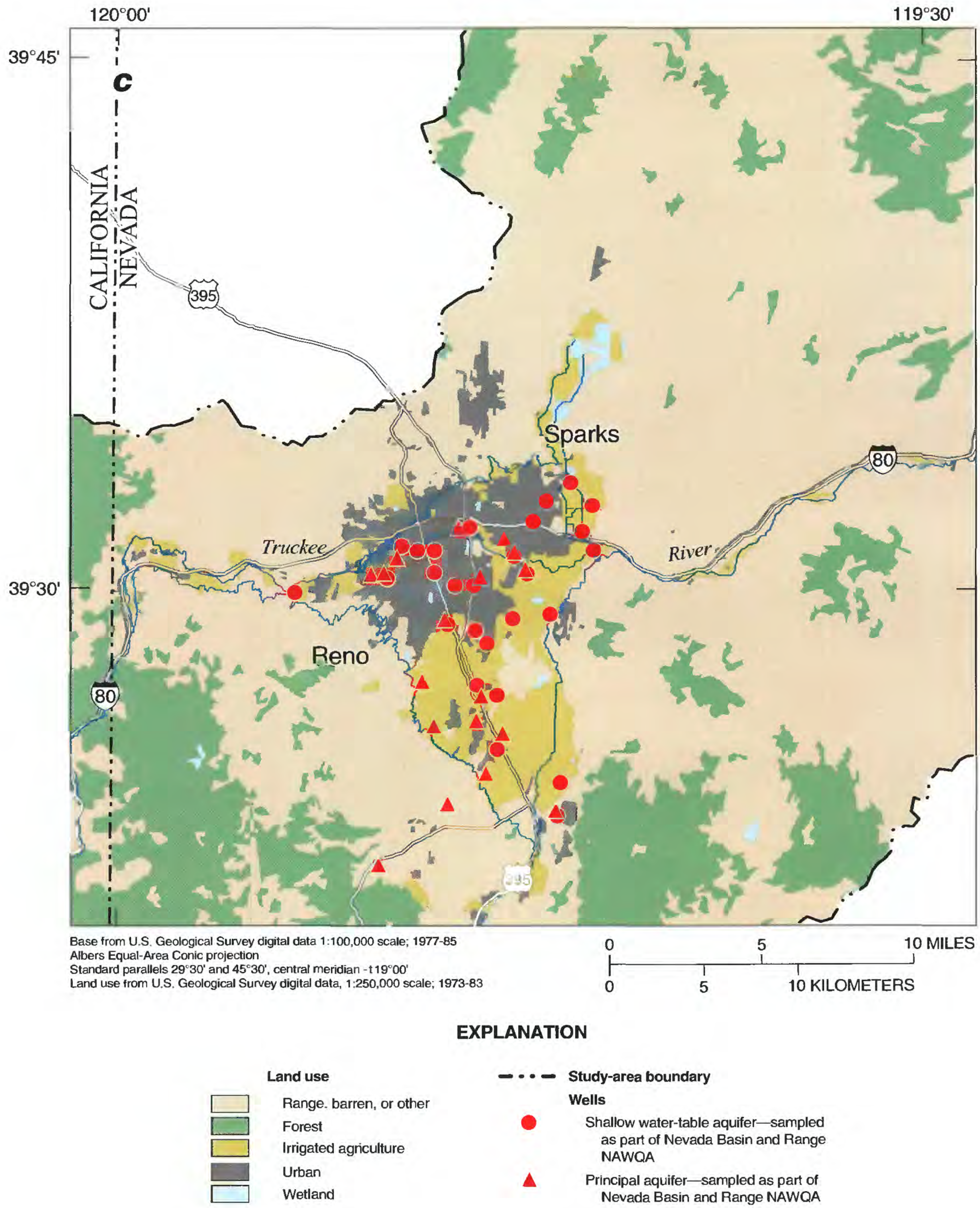

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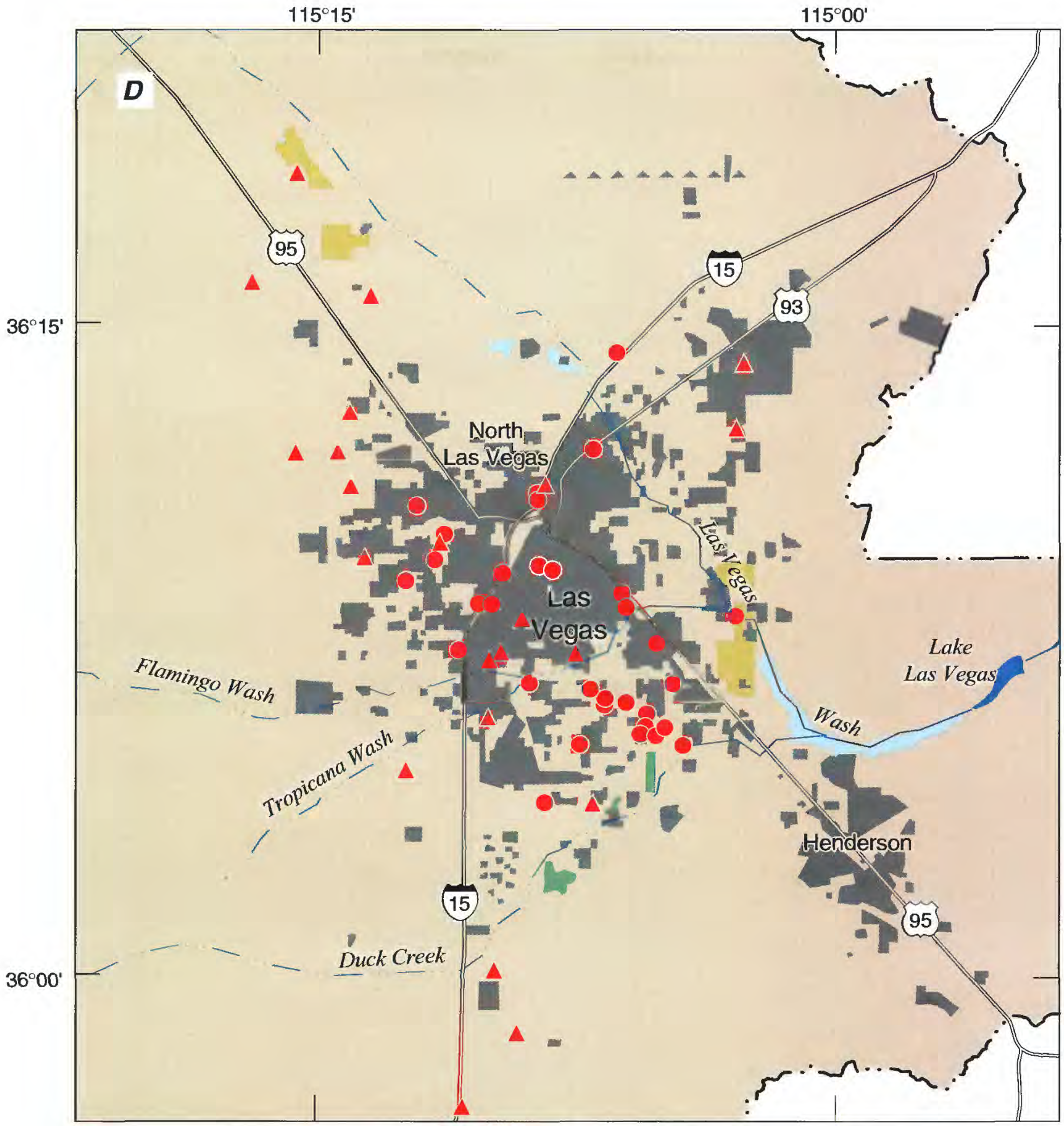


Base modified from U.S. Geological Survey digital data 1:100,000 scale; 1981-88
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian -115°00'
Land use from U.S. Geological Survey digital data, 1:250,000 scale; 1973-83

EXPLANATION

Land use
- Range, barren, or other
- Forest
- Irrigated agriculture
- Urban
- Wetland

Study-area boundary

Wells
- Shallow water-table aquifer—sampled as part of Nevada Basin and Range NAWQA
- Principal aquifer—sampled as part of Nevada Basin and Range NAWQA

Figure 2. Continued.

area, water is derived from surface (Lake Mead) and (deep) ground-water sources in the Valley. In both areas, reclaimed sewage effluent is used to irrigate many public and private golf courses, parks, and other turf areas. Currently, treated sewage effluent is not discharged directly into the Truckee River upstream from Reno-Sparks or into ephemeral Las Vegas Wash upstream from Las Vegas. With these diverse sources of irrigation water, the excess water that may recharge the shallow ground water has a variable composition and, thus, may affect the water quality of the shallow aquifer in different ways.

Water in the shallow water-table aquifer beneath the Reno-Sparks area is a dilute calcium bicarbonate type, as indicated from analysis of water samples from 28 monitoring wells (fig. 2*C*). The median dissolved-solids concentration was 434 mg/L (fig. 3*A*). Water samples from monitoring wells in the Reno-Sparks area had high concentrations of manganese and radon (median concentrations of 92 µg/L and 705 pCi/L, respectively; figs. 3*D* and *G*). Manganese concentrations exceeded the SMCL of 50 µg/L in more than half of the samples analyzed for this study. Radon concentrations commonly exceeded the formerly proposed but subsequently cancelled MCL of 300 pCi/L. The shallow water-table aquifer is not used as a drinking-water supply for the Reno-Sparks area, with the exception of some domestic wells in the extreme western part of the area. A thorough description of the water quality in the Reno-Sparks area can be found in a report by Covay and Bevans (1997).

Water in the shallow water-table aquifer beneath the Las Vegas area is a moderately saline, magnesium calcium sulfate type, as indicated from analysis of water samples from 31 monitoring wells (fig. 2*D*). The median dissolved-solids

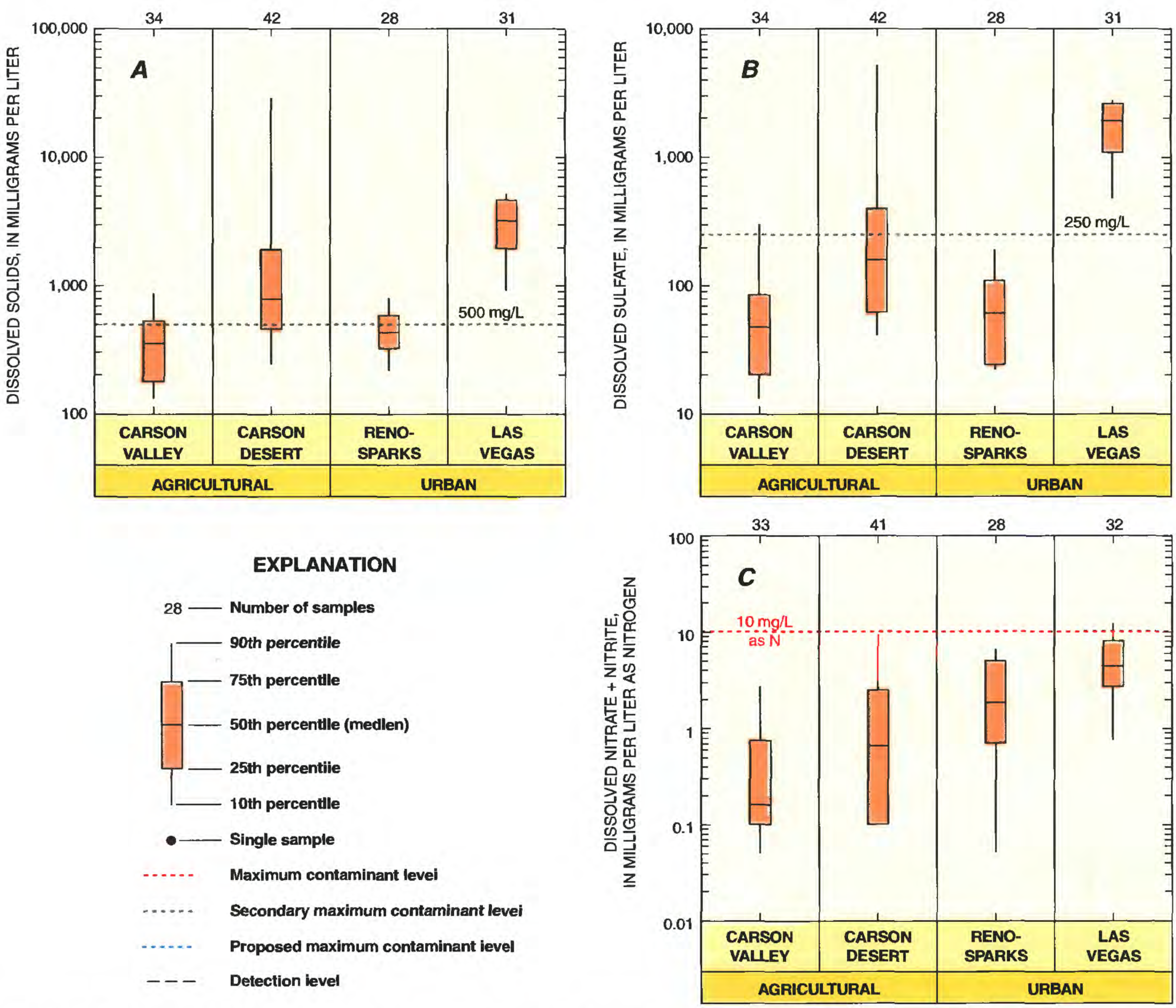


Figure 3. Concentrations of dissolved (*A*) solids, (*B*) sulfate, (*C*) nitrate plus nitrite, (*D*) manganese, (*E*) arsenic, (*F*) uranium, and (*G*) radon in samples from shallow water-table wells in Nevada Basin and Range study unit, National Water-Quality Assessment Program, 1993-95. Graphs for Carson Valley and Carson Desert include data collected in 1987-89 during a previous study (Lico and Seiler, 1994).

concentration was 3,240 mg/L (fig. 3*A*). Water samples from monitoring wells in Las Vegas area had high concentrations of dissolved solids, sulfate, and nitrate plus nitrite as N (median concentrations of 3,240 mg/L, 2,000 mg/L, and 4.6 mg/L, respectively). Dissolved-solids concentrations commonly exceeded the SMCL of 500 mg/L (fig. 3*A*). Sulfate concentrations were greater than the SMCL (250 mg/L) in all but two samples (fig. 3*B*). Uranium concentrations exceeded the proposed MCL of 20 µg/L in three of the five samples collected (fig. 3*F*). Analytical data for these water samples are provided in detail by Clary and others (1995) and Neal and Schuster (1996). Water in the shallow aquifer in the Las Vegas area is not used as a drinking-water supply but could move downward into the principal aquifer.

QUALITY OF WATER IN PRINCIPAL AQUIFERS

Water from principal aquifers is used for public supply and self-supplied domestic purposes in all the areas (Carson Valley, Carson Desert, Reno-Sparks, and Las Vegas) included in this report. For the purposes of this report, principal aquifers are defined as those that (1) are deeper than 50 ft below land surface and (2) underlie the shallow water-table aquifer. Principal aquifers usually are not as directly affected by activities on the land surface as are the shallow water-table aquifers.

Stable isotopes of water can be indicative of the sources of recharge to a ground-water system because, generally, the isotopic composition of ground water directly reflects that of the recharge sources. Evaporation and mixing with water of a different isotopic composition are the only significant processes that

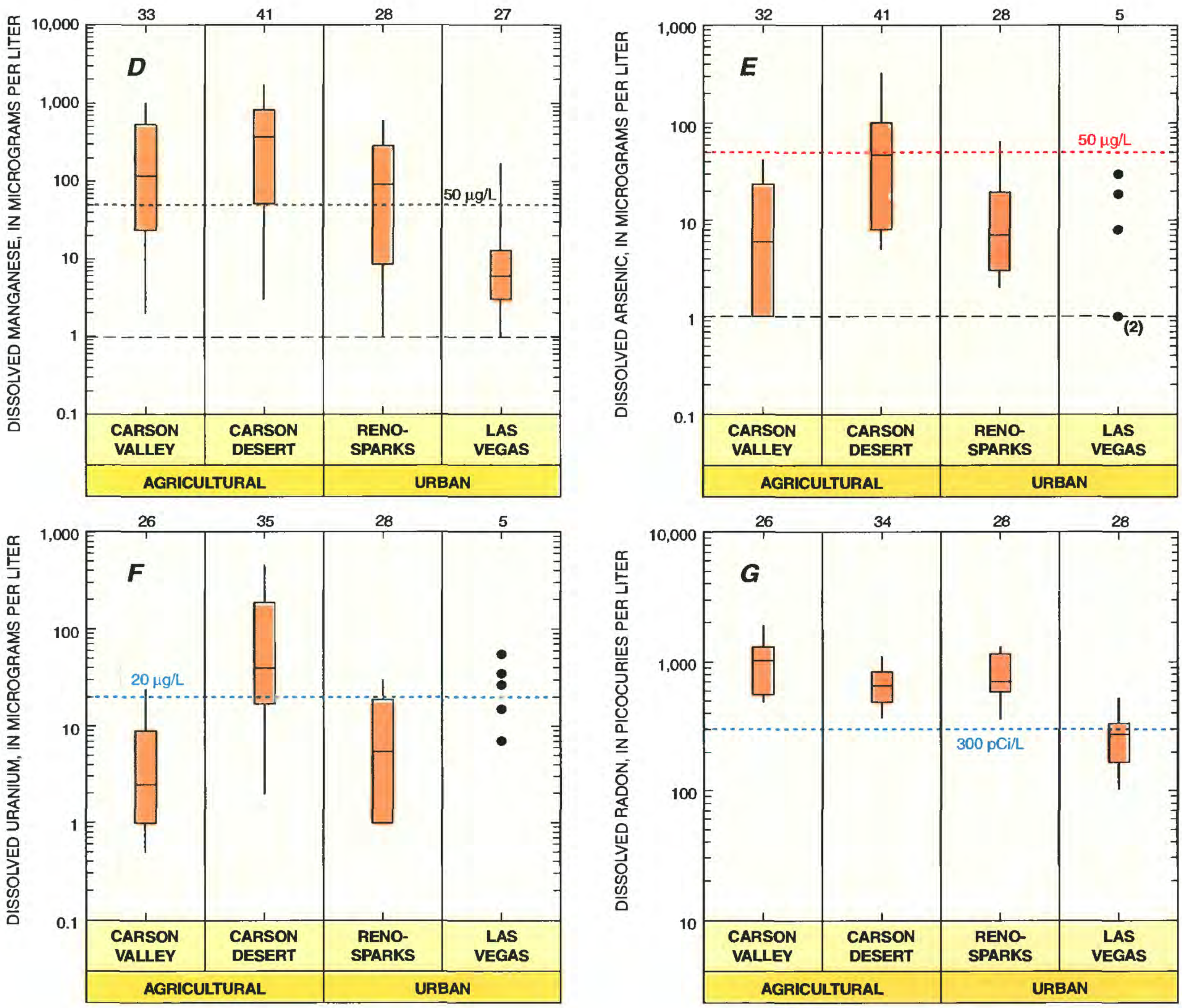


Figure 3. Continued.

affect the isotopic composition of nonthermal water. Water molecules, composed of hydrogen and oxygen, have variable concentrations of the stable isotopes of hydrogen and oxygen. Stable isotopes of hydrogen with masses of 1 and 2 (deuterium) and oxygen with masses of 16 and 18 are commonly used in groundwater studies. The concentrations of these isotopes are compared to those of a standard (Vienna Standard Mean Ocean Water) and expressed in units of "permil" or "parts per thousand" (Fritz and Fontes, 1980). Because precipitation that provides recharge to the deep aquifers in the study area is lighter than the standard (meaning it contains less D and ^{18}O than the standard), all values are negative. A plot of δD against $\delta^{18}O$ is a useful tool for using isotopes to determine source and history of a particular water. On these plots, samples generally are scattered around a line known as the "local meteoric water line" unless they are affected by evaporation or mixing. Evaporation makes the isotopic composition of water heavier; that is, the water preferentially loses the lighter isotopes (hydrogen-1 and oxygen-16), leaving the residual water enriched in the heavier isotopes. Thus, the sample affected by evaporation will plot with a less negative number than one not affected. Mixing of two waters with different isotopic compositions will result in a value between the two endmembers whose value is dependent on the proportions of each water in the final mixture.

Water quality of the principal aquifers is best evaluated by grouping samples from the upper parts of the flow systems (headwater areas) and those from the more distal parts of the flow system (basin areas), rather than grouping by agricultural and urban land uses.

Headwater Areas

Water in principal aquifers of Carson Valley is recharged by the Carson River, streams draining the Sierra Nevada and Pine Nut Mountains, and upland aquifers (Welch, 1994). The Carson River is the likely source of recharge for water in principal aquifers with hydrogen-isotope composition more positive than -110 permil (fig. 4*A*). Precipitation and runoff from the Sierra Nevada and Pine Nut Mountains are likely sources of recharge for water in principal aquifers with

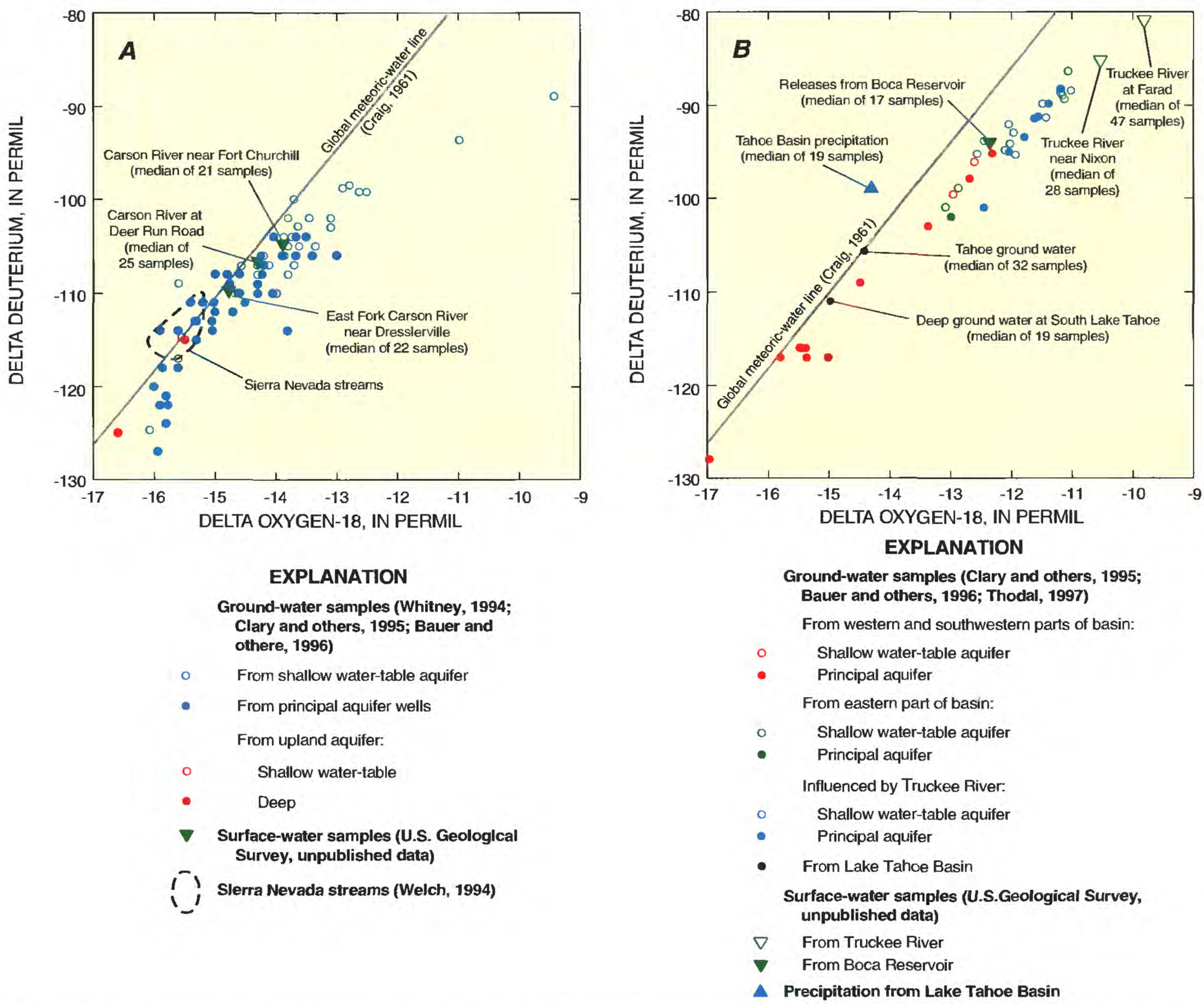


Figure 4. Relation between stable-isotope composition of hydrogen (deuterium) and oxygen for water samples from (*A*) Carson Valley, (*B*) Reno-Sparks area, (*C*) Carson Desert, and (*D*) Las Vegas area.

hydrogen-isotope compositions more negative than -110 permil, as reported by Welch (1994).

Principal aquifers in Carson Valley contain water that is a dilute calcium bicarbonate type, as indicated from analyses of samples from 62 wells (fig. 2*A*). The median dissolved-solids concentration was 174 mg/L (fig. 5*A*). Principal-aquifer wells in Carson Valley had the highest concentrations of radon in the four areas (median concentration of 860 pCi/L; fig. 5*F*), but generally did not exceed MCL's for any other constituents. Radon concentrations commonly exceeded the formerly proposed MCL of 300 pCi/L. Information regarding the water quality and processes affecting water quality in the principal aquifers is discussed by Welch (1994).

Principal aquifers in the Reno-Sparks area are recharged by two major sources—the Truckee River and precipitation in the Sierra Nevada. Precipitation in the Sierra Nevada near Lake Tahoe has a highly variable hydrogen-isotope composition (Larry V. Benson, U.S. Geological Survey, unpub. data, 1986), ranging from -165 to -58 permil with a median value of -99 permil (fig. 4*B*). Principal aquifers containing water with light hydrogen-isotope compositions (more negative than -110 permil) most likely are recharged by precipitation and runoff from the Sierra Nevada that infiltrates on the alluvial fans bordering the west side of Truckee Meadows. Some recharge also may occur on the east side of Truckee Meadows by runoff and infiltration of precipitation in the Virginia Range. Water in principal aquifers in the southern and western parts of Truckee Meadows has light hydrogen-isotope compositions, indicating that recharge is from precipitation. The Truckee River has a hydrogen-isotope composition averaging about -81 permil (Larry V. Benson, U.S. Geological Survey, unpub. data, 1986), much heavier than precipitation in the Sierra Nevada. Water samples from principal-aquifer wells near the Truckee River have hydrogen-isotope compositions that are heavier than those for samples from parts of the aquifer recharged by precipitation (fig. 4*B*). These water samples could obtain their hydrogen-isotope compositions in two ways: mixing of lighter deep water and Truckee River water or evaporation of lighter precipitation before recharge.

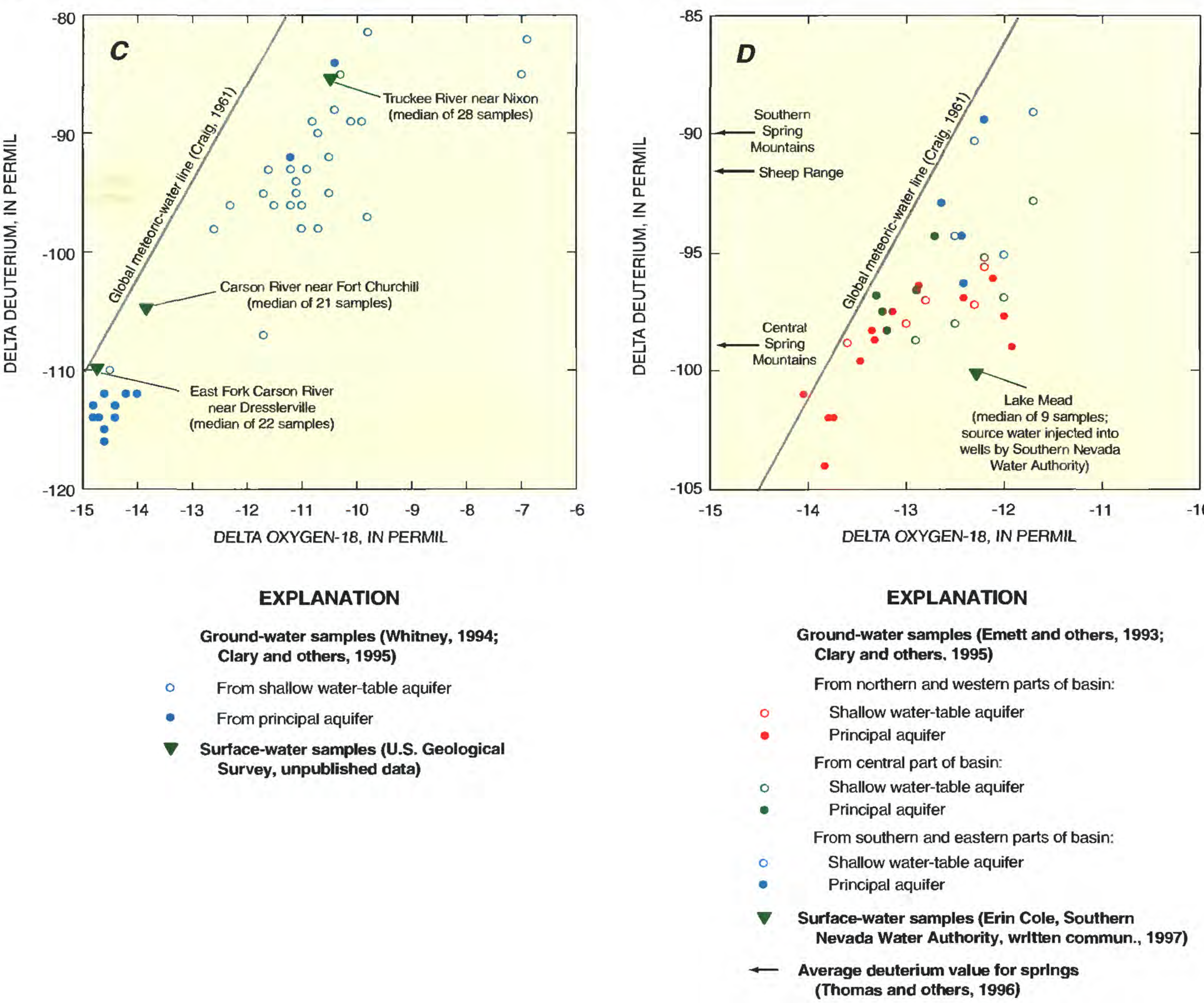


Figure 4. Continued.

Water in principal aquifers in the Reno-Sparks area is a dilute calcium bicarbonate type, as indicated from analyses of water samples from 18 wells (fig. 2*C*). The median dissolved-solids concentration was 224 mg/L (fig. 5*A*). Principal-aquifer well waters had high concentrations of radon (median concentration of 760 pCi/L; fig. 5*F*), but generally did not exceed MCL's for any constituents.

Basin Areas

Basin areas described in this report are Carson Desert and Las Vegas area. Carson Desert represents a basin area where the major land use is agriculture, whereas the Las Vegas area is representative of an urban-dominated land use.

Water in principal aquifers in Carson Desert may have several sources of recharge. Stable isotopes of water do not conclusively support any one source. As seen in figure 4*C*, the hydrogen-isotope composition of water from wells in most of the principal aquifers is isotopically lighter than water from the Carson River, so, present-day Carson River is not the sole source of water for most of the principal aquifers. Lico and Seiler (1994) list three possible sources for water in the principal aquifer as (1) water from the Carson River prior to the construction of Lahontan Reservoir, (2) mixing of present-day Carson River water with lighter precipitation, and (3) recharge during the Pleistocene before ancient Lake Lahontan was desiccated (about 4,000 years ago).

Water in the principal aquifer in Carson Desert is a dilute sodium bicarbonate type, as indicated from analyses of water samples from 20 wells (fig. 2*B*). The median dissolved-solids concentration was 346 mg/L (fig. 5*A*). The ground water had high concentrations of arsenic with a median concentration of 46 µg/L (fig. 5*E*). About one-half of the samples

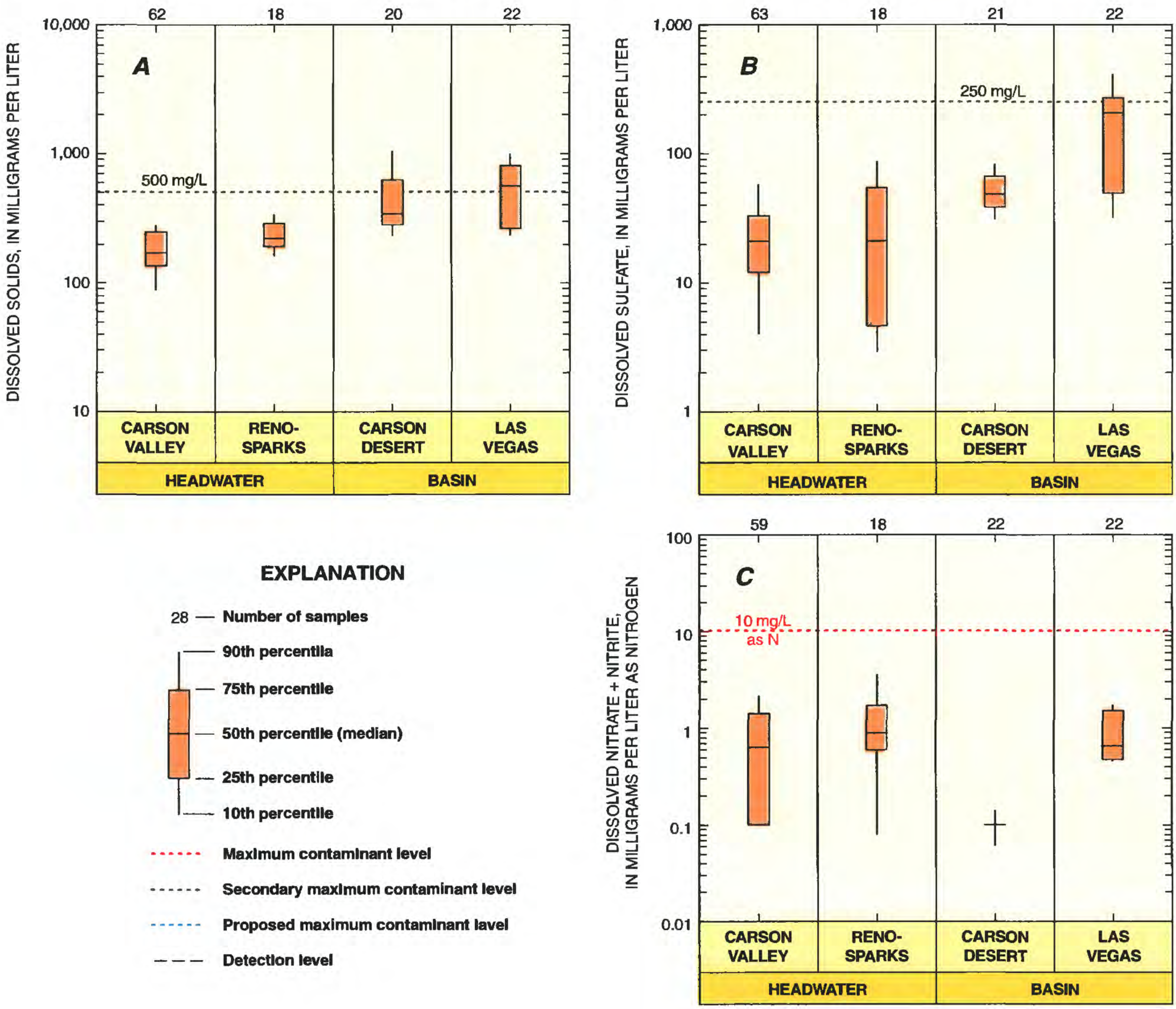


Figure 5. Concentrations of dissolved (*A*) solids, (*B*) sulfate, (*C*) nitrate plus nitrite, (*D*) manganese, (*E*) arsenic, and (*F*) radon in samples from principal aquifers in Nevada Basin and Range study unit, National Water-Quality Assessment Program, 1993-95. Graphs for Carson Valley and Carson Desert include data collected in 1987-89 during a previous study (Lico and Seiler, 1994).

exceeded the MCL for arsenic (50 µg/L). Manganese concentrations were higher than the SMCL (50 µg/L) in about 25 percent of the samples and the median was 24 µg/L (fig. 5*D*). Many domestic wells are completed in the principal aquifer and supply water for human consumption.

Water from the principal aquifer in the Las Vegas area has two sources—recharge of precipitation in the Spring Mountains and injection of Lake Mead (mostly Colorado River) water. Water samples with hydrogen-isotope compositions near the meteoric-water line (fig. 4*D*) have precipitation as their source. Water from springs in the central part of the Spring Mountains has an average hydrogen-isotope composition of -99 permil. During the low-use months (winter), the Southern Nevada Water Authority injects treated water from Lake Mead to augment ground-water supplies, mainly along the western edge of Las Vegas. This water has a hydrogen-isotope composition of about -100 permil but plots well off the meteoric-water line, indicating it has been affected by evaporation. Some of the water samples from the principal aquifer in the area of injection have stable-isotopic compositions that indicate the water is partly or entirely from Lake Mead.

Water in the principal aquifer in the Las Vegas area generally is a dilute calcium-sulfate type, as indicated from analyses of water samples from 22 wells (fig. 2*D*). The median dissolved-solids concentration was 565 mg/L (fig. 5*A*) and median sulfate concentration was 205 mg/L. Dissolved-solids concentrations exceeded the SMCL (500 mg/L) in more than one-half of the samples. Median sulfate concentration (fig. 5*B*) in water samples approached the SMCL (250 mg/L).

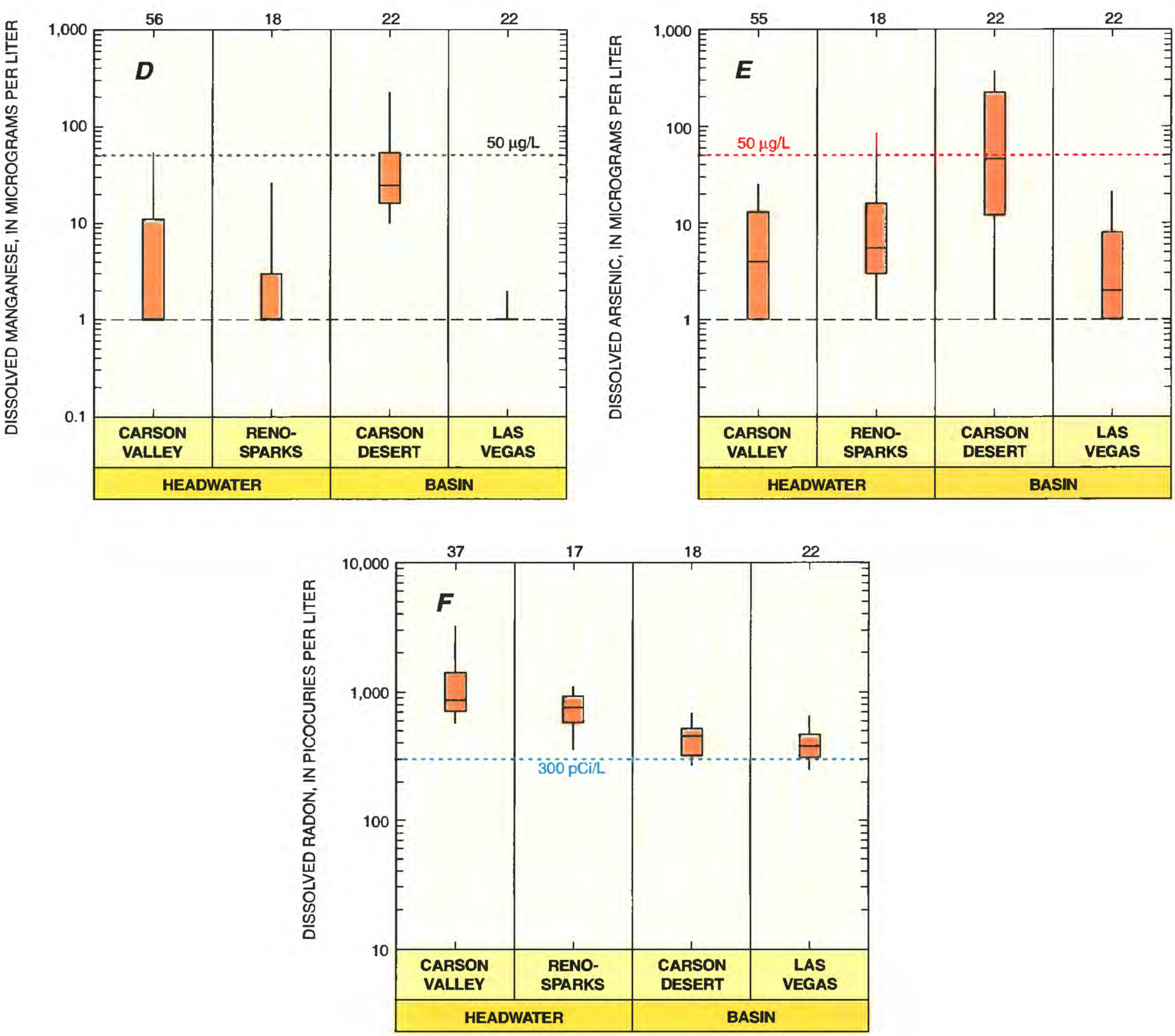


Figure 5. Continued.

Alfalfa is the major crop grown in the Carson Desert agricultural area, November 1995. Photograph by Armando R. Robledo, U.S. Geological Survey.

INDICATORS OF ANTHROPOGENIC INFLUENCE ON QUALITY OF WATER IN SHALLOW WATER-TABLE AQUIFERS

Certain chemical compounds used by humans in everyday activities can contaminate water resources if they are not properly used. In agricultural and urban areas, contaminants in shallow ground water may pose a threat to the drinking-water resource that typically underlies the shallow water-table aquifer. Types of compounds that can reach the shallow ground water are manmade organic compounds (solvents, gasoline products, and pesticides), detergents and surfactants, and nitrate (typically from sewage and fertilizer).

Agricultural Areas

Agricultural areas discussed in this section of the report include Carson Valley (headwater area) and Carson Desert (basin area). Synthetic-organic compounds (insecticides and herbicides) commonly are used in agricultural areas to improve the yield and quality of crops and to rid areas of unwanted weeds and other vegetation. Many ranchers use herbicides along roadways and irrigation ditches to kill weeds. Five compounds were detected in samples from the shallow water-table aquifer in agricultural areas—acetochlor, atrazine, bromacil, deethylatrazine (a degradation product of atrazine), and simazine (table 1). In all, water samples from eight wells had detectable concentrations of one or more of these herbicide compounds. All detections, except one for atrazine (1.2 µg/L), were at concentrations less than 1 µg/L; all concentrations were less than the MCL's of 3 µg/L for atrazine, 80 µg/L for bromacil, and 4 µg/L for simazine.

Volatile organic compounds (VOC's) commonly are used in agricultural areas. Many pesticide formulations use volatile organic compounds as carriers for the more insoluble pesticide compound. Ranchers and farmers commonly have above- or under-ground storage tanks for gasoline and diesel fuels to run their farm equipment. Septic-tank degreasers also may contaminate the shallow ground water near rural homes. All these are potential sources that could contaminate water in the shallow water-table aquifer with VOC's. In the agricultural areas discussed in this report, no VOC's were detected in samples from 29 shallow water-table wells, indicating that contamination of the water in this part of the aquifer by VOC's in agricultural land-use areas is not widespread.

Detergents and surfactants commonly are used in cleaning products and as ingredients in some pesticide formulations. These compounds also are present in treated sewage effluent, which is used in several places within the study area to irrigate crops or turf. These compounds are collectively grouped and reported as methylene blue active substances (MBAS). Thirteen of 29 water samples from wells tapping the shallow water-table aquifer (30 percent of the samples from Carson Desert and 53 percent from Carson Valley) had detectable concentrations of MBAS (table 2). Concentrations of MBAS ranged from 20 to 100 µg/L in these water samples. Three of the samples were from areas irrigated by treated sewage effluent, which may explain the source of contamination. The other 10 samples from shallow water-table wells with detections have no obvious source of MBAS.

Phenolic compounds are used as wood preservatives and intermediate compounds in the manufacture of many products, including pharmaceuticals, herbicides, and phenolic resins (Smith and others, 1988). Some phenolic compounds can be naturally occurring and are formed by the breakdown of plant material such as lignins and tannins. The concentration of phenolic compounds due to these natural sources generally is less than 1 µg/L (Thurman, 1985). Analytically, all phenolic compounds are grouped together and reported as phenols. About one-third (9 of 29 samples) of the samples from shallow water-table wells in the agricultural areas had phenol concentrations above the reporting level of 1 µg/L (table 2). Concentrations of phenols ranged from 1 to 4 µg/L in the samples with detectable concentrations.

Nitrate is a common contaminant of shallow ground water in agricultural areas. The major sources of nitrate are application of fertilizer to crops, septic-tank effluent near rural homes, and application of treated sewage effluent for irrigation of crops. In some areas, confined feed lots or dairies may be a source for nitrate that could contaminate the shallow ground water. For purposes of this report, the combined concentration of nitrate plus nitrite, as determined by laboratory analysis, is herein termed "nitrate" because the concentration of nitrite generally is small relative to that of nitrate.

Of 74 samples from shallow water-table wells in agricultural land-use areas of Carson Valley and Carson Desert, nitrate exceeded the MCL of 10 mg/L as N in only four samples. All four samples with nitrate concentrations greater than the MCL were from the Carson Desert, with the highest concentration being 18 mg/L as N. The median concentrations of nitrate in samples from Carson Valley and Carson Desert were 0.16 and 0.66 mg/L as N, respectively (fig. 3*C*). Natural background concentrations of nitrate have been reported as less than 2 mg/L as N by Mueller and Helsel (1996).

Urban Areas

Reno-Sparks (Truckee Meadows) and Las Vegas represent headwater and basin urban areas, respectively, in the NVBR NAWQA study unit. Pesticide use in urban areas is common by homeowners and commercial applicators. This could lead to an increased risk of pesticides reaching the shallow ground water. In fact, pesticides were detected in 47 percent (28 of 60 sites) of the samples from shallow water-table wells in urban land-use areas in the NVBR NAWQA study unit. The Reno-Sparks area had a higher frequency of pesticide detection (68 percent of samples) than Las Vegas (28 percent of samples). Atrazine and its degradation product deethylatrazine were the two most commonly detected pesticides (13 and 11 detections, respectively). Prometon and simazine also were prevalent with 10 and 9 detections, respectively (table 1). All these compounds with numerous detections are triazine herbicides common in many commercial products. Several other compounds were detected in one or two samples each; these include diazinon, diuron, oryzalin, *p,p'*-DDE, tebuthiuron, and terbacil.

Urban land-use activities commonly involving VOC's include gasoline stations (and associated underground-storage tanks), repair shops and dry cleaners (which use solvents), and other industrial operations. Almost two-thirds (64 percent) of the samples analyzed from the urban areas in the NVBR NAWQA study unit had detections of one or more VOC(s). In the Las Vegas urban area, 80 percent of the samples from shallow water-table wells had detections of at least one VOC. In the Reno-Sparks area, 46 percent of the samples had VOC detections of at least one compound. In all, 16 different compounds were detected in samples from shallow water-table wells in urban areas (table 2). By far, chloroform, a trihalomethane (THM) compound, was the most commonly detected VOC in samples from shallow water-table wells (27 detections in 59 samples).

Ground water supplements drinking-water supplies in the Las Vegas Valley. A typical public-supply well in Las Vegas, December 1995. Photograph by Kenneth J. Covay, U.S. Geological Survey.

Many other THM's also were detected in the 59 samples. The concentrations of these THM's, however, did not exceed the MCL of 100 µg/L. Potential sources for THM's include recharge by irrigation with chlorinated water (either drinking water or treated sewage effluent) or leakage from water-supply lines containing chlorinated water. In Reno-Sparks and Las Vegas areas, chlorinated surface water is used for public supply (Covay and others, 1996). Surface water generally has higher dissolved organic carbon than ground water (Thurman, 1985). Dissolved organic carbon can react with chlorine to form THM's (Thurman, 1985).

Solvents, such as tetrachloroethylene and trichloroethylene, were detected in 12 and 5 samples, respectively, among 59 samples from shallow water-table wells in the urban areas. The MCL for tetrachloroethylene (5 µg/L) and trichloroethylene (5 µg/L) was exceeded in three samples and one sample, respectively. Another commonly detected VOC was MTBE (methyl *tert*-butyl ether), which was detected in nine samples with a range in concentration of 0.3 to 220 µg/L. MTBE is a gasoline additive that increases the oxygen content of the fuel and reduces emissions; it is water soluble and thus may reach the water table. A drinking-water advisory (DA) for MTBE is currently being reviewed by the U.S. Environmental Protection Agency (1997). The level of the DA for MTBE will be between 20 and 40 µg/L. Concentrations of MTBE found in two samples from shallow water-table wells in the Reno-Sparks area exceed the upper value (table 2).

Detergents and surfactants (MBAS) were detected in 10 of 55 water samples from shallow water-table wells (table 2). MBAS concentrations ranged from 20 to 60 µg/L in samples where they were detected. Likely sources for MBAS are leaky sewer lines, septic systems, surfactants in pesticide formulations, and use of detergents by homeowners and businesses in the urban areas.

Phenolic compounds were detected in 32 of the 59 samples from shallow water-table wells (table 2). Concentration of phenols in the samples with detections ranged from 1 to 4 µg/L, much below the 4,000 µg/L MCL. Las Vegas area had a higher percentage of detections (68 percent) than the Reno-Sparks area (39 percent). Sources for these compounds have not been identified for this report.

Nitrate concentrations in samples from shallow water-table wells were statistically higher ($\alpha = 0.05$) in urban areas than in agricultural areas (median concentrations of 3.1 and 0.48 mg/L as N, respectively). Of the two urban areas discussed in this report, water samples from shallow water-table wells (fig. 3*C*) in the Las Vegas area had statistically higher ($\alpha = 0.05$) nitrate concentrations (median concentration of 4.6 mg/L as N) than those from the Reno-Sparks area (median concentration of 1.8 mg/L as N). Although water from shallow water-table wells is not consumed by humans, four samples exceeded the MCL for nitrate (10 mg/L as N). All samples with nitrate concentrations exceeding the MCL were from wells in the Las Vegas area. Sources of nitrate in urban settings can include fertilizer applied to lawns and gardens, leaky sewer pipes, septic systems, irrigation by treated sewage effluent, and naturally occurring nitrate.

IMPLICATIONS FOR WATER SUPPLY

This section of the report discusses two major questions: (1) is the water supply in principal aquifers contaminated, and (2) is there potential for the water supply to be contaminated by current land-use practices? Ground-water resources in principal aquifers in the study areas are a major source of supplies for municipalities and rural homeowners. Thus, protection of these resources is imperative.

The information gathered during this study indicates that, currently (1995), manmade compounds are present in some parts of the principal aquifers. Sampled ground water from principal aquifers in

Table 1. Pesticides detected and ranges of concentration in ground-water samples collected in Nevada Basin and Range study unit, National Water-Quality Assessment Progam, 1993-95

[Abbreviations: E, estimated value;HA, health advisory; MCL, maximum contaminant level; µg/L, micrograms per liter; --, no MCL or HA reported]

Compound	MCL or HA[1] (µg/L)	Number of samples	Number of detections	Concentration range of detections (µg/L)
Shallow Water-Table Aquifers				
Carson Valley agricultural area				
Atrazine	3 F	20	4	0.006 - 1.2
Bromacil	80 F	20	1	0.02
Deethylatrazine	--	20	3	0.005 - 0.032
Simazine	4 F	20	4	0.008 - 0.13
Carson Desert agricultural area				
Simazine	4 F	10	3	0.005 - 0.016
Deethylatrazine	--	10	1	E 0.003
Acetochlor	--	10	1	E 0.023
Reno-Sparks urban area				
Atrazine	3 F	28	10	0.002 - 0.10
Deethylatrazine	--	28	11	0.003 - 0.09
p,p'-DDE	--	28	2	0.002
Diazinon	0.6 F	28	2	0.007 - 0.01
Diuron	10 F	28	1	0.01
Prometon	100 F	28	5	0.007 - 4.0
Simazine	3 F	28	7	0.016 - 1.1
Terbacil	90 F	25	1	0.034
Las Vegas urban area				
Atrazine	3 F	32	3	0.008 - 0.045
Oryzalin	--	31	1	0.08
Prometon	100 F	32	5	0.004 - 0.065
Simazine	4 F	32	2	0.015 - 0.022
Tebuthiuron	500 F	29	1	0.035
Principal Aquifers				
Carson Valley agricultural area				
Atrazine	3 F	17	1	0.013
Deethylatrazine	--	17	1	0.014
Prometon	100 F	17	3	0.004 - 0.022
Simazine	4 F	17	1	0.017
Carson Desert agricultural area[2]				
No compounds detected		22	0	
Reno-Sparks urban area				
Atrazine	3 F	18	3	0.002 - 0.009
Carbaryl	700 F	18	1	0.011
Deethylatrazine	--	18	6	0.001 - 0.008
Linuron	--	18	1	0.1
Prometon	100 F	18	3	0.002 - 0.004
Las Vegas urban area				
Atrazine	3 F	22	2	0.002 - 0.015
Deethylatrazine	--	22	1	0.005
Metolachlor	100 F	22	2	0.004 - 0.045
Prometon	100 F	22	1	0.033

[1] F, final (U.S. Environmental Protection Agency, 1996).

[2] Samples from Carson Desert agricultural area were collected in 1987-89 during a previous study (Lico and Seiler, 1994).

Table 2. Volatile organic compounds, methylene blue active substances, and phenols detected and ranges of concentration in ground-water samples collected in Nevada Basin and Range study unit, National Water-Quality Assessment Progam, 1993-95

[Abbreviations: HA, health advisory; MBAS, methlyene blue active substances; MCL, maximum contaminant level; MTBE, methyl *tert*-butyl ether; µg/L, micrograms per liter; --, no MCL or HA reported]

Compound	MCL or HA[1] (µg/L)	Number of samples	Number of detections	Concentration range of detections (µg/L)	Number of exceedences of MCL or HA
Shallow Water-Table Aquifers					
Carson Valley agricultural area					
MBAS	--	19	10	20 - 80	--
Phenols	4,000 D	19	6	1 - 4	0
Carson Desert agricultural area					
MBAS	--	10	3	30 - 100	--
Phenols	4,000 D	10	3	2 - 3	0
Reno-Sparks urban area					
Benzene	5 F	28	2	0.3 - 5	0
Chloroform	100 P	28	6	0.3 - 1.2	0
1,2-Dichloroethane	5 F	28	1	0.6	0
Freon-113	--	28	1	10	--
MBAS	--	26	6	20 - 50	--
Methylene chloride	5 F	28	1	0.3	0
MTBE	20-40 D[2]	28	6	0.3 - 220	2
Phenols	4,000 D	28	11	1 - 4	0
Tetrachloroethylene	5 F	28	4	0.8 - 20	2
Trichloroethylene	5 F	28	4	0.3 - 4.9	0
Las Vegas urban area					
o-Chlorobenzene	--	31	1	0.2	--
Chlorodibromomethane	100 P	31	1	0.9	0
Chloroform	100 P	31	21	0.2 - 12	0
Dichlorobromomethane	--	31	2	0.2 - 0.9	--
Dichlorodifluoromethane	1,000 L	31	1	38	0
1,1-Dichloroethylene	7 F	31	1	0.2	0
Freon-113	--	31	1	0.4	--
MBAS	--	29	4	20 - 60	--
MTBE	20-40 D[2]	31	3	0.4 - 0.7	0
Phenols	4,000 D	31	21	1 - 4	0
1,2-Transdichloroethene	100 F	31	1	4.5	0
Tetrachloroethylene	5 F	31	8	0.2 - 89	1
1,1,1-Trichloroethane	200 F	31	2	0.5 - 3.7	0
Trichloroethylene	5 F	31	1	19	1
Trichlorofluoromethane	--	31	3	0.6 - 2.6	--
Principal Aquifers					
Carson Valley and Carson Desert agricultural areas[3]					
No compounds detected		39	0		
Reno-Sparks urban area					
Bromoform	100 P	18	1	0.4	0
Chloroform	100 P	18	5	0.3 - 0.4	0
MBAS	--	18	1	30	--
Phenols	4,000 D	18	6	1 - 3	0
Tetrachloroethylene	5 F	18	3	0.8 - 1.3	0
Las Vegas urban area					
Bromochloromethane	90 F	20	2	0.2	0
Bromoform	100 P	20	2	0.9 - 3.5	0
Chlorodibromomethane	100 P	20	2	6.3 - 21	0
Chloroform	100 P	20	10	0.2 - 23	0
Dibromomethane	--	20	1	0.2	--
Dichlorobromomethane	--	20	1	23	--
Dichlorodifluoromethane	1,000 F	20	1	0.4	0
MBAS	--	20	3	20 - 550	--
Methylene chloride	5 F	20	1	1.5	0
MTBE	20-40 D[2]	20	1	0.3	0
Phenols	4,000 D	20	10	1 - 20	0
Tetrachloroethylene	5 F	20	2	0.4 - 21	1
Trichloroethylene	5 F	20	1	0.5	0
Trichlorofluoromethane	--	20	3	0.5 - 1.4	--

[1] D, draft; F, final; L, listed for regulation; P, proposed (U.S. Environmental Protection Agency, 1996).

[2] Draft drinking-water advisory for MTBE ranges from 20 to 40 µg/L (U.S. Environmental Protection Agency, 1997).

[3] Samples from Carson Desert agricultural area (22 samples) are from a previous study (Lico and Seiler, 1994).

agricultural areas had pesticide detections in 4 of 17 samples (24 percent) and no VOC detections. The pesticide detections were all at very low concentrations (less than 0.1 μg/L) that did not exceed drinking-water standards (table 1) and were all triazine herbicides (atrazine, deethylatrazine, prometon, and simazine). In urban land-use areas, pesticides were detected in 12 of 40 samples (30 percent) from principal-aquifer wells. Six different compounds were detected and include atrazine, deethylatrazine, linuron, prometon, metolachlor, and carbaryl. Concentrations of pesticides in all samples were less than or equal to 0.1 μg/L. In general, samples from the principal aquifer in the Reno-Sparks area had a higher frequency of pesticide detection (44 percent) than those from Las Vegas (14 percent).

VOC's were detected in 45 percent of the samples from principal aquifers in urban areas. Among the 12 compounds detected (table 2), chloroform (a THM) was the most common (39 percent of samples), and had a greater percent of detection in Las Vegas (50 percent) than in the Reno-Sparks area (28 percent). Other VOC's detected in samples from principal aquifers in urban areas were tetrachloroethylene (13 percent), trichlorofluoromethane (8 percent), and numerous other THM's in one or two samples each. THM concentrations ranged from 0.2 to 23 μg/L, none of which exceeded the 100-μg/L MCL. One sample from the principal aquifer in Las Vegas had a tetrachloroethylene concentration (21 μg/L) greater than the MCL (5 μg/L).

Samples from principal-aquifer wells had MBAS detections at concentrations ranging from 20 to 550 μg/L in 4 of 38 samples (about 10 percent). Of the two urban areas included in this report, Las Vegas had a higher detection frequency (15 percent) than the Reno-Sparks area (6 percent). No samples from principal aquifers in agricultural areas had detectable concentrations of MBAS.

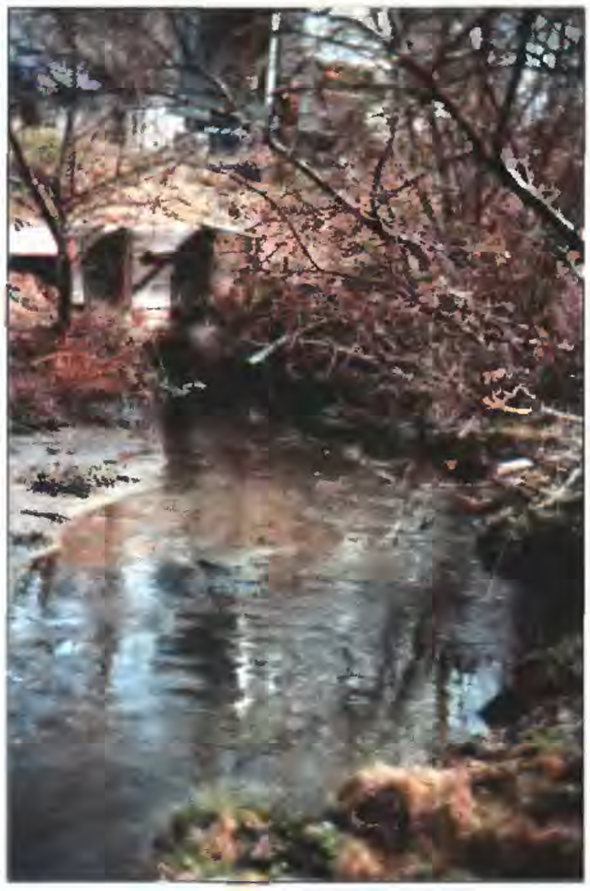
Phenolic compounds were present in 16 of 38 samples (42 percent) from principal-aquifer wells collected for this study. Concentrations of phenols ranged from 1 to 20 μg/L in samples where these compounds were detected. In samples from principal-aquifer wells in Las Vegas, phenolic compounds were detected in 10 of 20 samples (50 percent) and in the Reno-Sparks area, they were detected in 6 of 18 samples (33 percent). No samples from principal aquifers in agricultural areas had detections of phenolic compounds. In all cases, samples from principal aquifers did not exceed the MCL for phenols (4,000 μg/L).

Samples from principal-aquifer wells generally had low concentrations of nitrate (less than 1 mg/L). Median nitrate concentrations were Carson Valley, 0.63 mg/L as N; Carson Desert, 0.1 mg/L as N; Reno-Sparks area, 0.88 mg/L as N; and Las Vegas, 0.65 mg/L as N (fig. 5*C*). One water sample from a well in Carson Desert had a nitrate concentration of 22 mg/L as N; it was the only sample from a principal-aquifer well to exceed the MCL (10 mg/L as N). Statistical comparison of water samples from urban and agricultural principal-aquifer wells indicates that nitrate concentrations were significantly greater ($\alpha = 0.05$) in urban samples than agricultural samples.

The previous discussions of pesticides, VOC's, MBAS, phenolic compounds, and nitrate indicate that, as of 1995, principal aquifers generally are not contaminated to the point of endangerment to the human population using this resource. Other parts of the principal aquifers not sampled during this study, however, may be contaminated. Evidence that some contamination has reached the principal aquifers is indicated by small concentrations of manmade chemicals and nitrate found in samples. In fact, two samples from principal aquifers exceeded MCL's, one for tetrachloroethylene and one for nitrate. Also, previously discussed contaminants in the shallow water-table wells have the potential to make their way into principal aquifers. Several scenarios are discussed next that could enhance the potential for contamination of principal aquifers.

Alluvial basins where confining layers are not present, or are highly discontinuous, are susceptible to downward movement of shallow water and, if present, contaminants. Alluvial deposits in the Reno-Sparks area fit this description, especially in the western part of the Truckee Meadows. The area near the Truckee River also is highly susceptible to contamination by surface water and shallow ground water containing undesirable compounds. Many water-table wells in the Reno-Sparks area have low concentrations of pesticides and VOC's (see section "Quality of Water in the Water-Table Aquifers—Urban Areas"). Other basins in the NVBR NAWQA study unit have some type of confining layer that retards the downward movement of shallow ground water. In Las Vegas, semicontinuous layers of caliche (calcium carbonate) and clay are present beneath most of the urban area and act as local confining layers. In Carson Valley and

Typical public-supply well, North Las Vegas, January 1995.



Typical drain in the Carson Desert agricultural area, March 1995. Photograph by Ronald P. Collins, U.S. Geological Survey.

Carson Desert, layers of silt and clay are interbedded with the water-bearing sand and gravel deposits. These layers of fine-grained sediment act as confining layers, which generally prevent downward movement of shallow ground water.

Areas with hydraulic gradients favoring downward movement of shallow ground water also are susceptible to contamination. Specific land-use activities in areas where downward hydraulic gradients exist can cause contaminants to move down to deep aquifers. Areas where these conditions are naturally present include the western parts of Truckee Meadows and Carson Desert. In these areas, recharge occurs by infiltration of precipitation and irrigation water. The hydraulic gradient can be changed by overpumping an aquifer, thus inducing downward movement of shallow ground water and contaminants toward the deeper principal aquifers.

Disturbance of the confining layer may create the opportunity for shallow ground water to move down into the principal aquifers. This scenario can occur if overpumping of a confined aquifer causes subsidence, which can cause fissures in confining layers or can fracture the well casing, thus destroying the seal between the two aquifers. In Las Vegas, subsidence has occurred in the urban area (Poland and Davis, 1969) as a result of overpumping the deep aquifer. Examples of broken well casings caused by subsidence have been documented by Bell (1981) and can be visually seen at several of the older wells in the area. Bell (1981) documents several wells where casings are protruding above land surface, some as much as 4.1 ft. In Las Vegas, water-table aquifers in areas of subsidence have pesticides and VOC's, thus placing the principal aquifer at risk for contamination by this mechanism.

Another mechanism for shallow ground water to move through the confining layer is by way of abandoned wells that have not been properly sealed. This creates a direct path for surface water or shallow ground water to move down to the deeper ground-water resource. Downward movement of water in abandoned and nonpumping wells has been documented in the San Joaquin Valley, Calif., by Davis and others (1964). Typically, irrigation and public-supply wells are open to multiple aquifers, or zones in an aquifer, creating the opportunity for movement of water between the zones. Borehole flow in wells with long screens has been simulated using a finite-difference model and found to be significant even in homogeneous aquifers with small head differences (Reilly and others, 1989). Also, if a well is not properly sealed at the surface during construction, water can move down the annular space and reach the deeper ground-water resource.

In Las Vegas Valley, the Southern Nevada Water Authority augments ground-water supplies by injecting treated water from Lake Mead into the principal aquifer. If the injectant contains contaminants, this practice can introduce those contaminants into the drinking-water supply. Water analyzed from principal-aquifer wells near the injection points in Las Vegas Valley contains chloroform (table 2), which can result from chlorination of the surface water or reaction of free chlorine with dissolved organic carbon in the aquifer (Thurman, 1985).

SUMMARY

This report summarizes water-quality data collected from wells in the Carson and Truckee River Basins and the Las Vegas area of Nevada during 1993-95 and selected previous studies. As part of the NVBR NAWQA project, the potential for contamination of ground-water supplies by shallow water from the water-table aquifers was assessed in these areas. Water samples were collected from shallow water-table wells and deeper water-supply wells in Carson Valley (agricultural, headwater area), Carson Desert (agricultural, basin area), the Reno-Sparks area (urban, headwater area), and the Las Vegas area (urban, basin area).

Results of chemical analyses of samples indicate that the shallow water-table aquifers have a natural water quality that is highly variable. In headwater areas where precipitation is sufficient to

"The desert blooms"—agriculture in the Carson Desert, July 1989.

Flow-through chamber where pumped ground water is monitored for pH, specific conductance, dissolved oxygen, and temperature prior to obtaining a sample. Photograph by Kenneth J. Covay, U.S. Geological Survey.

produce ground-water recharge and surface runoff (Carson Valley and the Reno-Sparks area), concentrations of most dissolved constituents are lower than in basin areas (Carson Desert and Las Vegas area). Superimposed on this natural variability in water quality are the effects of land use, which include detections of manmade organic compounds (pesticides, VOC's, MBAS, and phenols) and nitrate (from sewage or fertilizers).

In 30 samples from shallow water-table wells in agricultural areas, three triazine herbicides, acetochlor, and bromacil were detected at concentrations ranging from 0.005 to 1.2 µg/L. Water samples from eight wells had detections of one or more of these compounds. No VOC's were detected in 29 samples; however, 13 and 9 of these samples had detections of MBAS and phenols, respectively. Four of 74 samples collected from water-table wells in agricultural areas exceeded the MCL for nitrate. All the exceedances for nitrate were in samples from Carson Desert.

Forty-seven percent of the water samples from shallow water-table wells in urban land-use areas (Reno-Sparks and Las Vegas areas) had pesticide detections. Triazine herbicides were the most commonly detected compounds and included atrazine, deethylatrazine, prometon, and simazine. The Reno-Sparks area had a higher frequency of detection (68 percent) than the Las Vegas area (28 percent). All detections of pesticides were at concentrations less than 1 µg/L. Pesticide occurrences in samples from shallow water-table aquifers were more prevalent in urban areas than in agricultural areas. More than one-half of the samples from shallow water-table wells had detections of one or more VOC's. Chloroform was commonly detected in samples from the Las Vegas (68 percent) and Reno-Sparks (21 percent) areas. In all, six samples exceeded MCL's for VOC's. The compounds having values exceeding MCL's were MTBE (two samples), tetrachloroethylene (three samples), and trichloroethylene (one sample). MBAS were detected in 10 samples from water-table wells and phenols were detected in 32 samples. The MCL for nitrate was exceeded in four samples from the Las Vegas area.

Principal aquifers show some indications that they are being affected by water from near the water table. In agricultural land-use areas, four samples from principal-aquifer wells had detections of pesticides at low concentrations (less than 0.1 µg/L). Four different triazine herbicides were detected in these four samples and all were from wells tapping the principal aquifer in Carson Valley. No VOC's, MBAS, or phenols were detected in samples from principal-aquifer wells in Carson Valley or Carson Desert agricultural areas. Nitrate concentrations generally were low in samples from principal-aquifer wells in agricultural areas, with one sample (22 mg/L as N) from the Carson Desert exceeding the MCL of 10 mg/L as N.

In urban land-use areas, 44 percent of samples from principal aquifer in the Reno-Sparks area and 14 percent from the Las Vegas area had detections of pesticides at low concentrations (less than 0.1 µg/L). Six different compounds, mostly triazine herbicides, were detected. VOC's were detected in 45 percent of the samples from principal aquifers in urban areas. Chloroform was the most commonly detected VOC (50 percent in Las Vegas and 28 percent in Reno-Sparks). One sample in the Las Vegas area had a tetrachloroethylene concentration (21 µg/L) that exceeded the MCL (5 µg/L). About 10 percent of the samples from principal aquifers in urban areas had detections of MBAS and 42 percent had detections of phenols. Nitrate concentrations generally were low in principal-aquifer wells in urban areas.

As of 1995, principal aquifers generally are not contaminated to the point of endangerment to the human population that uses this resource. Other parts of principal aquifers not sampled during this study, however, may be contaminated. Small concentrations of manmade compounds are present in many parts of the principal aquifers, which indicates that some water from the shallow water-table aquifers is moving into the principal aquifers. Because the shallow water-table aquifers are contaminated in many areas, especially in urban areas, the potential exists for water and accompanying contaminants to make their way into principal aquifers.

Contamination of principal aquifers may be enhanced by certain natural and human-induced factors. Areas where the hydraulic gradient is downward due to natural conditions or ground-water withdrawals and where no confining or low-hydraulic-conductivity layers separate the shallow water-table and principal aquifers are susceptible to contamination. Disturbance of low-conductivity or confining layers also can increase the potential for migration of contaminants into the principal aquifers used for water supply. Several mechanisms exist that could compromise the integrity of low conductivity or confining layers. Among these are overpumping of an aquifer, causing subsidence and fissuring of confining layer; fracture or collapse of a well casing due to subsidence; improper well construction; and movement of water in abandoned or nonpumping wells. Another mechanism to move contaminants into ground-water supplies is by artificial recharge of aquifers. In the Las Vegas area, injection of recharge water into the principal aquifer provides a direct route of entry for any accompanying contaminants.

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