GEOHYDROLOGY AND WATER CHEMISTRY IN THE RIALTO-COLTON BASIN, SAN BERNARDINO COUNTY, CALIFORNIA

By Linda R. Woolfenden *and* Dina Kadhim

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CONVERSION FACTORS, VERTICAL DATUM, WATER-CHEMISTRY UNITS, DEFINITION OF WATER YEAR, AND WELL- AND SPRING-NUMBERING SYSTEM

Multiply	By	To obtain
acre	0.4047	hectare
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/y)	0.001233	cubic hectometer per year
foot (ft)	0.3048	meter
feet per day (ft/d)	0.3048	meters per day
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	259.0	hectare
foot per mile (ft/mi)	0.1894	meter per kilometer

Temperature is given in degrees Celsius (°C) which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8(°C) + 32.$$

Vertical Datum

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Water-Chemistry Units

Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (μg/L). Micrograms per liter is equivalent to "parts per billion."

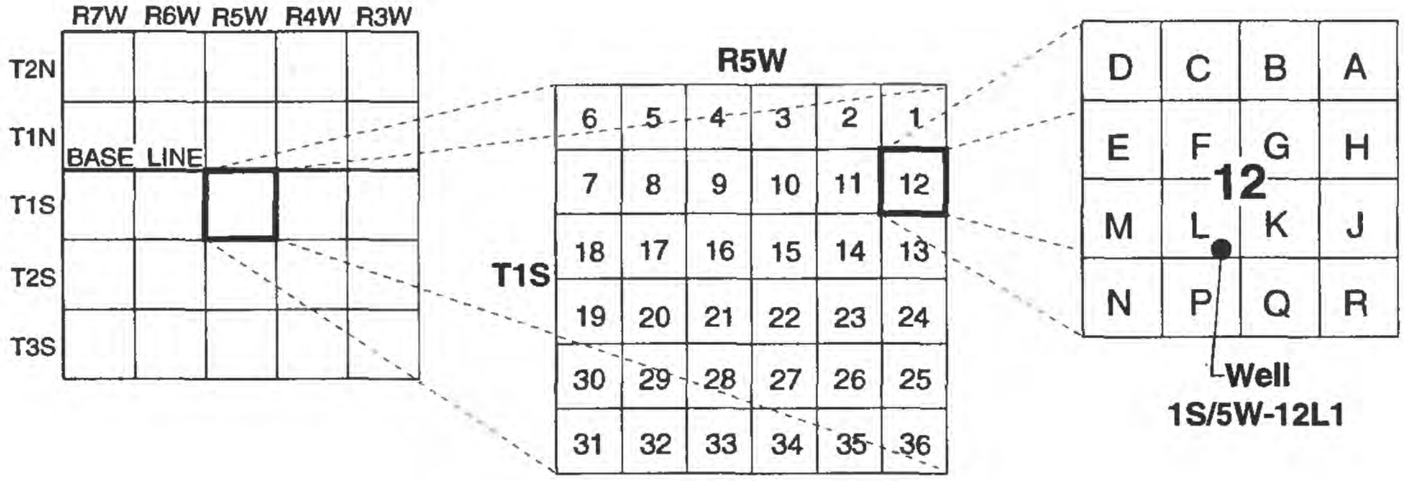
Stable-isotope data for oxygen, hydrogen, and carbon-13 are reported in delta (δ) notations as permil (‰) parts per thousand; Carbon-14 data are reported as percent modern carbon. Tritium concentration is reported in tritium units (TU).

Water Year

"Water year" refers to the 12-month period that starts October 1 and ends September 30; it is designated by the calendar year in which it ends and which contains 9 of the 12 months.

Well- and Spring-Numbering System

Wells and springs are identified and numbered by the State of California according to their location in the system for the subdivision of public lands. Identification consists of the township number, north or south; the range number, east or west; and the section number. Each section is divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with "A" in the northeast corner of the section and progressing in a sinusoidal manner to "R" in the southeast corner. Within the 40-acre tract, wells are numbered sequentially in the order in which they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians: Humboldt (H), Mount Diablo (M), and San Bernardino (S). Because all wells in the study areas of this report are referenced to the San Bernardino base line and meridian, the final letter "S" will be omitted. Well numbers consist of 15 characters and follow the format 001S005W12L001S. The numbering system for springs is identical to that for wells except that the letter "S" is added after the letter that indicates the 40-acre subdivision. In this report, well numbers are abbreviated and written 1S/5W-12L1. The following diagram of the well-numbering system shows how well number 1S/5W-12L1 is derived.



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Abstract

The 40-square-mile Rialto-Colton ground-water basin is in western San Bernardino County, California, about 60 miles east of Los Angeles. This basin was chosen for storage of imported water because of the good quality of native ground water, the known capacity for additional ground-water storage in the basin, and the availability of imported water. Because the movement and mixing of imported water needed to be determined, the San Bernardino Valley Municipal Water District entered into a cooperative program with the U.S. Geological Survey in 1991 to study the geohydrology and water chemistry in the Rialto-Colton basin. Ground-water flow and chemistry were investigated using existing data, borehole-geophysical and lithologic logs from newly drilled test holes, measurement of water levels, and chemical analyses of water samples.

The Rialto-Colton basin is bounded on the northwest and southeast by the San Gabriel Mountains and the Badlands, respectively. The San Jacinto Fault and Barrier E form the northeastern boundary, and the Rialto-Colton Fault forms the southwestern boundary. Except in the southeastern part of the basin, the San Jacinto and Rialto-Colton Faults act as ground-water barriers that impede ground-water flow into and out of the basin. Barrier E generally does not impede ground-water flow into the basin.

The ground-water system consists primarily of gravel, sand, silt, and clay. The maximum thickness is greater than 1,000 feet. The ground-water system is divided into four water-bearing units: river-channel deposits, and upper, middle, and lower water-bearing units. Relatively impermeable consolidated deposits underlie the lower water-bearing unit and form the lower boundary of the ground-water system.

Ground water moves from east to west in the river-channel deposits and upper water-bearing unit in the southeastern part of the basin, and from northwest to southeast in the middle and lower water-bearing units. Two major internal faults, Barrier J and an unnamed fault, affect ground-water movement. Ground water moves across Barrier J in the unfaulted part of the ground-water system. The unnamed fault is a partial barrier to ground-water movement in the middle water-bearing unit and an effective barrier in the lower water-bearing unit. Imported water flows laterally across the unnamed fault above the saturated zone.

Major sources of recharge to the ground-water system are underflow; precipitation that collects in small streams that drain the San Gabriel Mountains and the Badlands or runs off the mountain front as sheet flow, and sub-surface inflow; imported water; seepage loss from the Santa Ana River and Warm Creek; infiltration of rainfall; and irrigation return flow. The main component of discharge is pumpage.

Long-term water levels in production wells reflect precipitation cycles. During a 1947-77 dry period, water levels in three wells declined almost continuously—as much as 100 feet in one well. Water levels in a well north of Barrier J are not affected by stresses on the ground-water system south of the barrier, indicating that these two parts of the ground-water system are not well connected.

Water levels in cluster wells east of the unnamed fault north and south of the Linden Ponds artificial-recharge site rose as much as 70 feet during 1992-95. The rise in water levels in wells near the recharge ponds was observed within 2 months after the beginning of recharge. Water levels in most wells west of the unnamed fault changed very little during 1992-95.

Water-chemistry data indicate that chemical characteristics vary within the ground-water system, and that dissolved-solids concentrations are generally higher in the river-channel deposits, upper water-bearing unit, and the consolidated deposits than in the middle and lower water-bearing units. The chemical characteristics in water from the middle water-bearing unit were similar for most wells sampled west of the unnamed fault. In water from wells perforated in the lower water-bearing unit, chemical characteristics generally were different from those in water from the middle water-bearing unit. Chemical characteristics of water samples from the production wells were similar to those of water from the middle water-bearing unit, suggesting that this unit is the principal source of water to production wells.

Stable-isotope ratios varied within the ground-water system. Deuterium ratios in ground water east of the unnamed fault were generally lighter than ratios west of the fault. This difference was more pronounced in the lower water-bearing unit than in the other units, suggesting that the barrier effect of the fault is greater in the lower water-bearing unit than in other parts of the ground-water system.

INTRODUCTION

The Rialto-Colton basin, located in western San Bernardino County, California (fig. 1), is in one of the fastest growing areas in the country. Water purveyors rely on native ground-water resources to meet local water-supply needs. To supplement ground-water resources and offset overdraft conditions in the basin during dry periods, artificial-recharge operations were begun in 1982 to store surplus imported water originating in the Sierra Nevada during wet periods; these artificial-recharge operations ended in 1994. Because little was known about the ground-water system and ground-water chemistry in the Rialto-Colton basin, the ultimate disposition of the artificially recharged imported water and its effects on ground-water flow and native ground-water chemistry were uncertain. To better understand the geohydrology and fate and movement of the imported water in the Rialto-Colton basin, the San Bernardino Valley Municipal Water District entered into a cooperative agreement with the U.S. Geological Survey in 1991 to study the ground-water system and to describe the water chemistry of the basin.

This report includes a description and evaluation of the geohydrology of the Rialto-Colton basin; sources of recharge and discharge; movement of ground water within the ground-water system; and areal and vertical variation in ground-water chemistry. Water-level and water-chemistry data collected from multiple-depth observation wells completed for this study and from selected production wells are included and evaluated in this report.

Description of Study Area

The Rialto-Colton basin is a northwest-southeast-trending alluvial basin in the upper Santa Ana River drainage area (fig. 1). The 40-square-mile Rialto-Colton basin is bounded on the northeast by the San Jacinto Fault and on the southwest by the Rialto-Colton Fault. The San Gabriel Mountains form the northwestern boundary, and the Badlands form the southeastern boundary. The Santa Ana River cuts across the southeastern part of the basin, and Warm and Lytle Creeks join the Santa Ana River near the eastern edge of the basin.

Historically, irrigated and nonirrigated agriculture were the main land uses in the developed part of the Rialto-Colton basin. Both agricultural and urban development in the upper Santa Ana River drainage area, including the Rialto-. Colton basin, increased sharply during the 1940's. In 1949, agricultural development, primarily citrus groves and vineyards, covered about half of the basin, and native vegetation covered most of the rest (Marisue Meza, San Bernardino Valley Municipal Water District, written commun., 1996). Urban development occupied only a small part of the basin (fig. 2). In 1957, agriculture began to decline. At the same time, urban development began to increase rapidly (California Department of Water Resources, 1970). In 1993, the primary land

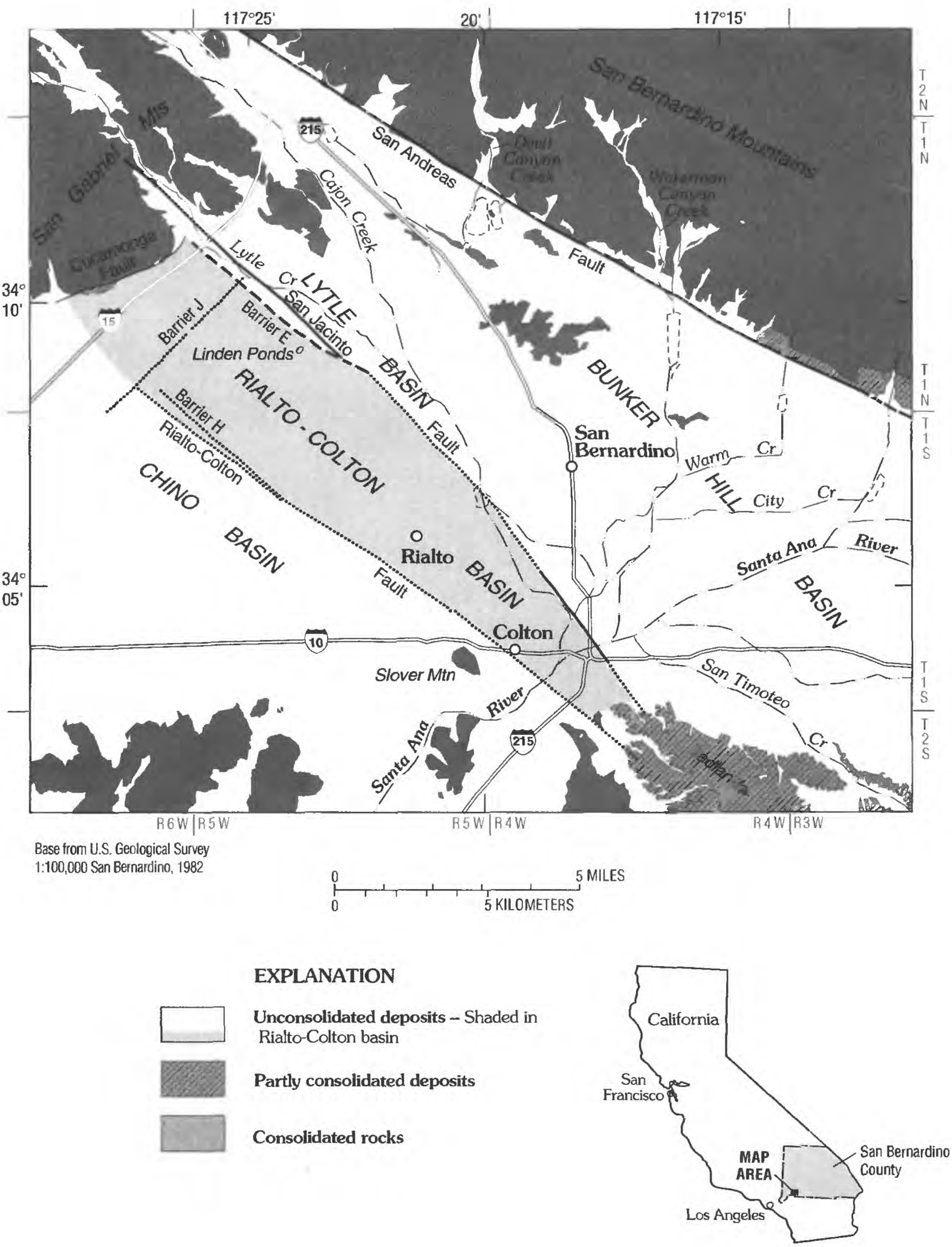


Figure 1. Location and geographic setting of the Rialto-Colton basin, San Bernardino County, California.

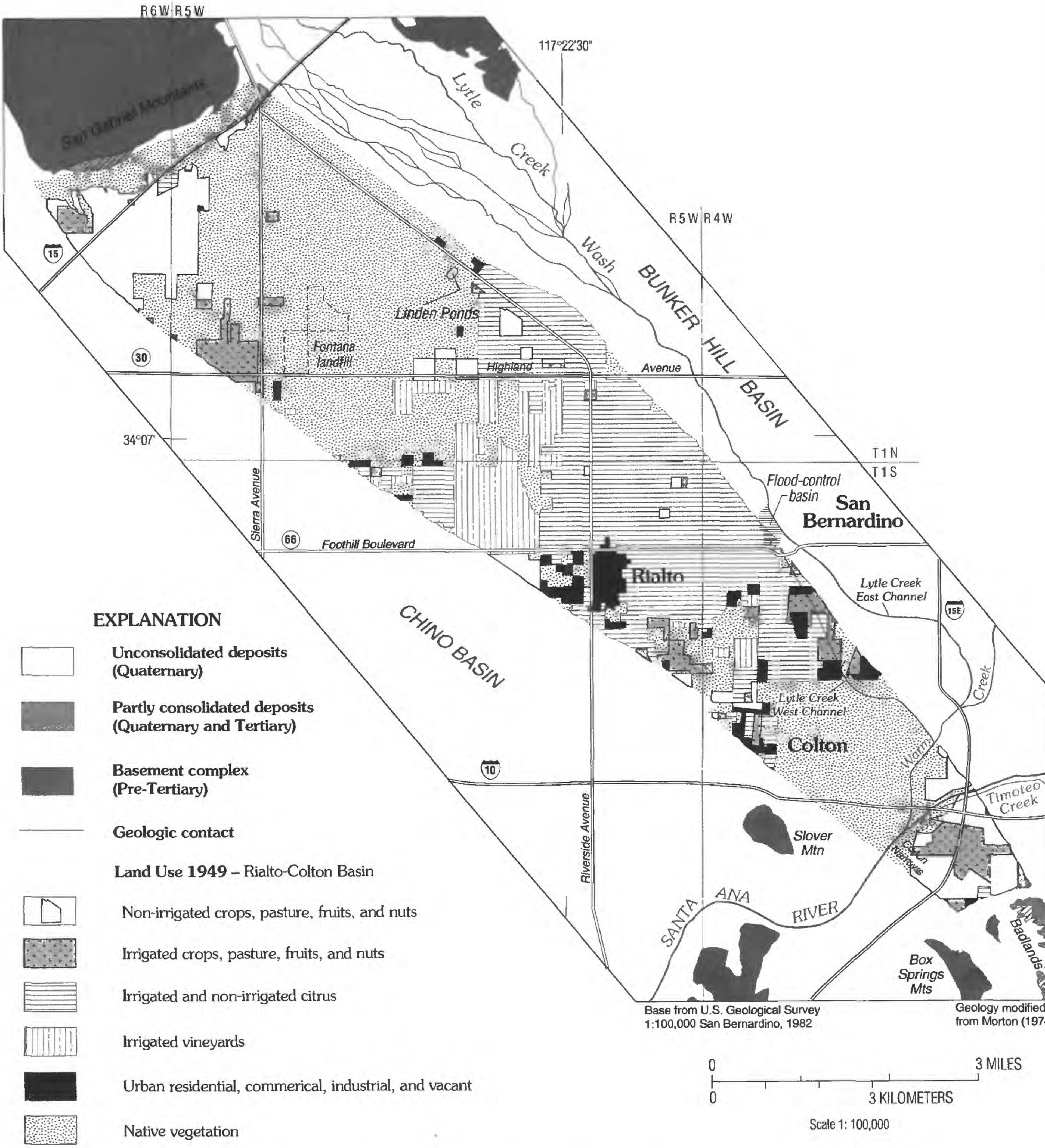


Figure 2. Land use in the Rialto-Colton basin, San Bernardino County, California, 1949. (From Meza, Marisue, San Bernardino Valley Municipal Water District, Written Commun., 1996).

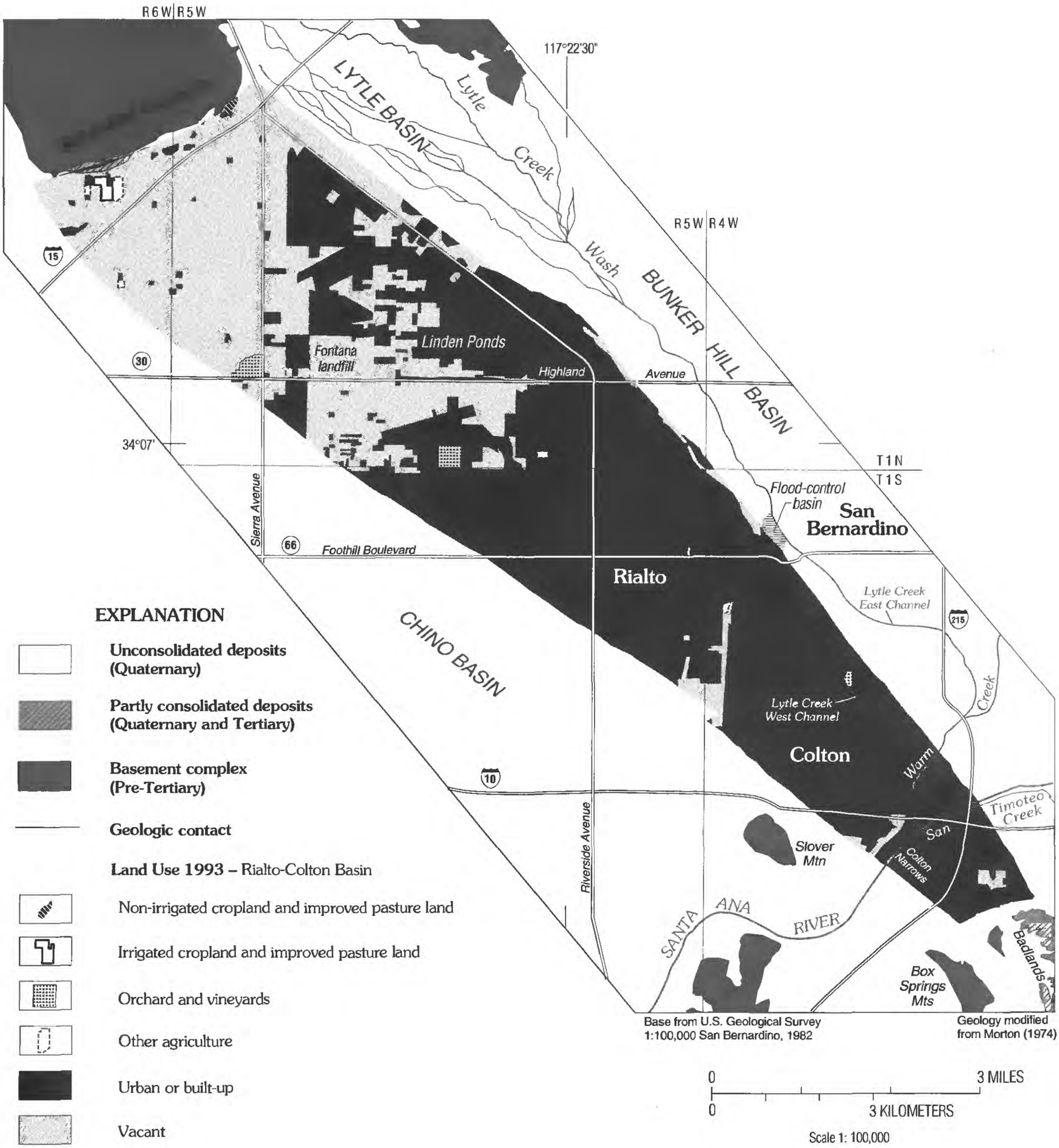


Figure 3. Land use Rialto-Colton basin, San Bernardino County, California, 1993. (From Meza, M., San Bernardino Valley Municipal Water District, Written Commun., 1996).

uses in the basin were residential, industrial, and commercial (Marisue Meza, San Bernardino Valley Municipal Water District, written commun., 1996). About one-third of the basin still was undeveloped and covered with native vegetation (fig. 3).

The upper Santa Ana River drainage is characterized by a warm-summer and mild-winter semiarid climate. Rainfall occurs principally from December through April; in summer, occasional thundershowers occur in the adjacent mountains. Mean annual precipitation at San Bernardino for 1871-1994 was 16.45 in. (fig. 4). Extremes in precipitation include 37.08 in. in 1884 and 5.46 inches in 1881 (National Oceanic and Atmospheric Administration, 1871-1994). A plot of the cumulative departure from mean annual precipitation (fig. 4) shows wet, dry, and average periods between 1871 and 1994. A positive slope indicates above-average rainfall and a negative slope, below-average rainfall. Major wet periods were 1883-89, 1935-46, and 1977-83. Major dry periods were 1889-1904, 1947-77, and 1984-90. The dry period during 1984-90 was, in part, a reflection of the statewide 6-year drought that occurred during 1987-92.

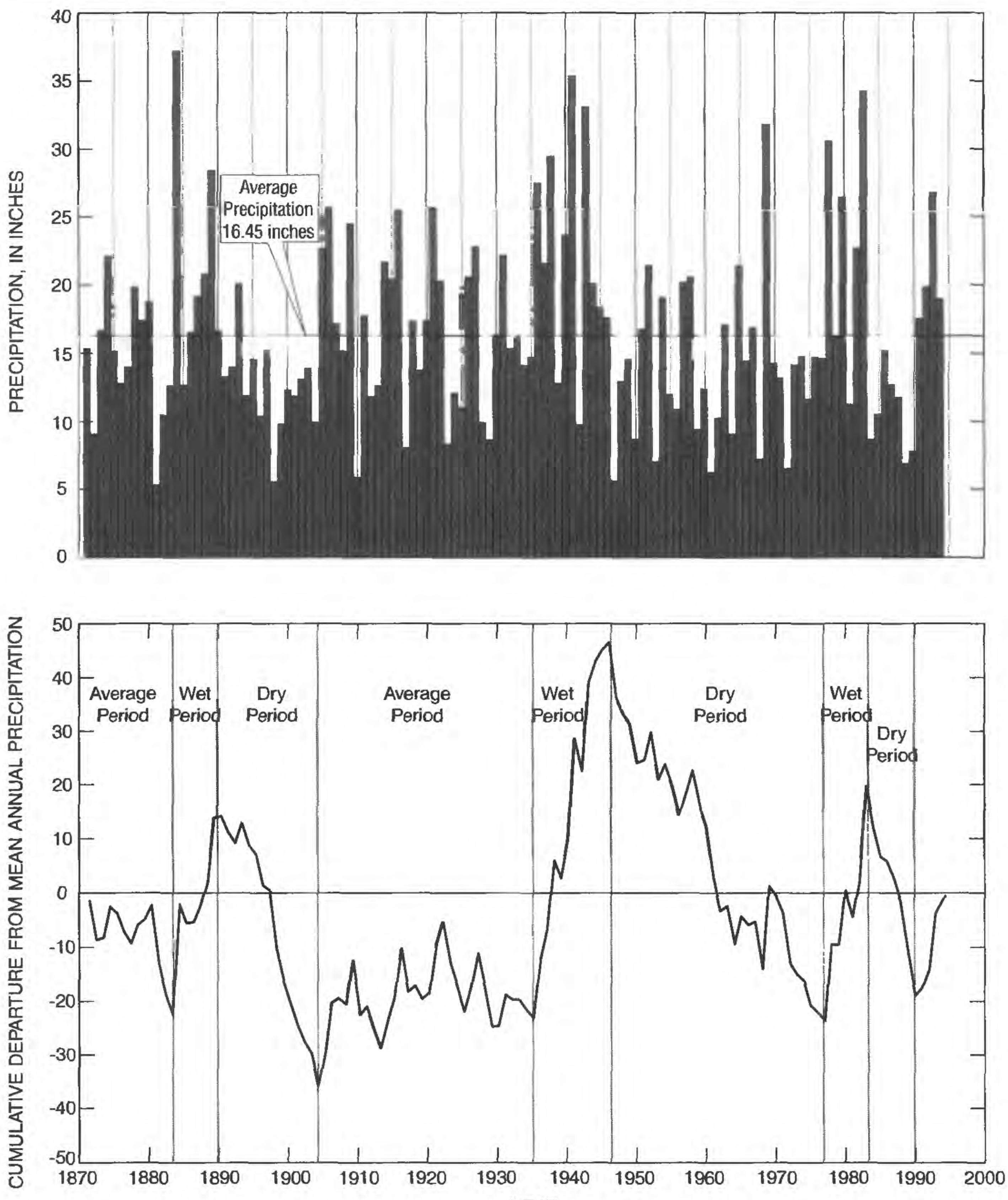


Figure 4. Annual precipitation and cumulative departure from mean annual precipitation at San Bernardino, California, 1871-1994. (Data from the National Oceanic and Atmospheric Administration.)

Acknowledgments

Gratefully acknowledged is the staff of the San Bernardino Valley Municipal Water District—Louis Fletcher, Bob Reiter, Randy Van Gelder, Sam Fuller, Bob Tincher, and Marisue Meza—for their support of this study. Also acknowledged is the cooperation extended by Bill Freels formerly of the city of Rialto, who provided space to store equipment and supplies during drilling, assistance in locating drilling sites, and hydrologic data; and Anthony Araiza of the West San Bernardino County Water District and Kathleen Robles, formerly of the San Bernardino County solid waste disposal department, both of whom provided hydrologic data and assisted in locating drilling sites. The hydrologic data provided by Rex Meyers of the city of Colton and Gene McMeans of the Riverside-Highland Water District are greatly appreciated. The cooperation extended by Buzz Fabrizzio, Jim Henry, and the staff of the Crawford Canyon Water Company in allowing access to their spring also is greatly appreciated.

SCOPE AND METHODS OF STUDY

To gain a better understanding of the ground-water system, 11 test holes were drilled in the Rialto-Colton basin using mud-rotary methods during 1992-94. Eight holes were drilled to depths of 935 to 1,000 ft and three were drilled to depths of 358 to 478 ft. Diameter of the test holes ranged from 6 3/4 to 14 in. Geophysical logs were obtained for all test holes. Four to six wells were completed at different depths in each of the eight deeper test holes, and one to three wells were completed in each of the three shallower test holes. In this report, these 11 multiple-depth well sites are referred to as cluster sites, and the wells at each site, as cluster wells. Prior to sampling, the water level in each well was measured. Currently (1996), water levels are measured in 33 wells by transducers and recorded by data loggers every 15 minutes. Manual measurements are made every four to six weeks when the equipment is serviced. Water levels measured by the transducers are stored in the U.S. Geological Survey's Automated Data Processing System (ADAPS) data base; manual measurements are stored in the Ground-Water Site Inventory System (GWSI) data base.

Well Drilling and Construction

The criteria for selecting sites for the collection of borehole geophysical data and the installation of multiple-depth wells were based on the need for information on subsurface geology, ground-water levels, and water chemistry. Priority was given to selecting drill sites along the presumed regional ground-water gradient passing through the Linden Ponds artificial-recharge site. Six cluster sites are located along this gradient; one upgradient (1N/5W-21K1-4) from Linden Ponds and five downgradient (1N/5W-22N1-6, 1N/5W-26L1, 1N/5W-35B1-4, 1S/4W-8E1-4, and 1S/4W-20H1-5) (fig. 5). Consideration also was given to locating the cluster sites on public property in order to readily monitor water levels after the conclusion of this study. Construction data for all 11 cluster sites are given in table 1 (at back of report). Each well was screened and packed with gravel, and wells were isolated from vertically adjacent screened intervals by bentonite grout placed in the annular space. A diagram showing the well construction of cluster site 1S/4W-20H1-5, which is a typical installation, is shown in figure 6.

Lithologic logs were compiled from descriptions of drill cuttings from the 11 test holes and are shown in the Appendix. The rock-type nomenclature used to summarize the lithology at each test hole is depicted in figure 7.

A borehole-geophysical survey was done at each of the 11 test holes. The survey included electric logs (spontaneous potential, 16- and 64-inch normal resistivity, point resistance, and either guard resistivity or 6-foot lateral logs); natural gamma logs; and caliper logs. In addition, sonic logs were obtained at five sites: 1N/5W-22N1-6, 1N/5W-34D1-4, 1S/5W-11F1-4, 1N/5W-35B1-4, and 1S/4W-8E1-4. Shown in figure 8 are spontaneous potential, 16-inch normal resistivity, and natural gamma logs; generalized lithology; and well construction for all cluster sites.

Electric logs measure the electrical properties of the formation around the borehole and the fluid in the formation. Spontaneous potential (SP) and normal resistivity logs (16-, 64-inch, and point resistance) are used to distinguish fine-grained silt and clay from coarser sand and gravel. In

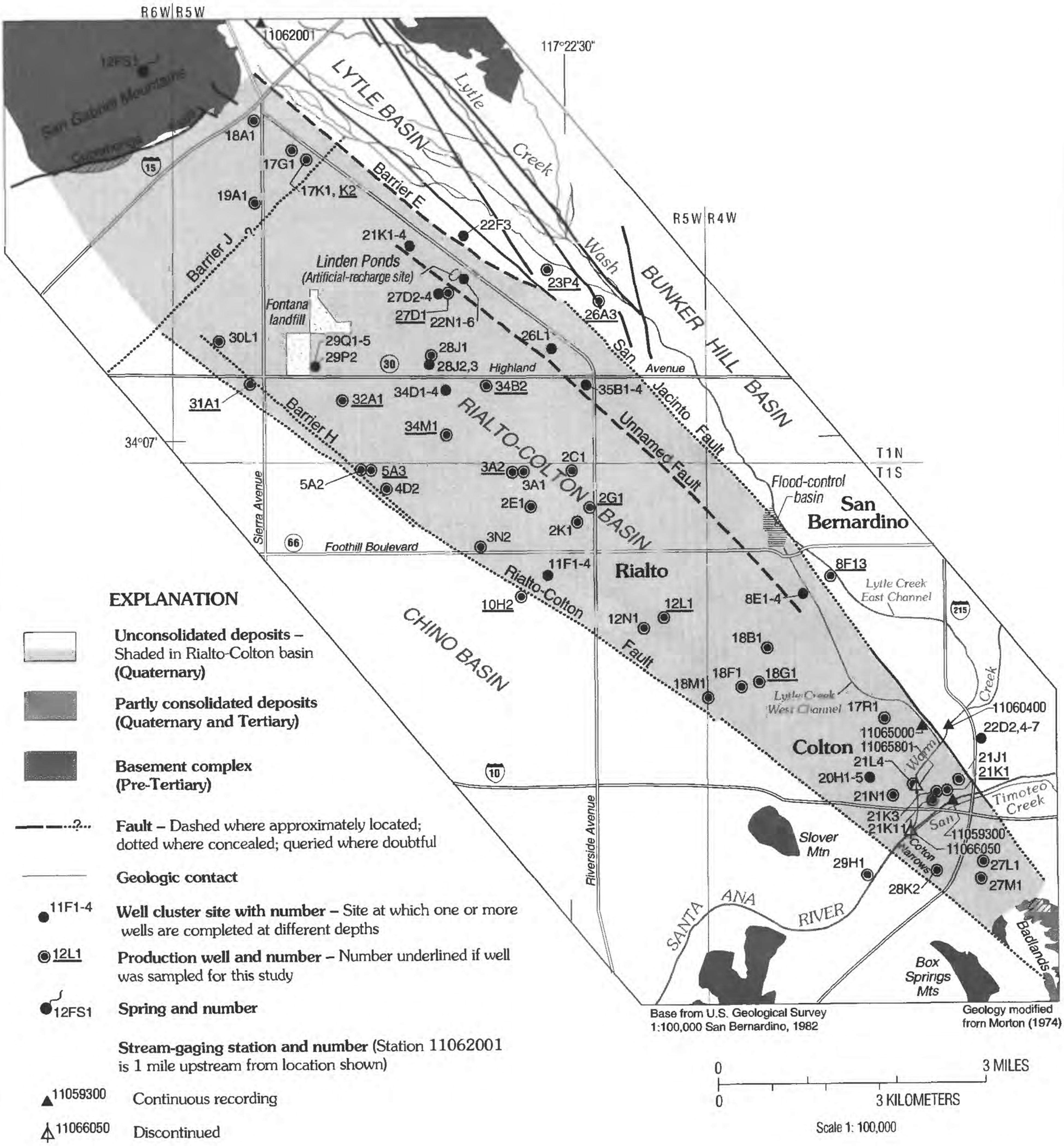


Figure 5. Location of cluster sites, selected production wells, a spring, and stream-gaging stations in the Rialto-Colton basin, San Bernardino County, California.

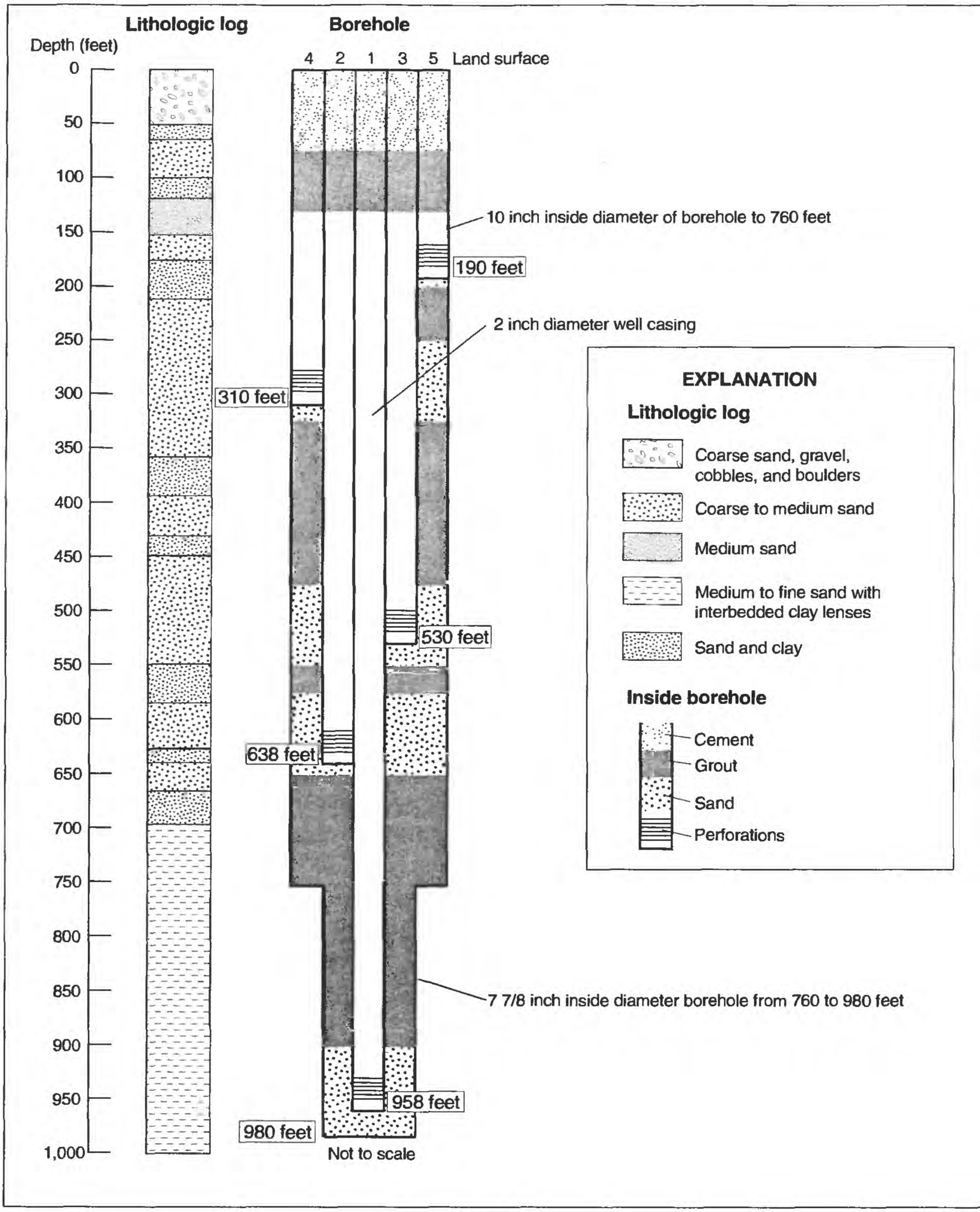


Figure 6. Well construction of cluster site 1S/4W-20H1-5 in the Rialto-Colton basin, San Bernardino County, California.

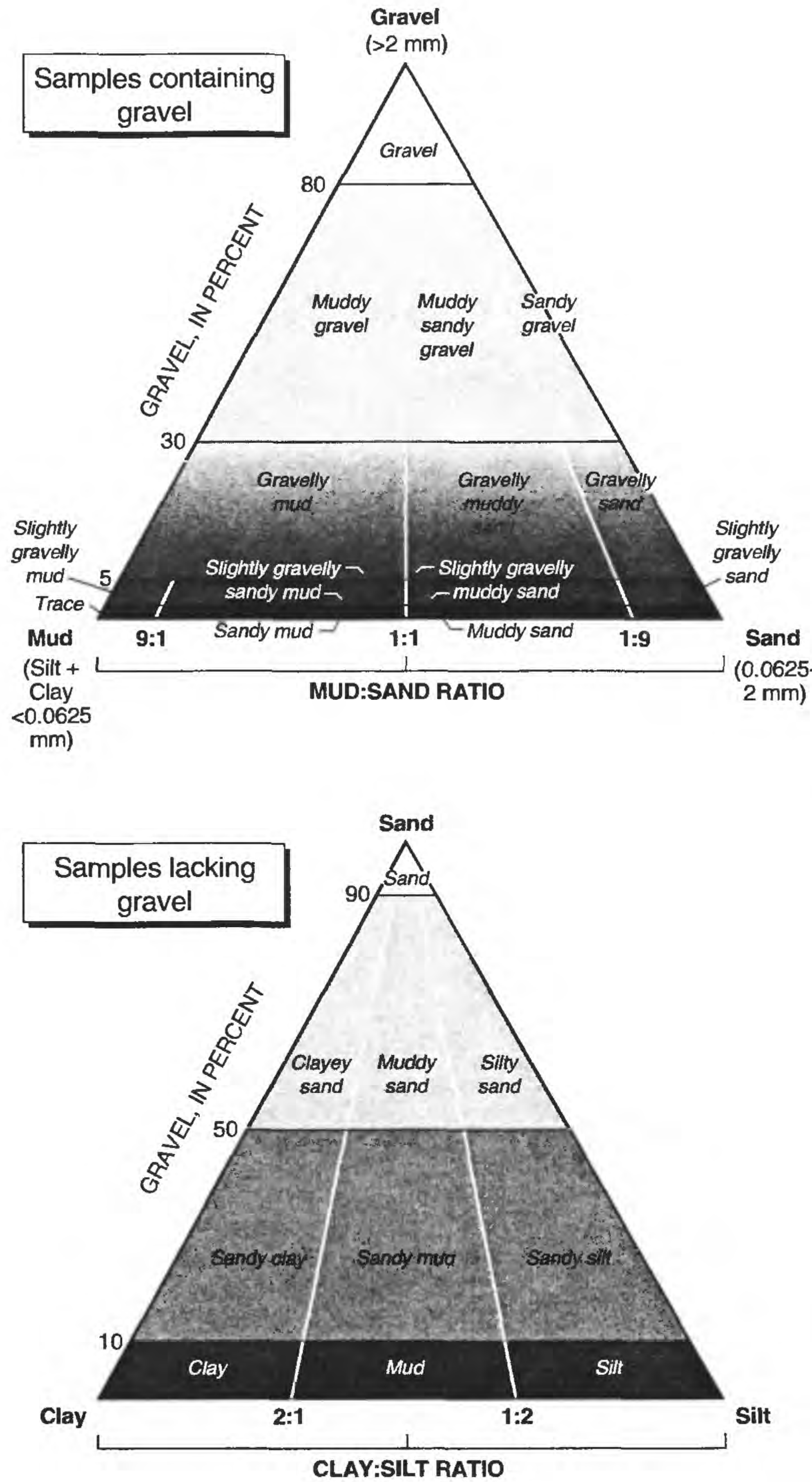


Figure 7. Rock-type nomenclature used for stratigraphic columns (fig. 8). (Modified from Folk, 1974, fig, 1.)

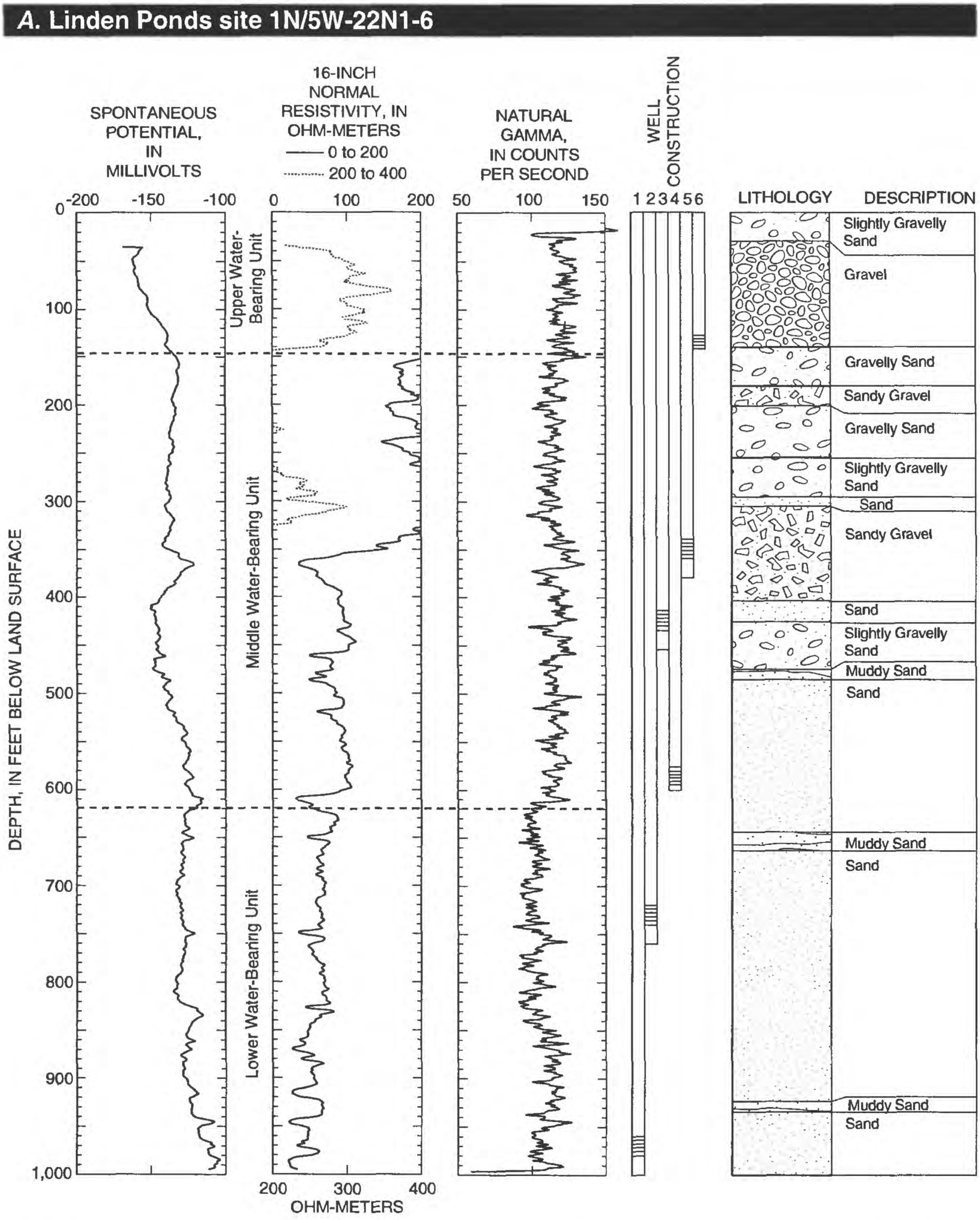


Figure 8. Borehole geophysical logs, well-construction diagrams, and lithologic logs for cluster sites in the Rialto-Colton basin, San Bernardino County, California, 1992-94.

B. El Verde site 1N/5W-21K1-4

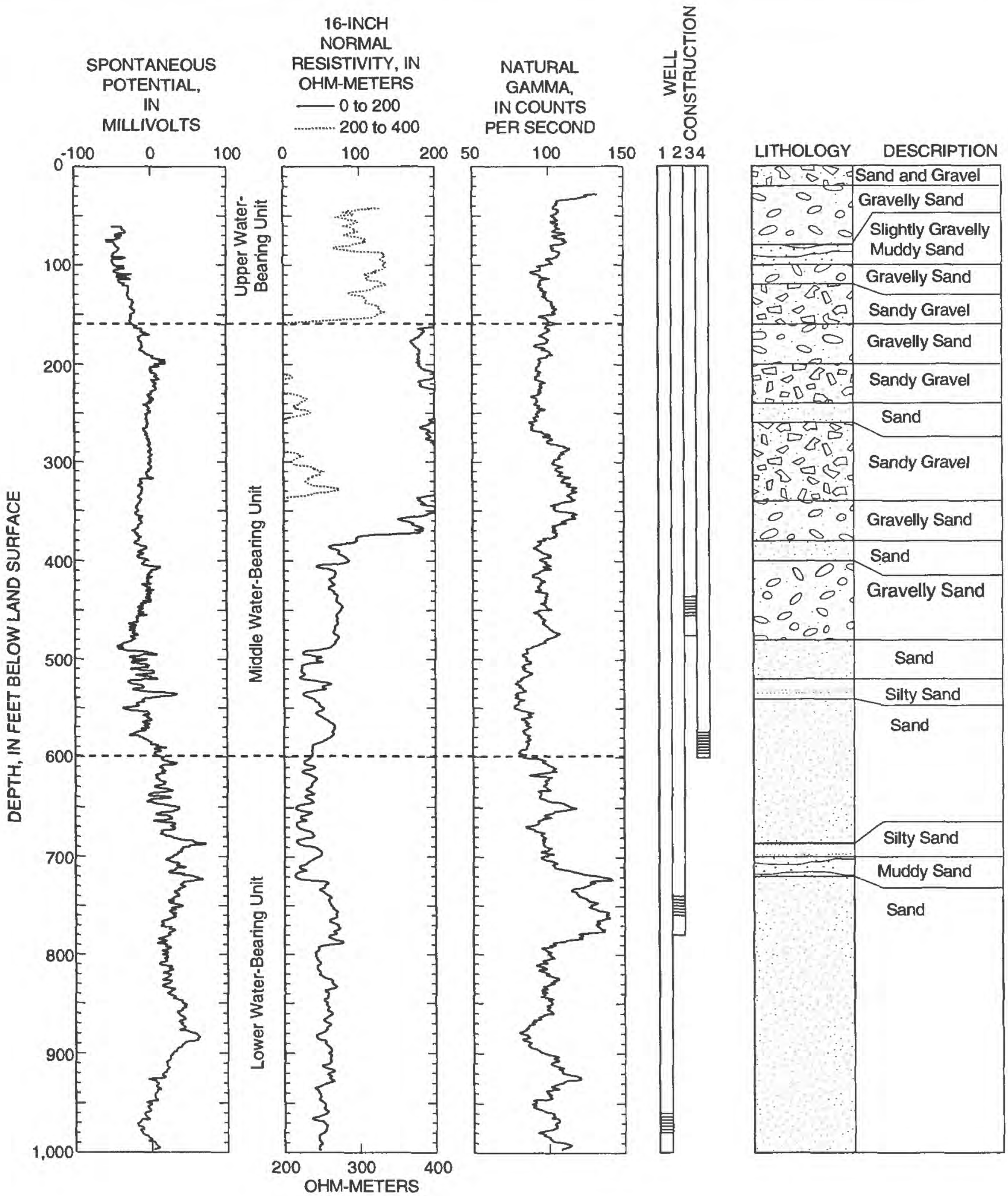
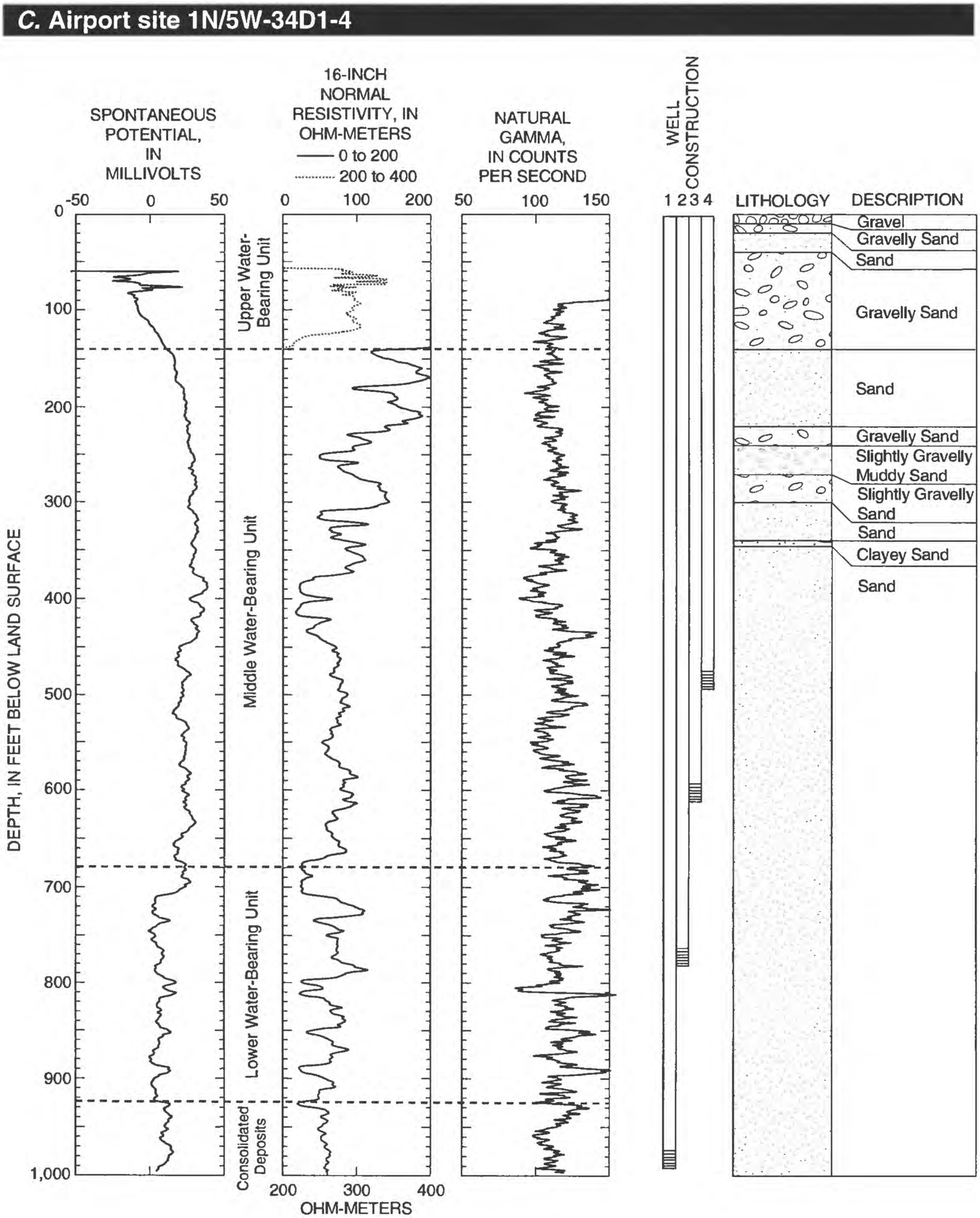


Figure 8—Continued.



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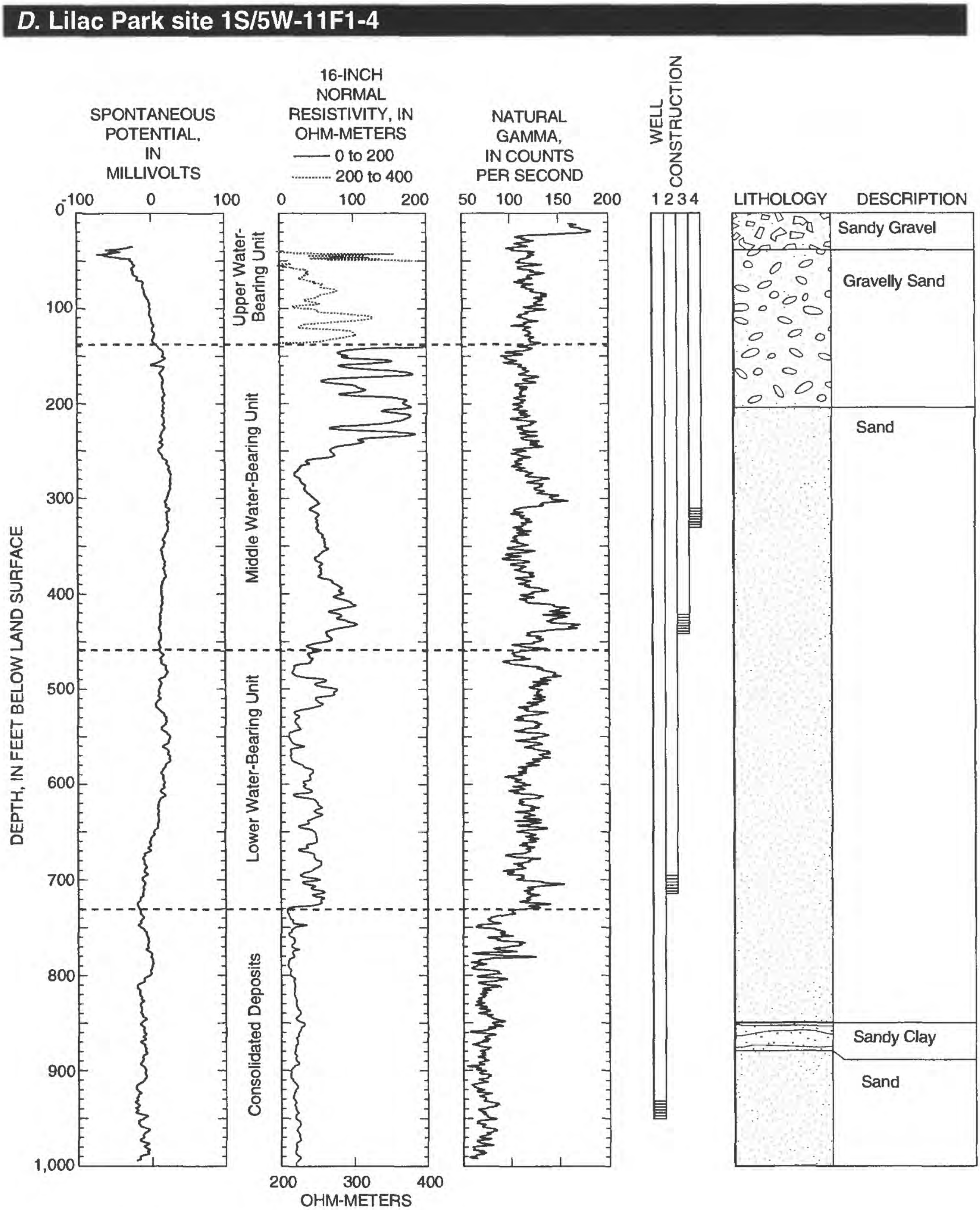


Figure 8—Continued.

E. Easton Reservoir site 1N/5W-35B1-4

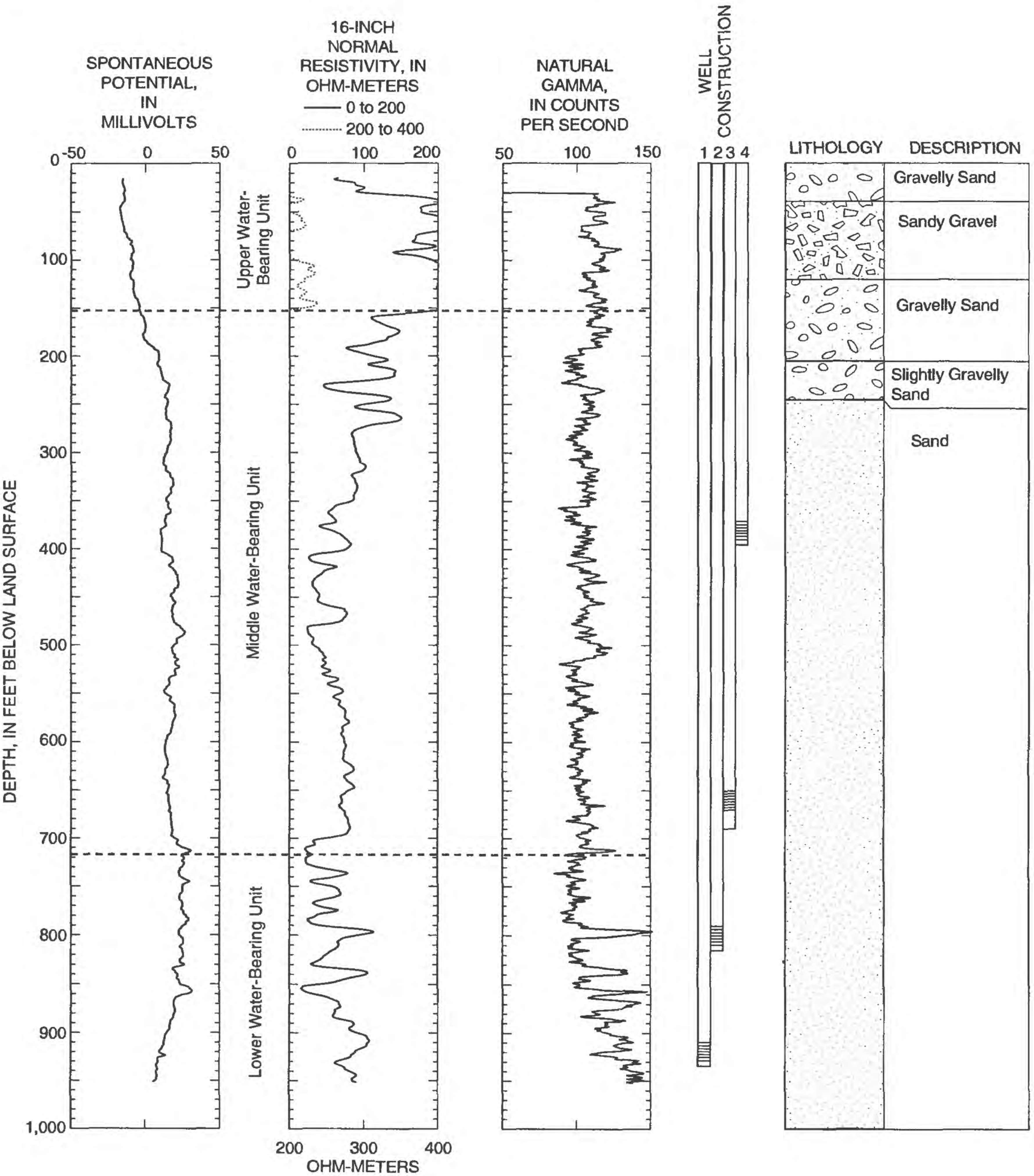


Figure 8—Continued.

F. Rialto Avenue site 1S/4W-8E1-4

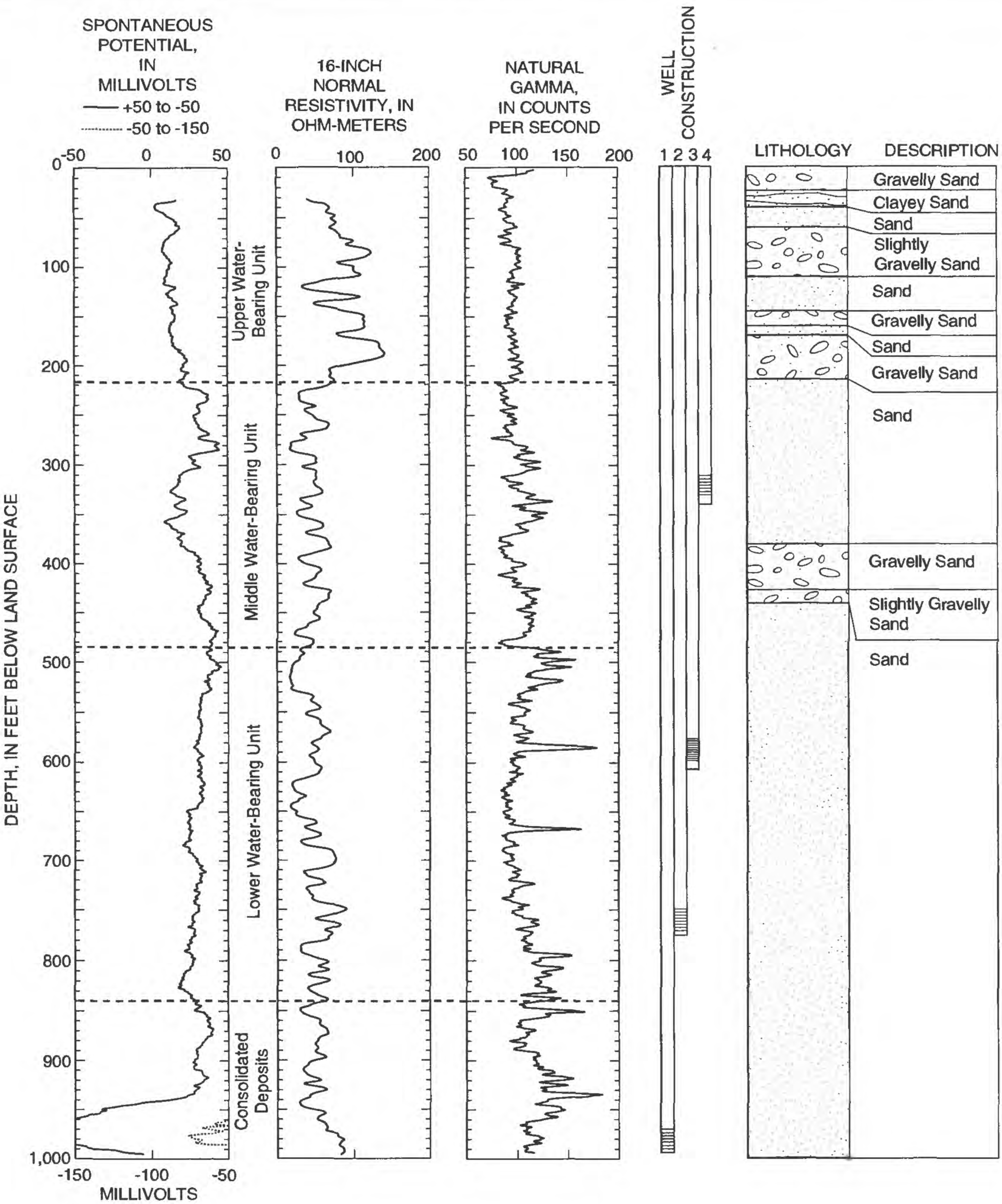


Figure 8—Continued.

G. Colton Plunge Park site 1S/4W-20H1-5

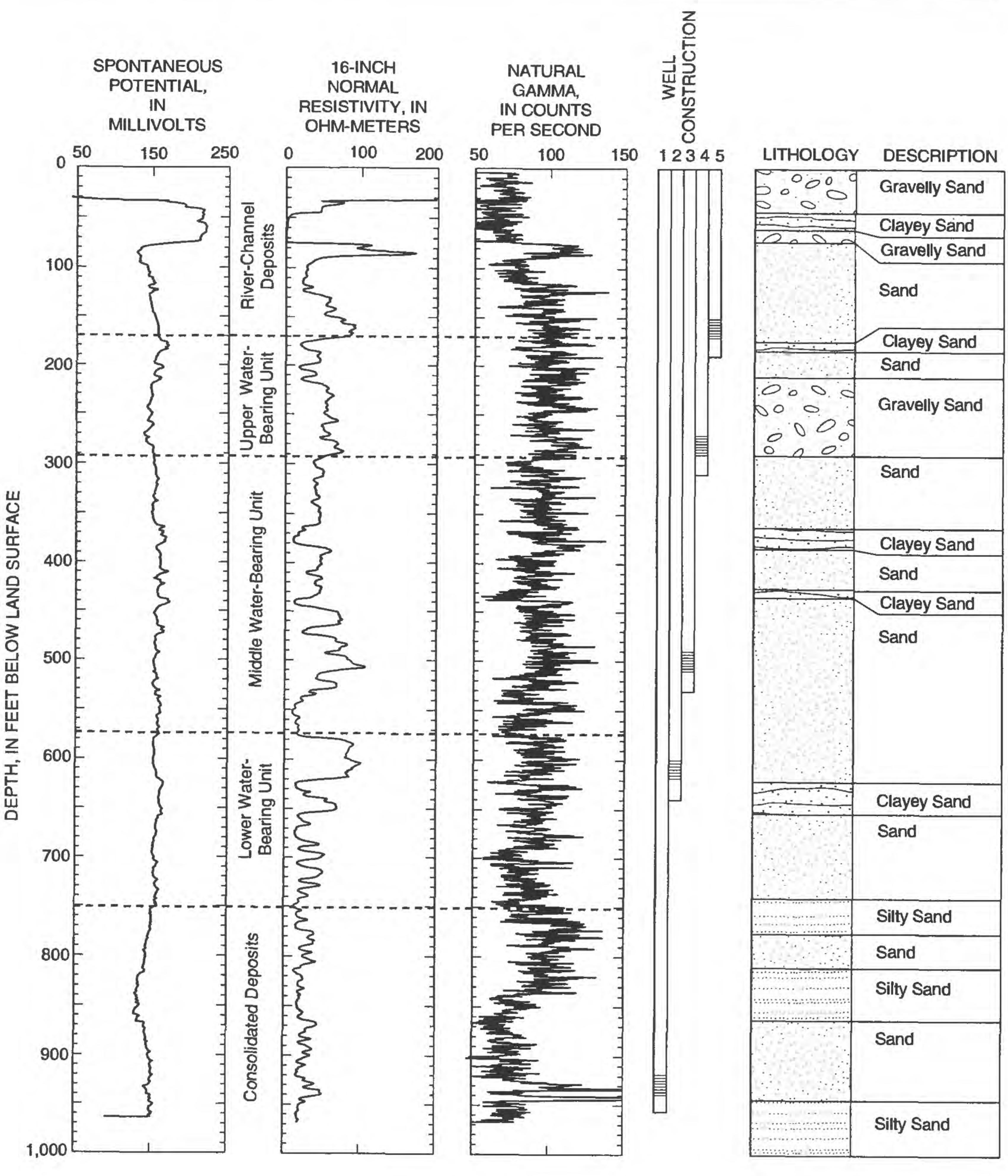


Figure 8—Continued.

H. Fontana Landfill site 1N/5W-29Q1-5

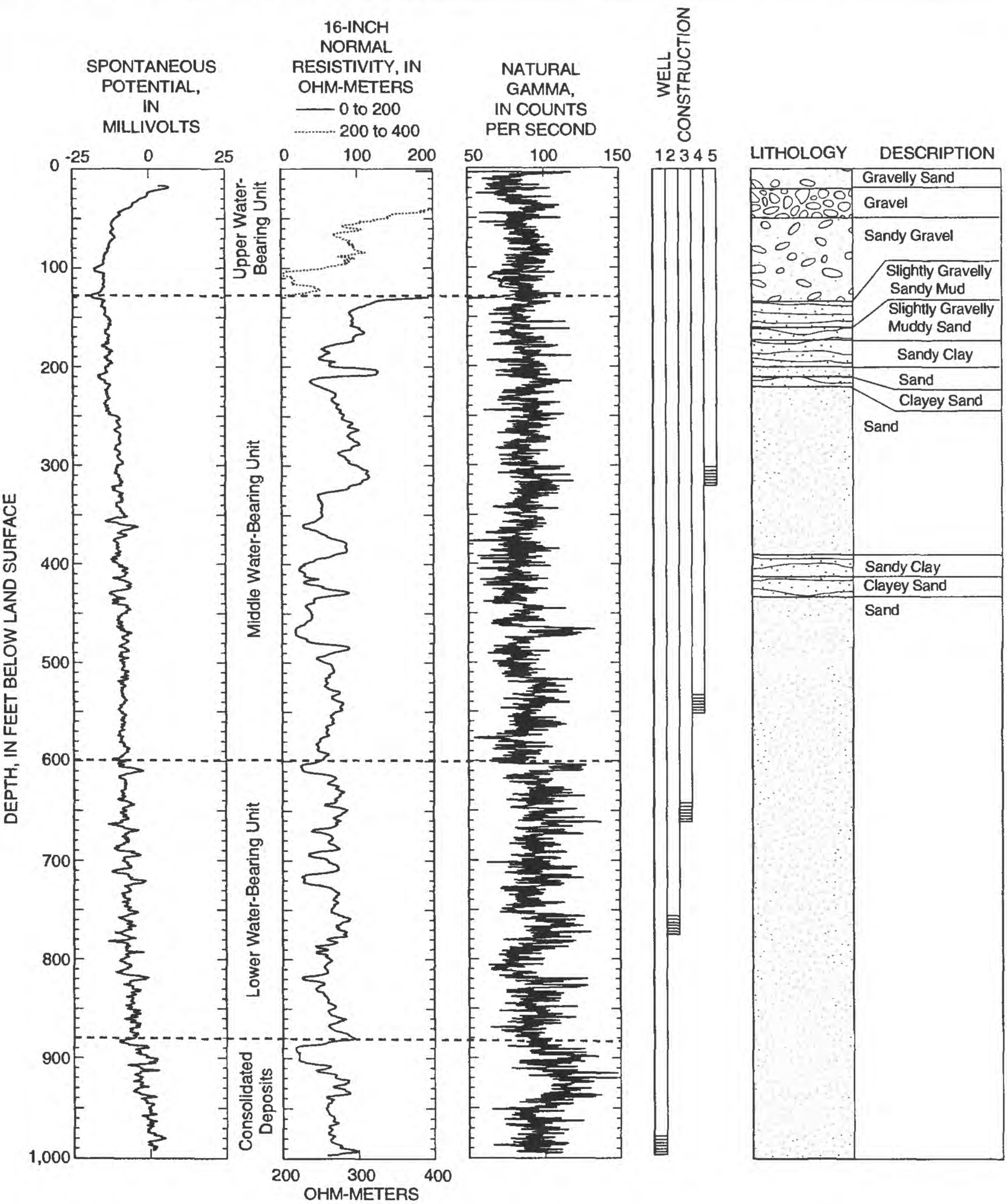


Figure 8—Continued.

I. Cedar Avenue site 1N/5W-27D2-4

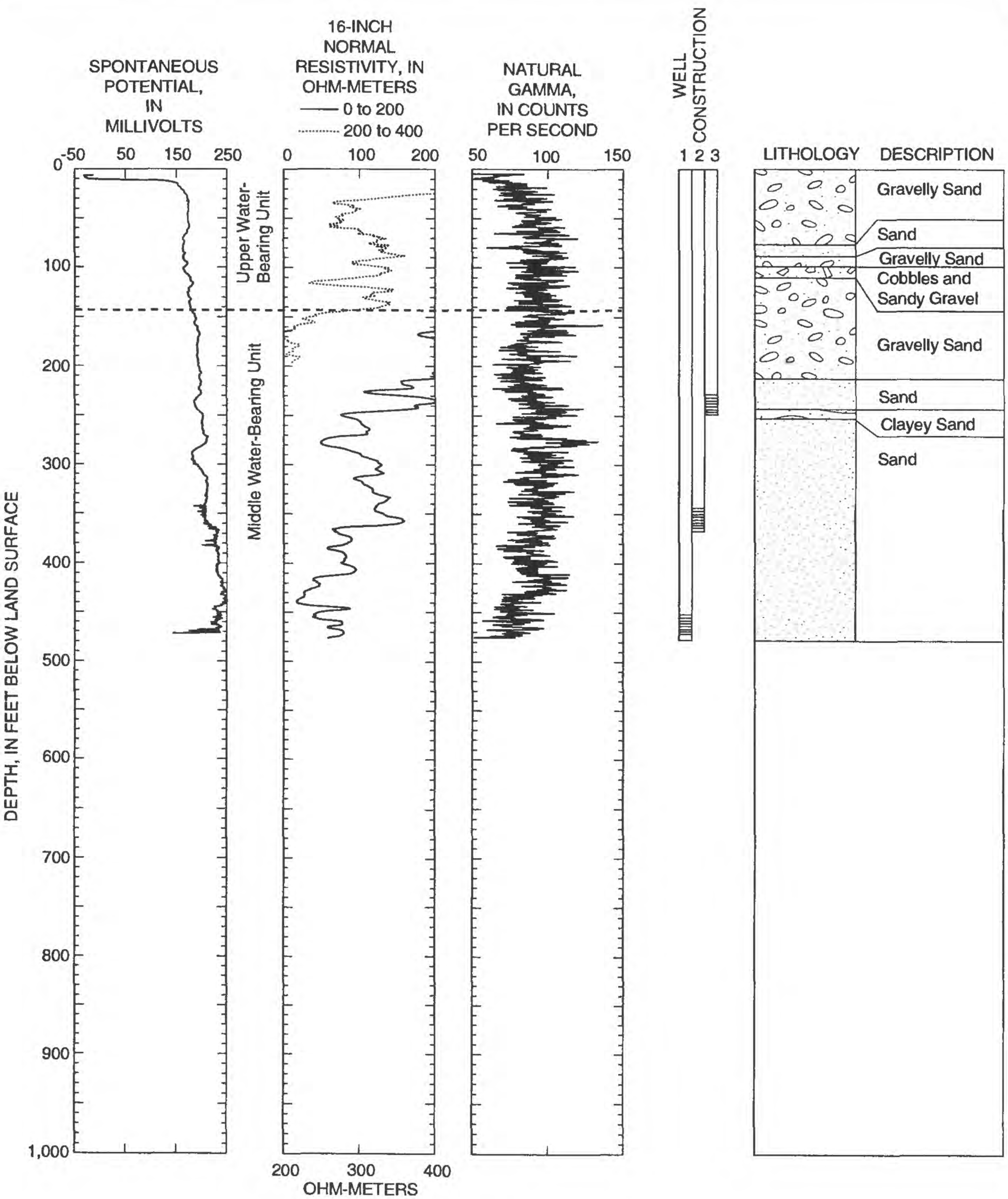


Figure 8—Continued.

J. Apple Street site 1N/5W-26L1

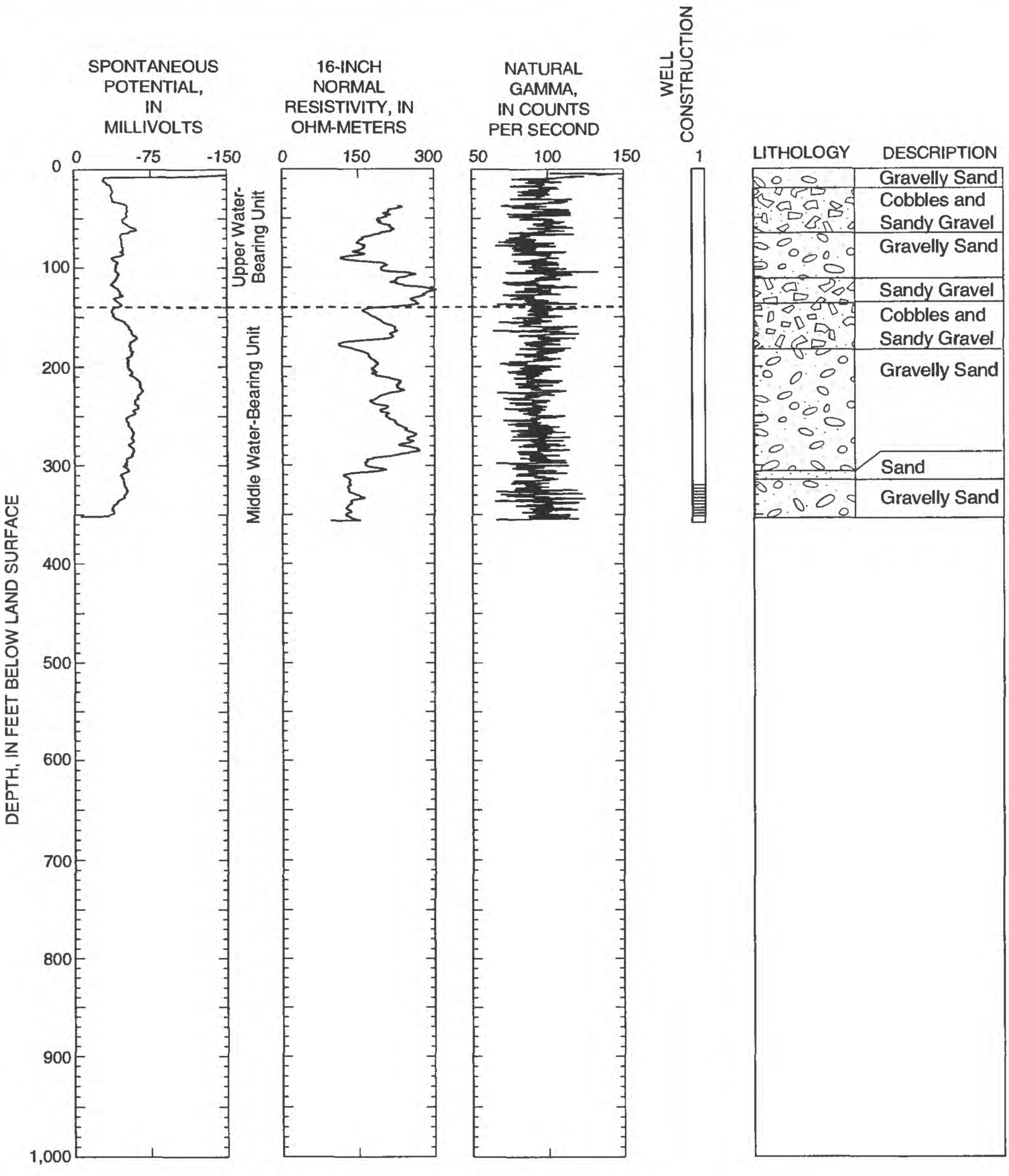


Figure 8—Continued.

K. Vineyard Avenue site 1N/5W-28J2, 3

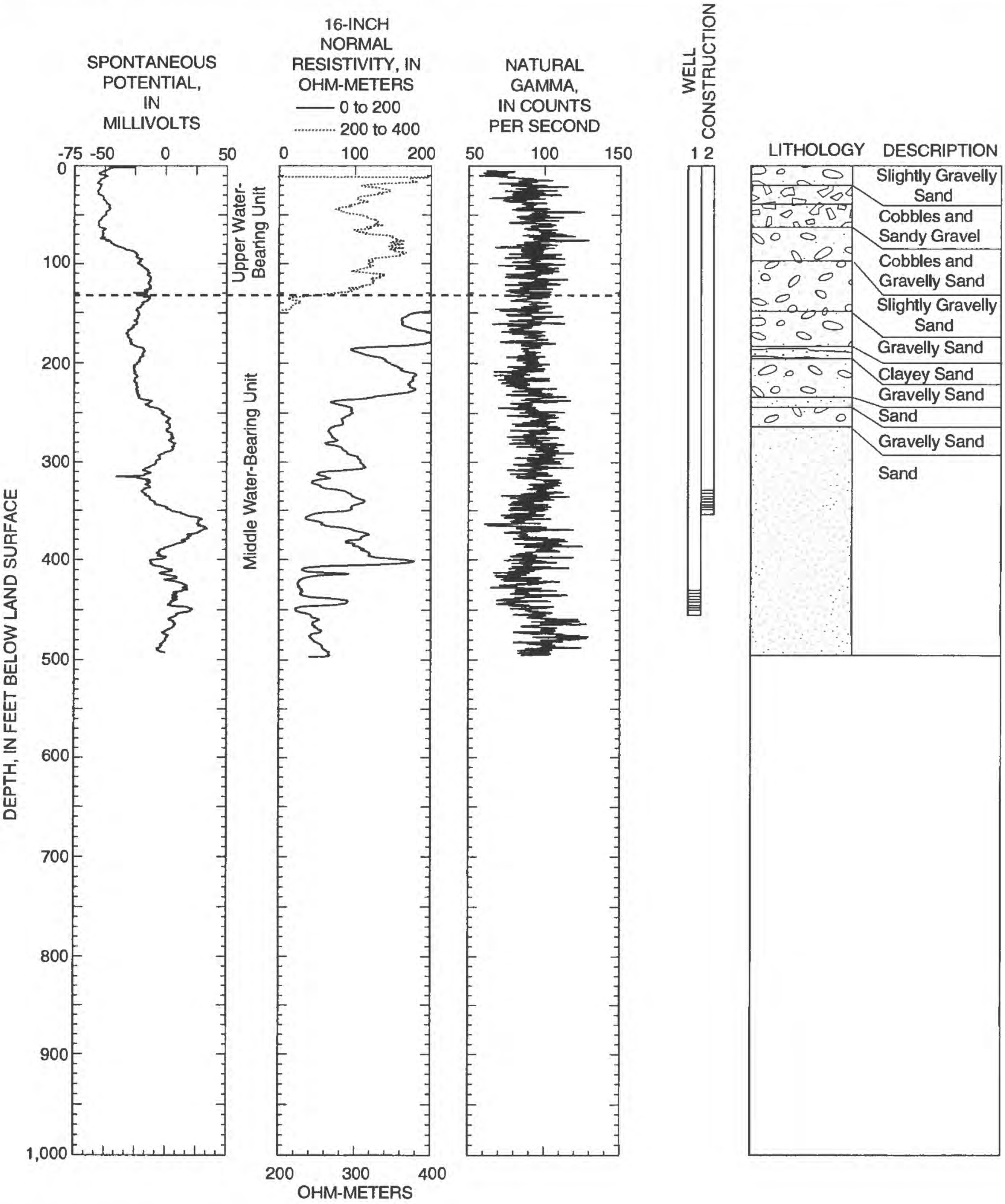


Figure 8—Continued.

freshwater systems, sand and gravel beds are indicated by a negative deflection (toward the left) on the SP log and by a high resistivity response (toward the right) on the resistivity logs. Guard resistivity is similar to the normal resistivity, except guard resistivity measurement is focused on a smaller interval and records discrete changes in resistivity, and thus is capable of detecting thin layers in the section.

The natural gamma log measures the amount of gamma emission from materials that have relatively high concentrations of potassium-40, uranium-238, uranium-235, and thorium-232. Clay, as well as feldspar-rich gravel, generally has higher concentrations of potassium-40. The sonic log measures the velocity of an acoustic pulse between a transmitter and a receiver on the probe. The sonic log gives an indication of the degree of consolidation of the formation, as well as an approximate location of the water table; it is useful in identifying contrasting lithologic units that may cause seismic refractions along the contact. The caliper logs show the diameter of the borehole with depth. For this study, these borehole-geophysical logs, along with the lithologic log, were used to select intervals for perforations at each cluster site and to delineate water-bearing units within the ground-water basin.

Sampling and Analytical Methods

Water was sampled at least twice at all cluster wells during 1992-94, and analyzed for major ions, trace elements, nutrients, and the stable isotopes of oxygen and hydrogen (oxygen-18 and deuterium). Selected samples also were analyzed for carbon 13/14 and tritium. During 1992-95, selected production wells, a spring in the San Gabriel Mountains, Lytle Creek, and the Santa Ana River were sampled, and the samples were analyzed for major ions, trace elements, nutrients, oxygen-18, and deuterium. Samples from six of the production wells, from Lytle Creek, and from the Santa Ana River, were analyzed for tritium. Water from the spring was analyzed for tritium and carbon 13/14. Major-ion, trace-element, and nutrient data are given in table 2 (at back of report). Stable-isotope, tritium, and carbon 13/14 data are given in table 3 (at back of report).

Ground-water samples at 11 cluster sites were collected by first purging at least three casing volumes of water using either a positive displacement pump or compressed air. When compressed air was used, the final casing volume was pumped. Ground-water samples then were collected through a rinsed teflon tube. Samples were collected after the specific electrical conductance of the discharge water did not vary more than 5 percent. The exception to this procedure was cluster site 1N/5W-29Q1-5, which was purged with compressed air for three casing volumes and then sampled with a thief sampler because the depth to water was nearly 500 ft below land surface in all wells sampled.

All sampling and filter apparatuses were rinsed thoroughly with water from the sampled well prior to sample collection. Bicarbonate and carbonate concentrations were determined in the field by incrementally titrating unfiltered samples with dilute sulfuric acid. Unfiltered samples for the analysis of stable isotopes and tritium were collected in glass or polyethylene bottles equipped with polyethylene cap liners, leaving no air space in the bottle. Samples for the determination of anions and trace elements were pressure filtered through a 0.45-micrometer membrane filter and acidified with ultrex-grade nitric acid to a pH of less than 2. Samples collected for the determination of boron, chloride, sulfate, and silica were filtered but untreated. Samples for the determination of nitrate were collected in colored bottles and preserved with mercuric chloride or by storage in ice at 4 °C.

The variation of major-ion concentrations in ground water was assessed by means of Stiff diagrams (Stiff, 1951). Stiff diagrams plot in an identical sequence the concentration [in milliequivalents per liter (meq/L)] of major cations to the left of zero and major anions to the right of zero [as depicted in figs. 21-22 in the "Water Chemistry" section]. The width of the diagram is an approximate indication of the total ionic content of the water sample. The resulting points are connected to form polygons that provide a visual assessment of the relative differences in ground-water chemistry.

The ratios of isotopes of oxygen (oxygen-18 [^{18}O] to oxygen-16 [^{16}O]) and hydrogen (deuterium, D [^{2}H] to hydrogen [^{1}H]) in ground water are indicators of its hydrologic history. The isotope ratios are expressed in delta notations (δ) as permil (part per thousand [‰]) differences relative to a standard known as Vienna Standard Mean Ocean Water (VSMOW)(Gonfiantini, 1978):

$$\delta^{18}O = \frac{(^{18}O/^{16}O)sample - (^{18}O/^{16}O)standard}{(^{18}O/^{16}O)standard} \times 1,000, \text{ and}$$

$$\delta D = \frac{(^{2}H/^{1}H)sample - (^{2}H/^{1}H)standard}{(^{2}H/^{1}H)standard} \times 1,000.$$

Craig (1961) found that a linear relation exists between δD and $\delta^{18}O$ in meteoric waters throughout the world. This relation is referred to the global-meteoric-water line. Evaporation and condensation are the most significant processes that change the proportions of these isotopes. Variations in $\delta^{18}O$ and δD in ground water reflect the general atmospheric conditions that existed when precipitation occurred, and the degree of evaporation prior to percolation to the water table. Water that has not undergone significant evaporation will plot near the global-meteoric-water line. Water that has been evaporated will plot below the line.

Tritium (^{3}H) is a naturally occurring radioactive isotope of hydrogen having a half-life of 12.4 years. Tritium concentration is measured in tritium units (TU); each tritium unit equals one ^{3}H atom in 10^{18} atoms of hydrogen. Approximately 800 kg of ^{3}H was released as a result of atmospheric testing of nuclear weapons during 1952-62 (Michel, 1976). As a result, ^{3}H concentrations in precipitation, and in ground water recharged during that time, increased. Because ^{3}H is part of the water molecule and its concentration is not affected significantly by reactions other than radioactive decay, ^{3}H is an excellent tracer of the movement of water on time scales ranging from 0 to 44 years before present (1996). Ground water having ^{3}H concentrations less than the detection limit of 0.3 TU is interpreted as water recharged prior to 1952; ground water having detectable levels of ^{3}H is interpreted as water recharged after 1952.

Carbon-14 (^{14}C) is a naturally occurring radioactive isotope of carbon having a half-life of about 5,730 years. Concentrations of radioactive isotopes are referred to as activities because they are a measure of the energy emissions in a given volume of sample rather than the mass of the isotope. Carbon-14 data are expressed as percent modern carbon by comparing ^{14}C activities to the specific activity of National Institute of Standards and Technology oxalic acid (12.88 disintegrations per minute per gram of carbon in the year 1950). Carbon-14 is a tracer of the movement of recharge water and an indication of the relative age of a water sample on time scales ranging from recent to more than 40,000 years before present. Unlike ^{3}H, ^{14}C is not part of the water molecule, and ^{14}C activities are affected by chemical reactions between dissolved constituents and material within the aquifer. The uncorrected ^{14}C data are an indicator of the maximum age of the sampled water. Carbon-13, a stable isotope of carbon, is used to evaluate chemical reactions that occur within an aquifer and its abundance is expressed in delta notation, as parts per mil differences relative to the ratio of ^{13}C to ^{12}C in standard Peedee belemnite. The chemical models developed to calculate the mass balance of dissolved constituents as water flows through the aquifer, to adjust for inputs and outputs of carbon, and to estimate the age of water from wells were not used for this report. According to Izbicki and others (1995), correction of ^{14}C data for mineralogical reactions produced ^{14}C ages that were as much as 10,000 years younger than uncorrected ^{14}C ages in the Mojave River basin.

GEOHYDROLOGY

Geology

Stratigraphic units in the Rialto-Colton basin consist of unconsolidated dune sand (Holocene), river-channel deposits (Holocene), younger alluvium (Holocene), and older alluvium (late Pleistocene); partly consolidated Tertiary to Quaternary continental deposits (late Pliocene and early Pleistocene); consolidated Tertiary continental deposits (Pliocene ?); and basement complex (pre-Tertiary) (Dutcher and Garrett, 1963). The unconsolidated alluvial material that fills the Rialto-Colton basin consists of sand, gravel, and boulders interbedded with lenticular deposits of silt and clay. The partly consolidated continental deposits, which consist of gravel, sand, silt, and clay and are somewhat compacted, underlie the alluvial deposits as lenticular bodies; crop out in the Badlands, which form the southeastern boundary of the Rialto-Colton basin; and crop out at the base of the San Gabriel Mountains, which form the northwestern boundary of the basin (fig. 5). The consolidated continental deposits consist primarily of clay that contains lenses of compacted, cemented sand. These deposits underlie the partly consolidated or alluvial deposits. The basement complex is composed of metamorphic and igneous rocks; it underlies the alluvial and continental deposits, and crops out in the San Gabriel Mountains (Dutcher and Garrett, 1963). No attempt was made to correlate stratigraphic units within the unconsolidated deposits in this report because of their variability and lack of traceable beds.

Faults are the major structural features bordering and lying within the Rialto-Colton basin. The San Jacinto Fault is a currently active right-lateral strike-slip fault with a vertical component (Dutcher and Garrett, 1963). It extends southeastward from the mouth of Lytle Creek canyon on the north to the Badlands on the south. In the northeastern part of the basin, Barrier E splays from the San Jacinto Fault to the west (fig. 5).

The Rialto-Colton Fault is subparallel to the San Jacinto Fault and trends southeastward from Barrier J to the Badlands. Vertical displacement along the Rialto-Colton Fault (Dutcher and Garrett, 1963) is reflected by the shallower depths to the basement complex in the Chino basin (well 1S/5W-10H2) (Geosciences Support Service, Inc., 1990) in comparison with the Rialto-Colton basin (well 1S-5W-11F1-4) (fig. 5). The Rialto-Colton Fault probably is an abandoned trace of the San Jacinto Fault (J. C. Matti, U.S. Geological Survey, oral commun., 1996).

Barrier J separates the southeastern three-quarters of the Rialto-Colton basin from the area to the northwest. Barrier J, the existence of which was determined from hydrologic data (Dutcher and Garrett, 1963), trends northeastward from west of the Rialto-Colton Fault in the Chino basin to east of Barrier E in the Lytle basin.

Barrier H subparallels the Rialto-Colton Fault in the northwest (fig. 5). The altitude at which the Tertiary continental rocks are reached is higher in the main part of the Rialto-Colton basin than that between Barrier H and the Rialto-Colton Fault, suggesting that this narrow compartment is down-faulted (Dutcher and Garrett, 1963).

The existence of an unnamed fault that subparallels (about one-half mile to the west of) the San Jacinto Fault was described by Woolfenden (1994). Stable-isotope and water-level data indicated that the fault extended from cluster site 1N/5W-21K1-4 to cluster site 1N/5W-35B1-4. Analysis of additional stable-isotope data (table 3), and lithologic and borehole-geophysical logs (Appendix; fig. 8*C-E*), indicate that the fault extends at least to cluster site 1S/4W-8E1-4 (fig. 5). The deuterium ratio in water from the middle and lower water-bearing units on the east side of the fault generally was lighter (more negative) than that on the west side of the fault (figs. 9 and 10). The lithologic and borehole-geophysical logs indicate vertical offset along its mapped length (fig. 10).

Water-Bearing Units

The generalized lithology, selected borehole-geophysical logs, and well construction for the 11 cluster sites are shown in figure 8. After examination of these logs, it was determined that the fine-grained beds within the basin do not separate the ground-water system into well-defined aquifers and confining beds. Therefore, the ground-water system was divided for this study into water-bearing units on the basis of water levels, water chemistry, and lithologic and borehole-geophysical logs. The water-bearing units include the river-channel deposits, and the upper, middle, and lower water-bearing units. These water-bearing units may include more than one stratigraphic unit. Lithologic logs indicate that subsurface materials are largely heterogeneous alluvium that consists of various thicknesses of interbedded gravel, sand, silt, and clay. The water-bearing units are unconfined to partly confined and are in hydraulic connection with each other. Consolidated deposits underlying the lower water-bearing unit are not part of the ground-water system.

The river-channel deposits underlie the present channels of Warm Creek and the Santa Ana River in the southeastern part of the basin (fig. 10, sections *A-A′*, *B-B′*, *F-F′*). These deposits consist of coarse sand and gravel interbedded with lower permeability deposits of medium to fine sand and clay. Thickness of the river-channel deposits ranges from about 150 to about 200 ft. At cluster site 1S/4W-20H1-5, a 17-foot-thick fine-grained unit is present from 43 to 60 ft below land surface. This fine-grained unit may be the same unit described by Dutcher and Garrett (1963) in the Bunker Hill basin, where the unit acts as a confining member above the upper water-bearing unit in the Warm Creek area. In the Rialto-Colton basin, this lower permeability deposit is above the water table at cluster site 1S/4W-20H1-5; however, it may impede downward movement of water from the river-channel deposits underlying Warm Creek to the underlying water-bearing units.

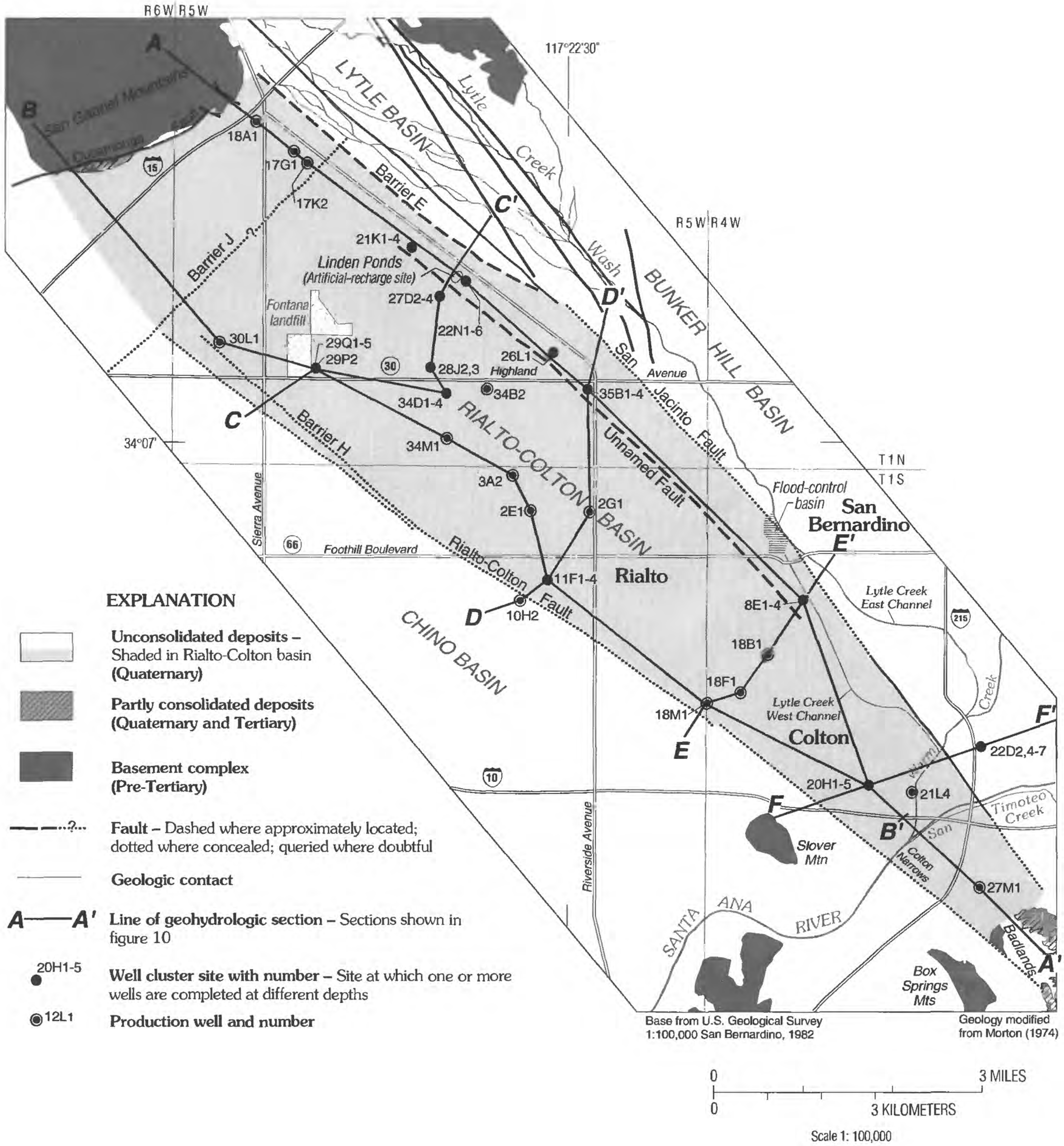


Figure 9 Location of geohydrologic sections, Rialto-Colton basin. San Bernardino County, California.

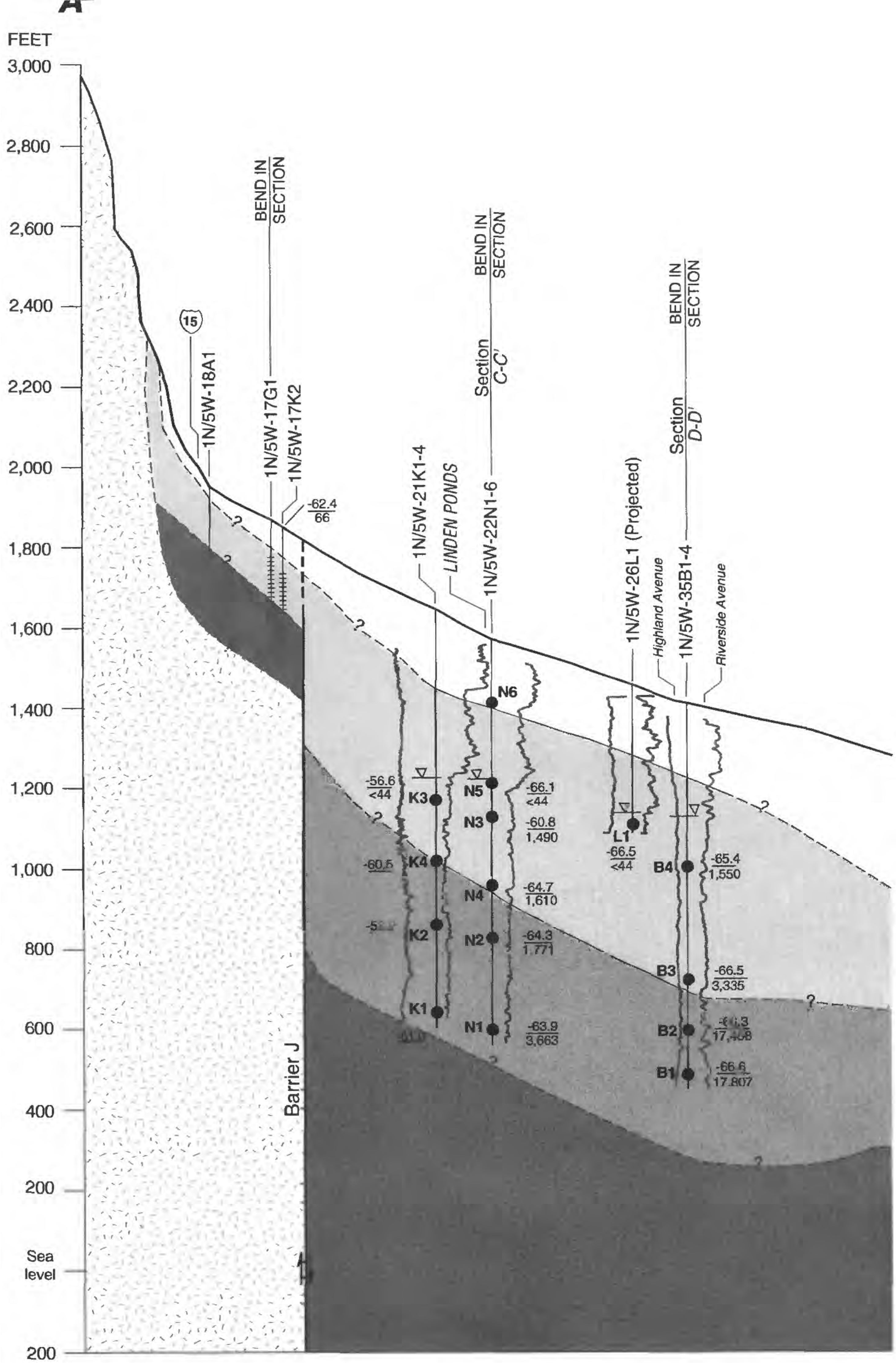


Figure 10. Geohydrologic sections of the Rialto-Colton ground-water basin, San Bernardino County, California.

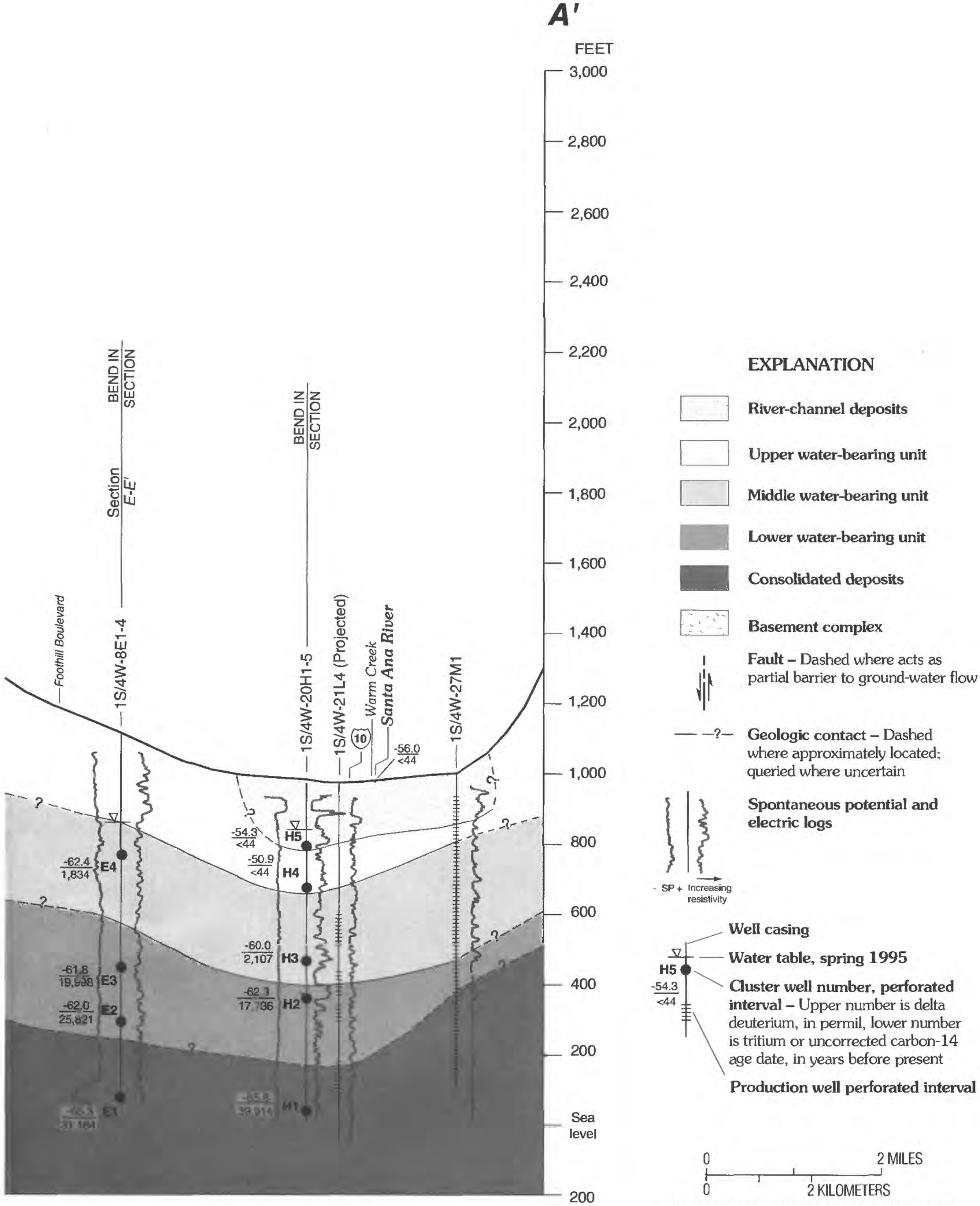
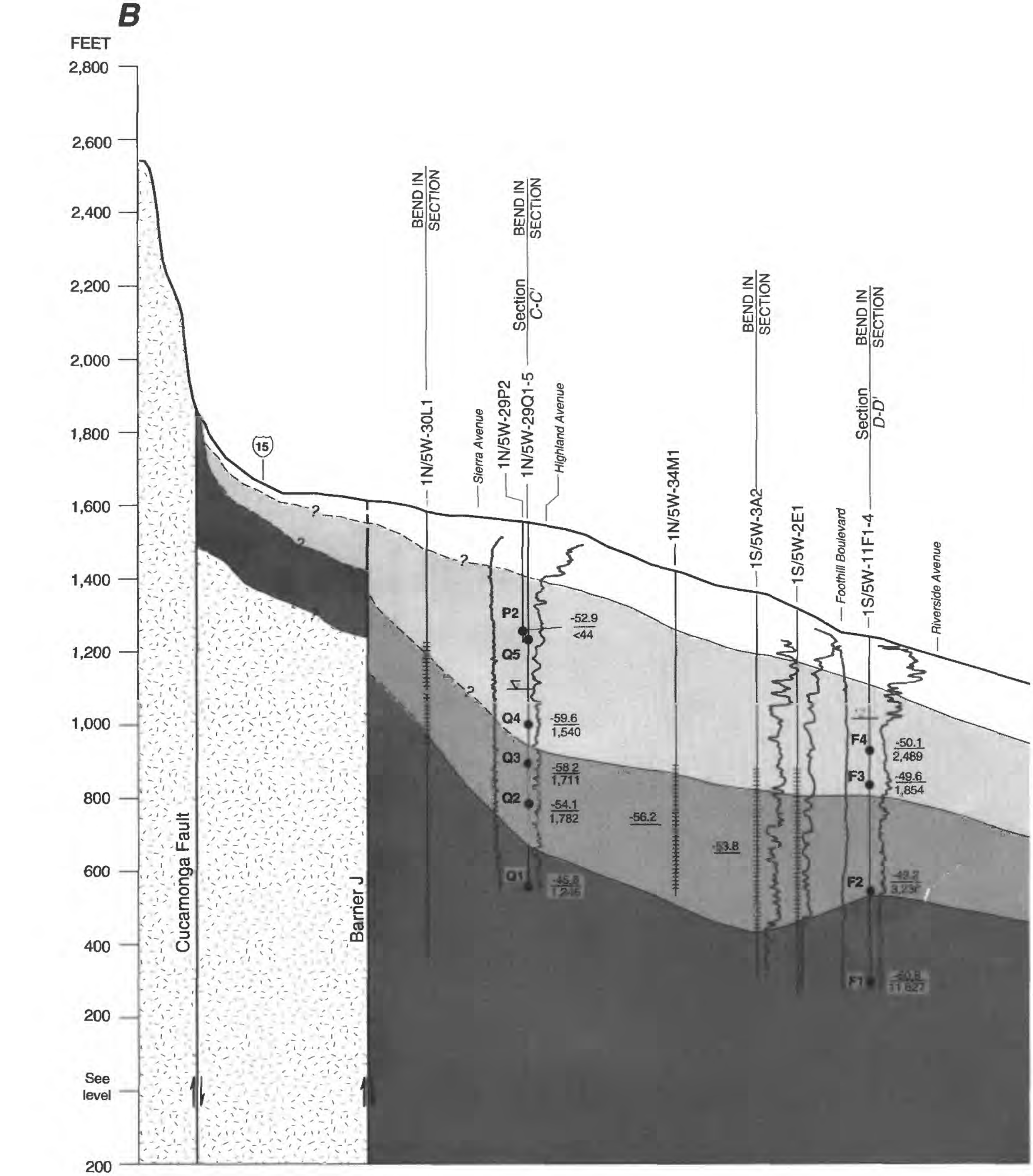


Figure 10—Continued.



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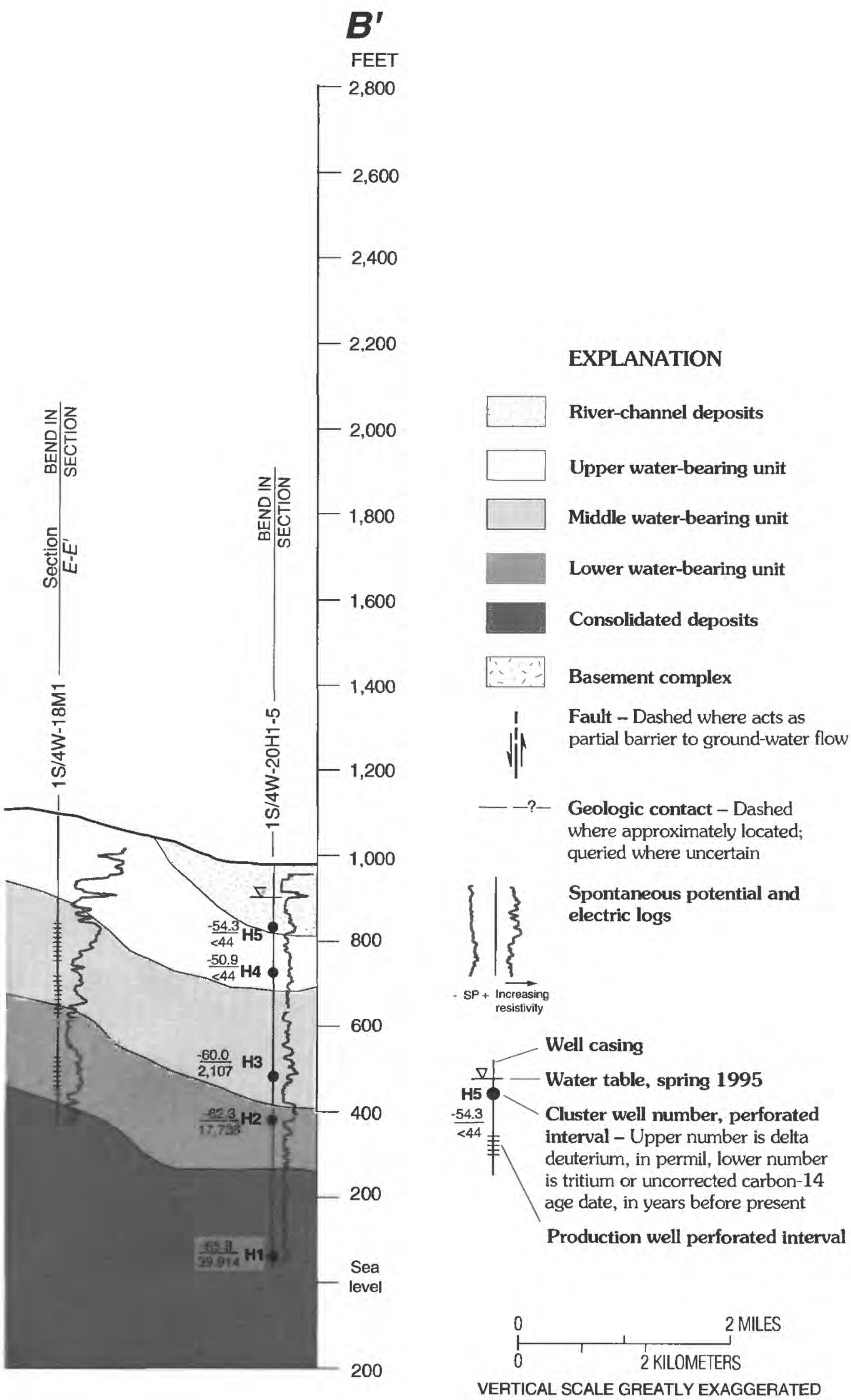

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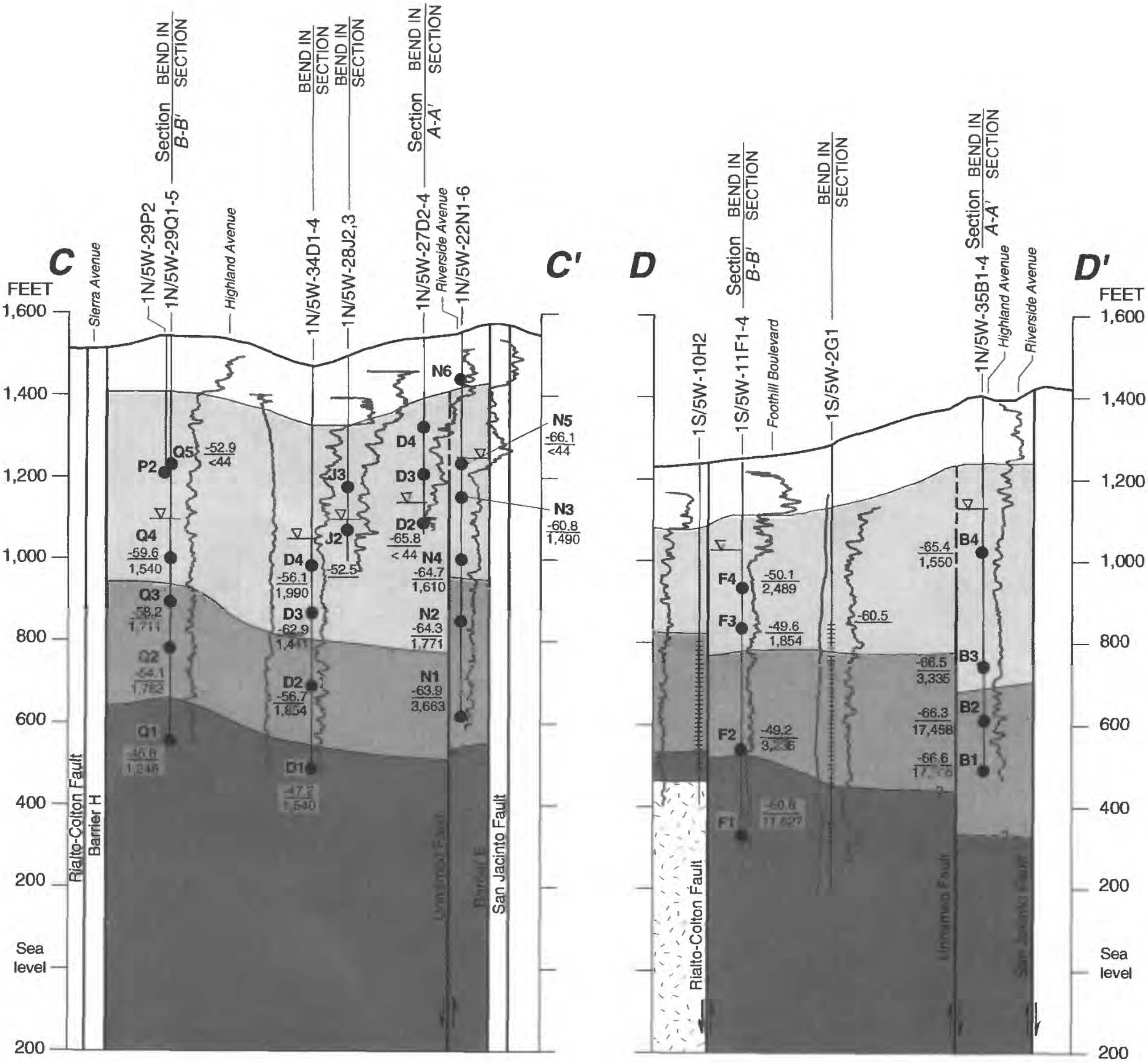


Figure 10—Continued.

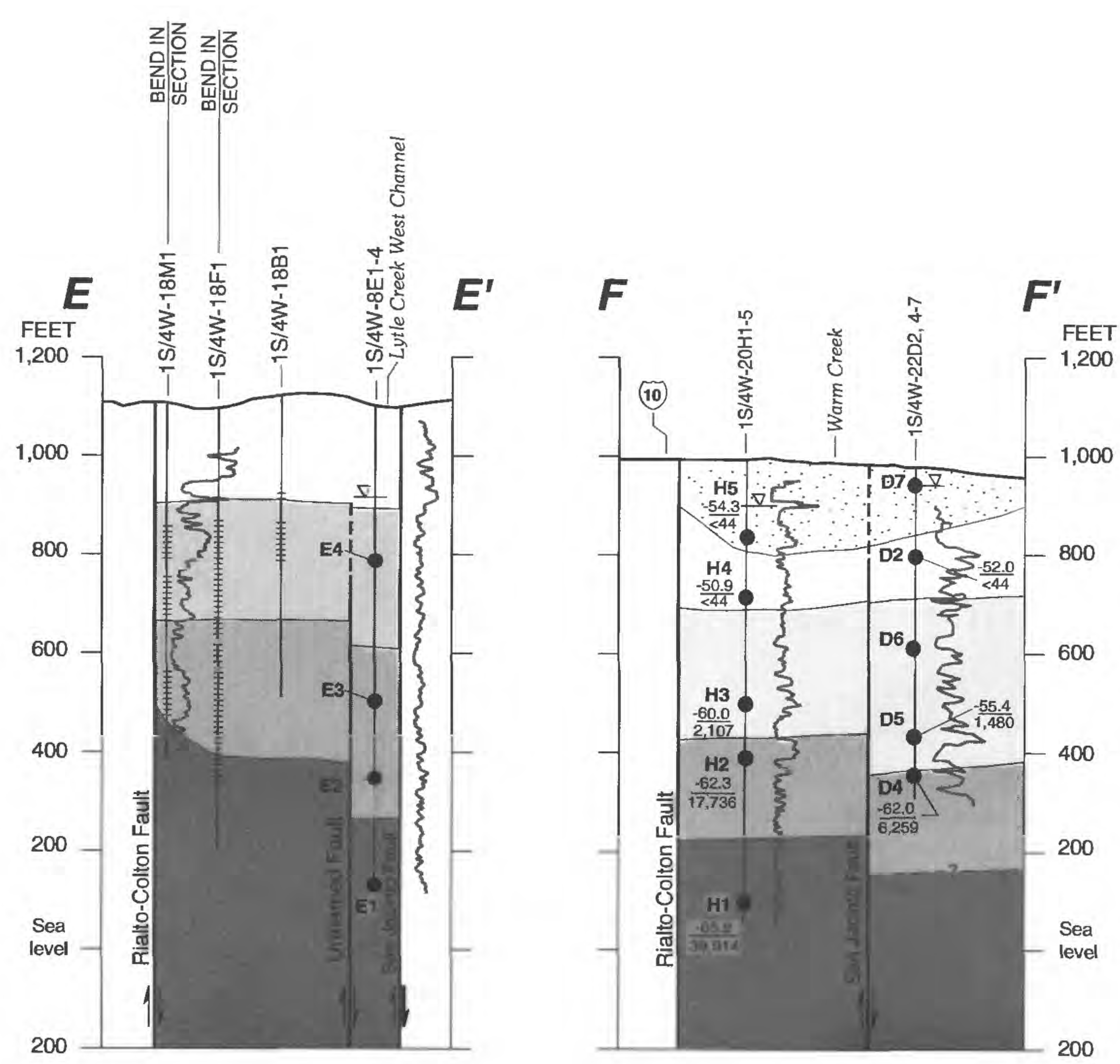


Figure 10—Continued.

The upper water-bearing unit is present throughout the Rialto-Colton basin. This unit consists of alluvial fan deposits that grade into older river-channel deposits near the Santa Ana River and Warm Creek (Peter Martin and J.A. Izbicki, U.S. Geological Survey, written commun., 1996). The upper water-bearing unit underlies the river-channel deposits near the Santa Ana River and Warm Creek, and it is the uppermost unit throughout the rest of the basin (fig. 10, sections *A-A′*, *F-F′*). The alluvial fan deposits consist of coarse sand and gravel, cobbles, and boulders. At cluster site 1S/4W-8E1-4 in the southeastern part of the basin east of the unnamed fault (fig. 9), the upper water-bearing unit contains clay lenses. The older river-channel deposits generally are finer grained than the alluvial fan deposits. At cluster site 1S/4W-20H1-5, the older river-channel deposits consist of coarse sand and gravel and interbedded clay. The upper water-bearing unit ranges in thickness from about 120 to about 300 ft. The upper water-bearing unit is unsaturated throughout most of the basin except for the southeastern part near the Santa Ana River and Warm Creek. At cluster site 1S/4W-8E1-4 (fig. 10, section *A-A′*), the upper water-bearing unit was saturated near its base in spring 1995. This unit is highly permeable and freely allows infiltration of precipitation, streamflow, and artificially recharged imported water, which percolates to the water table.

The middle water-bearing unit is areally extensive throughout the basin and primarily consists of coarse to medium sand and interbedded fine sand and clay. The deposits of the middle water-bearing unit are finer in the southeastern part of the basin. At cluster site 1S/4W-20H1-5, these deposits consist mainly of medium to fine sand. The clay beds are more extensive in the northwestern part of the basin near the Rialto-Colton Fault. At cluster site 1N/5W-29Q1-5, an 85-foot-thick fine-grained bed containing extensive clay (Appendix; fig. *8H*) is present above the water table. The shallowest well at this site, 29Q5, is perforated above this bed at a depth of 300-320 ft, and is dry. The middle water-bearing unit ranges in thickness from about 240 to about 600 ft (fig. 10) and is thickest in the northwestern part of the basin south of Barrier J.

The areally extensive lower water-bearing unit consists mainly of interbedded sand and clay. The thickness of this unit ranges from about 100 ft in the southeastern part of the basin to about 400 ft in other parts of the basin.

Consolidated Deposits

The uppermost surface of the consolidated deposits forms the base of the ground-water system and generally is at a higher altitude in the northwestern part of the basin west of the unnamed fault (fig. 11). These deposits yield very little water to wells and are not considered part of the ground-water system. The consolidated deposits are penetrated by five test holes drilled for this study (1N/5W-29Q1-5, 1N/5W-34D1-4, 1S/5W-11F1-4, 1S/4W-8E1-4, and 1S/4W-20H1-5). Depth of penetration ranged from about 75 to about 270 ft at cluster sites 1N/5W-34D1-4 and 1S/5W-11F1-4, respectively (fig. 10, sections *C-C′*, *B-B′*). The consolidated deposits generally consist of medium to fine sand, grading in places into fine to very fine sand and clay. At cluster site 1S/5W-29Q1-5, some coarse sand was encountered at the top of the consolidated deposits (Appendix). At cluster site 1S/5W-11F1-4, fine to very fine sand was present throughout the 270-foot-thickness that was penetrated. Each of the five test holes was completed with a perforated section within the consolidated deposits.

Boundaries

The San Jacinto Fault and Barrier E form the northeastern boundary of the Rialto-Colton ground-water system. Water-level contours for the Bunker Hill basin (W.R. Danskin, USGS, written commun., 1996) indicate that the San Jacinto Fault is a barrier to ground-water flow throughout most of its length. Dutcher and Garrett (1963) stated a similar conclusion. However, the concentrations of major cations (sodium, magnesium, and calcium), anions (chloride, sulfate, and bicarbonate), and dissolved solids for well 1S/4W-22D2, which is perforated in the upper water-bearing unit in the Bunker Hill basin, are similar to those in water

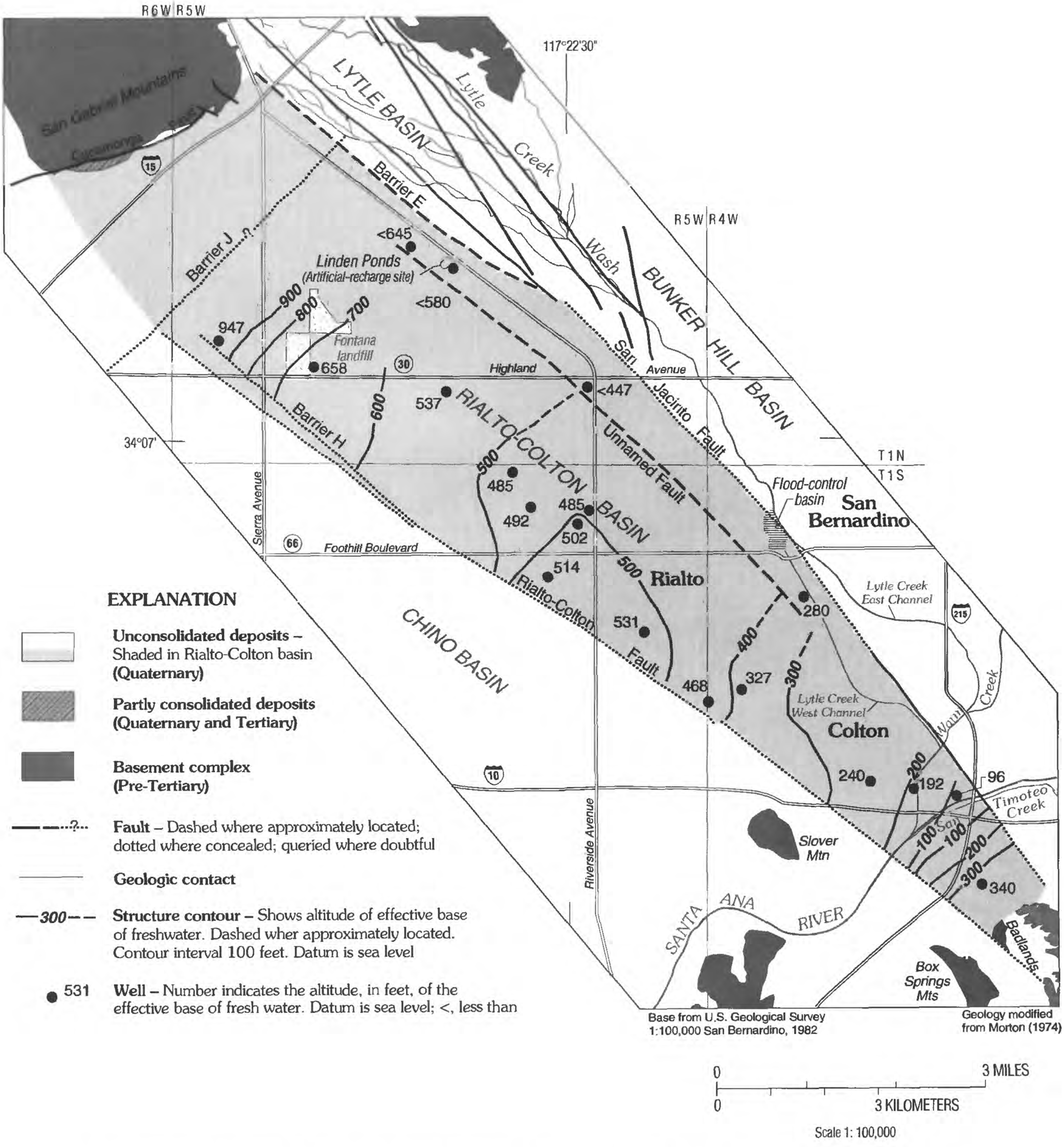


Figure 11. Altitude of the base of the ground-water system in the Rialto-Colton basin, San Bernardino County, California.

from wells 1S/4W-20H5 and 20H4 (table 2), which are perforated in the river-channel deposits and upper water-bearing unit, respectively, in the Rialto-Colton basin. These data indicate that the San Jacinto Fault is not a barrier to ground-water flow in those units.

Barrier E forms the northern boundary of the northeast part of the basin (fig. 5). Water-level contours mentioned above indicate that Barrier E does not affect ground-water movement above Barrier J, but does affect movement below BarrierJ. The water-level difference in spring 1993 for well 1N/5W-22F3 (average water-level altitude, 1,500 ft) in the Lytle basin and cluster wells 1N/5W-22N1-5 (average water-level altitude, 1,300 ft) in the Rialto-Colton basin, indicates that Barrier E is an effective barrier to ground-water movement near its intersection with the San Jacinto Fault (fig. 5).

The Rialto-Colton Fault forms the southwestern boundary of the ground-water system. Although there is no evidence that the Rialto-Colton Fault extends beyond Barrier J, the boundary of the ground-water system was extended arbitrarily along the trend of the fault (fig. 5). On the basis of hydrologic data, the Rialto-Colton Fault acts as a barrier to ground-water flow to the Chino basin in all saturated water-bearing units except where it crosses the Santa Ana River. Historically, water-level differences in wells ranged from about 400 ft across the fault and Barrier H in the northwestern part of the basin, to about 200 ft across the fault farther southeastward (Dutcher and Garrett, 1963). South of the Slover Mountain area (fig. 5) ground water from the Rialto-Colton basin moves across the Rialto-Colton Fault to the Chino basin (Gosling, 1967).

The San Gabriel Mountains form the northwestern boundary of the ground-water system (fig. 5). The basement complex that crops out in the San Gabriel Mountains is virtually non-water bearing, except in fractured or weathered zones. According to the Dutcher and Garrett (1963), the Badlands form the southeastern boundary of the Rialto-Colton basin and consist of relatively unconsolidated Tertiary to Quaternary continental deposits that have been uplifted and dissected.

Internal Barriers to Ground-Water Flow

Barrier J and the unnamed fault act as barriers to ground-water flow within the Rialto-Colton basin. The existence of Barrier J is based on water-level differences and lithology. Dutcher and Garrett (1963) reported the following hydraulic gradients: north of Barrier J, as much as 175 ft/mi; across Barrier J, as much as 500 ft/mi; and farther south, about 75 ft/mi. These data indicate a steeper gradient across Barrier J than above or below it. According to Dutcher and Garrett (1963), Barrier J effectively impedes ground-water movement in most of the older alluvium but not in the overlying younger alluvium. The California Department of Water Resources (1970) reported that ground water cascades across Barrier J into the main part of the ground-water system in the Rialto-Colton basin.

The unnamed fault is probably a partial barrier to ground-water movement in the middle water-bearing unit and probably an effective barrier in the lower water-bearing unit. In spring 1995, the difference between the average water-level altitudes in cluster wells 1N/5W-22N3 and -22N4 near the artificial-recharge ponds, and the water-level altitude in cluster well 1N/5W-27D2, on the opposite side of the fault one-third mile south of the ponds, was 106 ft. The hydraulic gradient across the fault between these two sites was 321 ft/mi. In contrast, the hydraulic gradient west of the unnamed fault between cluster wells 1N/5W-27D2 and 1N/5W-28J2 was 59 ft/mi. Woolfenden (1994) reported that imported water recharged at the artificial-recharge ponds was detected at well 1N/5W-27D2, west of the unnamed fault. This may be the result of lateral flow of imported water above the saturated zone where the fault may not be an effective barrier to flow. Another possible explanation of movement of imported water across the fault is that the fault may impede but not prevent movement of ground water in the middle water-bearing unit. No water-level data were available to determine the hydraulic gradient across the fault in the lower water-bearing unit.

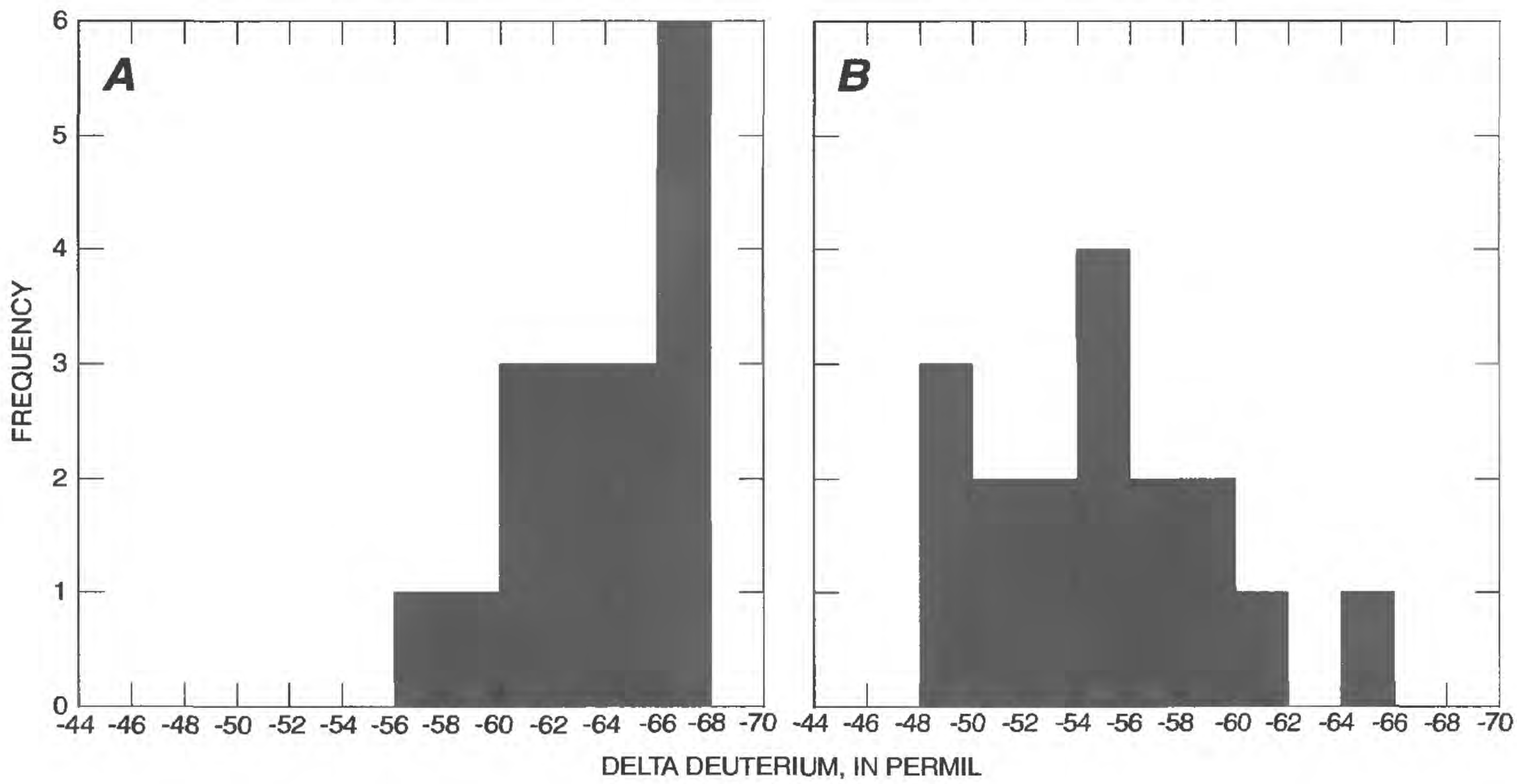
Stable-isotope data for 1992-94 indicate that the unnamed fault is only a partial barrier to ground-water flow. Deuterium ratios in water from cluster wells and selected production wells perforated in the middle and lower water-bearing units east (fig. 12*A*) of the unnamed fault have a more negative (isotopically lighter) mean and a smaller standard deviation than those in water from wells west of the fault (fig. 12*B*). These characteristics indicate less variability in the deuterium ratios in water on the east side of the fault than on the west side. The greater variability in the deuterium ratios in water west of the fault indicates that there is mixing with water from the east side of the fault. The stable-isotope data are discussed in greater detail in the "Water Chemistry" section of this report.

Recharge

The primary sources of recharge to the Rialto-Colton ground-water system are underflow across the San Jacinto Fault in the southeast and Barrier E in the northwest; ungaged runoff in small streams that drain the San Gabriel Mountains and Badlands, and subsurface inflow; imported water; seepage loss from the Santa Ana River and its tributaries; areal recharge of rainfall; and irrigation return flow.

Underflow

Underflow from the upgradient Bunker Hill and Lytle basins occurs across the San Jacinto Fault and Barrier E, respectively. Dutcher and Garrett (1963) reported that underflow from the Bunker Hill basin near the Santa Ana River occurs within the younger alluvium. The chemical characteristics of water in cluster wells 1S/4W-20H4 and 20H5 were similar to those in cluster wells 1S/4W-22D2 and -22D5 in the Bunker Hill basin (table 2), indicating that underflow occurs within the river-channel deposits and the upper water-bearing unit near Warm Creek and the Santa Ana River where the San Jacinto Fault does not act as a barrier to ground-water flow.



A	B
median: 63.9	median: -56.1
mean: -63.19	mean: -55.91
standard deviation: 3.00	standard deviation: 4.54
minimum: -66.6	minimum: -65.8
maximum: -56.6	maximum: -49.2

Figure 12. Histograms and statistical measures of delta deuterium concentration in water from wells **(A)** east of unnamed fault, and **(B)** west of unnamed fault, 1993-94, Rialto-Colton basin, San Bernardino County, California.

Dutcher and Garrett (1963) calculated underflow from the Bunker Hill basin for 1936-49 using Darcy's law and assuming 1-dimensional flow. Water levels in 1936 generally reflected the effects of 30 years of average precipitation (fig. 4) and primarily agricultural and native vegetation land uses. During 1936-46, wet conditions prevailed in the basin and land use continued to be primarily agricultural and native vegetation. The estimated underflow ranged from 23,700 acre-ft in 1936 to 14,300 acre-ft in 1948 (Dutcher and Garrett, 1963). "The high rate of underflow during 1936...was caused by the great steepening in hydraulic gradient in the younger alluvium downstream, induced by very heavy withdrawals at wells in sections 21, 28 and 29." (Dutcher and Garrett, 1963). The average estimated underflow for the period 1936–49 was 16,700 acre-ft/yr.

Several estimates of underflow from Lytle basin to Rialto-Colton basin across Barrier E were made by previous investigators. Estimated annual underflow reported by Dutcher and Garrett (1963) was 4,000 acre-ft for 1952. They did not extend Barrier E above Barrier J, and they reported that underflow occurred only above Barrier J. Estimates of underflow made by California Department of Water Resources (1970) ranged from 3,700 to 4,200 acre-ft for 1936-60 water years (see Conversion Factors in preliminary pages for definition of "water year"). Estimates from Geosciences Support Services, Inc. (1992b) ranged from 1,493 acre-ft in 1986 to 2,274 acre-ft in 1984, with an average of 1,880 acre-ft for 1980-87. Geosciences Support Services, Inc. (1994b) reported that underflow occurred above and below Barrier J. The estimated annual average underflow during 1978-93 was 3,800 acre-ft north of Barrier J, and 3,000 acre-ft south of Barrier J. Underflow from Lytle basin to the Rialto-Colton basin could be as low as 500 acre-ft/yr (W. R. Danskin, U.S. Geological Survey, written commun., 1996).

Ungaged Runoff and Subsurface Inflow

Precipitation that falls in the San Gabriel Mountains and Badlands can reach the ground-water system by collecting in small creeks and infiltrating through the creek channel; by running off the mountain front as sheet flow; or by seeping through the fractured and weathered zones within the basement complex of the San Gabriel Mountains. Annual precipitation in the San Gabriel Mountains varies widely; extremes were 10.87 in. in 1953 and 88.55 in. in 1978 (National Oceanic and Atmospheric Administration, 1871-1994). The quantity of ungaged surface runoff is a function of the drainage areas for the small creeks and mountain fronts. Estimates of ungaged runoff can be calculated by multiplying these drainage areas by a unit discharge value obtained from a gaged creek draining the same mountains (J.C. Bowers, U.S. Geological Survey, oral commun., 1994). Discharge values from Lytle Creek and San Timoteo Creek were used to obtain the unit discharges for the San Gabriel Mountains and the Badlands, respectively. Estimated ungaged runoff values for 1945-95 are given in table 4 (at back of report). In the San Gabriel Mountains, annual estimated ungaged runoff ranged from about 300 acre-ft in 1994 to about 8,000 acre-ft in 1969. Average runoff was about 1,800 acre-ft. Estimated ungaged runoff in the Badlands ranged from about 700 acre-ft in 1980 to no runoff during 1988-90. Average runoff was about 100 acre-ft.

Ground-water inflow from the San Gabriel Mountains was estimated by Geosciences Support Services, Inc. (1994b) to be about 1,200 acre-ft during 1978-93. The quantity of ground-water inflow from the Badlands is unknown.

Imported Water

Since 1982, surface spreading of imported water that originated in the Sierra Nevada has been used to supplement natural recharge to the ground-water system underlying the Rialto-Colton basin. Because the deposits underlying the recharge basins are highly permeable sand and gravel, and infiltration rates for these deposits are high (generally 3 ft/d) (Geoscience Support Services, Inc., 1994a), it is assumed that evaporation is negligible and that all the water infiltrates into the ground-water system. The quantities of imported water recharged ranged from no water in 1995 to 5,345 acre-ft in 1986. The average annual recharge during 1982-95 was 2,776 acre-ft (fig. 13). The quantities of imported water recharged during 1982-86 were above the average because wet conditions prevailed during that period (fig. 4) and imported water was readily available. During the 1987-92 drought in California, the quantities of imported water spread in 1990 and 1991 were well below the average because the availability of imported water was limited. Large-scale spreading of imported water was discontinued in 1994.

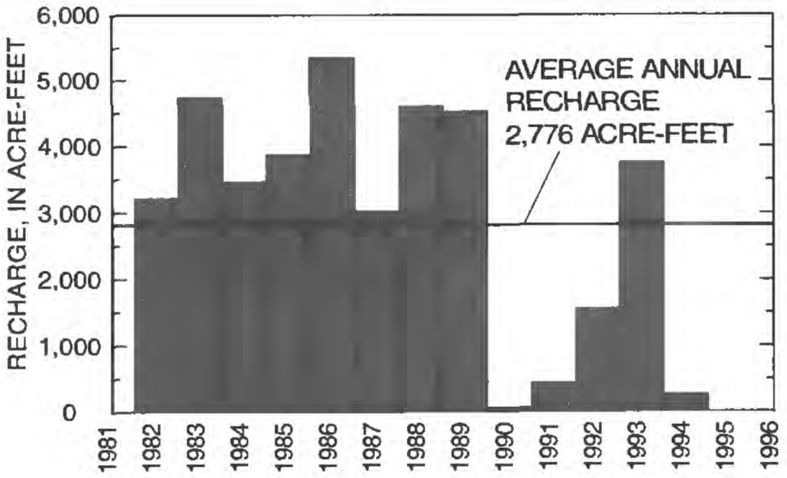


Figure 13. Annual recharge of imported water in the Railto-Colton basin, San Bernardino County, California, 1982-95.

Seepage Loss

Seepage loss occurs from the Santa Ana River and Warm Creek. The west channel of Lytle Creek, which crosses the San Jacinto Fault into the Rialto-Colton basin (fig. 5), has a concrete-lined channel, which, for the most part, prevents streamflow from seeping into the ground-water system. The Lytle Creek channel joins Warm Creek west of the San Jacinto Fault, just inside the Rialto-Colton basin. Warm Creek has a natural channel, and streamflow historically (1934-72) has included wastewater discharge in addition to runoff from the San Bernardino Mountains and ground water from the Bunker Hill basin. Discharge in the Santa Ana River, which has a natural channel, included wastewater from 1959 to March 1996.

Quantities of surface-water inflow that potentially would be available to recharge the ground-water system are given in table 5 (at back of report), although during floodflows most of the water will leave the basin. The measured values were obtained from the U.S. Geological Survey's ADAPS data base, and the estimated values were calculated from partial daily-value records from the data base or by linear regression comparison to a nearby streamflow-monitoring station (W.R. Danskin, U.S. Geological Survey, written commun., 1996). Annual surface-water inflow into the Rialto-Colton basin for 1945-95 ranged from about 13,000 acre-ft in 1968 to about 370,000 acre-ft in 1980. Average annual inflow was about 68,000 acre-ft. Total annual inflow from 1945 to 1962 included wastewater discharges into Warm Creek, and total annual inflow from 1945 to 1995 included wastewater discharges into the Santa Ana River.

Historically, water-level altitudes in the river-channel deposits generally were lower than the base of the streambed altitudes, suggesting that streamflow percolates through the river-channel deposits to recharge the underlying water-bearing units. Water-chemistry data also suggest recharge from surface-water sources. The chemical characteristics of water from production well 1S/4W-21K1, which is between the Santa Ana River and Warm Creek (fig. 5), were similar to those of the water in the Santa Ana River (table 2), indicating that water in the river had recharged that well.

Areal Recharge of Rainfall

Areal recharge from precipitation occurs when rainfall infiltrates the land surface and percolates past the root zone to the water table, and it generally is a small part of the total precipitation. Estimates of rainfall potentially available for recharge reported by Geosciences Support Services, Inc. (1994b) ranged from 28 to 21,000 acre-ft during 1978-93. Especially during wet years, such as 1969, 1978, 1980, and 1983, most of the potentially available water runs off into stream channels and drains, leaving the basin; however, recharge from direct infiltration of rainfall may occur where water collects in natural ponds or depressions.

Irrigation Return Flow

Irrigation return flow from pumpage is the quantity of pumpage that is returned to the ground-water system. Water is returned to the ground-water system as a result of percolation of excess water that is applied to crops and excess water from domestic or municipal irrigation of lawns, parks, and golf courses. As agricultural land use has decreased and urbanization has increased, return flow probably has become a lesser source of recharge. Ground water may be pumped from different depths within the ground-water flow system; however, return flow recharges only to the top of the system. Hardt and Hutchinson (1980) estimated return flow in the San Bernardino area to be 30 percent of annual pumpage. On the basis of reported annual pumpage from 1947 to 1994, annual recharge from irrigation return flow is estimated to have ranged from about 2,600 to about 7,500 acre-ft.

Discharge

The primary components of ground-water discharge in the Rialto-Colton basin include pumpage; underflow across the Rialto-Colton Fault to Chino basin; transpiration by phreatophytes along Warm Creek and the Santa Ana River; and seepage to the Santa Ana River and Warm Creek during wet years when water levels in the upper water-bearing unit and river-channel deposits rise above the base of the streambed.

Pumpage

The main component of ground-water discharge in the Rialto-Colton basin has been pumpage. Historically, ground-water pumpage was primarily for agricultural irrigation. The amount of land irrigated peaked in the early 1930's and remained constant through 1949. Accompanied by an increase in urbanization, irrigated agricultural acreage decreased slowly through the late 1950's and more rapidly since then (California Department of Water Resources, 1985; Marisue Meza, San Bernardino Valley Municipal Water District, written commun., 1996). In 1993, the year for which the most current land-use data are available, irrigated agriculture was almost nonexistent in the Rialto-Colton basin (fig. 3). The decrease in irrigated acreage significantly reduced the quantity of ground-water pumped because consumptive use of crops, mostly citrus and vineyards in the Rialto-Colton basin, is as much as twice that of municipal and industrial uses (California Department of Water Resources, 1971).

Annual ground-water pumpage for the 1947-94 period of record (shown in figure 14) was about 14,000 acre-ft. Because the irrigated acreage remained at its peak from the early 1930's to the late 1940's, the 25,000 acre-ft pumped in 1947 probably was at or near the maximum level of pumpage in the Rialto-Colton basin. Pumpage decreased rapidly from 1947 to 1952 when urbanization began to rapidly increase. During

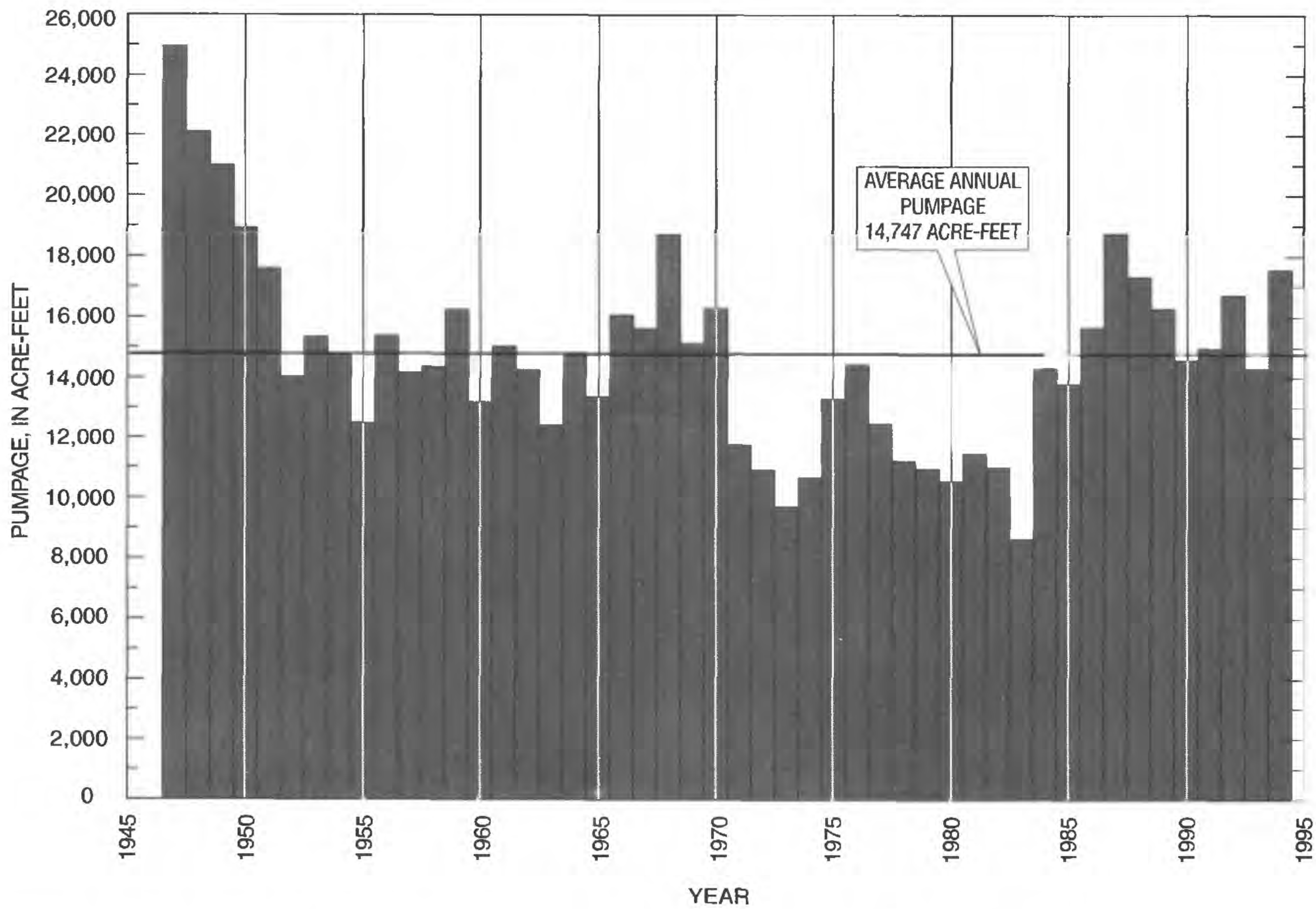


Figure 14. Annual pumpage in the Rialto-Colton basin, San Bernardino County, California, 1947-94.

1952-70, the quantity of water pumped averaged about 15,000 acre-ft/yr, close to average pumpage for the period of record. During 1971-83, pumpage declined further, averaging only about 11,000 acre-ft/yr. The decline in pumpage during this period probably was due to well-above-average rainfall in 1969, the wet period from 1978 to 1986 (fig. 4), and changing land use. Pumpage increased during 1984-89 to above-average levels, about 16,000 acre-ft/yr for this period, owing, in part, to the drought during 1987-92.

Underflow

Underflow from the Rialto-Colton basin to the Chino basin across the Rialto-Colton Fault occurs primarily within the unfaulted river-channel deposits and upper water-bearing unit near the Santa Ana River. Underflow across the Rialto-Colton Fault at Colton Narrows was estimated by the California Department of Water Resources (1970) for the 1936-60 water years; the estimates ranged from 3,900 acre-ft for the 1960 water year to 19,700 acre-ft for the 1936 water year. Average annual underflow for this period was 10,300 acre-ft. The quantity of underflow above Barrier J from the Rialto-Colton basin to Chino basin is unknown.

Transpiration

Transpiration by phreatophytes occurs along Warm Creek and the Santa Ana River whenever the water table rises to near land surface. The quantity of water transpired depends on the consumptive-use factors for the type of phreatophyte, the area occupied by phreatophytes, and the depth to water. The average quantity of water transpired in the Rialto-Colton basin was estimated to be about 600 acre-ft/yr.

Seepage Loss

Seepage from the ground-water system to the Santa Ana River and Warm Creek may occur when the ground-water-level altitudes rise above the base of the streambed. Estimates of the quantity of ground water discharged into the Santa Ana River and Warm Creek were not made for this report.

Ground-Water Levels and Movement

Ground-water levels in the Rialto-Colton basin during 1992-95 were determined from measurements of static water levels in 37 cluster wells at 11 cluster sites (fig. 5; table 1). Water-level measurements made during this study (table 6, at back of report) indicate that hydraulic head and direction of ground-water movement varied with the location and depth of wells in the Rialto-Colton basin.

Ground-water movement in the river-channel deposits and the upper water-bearing unit generally was from east to west (table 6) in the southeastern part of the basin. Ground water flows across the San Jacinto Fault from the Bunker Hill basin to the Rialto-Colton basin, and across the Rialto-Colton Fault from the Rialto-Colton basin to the Chino basin. In spring 1993, the head difference between well 1S/4W-22D2 in the Bunker Hill basin and well 1S/4W-29H1 in the Chino basin was 91.39 ft (table 6).

Ground-water movement in the middle water-bearing unit in spring 1994 generally was from northwest to southeast (fig. 15). Ground water moves from the fractured and weathered basement complex in the San Gabriel Mountains and across Barrier E from Lytle basin into Rialto-Colton basin. Water-level contour lines drawn by Dutcher and Garrett (1963) and Geosciences Support Services, Inc. (1992b) show that ground water moves southwestward above Barrier J. Although Barrier J acts as a barrier to ground-water movement in the northwestern part of the basin, ground water can flow over the top of the barrier in the unfaulted part of the alluvium. Once across Barrier J, ground water in the middle water-bearing unit moves southeastward (fig. 15).

The unnamed fault that subparallels the San Jacinto Fault acts as a partial barrier and restricts ground-water movement to a narrow corridor between the two faults. Ground water within the corridor flows southeastward. In the northeastern part of the basin, the difference in head between wells 1N/5W-22N3 east of the fault and 1N/5W-27D2 west of the fault was 110 ft; in the southeastern part of the basin water levels appear to be similar on either side of the fault (fig. 15).

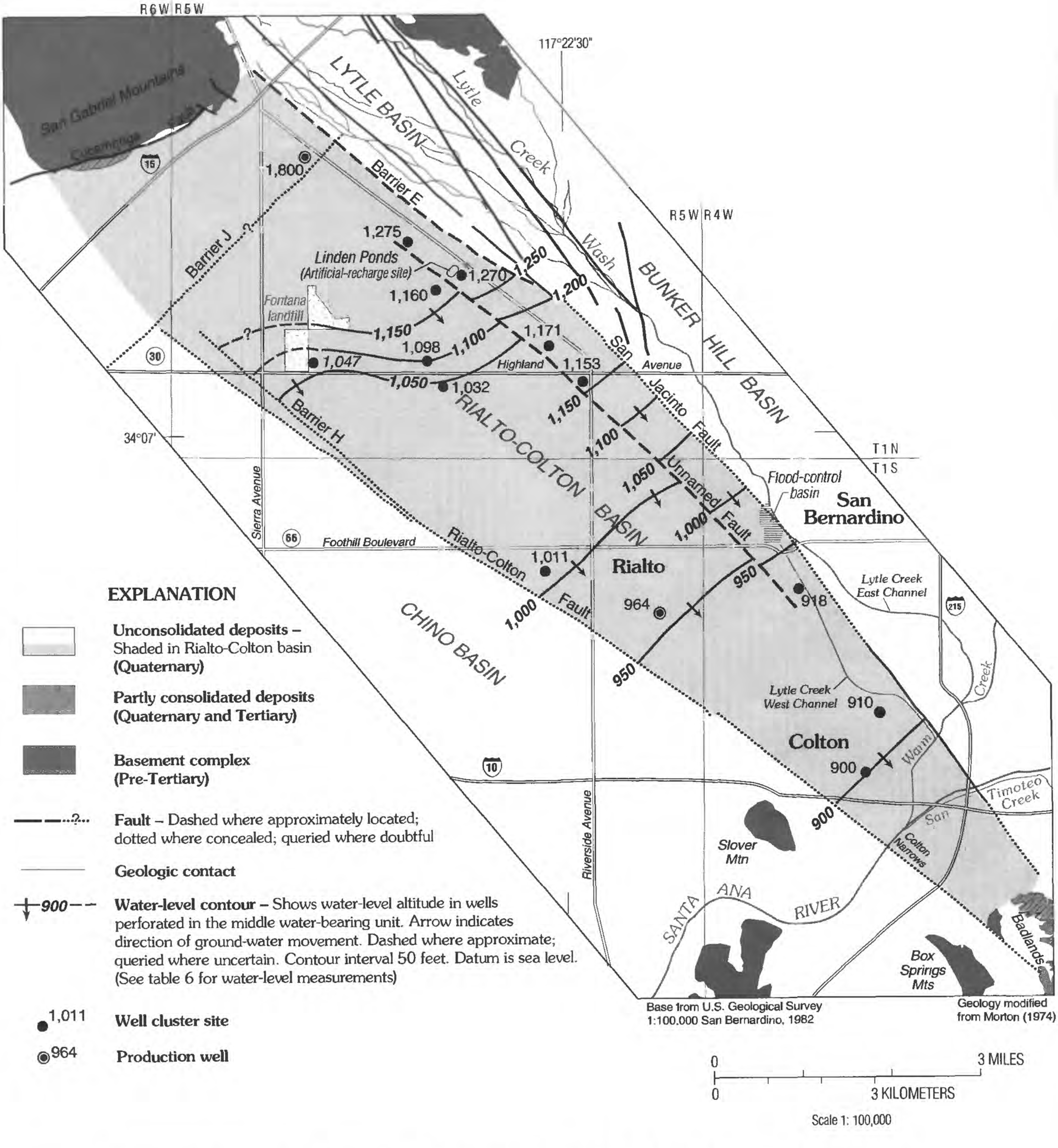


Figure 15. Water-level contours for the middle water-bearing unit in the Rialto-Colton basin, San Bernardino County, California, spring 1994.

Ground water in the lower water-bearing unit also moves from the northwest to the southeast (see fig. 16) along the axis of the basin. Analysis of isotope data, which will be discussed further in the "Water Chemistry" section, indicates that the unnamed fault acts as an effective barrier to ground-water flow in this unit.

Long-Term Changes in Water Levels

Long-term water-level changes for three wells are shown in figure 17. Well 1S/5W-3A1 is in the central part of the basin and is a key well mentioned in a 1969 Superior Court judgement requiring that water levels be maintained at specified levels; well 1S/5W-12L1 is in the southwestern part of the basin and also is a key well; and well 1S/4W-21N1 is in the southeastern part of the basin near the Santa Ana River and Warm Creek (fig. 5). Long-term water-level changes for well 1N/5W-17K1, which is located north of Barrier J, and stream discharge for Lytle Creek are shown in figure 18 . Wells 1N/5W-17K1 and 1S/5W-12L1 are perforated exclusively in the middle water-bearing unit; well 1S/5W-3A1 is perforated in the middle and lower water-bearing units; and well 1S/4W-21N1 is perforated in all water-bearing units (table 1).

Ground-water levels declined almost continuously in wells 1S/5W-12L1, 1S/5W-3A1, and 1S/4W-21N1 during most of the 31-year dry period 1947-77 (fig. 17). In addition, the hydrographs (fig. 17*A*, *B*) show that in the central and south-central parts of the basin, the effects of wet and dry periods are not reflected by water levels immediately; there is a 2-year time lag between the end of a dry period and the rise in water levels. Water levels began to recover before the end of the dry period probably owing to years with above-average precipitation during the dry period and a further reduction in pumpage. Water levels in well 1S/4W-21N1 responded more quickly with less change during the different precipitation cycles (fig. 17*C*), probably because of its proximity to Warm Creek and the Santa Ana River. Although pumpage was reduced by one-half during 1947-77 (fig. 14), water levels in all three wells continued to decline during that period, indicating that even at the reduced pumpage levels, the quantity recharged to the basin was less than the quantity discharged. The water level in well 1N/5W-3A1 declined by as much as 100 ft.

The hydrographs for well 1N/5W-17K1 and a plot of stream discharge in Lytle Creek over time are shown in figure 18. Water levels in well 1N/5W-17K1 did not respond to stresses on the ground-water system in the same manner as those in the wells shown in figure 17, possibly indicating that the ground-water system north and south of Barrier J is not well connected. Water levels north of Barrier J do not appear to be affected by pumping in the main part of the ground-water system south of Barrier J. Water levels north of Barrier J are influenced, in part, by recharge from Lytle Creek. Water levels in well 1N/5W-17K1 increased rapidly during periods of high discharge in Lytle Creek, remained relatively constant during periods of average discharge, and declined sharply during periods of low or no discharge (fig. 18).

Recent Changes In Water Levels

Eleven cluster sites were constructed to monitor depth-dependent water-level changes throughout the basin. From periodic water-level measurements made during 1992-95, hydrographs (shown in fig. 19) were drawn for the 11 cluster sites. Twenty-three wells at five of the cluster sites were constructed east of the unnamed fault north and south of the Linden Ponds artificial-recharge site (fig. 5). Hydrographs for these sites are shown in fig. 19*A-F*. Discharge in Lytle Creek during 1992-95 is shown in figure 20.

Water levels in all wells east of the unnamed fault (fig. 5) appear to respond to artificial-recharge periods at Linden Ponds and discharge in Lytle Creek. Because imported water was detected in only two of the wells east of the unnamed fault (1N/5W-22N5 and 1N/5W-26L1) (Woolfenden, 1994), the rise in water levels in the other 21 wells probably resulted from a pressure response to the recharge of imported water and surface runoff, indicating that the ground-water system in this part of the basin is partly confined.

Water levels in wells 1N/5W-22N1-3 perforated in the middle and lower water-bearing units at Linden Ponds rose sharply about 1 1/2 months after the onset of the October 1992-March 1993, and May-August 1993 recharge events (fig. 19*B*). Recovery at these wells and at wells 1N/5W-22N4 and 5 was gradual, and water levels declined to near pre-recharge levels over a period of 1 1/2 to 2 years.

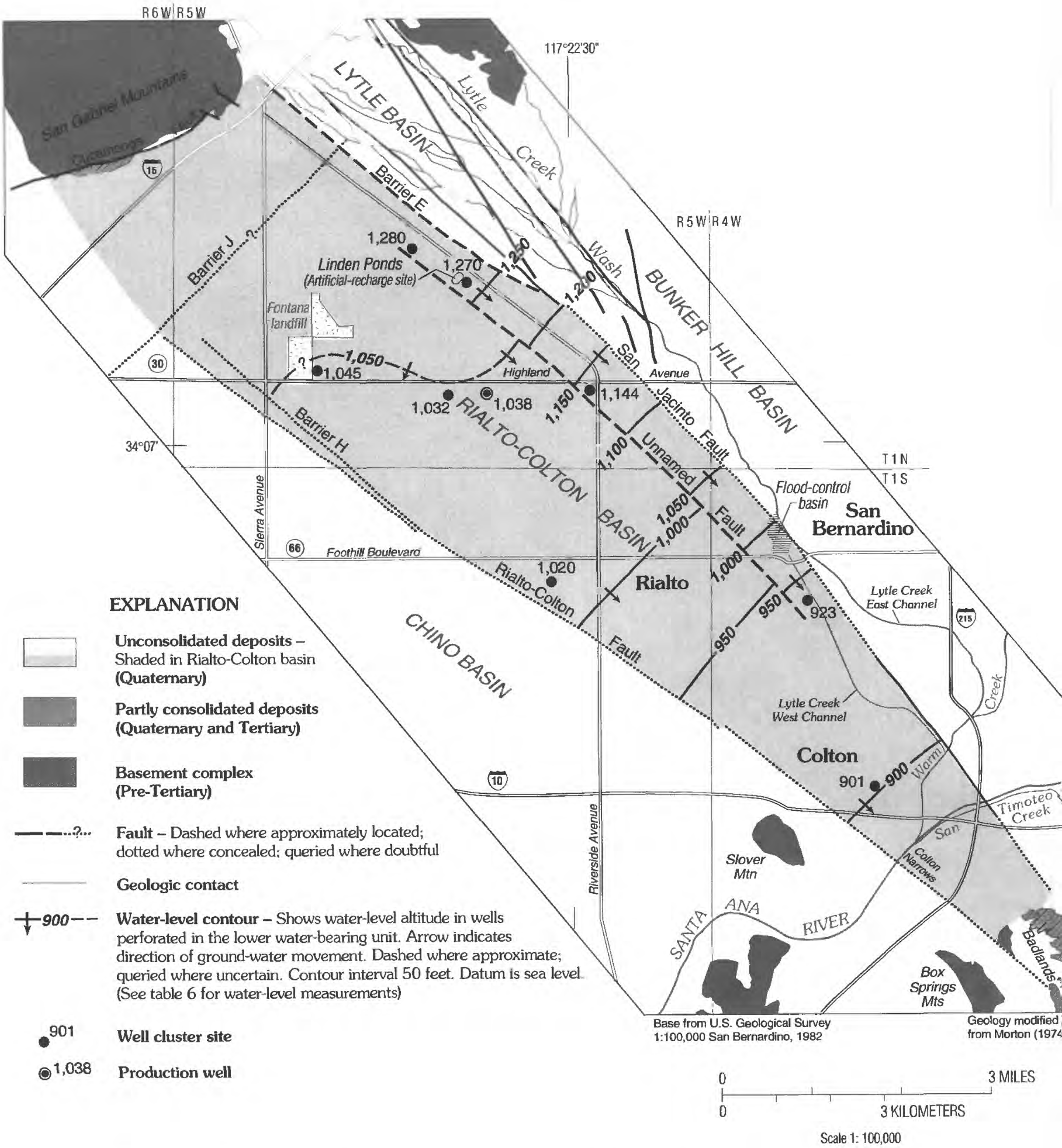


Figure 16. Water-level contours for the lower water-bearing unit in the Rialto-Colton basin, San Bernardino County, California, spring 1994.

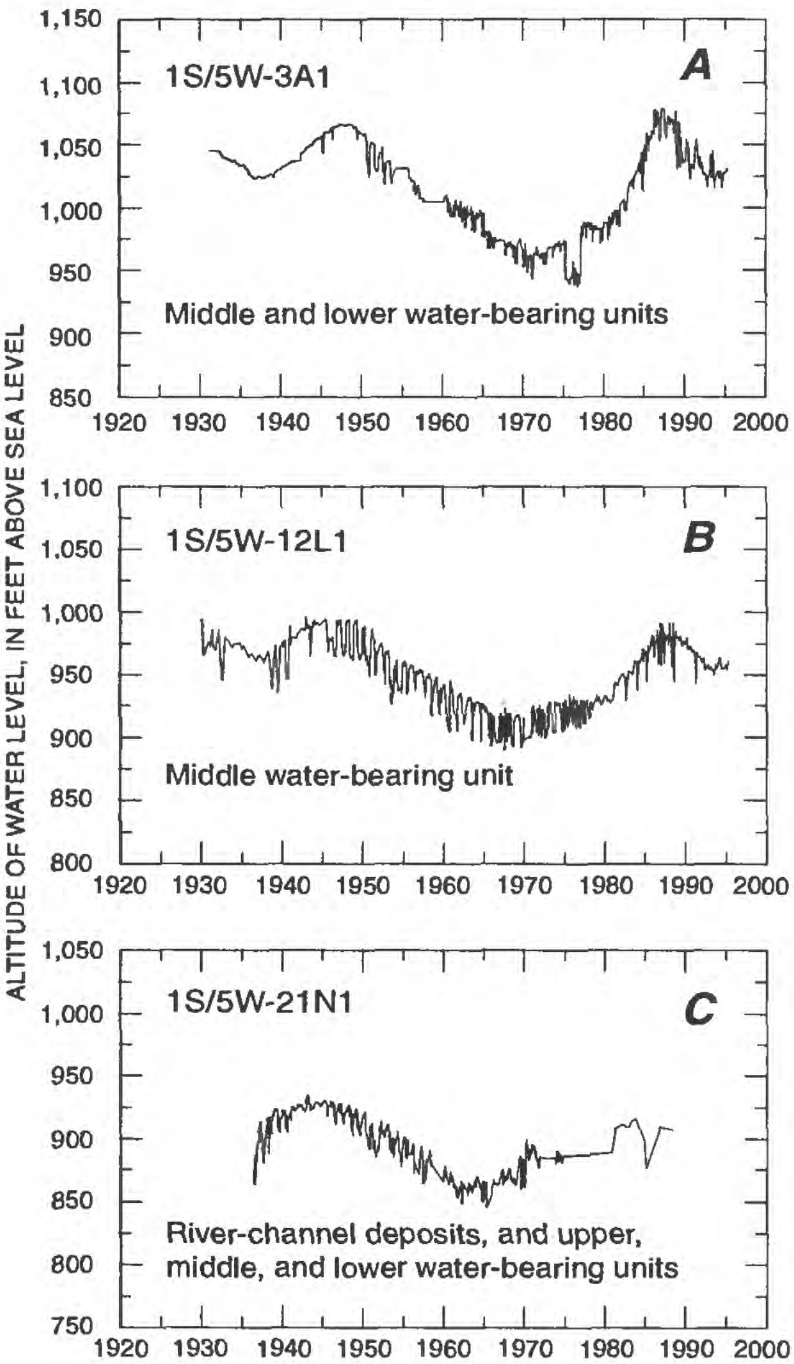


Figure 17. Altitude of water levels for selected production wells in the Rialto-Colton basin, San Bernardino County, California, 1928-95.

No reliable data were available prior to the recharge periods described above for cluster wells perforated in the middle water-bearing unit northwest of Linden Ponds (1N/5W-21K3 and -21K4); however, the data indicate that water levels were rising during the recharge periods (fig. 19*A*). Although water levels in these two wells are shown to decline prior to the end of the recharge period, data were collected sporadically and the peak in water levels may have occurred later than that shown in figure 19*A*. Water levels in wells perforated in the lower water-bearing unit (1N/5W-21K1 and 21K2) began to rise about 5 months after the onset of the 1992-93 recharge periods. Water levels in all wells at cluster sites 1N/5W-22N1-6 and 1N/5W-21K1-4 began to rise again in 1995, probably in response to above-average rainfall during 1992-94 (fig. 4) and, thus, increased discharge in Lytle Creek (fig. 20).

The water-level rise in wells at site 1N/5W-35B1-4 (fig. 19*D*), about 2 mi downgradient from Linden Ponds, was more gradual than the rise at the upgradient sites; at 1N/5W-35B1-4 the peak occurred 1 1/4 to 1 1/2 years after the 1992-93 recharge periods began. Water levels in the middle and lower water-bearing units responded similarly to recharge. Water levels in wells at site 1S/4W-8E1-4 (fig. 19*E*), which is 5.4 mi southwest of Linden Ponds, showed a relatively small rise, and water levels in all wells responded similarly in all units. At cluster site 1S/4W-20H1-5, about 7 1/2 mi southeast of Linden Ponds, water levels in wells rose slightly 1 1/4 years after recharge began (fig. 19*F*). Because the cluster site is near Warm Creek and the Santa Ana River, however, it cannot be determined whether the water-level response was due to artificial recharge, to discharge in Warm Creek and the Santa Ana River, or to ground-water pumping.

With the exception of well 1N/5W-27D2 (fig. 19*J*), water levels in wells at cluster sites on the west side of the unnamed fault show little change (4-11 ft) during 1992-95 (figs. 19*G-K*). Well 1N/5W-27D2 is perforated in the middle water-bearing unit about one-third mi south of Linden Ponds. Imported water was detected in this well in 1993 (Woolfenden, 1994). The elevated water level in this well probably was due to lateral movement of imported water across the fault above the saturated zone. Although water levels in the other wells west of the unnamed fault rose slightly at various times after artificial recharge began in 1992, it cannot be determined if these water-level responses resulted from the 1992-93 artificial-recharge period, an increase in natural recharge, and (or) a decrease in pumping.

Vertical hydraulic gradients varied within the ground-water system. At cluster site 1N/5W-22N1-6, well 1N/5W-22N5 is perforated in the shallowest part of the saturated middle water-bearing unit, and its water level represents the water table. Water levels in well 1N/5W-22N5 were lower than those in the other wells at this site, indicating that the deeper part of the ground-water system is confined. Water levels in the deeper wells were similar, indicating the absence of a vertical gradient between the deeper part of the middle water-bearing unit and lower water-bearing unit, and within the lower water-bearing unit.

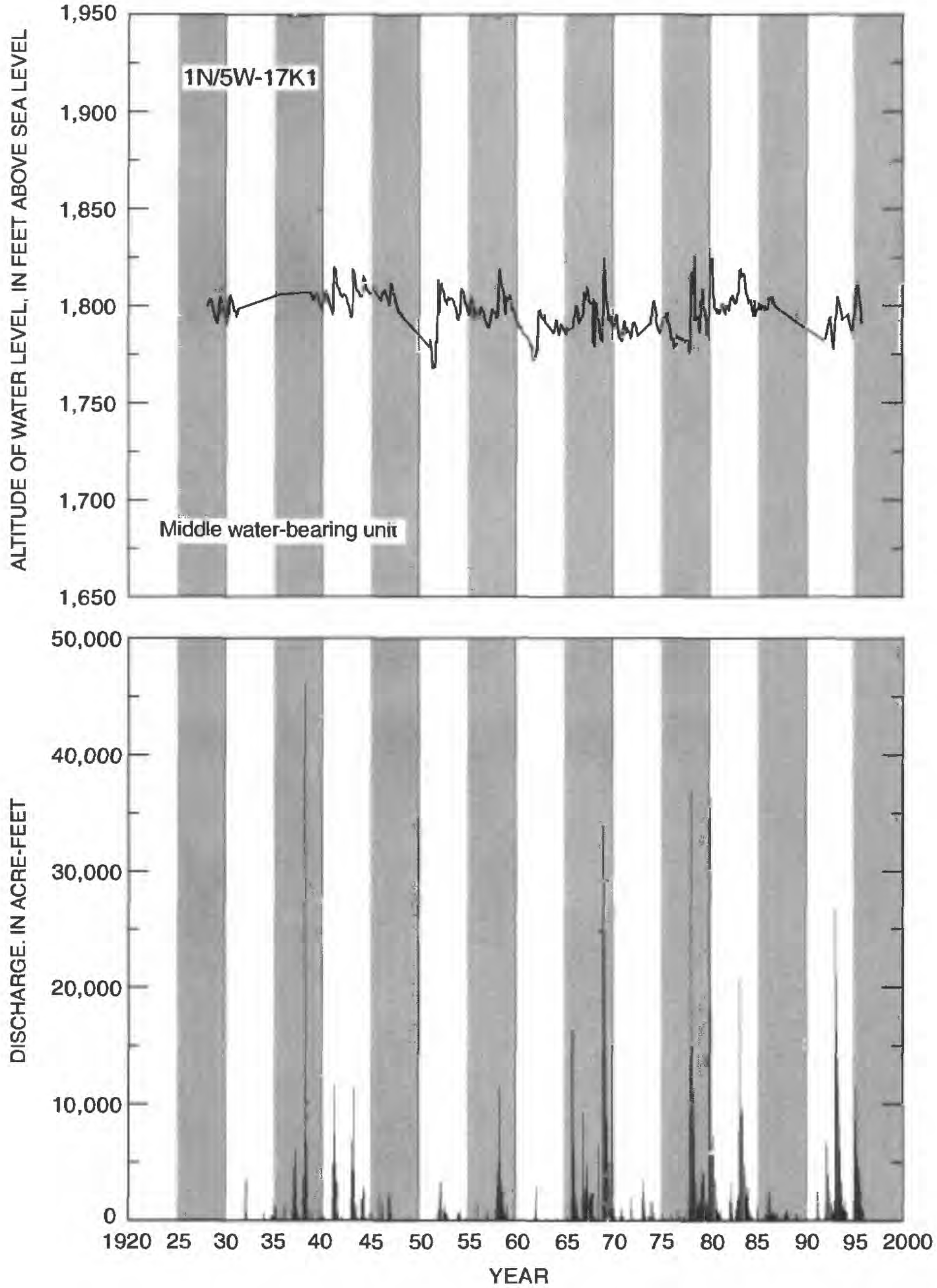


Figure 18. Altitude of water level in well 1N/5W-17K1 and monthly discharge in Lytle Creek, San Bernardino County, California, 1928-95.

At cluster site 1N/5W-21K1-4, water levels in well 1N/5W-21K3 were higher than those in well 1N/5W-21K4, which is perforated in a deeper part of the middle water-bearing unit. This indicates a downward gradient within the middle water-bearing unit at this site. A downward gradient existed between the middle and lower water-bearing units until early 1994, when the gradient reversed, probably in response to recharge.

At cluster site 1N/5W-35B1-4, vertical hydraulic gradients were upward within the middle water-bearing unit and downward from the middle water-bearing unit to the lower water-bearing unit. There was no vertical gradient within the lower water-bearing unit. At site 1S/4W-8E1-4, the vertical gradients were upward: from the consolidated deposits to the lower water-bearing unit; from the lower to the middle water-bearing

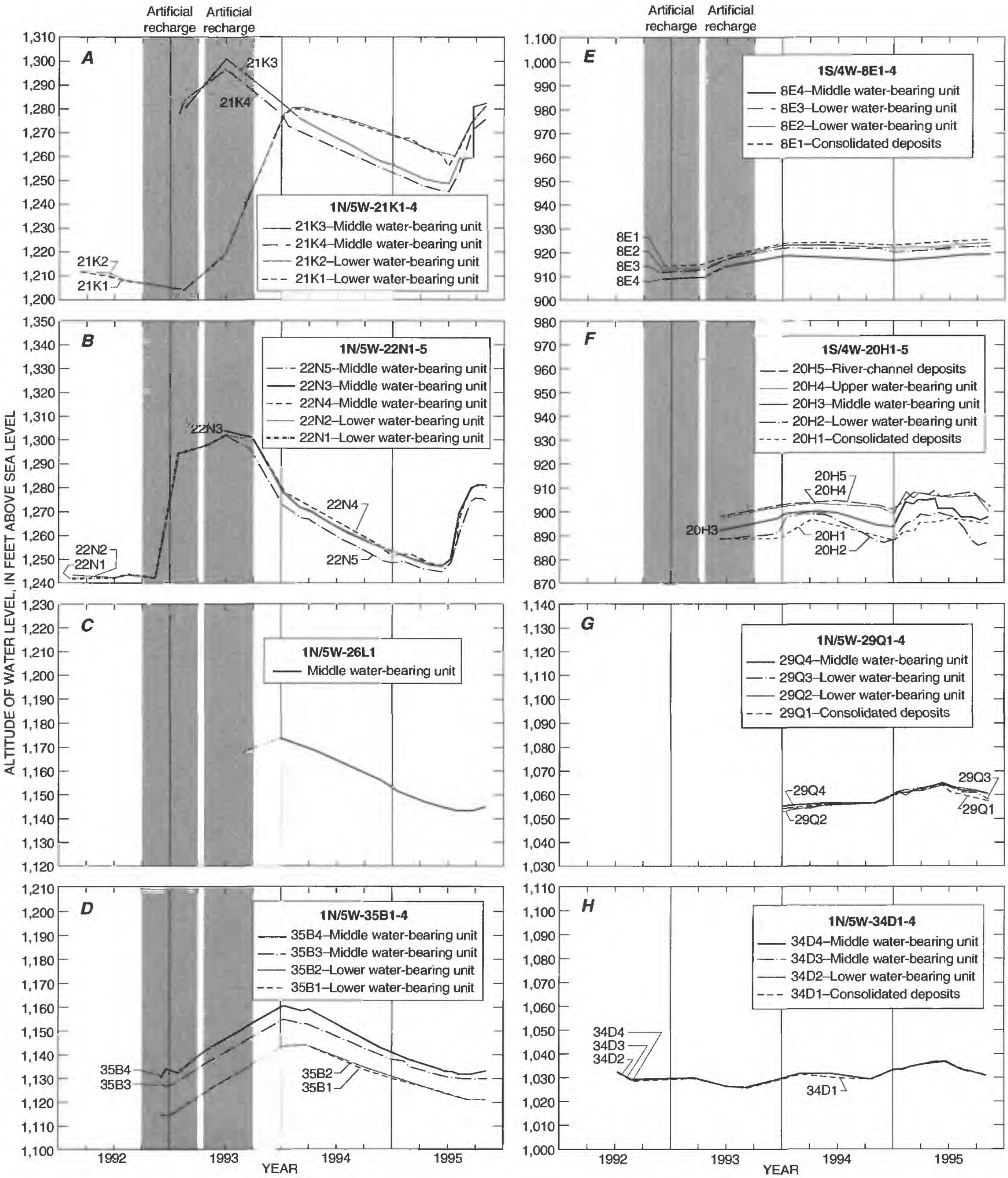


Figure 19. Altitude of water level for cluster sites in the Rialto-Colton basin, San Bernardino County, California, 1992-96.

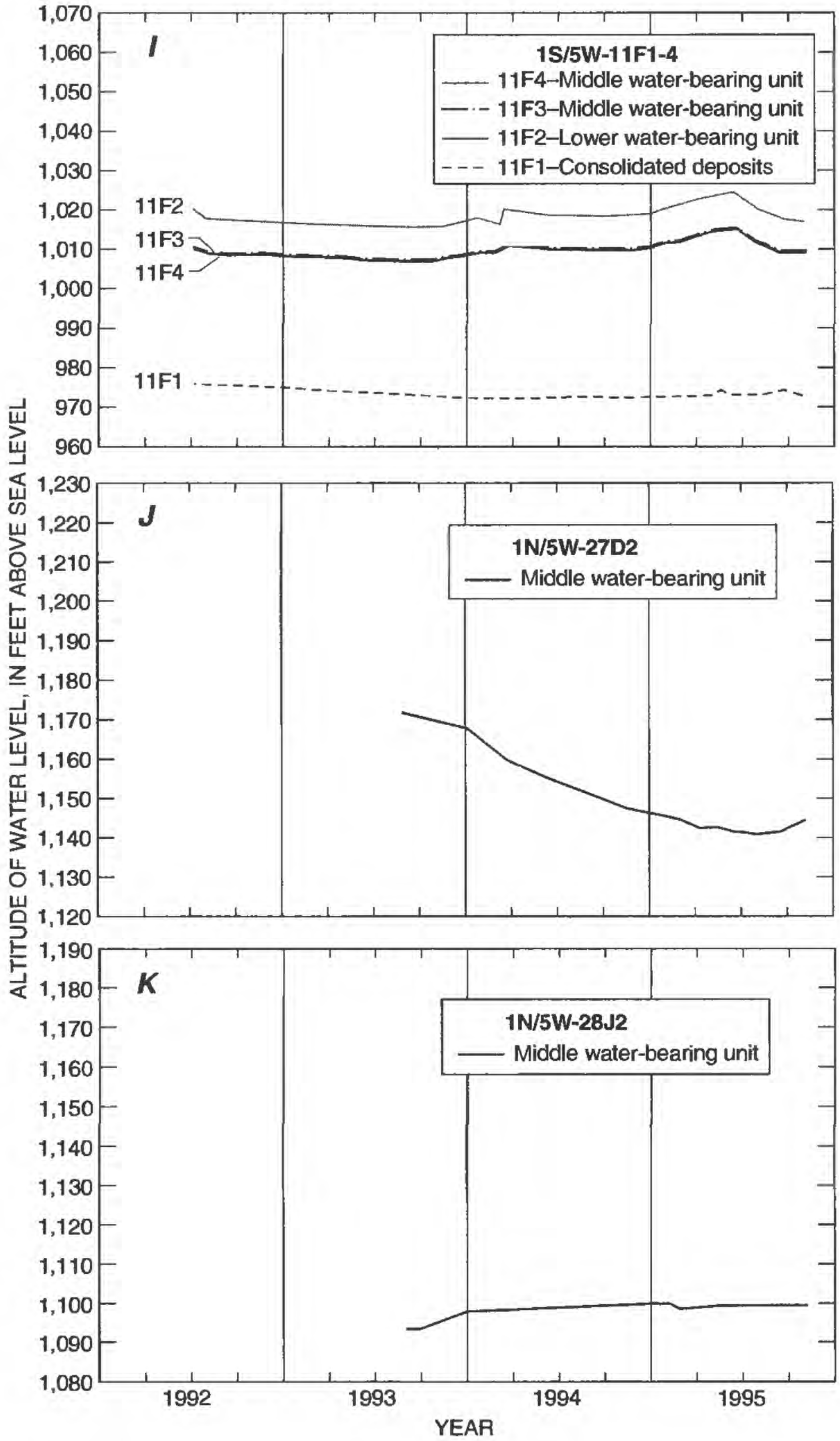


Figure. 19—Continued.

unit; and within the middle water-bearing unit (fig. 19*E*). This indicates what ground water is discharging from the part of the ground-water system between the unnamed fault and the San Jacinto Fault. At cluster site 1S/4W-20H1-5, the vertical hydraulic gradients were downward from one unit to the other. The gradients at this site probably indicate recharge from underflow from Bunker Hill basin to the river-channel deposits and upper water-bearing unit, infiltration of streamflow in the Santa Ana River and Warm Creek, and discharge from the middle and lower water-bearing units owing to pumpage. At cluster site 1N/5W-29Q1-5, the direction of the vertical gradients between wells varied with time; during part of 1994, there was no gradient. At site 1N/5W-34D1-4, there were no vertical gradients and water levels in wells perforated in the middle and lower water-bearing units were similar to those in wells perforated in the consolidated deposits. At cluster site 1S/5W-11F1-4, no vertical gradient was present within the middle water-bearing unit. Water levels in well 1S5W-11F2, which is perforated in the lower water-bearing unit, were higher than those in

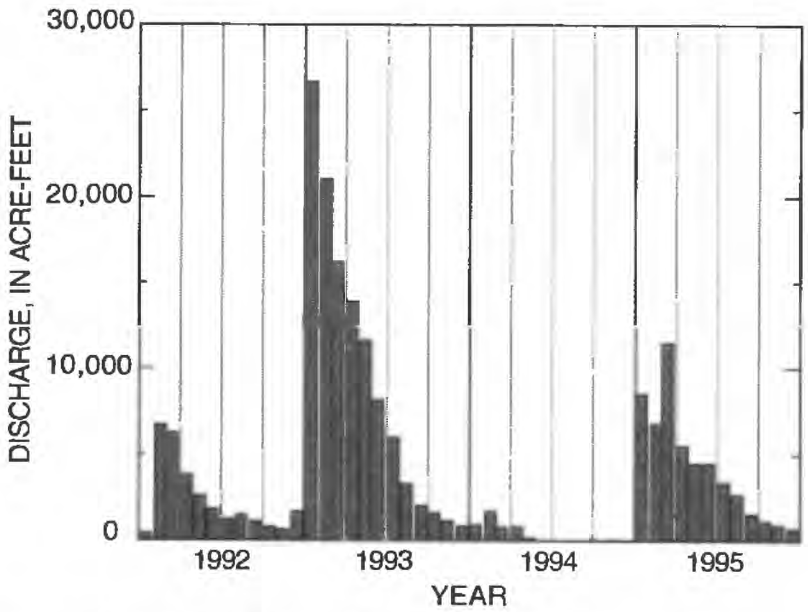


Figure 20. Monthly discharge in Lytle Creek, San Bernardino County, California, 1992-95.

wells perforated in the middle water-bearing unit, indicating an upward gradient from the lower to the middle water-bearing units. The water level in well 1S/5W-11F1, which is perforated in the consolidated deposits, is considerably lower than the water level in the other wells and does not respond to stresses on the overlying ground-water system, indicating that consolidated deposits at this site are hydraulically isolated from the overlying ground-water system.

WATER CHEMISTRY

To determine the areal and vertical variations in ground-water chemistry in the Rialto-Colton basin, samples were collected during 1992-95 from the 37 wells at 11 cluster sites, 1 observation well completed by San Bernardino County, and selected production wells as previously described. Most production wells sampled are perforated in more than one water-bearing unit, and water samples analyzed represent the composite chemical characteristics of water-bearing units tapped by the wells. Water samples also were collected from Lytle Creek and the Santa Ana River in October 1993, and from a spring in the San Gabriel Mountains in August 1995. Sampling locations are shown in figure 5, and water-chemistry data from these samples are given in tables 2 and 3.

The distribution of dissolved solids, nitrate (nitrate plus nitrite, as nitrogen), and chemical characteristics of water from selected wells is shown in figure 21*A-D* for the river-channel deposits and upper water-bearing unit; middle water-bearing unit; lower water-bearing unit; and consolidated deposits, respectively. The river-channel deposits and upper water-bearing unit are mostly unsaturated within the Rialto-Colton basin, and only two cluster wells are perforated in these units. The dissolved-solids and nitrate concentrations, and chemical characteristics of water from cluster well 1S/4W-22D2, in the Bunker Hill basin, are included in figure 21*A* to show the chemical similarity of ground water from these adjacent areas.

River-Channel Deposits and Upper Water-Bearing Unit

In the Rialto-Colton basin, well 1S/4W-20H5 is perforated at the river-channel deposits, and well 1S/4W-20H4 is perforated at the base of the upper water-bearing unit (fig. 10, section *F-F'*). Well 1S/4W-22D2 is perforated in the upper water-bearing unit in the Bunker Hill basin (fig. 10, section *F-F'*). Dissolved-solids concentrations in samples from these wells were 607 mg/L for well 20H4, 740 mg/L for well 20H5, and 760 mg/L for well 22D2 (fig. 21*A*). The similarity in chemical characteristics (fig. 21*A*) of water in all three wells indicated that ground water flows freely across the San Jacinto Fault from the Bunker Hill basin to the Rialto-Colton basin within the river-channel deposits and upper water-bearing unit. The water in the three wells, however, had different chemical characteristics from those of the Santa Ana River water, possibly owing to mixing between the water from underflow and the water in the river.

Nitrate concentrations for wells perforated in the river-channel deposits (1S/4W-20H5) and upper water-bearing unit (1S/4W-20H4) near the Santa Ana River were 5.2 and 3.0 mg/L, respectively. The Santa Ana River, in which nitrate concentration was 5.2 mg/L, probably was the source of the nitrate to these wells (fig. 21*A*; table 2). No nitrate was found (reporting limit 0.05 mg/L) in water from well 1S/4W-22D2, which is upgradient from the city of San Bernardino Plant No. 2 effluent discharge point in the Santa Ana River.

Middle Water-Bearing Unit

Eighteen of the wells sampled in the Rialto-Colton basin are perforated in the middle water-bearing unit (fig. 21*B*). Dissolved-solids

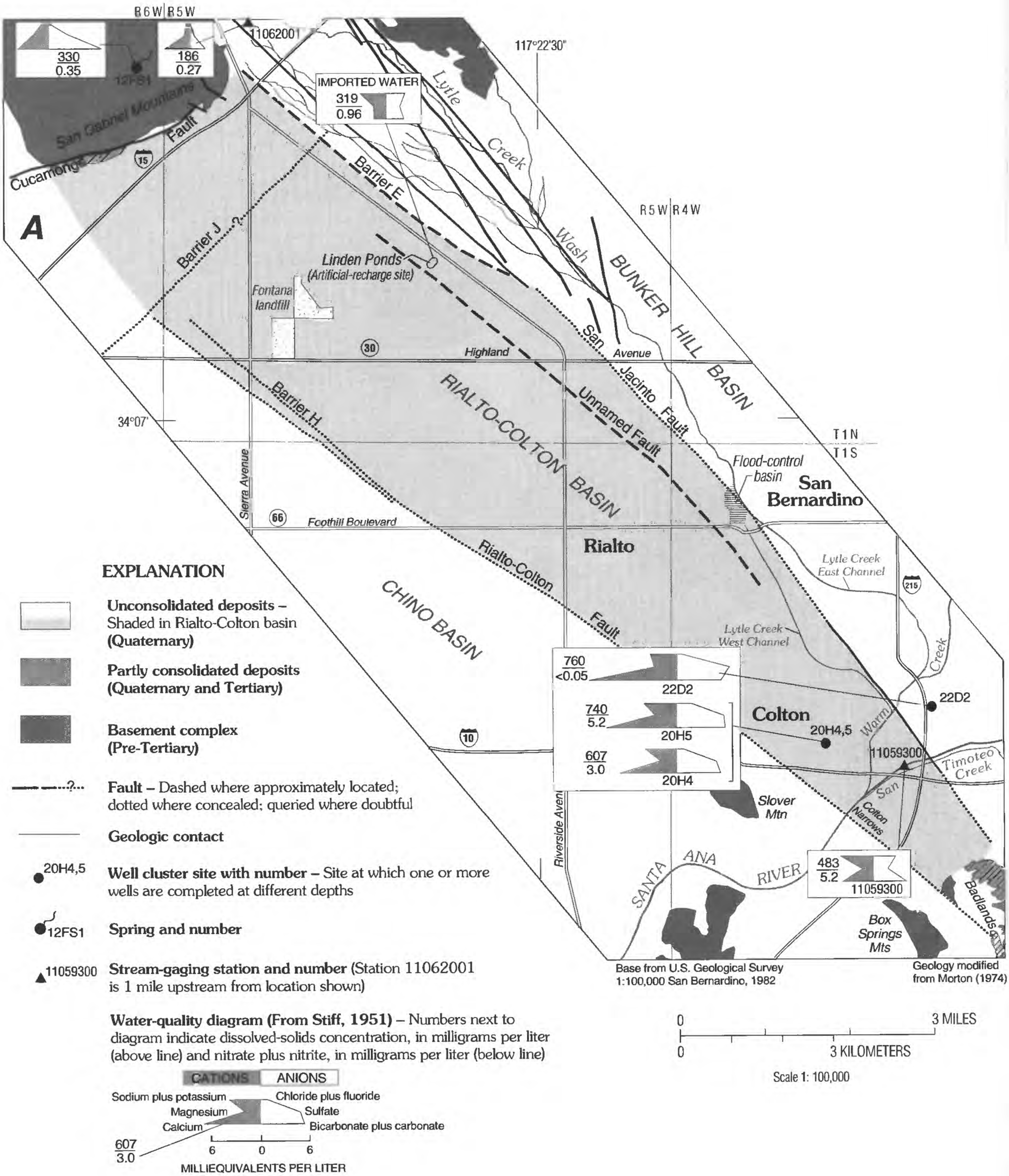
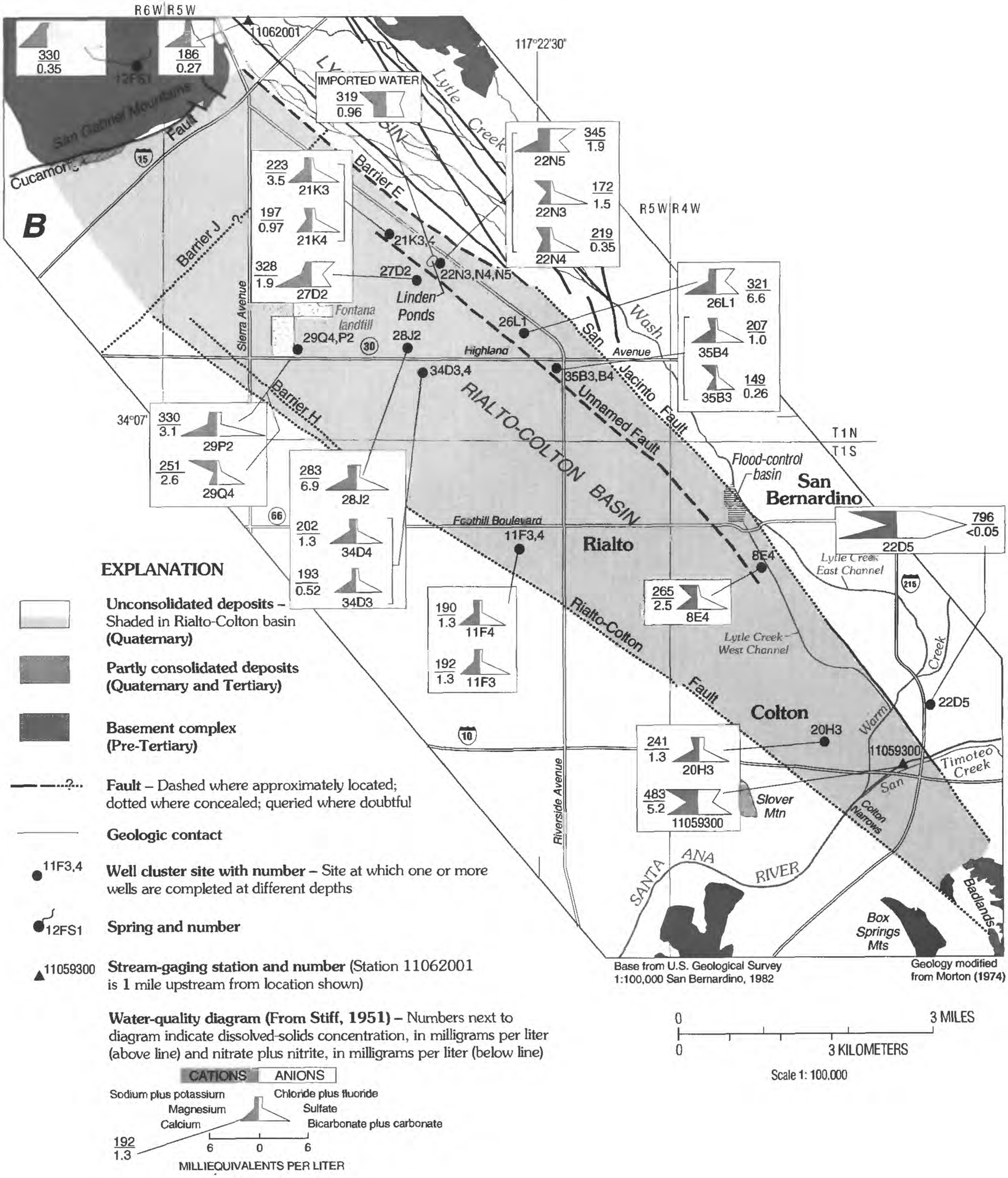


Figure 21. Chemical characteristics of water from wells perforated in the ***(A)*** river-channel deposits and upper water-bearing unit; ***(B)*** middle water-bearing unit; ***(C)*** lower water-bearing unit; and ***(D)*** consolidated deposits, Rialto-Colton basin, San Bernardino County, California, 1993-95.



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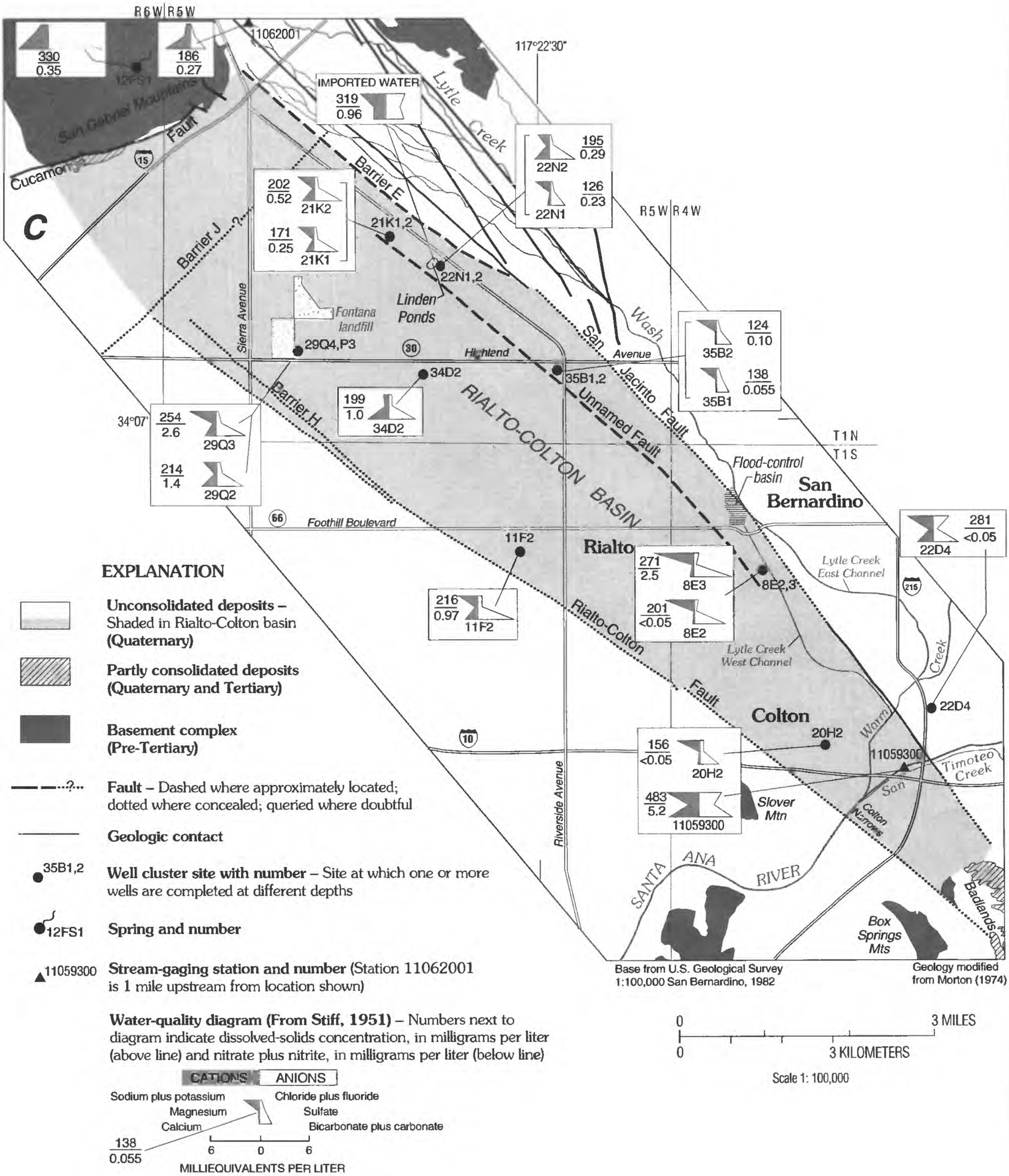

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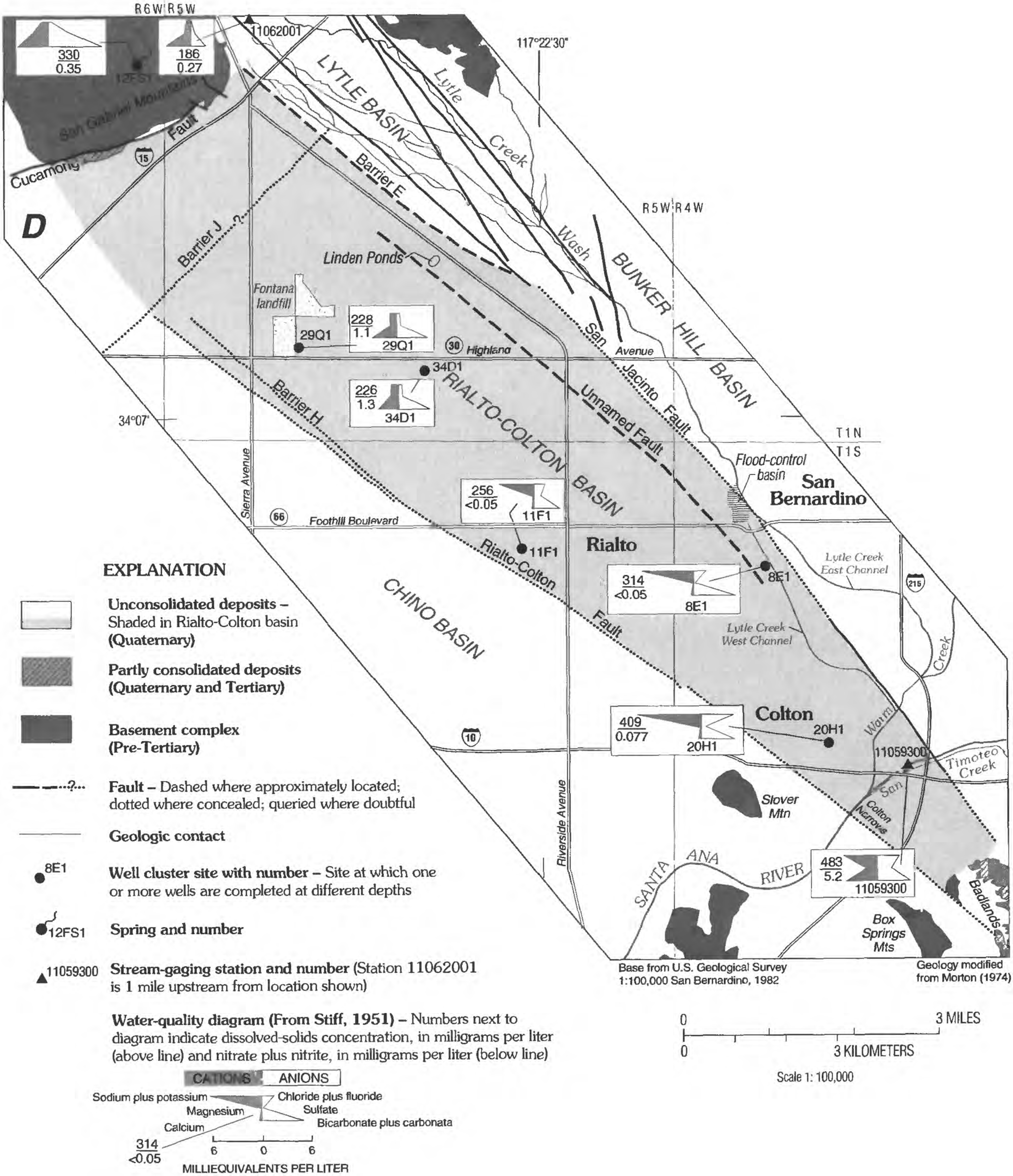

Figure 21.—Continued.

concentrations in samples ranged from 149 mg/L at well 1N/5W-35B3 to 345 mg/L at well 1N/5W-22N5. In samples from wells 1N/5W-22N5, 1N/5W-26L1, and 1N/5W-27D2, dissolved-solids concentrations were greater than 300 mg/L, and the chemical characteristics were similar to those of the imported water (predominant ions were calcium, sodium, chloride, and bicarbonate). All three wells contained imported water (Woolfenden, 1994). The dissolved-solids concentration in water from well 1N15W-29P2 was greater than 300 mg/L; however, the predominant ions in the sample were calcium and bicarbonate. The water in well 1N/5W-29P2 probably has been affected by the percolation of rainwater that collects in ponds at the Fontana Landfill.

Except where the chemical characteristics of water in the middle water-bearing unit are influenced by the artificially recharged imported water, the chemical characteristics of samples from throughout the middle water-bearing generally were similar (predominant ions, calcium and bicarbonate). The water sample from Lytle Creek also had similar chemical characteristics, possibly indicating that Lytle Creek is a source of recharge to this unit. Exceptions were samples from wells 1N/5W-22N3 and N4, 1N/5W-29Q4, 1N/5W-35B3, and 1S/4W-8E4, in which sodium also was a major constituent.

Nitrate concentrations in the middle water-bearing unit ranged from 6.9 mg/L in water from well 1N/5W-28J2 to 0.26 mg/L in water from 1N/5W-35B3 (fig. 21*B;* table 2). In 1949, the land use near well 1N/5W-28J2 was native vegetation (fig. 2); however, this well is downgradient from a former agricultural area, which may be the source of the relatively high nitrate concentration. The land use upgradient from 1N/5W-35B3 was native vegetation in 1949; current land use is residential.

Lower Water-Bearing Unit

Thirteen of the wells sampled in the Rialto-Colton basin are perforated in the lower water-bearing unit. Dissolved-solids concentrations in samples from these wells ranged from 124 mg/L for well 1N/5W-35B2 to 254 mg/L for well 1N/5W-29Q3 (fig. 21*C*). Dissolved-solids concentrations generally increased from east to west and from north to south. Wells at four sites east of the unnamed fault are perforated in the lower water-bearing unit at different depths. At all four sites, dissolved-solids concentrations decreased with depth. Predominant ions in water from most of the wells perforated in the lower water-bearing unit were calcium, sodium, and bicarbonate. The exception was well 1N/5W-34D2, in which the chemical characteristics were similar to those in the middle water-bearing unit and consolidated deposits.

Nitrate concentrations in the lower water-bearing unit were generally less than 1 mg/L, but ranged from 2.6 mg/L in water from well 1N/5W-29Q3 to below the reporting limit in wells 1S/4W-8E2 and E3, and 1S/4W-20H2. Well 1N/5W-29Q3 is located at the Fontana Landfill and is near a former agricultural area (fig. 2). These land uses may account for the relatively high nitrate concentration at this well.

Consolidated Deposits

Prior to this study, no wells were perforated solely in the consolidated deposits in the Rialto-Colton basin. These deposits are deep (more than 1,000 ft below land surface in many places), well yields are relatively low, and the water is generally of poorer quality than that of the overlying unit. As part of this study, five monitor wells (1N/5W-29Q1, 1N/5W-34D1, 1S/5W-11F1, 1S/4W-8E1, and 1S/4W-20H1) were perforated in the consolidated deposits to determine if the water quality in these deposits affects that of the overlying units.

The chemical characteristics of samples from wells perforated in the consolidated deposits are shown in figure 21*D*. The dissolved-solids concentrations of samples from these wells were higher than the concentrations in samples from the lower water-bearing unit at the same sites. The largest difference was at site 1S/4W-20H1-5, where the dissolved-solids concentration was 409 mg/L (20H1) for the consolidated deposits and 156 mg/L (fig. 21*C*) for the lower water-bearing unit (20H2).

The predominant ions in the samples from wells 1N/5W-29Q1 and 1N/5W-34D1 were calcium and bicarbonate. The chemical characteristics in the sample from 1N/5W-34D1 were similar to those in samples from the overlying lower and middle water-bearing units. There is no vertical hydraulic gradient at this site (fig. 19*G*), and the uncorrected carbon-14 ages of samples from the overlying units were similar to those of samples from the consolidated deposits (table 3). This suggests that the source of recharge to the consolidated deposits was the same as that to the overlying units. The chemical characteristics in the sample from well 1N/5W-29Q1 were dissimilar to those of the overlying water-bearing units at that site. Fluoride concentrations in samples from 1N/5W-34D1 were 0.3 to 0.4 mg/L and from 1N/5W-29Q1 0.3 mg/L (table 2).

Water samples from two of the five wells tapping the consolidated deposits contained nitrate concentrations of 1.1 mg/L (well 1N/5W-29Q1) and 1.3 mg/L (well 1N/5W-34D1) (fig. 21*D*). Both wells are in the northwestern part of the basin, and well 1N/5W-29Q1 is located at the Fontana Landfill. Well 1N/5W-29Q1 produces small quantities of water and may not have been fully developed after drilling and well installation. Therefore, the relatively high nitrate concentration for this depth, in addition to the similarity between the chemical characteristics for this sample and those of the sample from 1N/5W-29P2, may reflect the water used during the drilling operation and not water from the consolidated deposits at this site (1N/5W-29Q1-5).

The predominant ions in samples from wells 1S/5W-11F1, 1S/4W-8E1, and 1S/4W-20H1 were distinctly different from those in samples from wells 1N/5W-34D1 and 1N/5W-29Q1. The predominant ions were sodium and bicarbonate in samples from wells 1S/5W-11F1 and 1S/4W-8E1, and sodium, chloride, and bicarbonate in the sample from well 1S/4W-20H1. The vertical hydraulic gradient at site 1S/4W-8E1-4 was upward from the consolidated deposits to the lower water-bearing unit (fig. 19*E*). The chemical characteristics of samples from the lower water-bearing unit were similar to those of the sample from the consolidated deposits, indicating that the consolidated deposits may be the source of water to the lower water-bearing unit. The vertical gradient at site 1S/4W-20H1-5 was downward from each unit to the underlying unit. The chemical characteristics of the sample from the lower water-bearing unit at this site, however, were dissimilar to those of the sample from the consolidated deposits, suggesting that the lower water-bearing unit is not a source of water for the consolidated deposits. Chemical characteristics of the sample from well 1S/5W-11F1 were dissimilar to those of the overlying units; this dissimilarity supports the conclusion stated earlier that the consolidated deposits are hydraulically isolated at this site. Fluoride concentrations in samples from these three wells ranged from 4.4 mg/L (1S/4W-20H1) to 11 mg/L (1S/5W-11F1) (table 2).

Composite Production-Well Water Chemistry

The chemical characteristics of water from sampled production wells is shown in figure 22. Although wells 1N/5W-17K2 and 1S/5W-12L1 are perforated in only the middle water-bearing unit, most production wells in the Rialto-Colton basin are perforated in more than one water-bearing unit.

Dissolved-solids concentrations in samples from production wells in the Rialto-Colton basin ranged from 176 to 487 mg/L. The highest dissolved-solids concentration was in the sample from well 1S/4W-21K1, which is located between the Santa Ana River and Warm Creek. The sample from well 1S/4W-21K1 contained 2.7 TU of tritium (table 3), which indicates that the water in this well was recharged less than 44 years before present (1996). Although this well is not perforated in the river-channel deposits, the chemical characteristics, the dissolved-solids concentration, and tritium concentration, of the sample were similar to those of the sample from the Santa Ana River (fig. 22; table 3). This suggests that the main source of water to this well is the Santa Ana River.

The chemical characteristics of samples from the other production wells in the Rialto-Colton basin showed little variation (fig. 22). In these wells, calcium and bicarbonate were the predominant ions. The chemical characteristics and dissolved-solids concentrations generally were similar to those of samples from the middle water-bearing unit west of the unnamed fault (fig. 21*B*).

Nitrate concentrations in production wells sampled ranged from 7.2 mg/L in well 1N/5W-31A1 to 0.56 mg/L in well 1S/5W-2G1 (fig. 22). The higher concentrations were along the Rialto-Colton Fault in the northern part of the basin and in well 1S/4W-18G1 in the south-central part of the basin. Nitrate concentrations in these wells probably reflect past agricultural land uses.

Oxygen-18 and Deuterium

East of the unnamed fault and southeast of Barrier J, the $\delta^{18}O$ and δD values in the middle water-bearing unit become lighter downgradient along section *A-A′* to wells 1N/5W-35B3 and B4 (table 3; fig. 10). The most abrupt change occurs between well 1N/5W-21K4 (upgradient from the Linden Ponds) and well 1N/5W-22N4 (downgradient from the Linden Ponds). The main

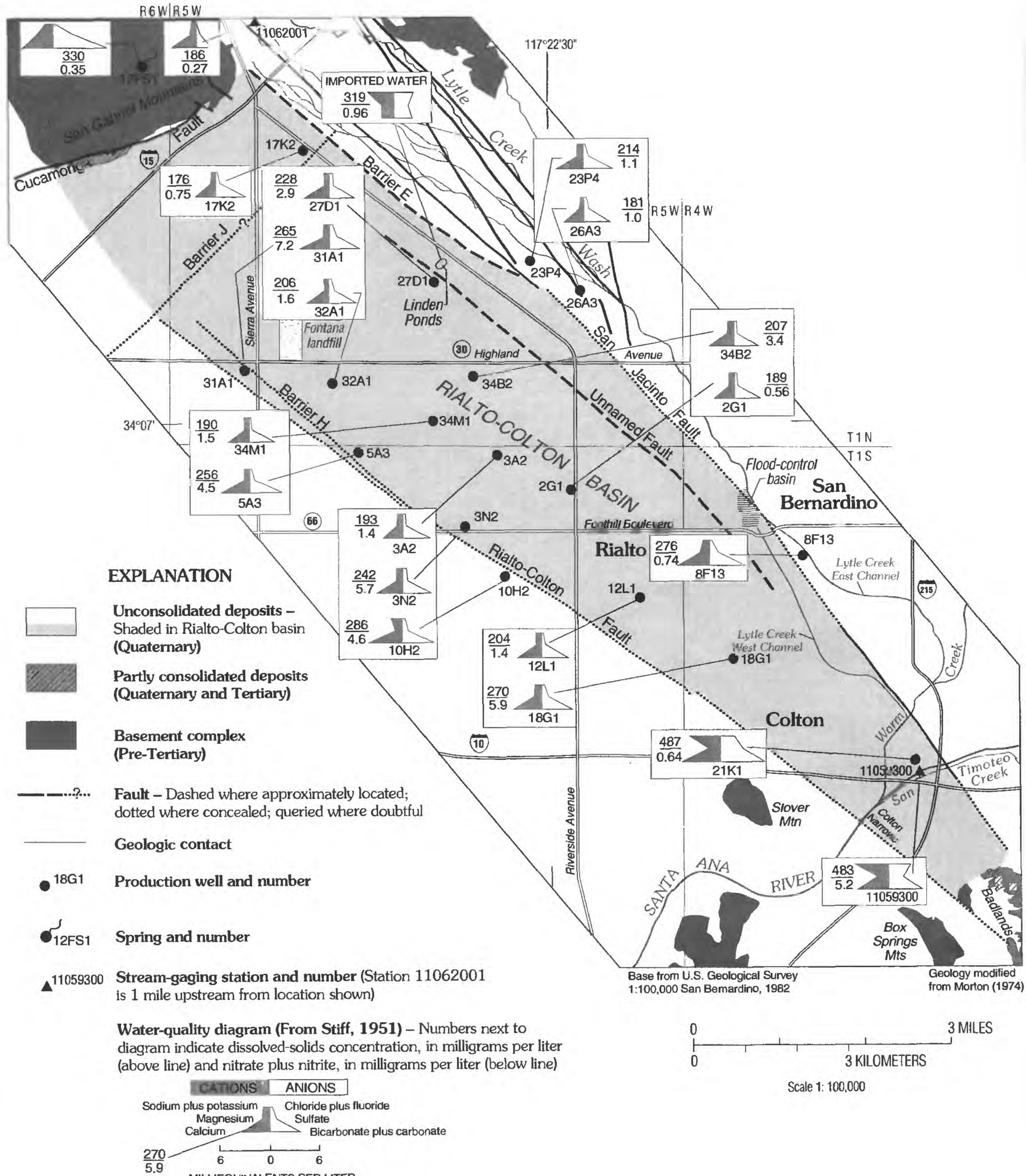

Figure 22. Chemical characteristics of water from selected production wells, a spring, Lytle Creek and the Santa Ana River, Rialto-Colton basin, San Bernardino County, California, 1992-95.

source of water east of the unnamed fault probably is Lytle Creek, in which δD was −72.9 permil in October 1993. These data suggest that Lytle Creek water is present in the middle water-bearing unit south of well 1N/5W-21K4. An alternative explanation for this abrupt change to isotopically lighter water is that relatively light imported water artificially recharged at the Linden Ponds is mixing with isotopically heavier native ground water. Woolfenden (1994) reported that the imported water moved at least to well 1N/5W-26L1, but not to well 1N/15W-35B4. Farther downgradient from the Linden Ponds, the water becomes progressively heavier (δD = −65.4 permil at well 1N/5W35B4 and −62.4 permil at well 1S/4W-8E4). Possible explanations for this trend toward heavier water include smaller proportions of Lytle Creek water; mixing with water from the flood control basin that probably is isotopically heavier than Lytle Creek water because of evaporation; and mixing with isotopically heavier water from west of the unnamed fault. A similar but less pronounced trend is observed for the lower water-bearing unit. Water from the lower water-bearing unit, in general, is isotopically similar to water from the middle water-bearing unit at the same cluster site.

Water from wells in the middle and lower water-bearing units west of the unnamed fault had δD values that, on average, were about 6 permil heavier than values for water from east of the fault south of the Linden Ponds. Downgradient along section *B-B′* (fig. 10), the data show a slight trend to isotopically heavier water. The δD value of −49.5 permil for water from spring 1N/6W-12FS1 (fig. 5; table 3) suggests that water west of the unnamed fault may be a mixture of water that moves through the fractured and weathered basement complex in the San Gabriel Mountains and water from Lytle Creek.

Delta deuterium in water from wells perforated in the consolidated deposits in the northwestern part of the basin (1N/5W-29Q1 and 1N/5W-34D1) is 15 to 20 permil heavier than that in water from three wells (1S/5W-11F1, 1S/4W-8E1, and 1S/4W-20H1) in the southeastern part of the basin. The three southern wells are perforated in deeper deposits within this unit than are the northern wells. The isotopic data indicate that the water in the southern deposits was recharged under cooler and wetter climatic conditions than was water in the northern deposits (Fournier and Thompson, 1980).

Plots of the relation between δD and $\delta^{18}O$ are shown in figure 23. Isotopic data for water from the river-channel deposits (fig. 23*A*) plot along the meteoric water line, suggesting that little evaporation had occurred prior to recharge. The imported water plots below the meteoric line, indicating that the water had been significantly evaporated. Data from sampled wells east and west of the unnamed fault that are perforated in the middle and lower water-bearing units generally plot above the meteoric-water line and show no evidence of mixing with the imported water (fig. 23*B-E*). However, data from two wells east of the fault (1N/5W-22N5 and 1N/5W-26L1) and one well west of the fault (1N/5W-27D2) plot below the meteoric-water line (fig. 23*B, C*), indicating some mixing with imported water. Although the δD and $\delta^{18}O$ ratios generally were heavier (less negative) in samples from west of the unnamed fault in the middle water-bearing unit, and lighter (more negative) in samples from east of the fault, most of the data points overlap (fig. 23*B, C*), indicating mixing of water across the fault in this unit. For the lower water-bearing unit, the separation of the data points is more pronounced (fig. 23*D, E*), indicating that the fault is a more effective barrier in this unit. In water from the consolidated deposits, the δD and $\delta^{18}O$ ratios were heavier in the northwestern part of the basin than in the southeastern part (fig. 23*F*), suggesting that the deposits in the northwest were recharged during climatic conditions that were different from those that existed when the deposits in the southeast were recharged.

Tritium and Carbon-14

Detectable levels (0.3 TU or greater) of tritium were found in samples from 15 wells (12 cluster wells and 3 production wells) in the Rialto-Colton basin. Tritium values ranged from 7.0 TU in water from cluster wells 1N/5W-22N5 and 1N/5W-26L1 to 0.3 TU in water from well 1N/5W-22N3 (table 3). Tritium concentrations in water from the three production wells were 0.7 TU in well 1N/5W-34B2, 0.3 TU in well 1S/4W-18G1, and 2.7 TU in well 1S/4W-21K1. Tritium concentrations in other samples were 4.4 TU for spring 1N/5W-12FS1; 5.4 TU for the imported water; 5.3 TU for Lytle Creek; and 5.0 TU for the Santa Ana River. Sources of recent recharge to wells with detectable levels of tritium are Lytle Creek, water that runs off the San Gabriel

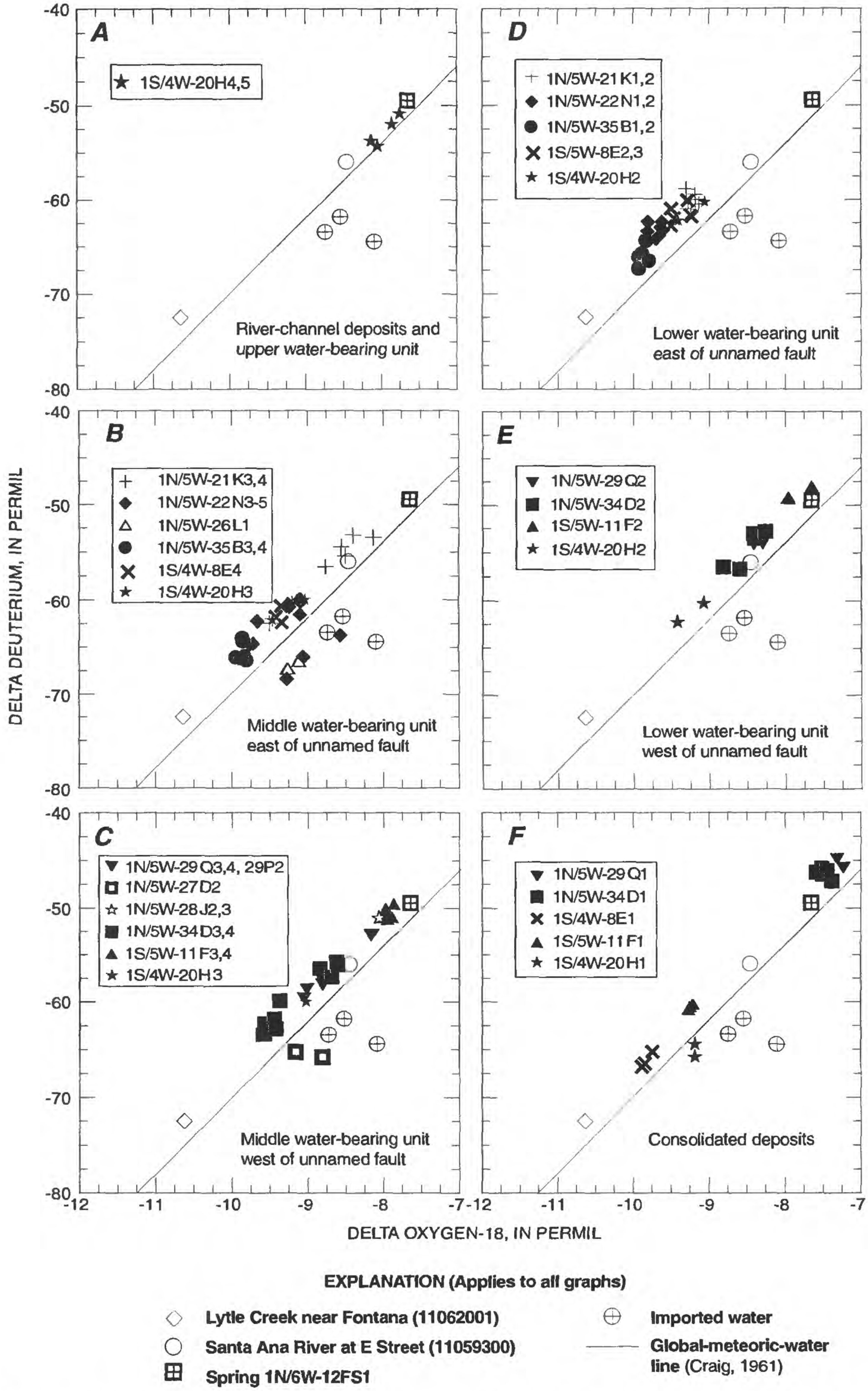

Figure 23. Relation between delta deuterium and delta oxygen-18 values from cluster wells, a spring, and surface-water sites, Rialto-Colton basin, San Bernardino County, California, 1992-95.

Mountains into small creeks or along mountain fronts in the northwestern part of the basin, the Santa Ana River in the southeastern part of the basin, and imported water artificially recharged in Linden Ponds.

Measured carbon-14 activities for water from 27 cluster wells, 1 production well, and spring 1N/6W-12FS1 ranged from 99.21 to 0.77 percent modern carbon. Uncorrected carbon-14 age dates, as determined from carbon-14 activities, can give an indication of the maximum age of the water sampled. The maximum age dates generally were younger in the northwestern part of the basin and older at the downgradient end of the flow paths shown in figure 10, sections *A-A′* and *B-B′*. The exception is in the lower water-bearing unit, where the age date for the sample from 1S/4W-20H2 is younger than that of the sample from the upgradient well 1S/4W-8E2. In addition, uncorrected carbon-14 age dates generally were younger west of the unnamed fault (fig. 10, sections *C-C′*, *D-D′*) than east of the fault. The youngest uncorrected age was 66 years before present for the sample from production well 1N/5W-17K2 in the northeast part of the basin north of Barrier J, thus indicating recent recharge to that well. The uncorrected carbon-14 age date for spring 1N/6W-12FS1 was 2,128 years before the present. Because there also was a detectable level of tritium in the sample, the water from the spring probably was a mixture of recent (less than 44 years before present [1996]) water and older water.

SUMMARY AND CONCLUSIONS

The Rialto-Colton basin is located in western San Bernardino County, California, about 60 mi east of Los Angeles. Ground-water resources are used to meet local water-supply needs. To supplement ground-water resources and offset overdraft conditions during dry periods, imported water originating in the Sierra Nevada was spread in artificial-recharge ponds during 1982-94. To better understand the mixing and movement of imported water in the Rialto-Colton basin, San Bernardino Valley Municipal Water District entered into a cooperative program with the U.S. Geological Survey to study the geohydrology and water chemistry of the basin.

This report includes a description and evaluation of the geohydrology and water chemistry of the Rialto-Colton basin. Ground-water flow and chemistry were investigated using existing data, borehole-geophysical and lithologic logs from newly drilled test holes, measurements of water levels, and chemical analyses of water samples.

The ground-water system in the Rialto-Colton basin consists of unconsolidated and partly consolidated deposits of gravel, sand, silt, and clay. The maximum thickness of the system is greater than 1,000 ft. Stratigraphic units within these deposits could not be areally correlated because of their variability and the lack of traceable beds. For this study, the ground-water system was divided into four water-bearing units: river-channel deposits, and upper, middle, and lower water-bearing units. The water-bearing units are underlain by the consolidated deposits, whose upper surface forms the base of the ground-water system.

The Rialto-Colton ground-water system is bounded by the San Gabriel Mountains and the Badlands on the northwest and southeast, respectively. The San Jacinto Fault and Barrier E form the northeastern boundary, and the Rialto-Colton Fault forms the southwestern boundary. Although there is no evidence that the Rialto-Colton Fault extends north of Barrier J, the boundary was arbitrarily extended along its trend to the San Gabriel Mountains. The San Jacinto Fault is a barrier to ground-water flow along its length in the middle and lower water-bearing units. Ground-water flow is not affected in the unfaulted river-channel deposits and upper water-bearing unit in the southeastern part of the basin. Barrier E does not prevent ground water from moving to the Rialto-Colton basin from Lytle basin. The Rialto-Colton Fault acts as a barrier to ground-water flow along its length except in the river-channel deposits and in the upper water-bearing unit near the Santa Ana River.

Sources of recharge to the ground-water flow system are underflow, ungaged runoff and subsurface inflow, imported water, seepage through stream channels, areal recharge of rainfall, and irrigation return flow. The main component of ground-water discharge in the Rialto-Colton basin has been pumpage.

Ground-water movement in the river-channel deposits, which are saturated only in the southeastern part of the basin, was from east to west. In the middle and lower water-bearing units, ground water moved from northwest to southeast. Two major internal faults, Barrier J and an unnamed fault, affect ground-water movement within the ground-water system. Ground-water moves across Barrier J in the unfaulted part of the ground-water system. The unnamed fault is a partial barrier to ground-water movement in the middle water-bearing unit and an effective barrier to ground-water movement in the lower water-bearing unit. Imported water flows laterally across the fault above the saturated zone.

Long-term water-level changes reflect precipitation cycles. Water levels in three production wells declined almost continuously during most of the 31-year dry period, 1947-77. Water levels declined by as much as 100 ft in one well. Water levels north of Barrier J do not respond to stresses on the ground-water system south of Barrier J, and are influenced by discharge in Lytle Creek.

The water levels rose in all cluster wells east of the unnamed fault northwest and southeast of the Linden Ponds artificial-recharge site during 1992-95. The water levels in wells perforated in the lower water-bearing unit northwest of the recharge ponds rose as much as 70 ft. A rise in water levels in wells at the recharge ponds was observed within 2 months from the beginning of recharge.

Water levels in wells at cluster sites west of the unnamed fault changed very little during 1992–95. Imported water was detected in one well west of the unnamed fault. The elevated water level in this well probably was due to lateral movement of imported water across the fault above the saturated zone.

Water-chemistry data indicate that major-ion concentrations varied within the ground-water system. Generally, concentrations were highest in the river-channel deposits and upper water-bearing unit. Predominant ions in the river-channel deposits and upper water-bearing unit were calcium, sulfate, and bicarbonate. Chemical characteristics in water from a well perforated in the upper water-bearing unit in the Bunker Hill basin were similar to characteristics in water from wells in the river-channel deposits and upper water-bearing unit in the Rialto-Colton basin, indicating these units were recharged from underflow from the Bunker Hill basin. The chemical characteristics in the middle water-bearing unit were similar from most wells sampled; exceptions were wells in which imported water was detected and some wells east of the unnamed fault. The predominant ions in the middle water-bearing unit generally were calcium and bicarbonate. Water in wells in the lower water-bearing unit also had similar chemical characteristics. Chemical characteristics of water from production wells sampled were similar to those of water in the middle water-bearing unit west of the unnamed fault, suggesting that these wells derive most of their water from that unit.

Stable-isotope ratios varied within the ground-water system. Delta deuterium in ground water east of the unnamed fault was generally lighter (more negative) than that west of the fault. The difference in δD in the middle water-bearing unit across the fault was less pronounced than that in the lower water-bearing unit. This suggests that mixing occurs in the middle water-bearing unit and that the fault is a more effective barrier in the lower water-bearing unit.

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APPENDIX

Lithologic logs for cluster sites

LINDEN PONDS
1N/5W-22N1-6

Depth, in feet	Thickness, in feet	Characteristics
0-30	30	Sand, coarse to very coarse, boulders, gravel, and cobbles, light olive gray
30-90	60	Gravel, cobbles, boulders, and sand, coarse to very coarse, olive gray
90-110	20	Sand, medium to very coarse, gravel, and cobbles, olive gray
110-130	20	Sand, medium to very coarse, gravel, cobbles, and clay (trace), olive gray
130-150	20	Gravel, sand, coarse to medium, and boulders, olive gray
150-165	15	Sand, medium to coarse, gravel, cobbles, and clay (trace), light olive brown
165-185	20	Sand, medium to coarse, gravel, and clay (trace), light olive brown
185-205	20	Sand, very coarse to medium, gravel, and cobbles, dark yellowish brown
205-245	40	Sand, coarse to very coarse, some medium to fine sand, gravel, cobbles, and clay (trace), olive gray
245-265	20	Sand, coarse to very coarse, some medium sand, and cobbles, dark yellowish brown, and clay (trace), light brown
265-305	40	Sand, very coarse to medium, and gravel, olive gray
305-325	20	Sand, very coarse to medium, dark yellowish brown
325-345	20	Sand, coarse to very coarse, some medium sand, gravel, and cobbles, olive gray
345-370	25	Sand, fine to medium, gravel, and cobbles, dark yellowish brown
370-385	15	Sand, very fine to coarse, silt, light brown, and clay (10-30%), moderate brown
385-405	20	Sand, medium to coarse, some fine to very fine sand, moderate yellowish brown, and clay (trace), light brown
405-425	20	Sand, medium to coarse, some fine sand, moderate olive brown, and clay (trace), light brown
425-445	20	Sand, medium to fine, moderate olive brown
445-485	40	Sand, fine to medium, moderate olive brown, and clay (trace), dark yellowish orange
485-505	20	Sand, fine to medium, some coarse sand, and clay (trace), light olive brown

Depth, in feet	Thickness, in feet	Characteristics
505-525	20	Sand, medium to fine, some coarse sand, and clay (trace), light olive brown
525-545	20	Sand, medium to coarse, some fine sand, and clay (trace), light olive brown
545-565	20	Sand, coarse to medium, some fine sand, and clay (5-10%), light olive gray
565-585	20	Sand, coarse to medium, moderate olive brown
585-605	20	Sand, medium to coarse, light olive gray
605-665	60	Sand, medium to coarse, and clay (trace), light olive gray
665-685	20	Sand, medium to coarse, some fine sand, light olive gray
685-705	20	Sand, coarse to medium, light olive gray
705-725	20	Sand, medium to coarse, moderate olive brown
725-745	20	Sand, coarse to medium, light olive gray
745-765	20	Sand, medium to coarse, light olive gray
765-805	40	Sand, medium to coarse, some fine sand, light olive gray
805-825	20	Sand, coarse to medium, dark yellowish brown
825-835	10	Sand, fine to coarse, silt, dark yellowish brown, and clay (5%), dusky yellow
835-865	30	Sand, medium to coarse, some fine sand, brown
865-918	53	Sand, medium to coarse, some fine sand, light olive gray
918-922	4	Sand, medium to coarse, some fine sand, and clay (trace), grayish orange
922-985	63	Sand, medium to coarse, some fine sand, and clay (trace at 940'-950'), dark yellowish brown
985-1,005	20	Sand, medium to fine, some coarse sand, moderate yellowish brown, and clay (trace), grayish orange

EL VERDE
1N/5W-21K1-4

Depth, in feet	Thickness, in feet	Characteristics
0-20	20	Sand, gravel, and cobbles
20-40	20	Sand, medium to coarse, gravel, cobbles, and boulders dark yellowish brown
40-60	20	Sand, very coarse to medium, gravel, and cobbles, dark yellowish brown
60-80	20	Sand, very coarse to fine, and gravel, dark yellowish brown
80-100	20	Silty sand, medium to fine, some coarse to very coarse sand, gravel, and cobbles, dark yellowish brown
100-120	20	Sand, very coarse to fine, gravel, and cobbles, olive gray
120-160	40	Gravel, and sand, very coarse to fine, light olive gray
160-180	20	Sand, coarse to medium, and gravel, olive gray
180-200	20	Sand, very coarse to fine, gravel, and cobbles, dark yellowish brown
200-240	40	Gravel, sand, very coarse to medium, and cobbles, olive gray
240-260	20	Sand, coarse to medium, and cobbles, light olive gray
260-340	80	Gravel, sand, very coarse to coarse, and cobbles, light olive gray
340-380	40	Sand, medium to very coarse, gravel, and boulders, olive gray
380-400	20	Sand, coarse to medium, and cobbles, dark yellowish brown
400-480	80	Sand, coarse to medium, some fine sand, and gravel, dark yellowish brown
480-520	40	Sand, medium to fine, some coarse sand, dark yellowish brown

Depth, in feet	Thickness, in feet	Characteristics
520-540	20	Silty sand, very fine to medium, some coarse sand, and clay (trace), light olive gray
540-560	20	Sand, medium to coarse, some fine sand, and clay (trace), light olive gray
560-600	40	Sand, medium to very fine, some coarse sand, light olive gray, and clay (trace), grayish orange
600-620	20	Sand, medium to fine, some coarse sand, light olive brown
620-625	5	Sand, medium to fine, some coarse sand, moderate yellowish brown, and clay (5%), moderate olive brown
625-680	55	Sand, medium to coarse, some fine sand, light olive gray
680-688	8	Sand, medium to fine, light olive gray
688-690	2	Silty sand, and clay (trace), olive black
690-700	10	Silty sand, very fine to medium, pale yellowish brown
700-720	20	Silty sand, very fine to medium, dark yellowish orange, and clay (5-10%), light olive brown
720-732	12	Sand, medium to very fine, pale yellowish brown
732-737	5	Sand, very fine to medium, and clay (5-10%), moderate yellowish brown
737-780	43	Sand,medium to very fine, light olive gray
780-880	100	Sand, medium to very fine, and clay (trace), light olive gray
880-940	60	Sand, medium to very fine, light olive gray
940-1,000	60	Sand, medium to fine, light olive gray

RIALTO AIRPORT
1N/5W-34D1-4

Depth, in feet	Thickness, in feet	Characteristics
0-10	10	Gravel, cobbles, boulders, and sand, coarse to very coarse, dark yellowish brown
10-20	10	Sand, very coarse to medium, gravel, cobbles, and boulders, dark yellowish brown
20-40	20	Sand, medium to coarse, dark yellowish brown
40-120	80	Sand, coarse to medium, some very coarse sand, gravel, and cobbles, olive gray
120-140	20	Sand, medium to coarse, some fine sand, and gravel, dark yellowish brown
140-147	7	Sand, medium to fine, some coarse sand, moderate yellowish brown, and clay (trace), moderate yellowish brown
147-180	33	Sand, medium to coarse, some fine sand, dark yellowish brown
180-185	5	Sand, medium to coarse, and clay, moderate yellowish brown
185-220	35	Sand, coarse to medium, some very coarse sand, dark yellowish brown
220-240	20	Sand, medium to very fine, some coarse sand, gravel, and cobbles, moderate yellowish brown, and clay (trace), moderate brown
240-270	30	Sand, medium to very fine, some gravel, moderate yellowish brown, and clay (5-10%), moderate yellowish brown
270-300	30	Sand, medium to fine, some coarse sand, gravel, and clay (trace), dark yellowish brown
300-320	20	Sand, medium to very fine, moderate yellowish brown, and clay (trace), dark yellowish orange
320-340	20	Sand, fine to medium, moderate yellowish brown
340-345	5	Sand, very fine to medium, moderate yellowish brown, and clay (5-10%), moderate yellowish brown

Depth, in feet	Thickness, in feet	Characteristics
345-380	35	Sand, fine to medium, dark yellowish brown, and clay (trace), moderate yellowish brown
380-430	50	Sand, medium to fine, some coarse sand, moderate yellowish brown, and clay (trace), light brown
430-460	30	Sand, medium to coarse, dark yellowish brown
460-480	20	Sand, medium, some fine and coarse sand, moderate yellowish brown
480-520	40	Sand, medium to very fine, dark yellowish brown, and clay (trace), grayish orange
520-540	20	Sand, medium to fine, dark yellowish brown
540-620	80	Sand, medium to fine, dark yellowish brown, and clay (trace), moderate yellowish brown
620-660	40	Sand, medium to coarse, dark yellowish brown
660-680	20	Sand, medium to very coarse, and gravel, dark yellowish brown
680-700	20	Sand, fine to coarse, dark yellowish brown
700-720	20	Sand, medium to fine, some coarse sand, and clay (trace), dark yellowish brown
720-740	20	Sand, medium to coarse, some fine sand, and clay (trace), dark yellowish brown
740-780	40	Sand, medium to fine, some coarse sand, dark yellowish brown, and clay (trace) light olive brown
780-830	50	Sand, fine to medium, dark yellowish brown, and clay (trace), moderate yellowish brown
830-930	100	Sand, medium to fine, some coarse sand, and clay (trace at 830', 850', 895'), dark yellowish brown
930-953	23	Sand, medium to fine, some coarse sand, dark yellowish brown, and clay (trace), moderate yellowish brown
953-1,000	47	Sand, medium to fine, dark yellowish brown

LILAC PARK
1S/5W-11F1-4

Depth, in feet	Thickness, in feet	Characteristics
0-40	40	Gravel, sand, very coarse to coarse, cobbles, and boulders, olive gray
40-60	20	Sand, medium to very coarse, gravel, and cobbles, olive gray
60-80	20	Sand, very coarse to medium, gravel, and cobbles, olive gray
80-120	40	Sand, coarse to medium, gravel, cobbles, and boulders, olive gray
120-155	35	Sand, very coarse to medium, gravel, boulders, and cobbles, olive gray
155-178	23	Sand, very coarse to fine, and gravel, dark yellowish brown, and clay (trace), moderate yellowish brown
178-180	2	Sand, very coarse to medium, and gravel, dark yellowish brown, and clay (trace), light brown
180-205	25	Sand, very fine to coarse, gravel, and cobbles, dark yellowish brown, and clay (trace), moderate brown
205-230	25	Sand, medium to coarse, some very fine to fine and coarse sand, and cobbles, dark yellowish brown
230-280	50	Sand, medium to coarse, some fine sand, cobbles, and clay (trace), dark yellowish brown
280-300	20	Sand, coarse to medium, and clay (trace), moderate yellowish brown
300-360	60	Sand, medium to coarse, some fine sand, moderate yellowish brown
360-380	20	Sand, medium to fine, some coarse sand, and clay (trace), moderate yellowish brown
380-400	20	Sand, coarse to fine, dusky yellow
400-420	20	Sand, fine to medium, some very fine and coarse sand, dark yellowish brown

Depth, in feet	Thickness, in feet	Characteristics
420-480	60	Sand, medium to coarse, some fine sand, and clay (trace), dark yellowish brown
480-485	5	Sand, very fine to fine, dark yellowish brown, and clay (trace), light brown
485-502	17	Sand, very fine to fine, dark yellowish brown
502-520	18	Sand, medium to fine, some coarse sand, dark brown
520-540	20	Sand, coarse to very coarse, some medium sand, light olive brown
540-580	40	Sand, very fine to fine, some medium sand, dark yellowish brown
580-680	100	Sand, medium to very fine, and clay (trace at 630', 658'), pale yellowish brown
680-703	23	Sand, medium to very fine, some coarse sand, and soft clay (trace at 687'-703'), dusky yellow
703-712	9	Sand, medium to fine, and clay (trace), moderate yellowish brown
712-726	14	Sand, medium, some fine and coarse sand, dark yellowish brown
726-740	20	Sand, very fine, and very hard clay (trace), dark yellowish brown
740-785	45	Sand, fine to very fine, some medium sand, moderate yellowish brown
785-790	5	Sand, very fine to medium, pale yellowish brown, and clay (trace), moderate yellowish brown
790-850	60	Sand, medium to fine, dark yellowish brown, and clay (trace at 818'), moderate yellowish brown
850-880	30	Clay and sand, fine to medium, moderate yellowish brown
880-920	40	Sand, fine to very fine, some medium and coarse sand, and clay (trace), dark yellowish brown
920-1,000	80	Sand, fine to medium, some coarse sand, dark yellowish brown

EASTON RESERVOIR
1N/5W-35B1-4

Depth, in feet	Thickness, in feet	Characteristics
0-20	20	Sand, coarse to medium, some very coarse sand, gravel, cobbles, and boulders, dark yellowish brown
20-40	20	Sand, very coarse to coarse, some medium sand, gravel, cobbles, and boulders, dark yellowish brown
40-80	40	Gravel, sand, very coarse to medium, cobbles, and boulders, grayish olive
80-120	40	Gravel, sand, very coarse to medium, cobbles, and boulders, moderate yellowish brown
120-140	20	Sand, medium to very coarse, gravel, cobbles, and boulders, pale olive
140-180	40	Sand, medium to very coarse, gravel, cobbles, and boulders, dark yellowish brown
180-205	25	Sand, medium to coarse, gravel, moderate yellowish brown, and clay (trace), moderate yellowish brown
205-220	15	Sand, medium to coarse, some gravel and cobbles, dark yellowish brown
220-248	28	Sand, medium to coarse, some gravel, dark yellowish brown, and clay (5%), moderate yellowish brown
248-258	10	Sand, medium to fine, some coarse to very coarse sand, dark yellowish brown
258-300	42	Sand, medium to fine, some coarse sand, dark yellowish brown
300-360	60	Sand, medium to coarse, some fine sand, dark yellowish brown
360-370	10	Sand, medium to fine, dark yellowish brown, and clay (trace), light olive brown
370-380	10	Sand, medium to coarse, some fine sand, dark yellowish brown, and clay (trace) light olive brown
380-400	20	Sand, fine to medium, some coarse sand, dark yellowish brown
400-420	20	Sand, medium to fine, some coarse sand, dark yellowish brown, and clay (trace), dark yellowish brown
420-440	20	Sand, medium to fine, some very coarse sand, and clay (trace), dark yellowish brown

Depth, in feet	Thickness, in feet	Characteristics
440-460	20	Sand, fine, and clay (trace), dark yellowish brown
460-480	20	Sand, coarse to medium, some very coarse and fine sand, dark yellowish brown
480-496	16	Sand, fine, some medium sand, moderate yellowish brown, and sticky clay (trace), dusky yellow
496-502	6	Sand, fine, moderate yellowish brown, and sticky clay (trace), dark yellowish orange
502-512	10	Sand, fine, dark yellowish brown
512-525	13	Sand, coarse to medium, dark yellowish brown
525-590	65	Sand, coarse to medium, some fine sand, and clay (trace at 573'), dark yellowish brown
590-620	30	Sand, fine to coarse, dark yellowish brown
620-632	12	Sand, medium to coarse, some fine sand, dark yellowish brown
632-680	48	Sand, medium to coarse, some very coarse and fine sand, dark yellowish brown, and clay (trace at 660'-680'), dusky yellow
680-700	20	Sand, coarse to medium, some fine sand, dark yellowish brown, and clay (trace), dusky yellow
700-730	30	Sand, fine to medium, some coarse sand, light olive brown, and clay (trace), light olive brown
730-780	50	Sand, medium to fine, some coarse sand, moderate yellowish brown, and clay (trace), dark yellowish orange to dusky yellow
780-800	20	Sand, medium to fine, moderate yellowish brown, and clay (trace), dusky yellow
800-830	30	Sand, medium to fine, pale yellowish brown
830-845	15	Sand, medium to fine, dark yellowish brown
845-860	15	Sand, medium to fine, moderate yellowish brown, and clay (trace ?) dusky yellow
860-957	97	Sand, fine to medium, pale yellowish brown, and clay (trace ?), dusky yellow

RIALTO AVENUE
1S/4W-8E1-4

Depth, in feet	Thickness, in feet	Characteristics
0-25	25	Sand, coarse, gravel, cobbles, and boulders, dark yellowish brown
25-40	15	Clay (>45% clay) and sand, medium to fine, some cobbles, moderate brown
40-60	20	Sand, medium to fine, and clay (trace), dark yellowish brown
60-80	20	Sand, medium, some gravel, dark yellowish brown
80-100	20	Sand, coarse, and gravel, some cobbles and boulders, pale yellowish brown
100-110	10	Sand, medium to fine, some gravel, pale yellowish brown
110-124	14	Sand, coarse to medium, and clay (trace), pale yellowish brown
124-145	21	Sand, coarse to medium, some cobbles, and clay (trace), moderate yellowish brown
145-160	15	Sand, coarse to medium, some gravel and cobbles, moderate yellowish brown
160-170	10	Sand, coarse to very coarse, dark yellowish brown, clay (trace to 5%), moderate yellowish brown
170-200	30	Sand, very coarse to coarse, some gravel, grayish olive
200-220	20	Sand, coarse to very coarse, some gravel and cobbles, grayish olive
220-225	5	Sand, coarse to medium, some very coarse sand and gravel, light olive brown
225-240	15	Sand, medium to coarse, some fine sand, light olive brown, and clay (5%), moderate yellowish brown
240-275	35	Sand, medium to coarse, some very coarse sand, dark yellowish brown, and clay (5%), moderate yellowish brown
275-287	12	Sand, medium to fine, moderate yellowish brown, clay (5%), moderate yellowish brown
287-300	13	Sand, very coarse to coarse, some gravel and medium sand, light olive brown
300-330	30	Sand, medium to coarse, some very coarse sand, light olive brown
330-360	30	Sand, medium to fine, some coarse sand, and clay (trace), moderate yellowish brown

Depth, in feet	Thickness, in feet	Characteristics
360-380	20	Sand, medium, some coarse to very coarse sand, dark yellowish brown
380-426	46	Sand, coarse to medium, some very coarse sand and gravel, olive gray, and clay (trace at 388'-400', 416'-426'), dusky yellow green
426-440	14	Sand, coarse to very coarse, some medium sand and gravel, light olive gray
440-466	26	Sand, medium to fine, some coarse sand, light olive gray
466-474	8	Sand, medium to fine, some coarse sand, and clay (trace), grayish olive
474-500	26	Sand, fine to medium, moderate olive brown
500-520	20	Sand, fine to medium, moderate olive brown, and clay (trace), olive gray
520-535	15	Sand, medium to fine, light olive gray
535-562	27	Sand, medium to coarse, light olive gray, and clay (trace at 536'-540'), dusky yellow
562-572	10	Sand, coarse to medium, light olive gray
572-580	8	Sand, medium to fine, light olive gray
580-592	12	Sand, coarse to medium, olive gray
592-615	23	Sand, medium to coarse, some fine sand, olive gray
615-654	39	Sand, medium to fine, grayish olive green
654-680	26	Sand, medium to fine, some coarse sand, wood, black
680-712	32	Sand, medium to coarse, some fine sand, dark gray
712-740	28	Sand, medium to fine, some coarse sand, olive gray
740-770	30	Sand, medium to fine, olive gray
770-784	14	Sand, fine, some medium and coarse sand, olive gray
784-800	16	Sand, fine to medium, some very fine sand, light olive gray, clay (trace), greenish gray
800-848	48	Sand, coarse to medium, olive gray
848-900	52	Sand, medium to fine, olive gray
900-920	20	Sand, medium to very fine, olive gray
920-1,000	80	Sand, fine to medium, some very fine sand, olive gray, and clay (trace at 920'-928'), olive gray, (trace at 940'-950'), greenish gray

COLTON PLUNGE PARK
1S/4W-20H1-5

Depth, in feet	Thickness, in feet	Characteristics
0-30	30	Sand, coarse to very coarse, some medium sand, gravel, and cobbles, dark yellowish brown
30-43	13	Sand, medium to coarse, some very coarse sand, gravel, cobbles, and clay (trace), pale yellowish brown
43-60	17	Sand, medium to fine, some coarse sand, moderate yellowish brown, dark yellowish brown clay (5-10%)
60-72	12	Sand, very coarse to medium, gravel cobbles, and clay (trace), pale yellowish brown
72-88	16	Sand, medium to coarse, some very coarse sand, and clay, grayish orange
88-148	60	Sand, medium to fine, and clay (trace at 114'-118', 120'-125'), moderate yellowish brown
148-170	22	Sand, medium, some coarse to very coarse sand, dark yellowish brown
170-172	2	Sand, very coarse to medium, some gravel, pale yellowish brown
172-183	11	Clay (>45%), and sand, medium to fine, some coarse sand, moderate brown
183-197	14	Sand, coarse to medium, some very coarse, and clay (trace to 5%), dark yellowish brown
197-220	23	Sand, coarse to fine, some very coarse sand, clay (trace at 197'-205', 211'-215')
220-250	30	Sand, very coarse to medium, some fine sand and gravel, and clay (trace at 230'-233')
250-290	40	Sand, coarse to very coarse, some medium sand and gravel, and clay (trace at 270'-273'), dark yellowish brown
290-339	49	Sand, medium to fine, some coarse to very coarse sand, and cobbles, pale yellowish brown
339-362	23	Sand, medium to coarse, some very coarse and fine sand, pinkish gray
362-383	21	Sand, medium to fine, some coarse sand, and clay (5-25%), dark yellowish brown
383-393	10	Sand, medium to coarse, some fine and very coarse sand, pale yellowish brown

Depth, in feet	Thickness, in feet	Characteristics
393-433	40	Sand, coarse to medium, some very coarse and fine sand, dark yellowish brown
433-447	14	Sand, medium to fine, and clay (5-10%), dark yellowish brown
447-475	28	Sand, coarse to very coarse, some medium sand, dark yellowish brown
475-489	14	Sand, medium to coarse, some fine and very coarse sand dark yellowish brown
489-512	23	Sand, coarse, some medium and very coarse sand, dark yellowish brown
512-535	23	Sand, fine to very fine, some medium sand, dark yellowish brown
535-579	44	Sand, fine to very fine, and clay (trace), dark yellowish brown, some white clay
579-620	41	Sand, medium to coarse, some fine sand, dark yellowish brown
620-640	20	Sand, fine to medium, some coarse sand, dark yellowish brown, and clay (5-10%) moderate yellowish brown
640-652	12	Sand, medium to fine, some coarse sand, and clay (trace at 652'), dark yellowish brown
652-685	33	Sand, very fine to fine, some medium sand, pale yellowish brown, and clay (trace to 5%), dark yellowish brown
685-720	35	Sand, medium, some fine and coarse sand, and clay (trace at 687'-693', 703'-710'), dark yellowish brown
720-740	20	Sand, fine, and clay (trace to 5%) some medium sand, moderate yellowish brown
740-775	35	Silty sand, very fine to fine, and clay (trace), yellowish gray, streaks of white and copper-colored clay
775-800	25	Sand, medium to very fine, some coarse sand, and clay (trace at 790'-800') dark yellowish brown, streaks of white and copper-colored clay
800-810	10	Sand, medium to fine, dark yellowish brown
810-863	53	Silty sand, very fine to medium, some coarse sand, and clay (trace), yellowish gray
863-920	57	Sand, medium to very fine, yellowish gray, and clay (trace), light olive gray
920-944	24	Sand, medium to very fine, greenish gray
944-970	26	Silty sand, medium to very fine, yellowish gray

FONTANA LANDFILL
1N/5W-29Q1-5

Depth, in feet	Thickness, in feet	Characteristics
0-20	20	Sand, coarse to very coarse, gravel, medium sand, cobbles, and boulders, light olive gray
20-50	30	Gravel, sand, very coarse to coarse, cobbles, and boulders, olive gray
50-120	70	Sand, very coarse, and gravel, some coarse to medium sand, cobbles, and boulders (80'-100'), olive gray
120-135	15	Sand, very coarse to medium, gravel, cobbles, boulders and clay (trace), moderate olive brown
135-160	25	Clay (>45%), sand, coarse to medium, some very coarse sand, and gravel, moderate yellowish brown
160-173	13	Sand, medium, clay (15-20%), some coarse to very coarse sand, and gravel, moderate yellowish brown
173-200	17	Clay (>45%), sand, medium, some coarse to very coarse sand, moderate yellowish brown
200-210	10	Sand, fine to medium, some coarse sand, and clay (trace to 5%), moderate brown
210-220	10	Clay (25-45%), light brown, and sand, medium to fine, some coarse sand, dark yellowish brown
220-225	5	Sand, medium to coarse, some fine sand, and clay (trace to 5%), moderate yellowish brown
225-250	25	Sand, coarse to medium, some fine sand, and clay (trace), dark yellowish brown
250-272	22	Sand, coarse to medium, some fine sand, dark yellowish brown
272-325	53	Sand, medium to coarse, some very coarse and fine sand, dark yellowish brown

Depth, in feet	Thickness, in feet	Characteristics
325-355	30	Sand, medium to coarse, some very coarse and fine sand, and clay (trace), moderate yellowish brown
355-370	15	Sand, medium, some coarse and fine sand, and clay (trace), moderate yellowish brown
370-390	20	Sand, medium to coarse, dark yellowish brown
390-412	22	Clay (>45%) and sand, fine to medium, moderate yellowish brown
412-422	10	Sand, medium to coarse, and clay (5-25%), moderate yellowish brown
422-430	8	Sand, medium to coarse, and clay (trace), moderate yellowish brown
430-480	50	Sand, medium to coarse, and clay (trace to 5%), moderate yellowish brown
480-500	20	Sand, coarse to very coarse, some medium sand, and clay (trace at 490'-500'), moderate yellowish brown
500-574	74	Sand, coarse, some medium sand, pale yellowish brown
574-590	16	Sand, medium to coarse, moderate yellowish brown
590-778	188	Sand, coarse to medium, pale yellowish brown, and clay (trace at 600'-610', 667'-670', 690'-696', and 710'-723')
778-882	104	Sand, medium to coarse, some very coarse sand, moderate yellowish brown, and clay (trace at 815'-820')
882-904	22	Sand, medium to fine, and clay (trace)
904-947	43	Sand, medium to fine, some coarse sand, moderate yellowish brown
947-955	8	Sand, medium to fine, and clay (trace), moderate yellowish brown
955-998	43	Sand, fine to medium, moderate yellowish brown

CEDAR AVENUE
1N/5W-27D2-4

Depth, in feet	Thickness, in feet	Characteristics
0-30	30	Sand, very coarse to medium, gravel, cobbles, and boulders, moderate yellowish brown
30-55	25	Sand, coarse to very coarse, some medium sand, gravel, and cobbles, dark yellowish brown
55-75	20	Sand, very coarse to coarse, gravel, and cobbles, dusky yellowish brown
75-88	13	Sand, very coarse to coarse, cobbles, and boulders, light olive gray
88-98	10	Sand, coarse to very coarse, gravel, cobbles, and boulders, olive gray
98-110	12	Cobbles, gravel, and very coarse to medium sand, light olive gray
110-155	45	Sand, coarse to medium, some very coarse sand, gravel and cobbles, dark yellowish brown
155-213	20	Sand, coarse to very coarse, medium sand, gravel, and cobbles, dark yellowish brown
213-230	17	Sand, very fine to fine, and clay, some medium to very coarse sand, dark yellowish brown
230-243	13	Sand, medium to coarse, some fine sand, dark yellowish brown
243-252	9	Sand, coarse to fine, and clay (40%), dark yellowish brown
252-270	18	Sand, medium to coarse, some fine sand, gravel, and clay (trace at 258'-262'), dark yellowish brown

Depth, in feet	Thickness, in feet	Characteristics
270-283	33	Sand, coarse to medium, some fine sand, dark yellowish brown, and clay, moderate yellowish brown
283-307	24	Sand, coarse to medium, some fine sand, and gravel, dark yellowish brown
307-311	4	Sand, coarse to medium, some fine sand, and clay (trace), dark yellowish brown
311-337	26	Sand, coarse to medium, some fine sand, dark yellowish brown
337-380	13	Sand, medium to coarse, some fine sand, grayish orange, and clay (trace to 5%), moderate yellowish brown
350-360	10	Sand, coarse to medium, some fine sand, moderate yellowish brown
360-370	10	Sand, coarse to fine, and clay (trace to 5%), moderate yellowish brown
370-381	11	Sand, coarse to medium, some very coarse sand, dark yellowish brown
381-386	5	Sand, coarse to medium, some fine sand, and clay (trace), dark yellowish brown
386-410	24	Sand, coarse to medium, some fine sand, dark yellowish brown
410-448	38	Sand, medium to fine, some coarse sand, moderate to dark yellowish brown
448-458	10	Sand, coarse to medium, and clay (trace), dark yellowish brown
458-478	20	Sand, coarse to medium, dark yellowish brown

APPLE STREET
1N/5W-26L1

Depth, in feet	Thickness, in feet	Characteristics
0-20	20	Sand, very coarse to medium, and gravel, dark yellowish brown
20-65	45	Cobbles, boulders, gravel, and very coarse to medium sand, moderate yellowish brown
65-104	39	Sand, coarse to medium, some very coarse sand, gravel, and cobbles, dark yellowish brown
104-113	9	Sand, very coarse to medium, gravel, and cobbles, pale yellowish brown
113-138	25	Cobbles, gravel, and very coarse to medium sand, pale yellowish brown
138-173	35	Gravel, cobbles, and very coarse to medium sand, pale yellowish brown
173-207	34	Sand, coarse to very coarse, gravel, medium sand, and cobbles, dark yellowish brown
207-228	21	Sand, coarse to very coarse, gravel, cobbles, and medium sand, dark yellowish brown
228-252	24	Sand, coarse to medium, some very coarse sand, gravel, and cobbles, light olive gray
252-290	38	Sand, very coarse to medium, gravel, and cobbles, pale yellowish brown
290-306	16	Sand, very coarse to medium, gravel, and cobbles, light olive gray
306-314	8	Sand, coarse to medium, very coarse sand, cobbles, and clay (trace), dark yellowish brown
314-358	44	Sand, coarse to medium, gravel, and cobbles, dark yellowish brown

VINEYARD AVENUE
1N/5W-28J2,3

Depth, in feet	Thickness, in feet	Characteristics
0-20	20	Sand, coarse, cobbles, very coarse sand, gravel, and medium sand, dark yellowish brown
20-39	19	Cobbles, gravel, very coarse to medium sand, dark yellowish brown
39-63	24	Gravel, cobbles, and very coarse to coarse sand, some medium sand, dark yellowish brown
63-97	34	Cobbles, very coarse to coarse sand, gravel, and medium sand, dusky yellowish brown
97-130	33	Sand, very coarse to coarse, medium sand, cobbles, and gravel, dusky yellowish brown
130-147	17	Sand, coarse to very coarse, medium sand, cobbles, and gravel, dusky yellowish brown
147-166	19	Sand, coarse to medium, some very coarse sand, gravel, cobbles, and clay (trace at 152'-156'), dark yellowish brown
166-182	16	Sand, very coarse to coarse, gravel, medium sand, and cobbles, dark yellowish brown
182-195	13	Sand, coarse to medium, and clay (25-40%), some very coarse sand and cobbles, dark yellowish brown
195-233	38	Sand, coarse to very coarse, some medium sand, gravel, and cobbles, dark yellowish brown
233-243	10	Sand, coarse to medium, some very coarse sand, and clay (trace to 5%), dark yellowish brown
243-264	21	Sand, coarse to medium, some very coarse sand, and gravel, dark yellowish brown
264-284	20	Sand, coarse to medium, some very coarse sand, and clay (trace to 5%), dark yellowish brown
284-309	25	Sand, coarse to fine, some very coarse sand, dark yellowish brown
309-322	13	Sand, coarse to fine, some coarse sand, dark yellowish brown, and clay (trace to 5%), dusky yellow
322-350	28	Sand, coarse to fine, some very coarse sand, dark yellowish brown
350-367	17	Sand, coarse to fine, dark yellowish brown, and clay (trace to 5%), light yellow brown
367-405	38	Sand, coarse to fine, some very coarse sand, dark yellowish brown
405-420	15	Sand, medium to coarse, some fine sand, dark yellowish brown
420-435	11	Sand, medium to fine, some coarse sand, and clay (trace), dark yellowish brown
435-445	10	Sand, medium to coarse, some fine sand, dark yellowish brown
445-453	8	Sand, medium to coarse, some fine sand, and clay (trace), dark yellowish brown
453-498	45	Sand, medium to coarse, some fine sand, pale yellowish brown

— 'AGE 83 FOLLOWS —

TABLES

Table 1. *Well-construction data, Rialto-Colton basin, San Bernardino County, California*

[Measured unit was determined on the basis of well perforations. See figure 5 for well locations. Altitude of land surface in feet above sea level. Well depth and perforated interval in feet below land surface. --, no data]

State well No.	Altitude of land surface	Well depth	Perforated interval	Water-bearing unit perforated
		Cluster sites		
1N/5W-21K1	1,645	1,000	960-980	Lower
1N/5W-21K2		780	740-760	Lower
1N/5W-21K3		475	435-455	Middle
1N/5W-21K4		600	575-595	Middle
1N/5W-22N1	1,580	1,000	960-980	Lower
1N/5W-22N2		760	720-740	Lower
1N/5W-22N3		455	415-435	Middle
1N/5W-22N4		600	575-595	Middle
1N/5W-22N5		380	340-360	Middle
1N/5W-22N6		148	118-138	Upper
1N/5W-26L1	1,455	358	322-352	Middle
1N/5W-27D2	1,543	478	450-470	Middle
1N/5W-27D3		367	342-362	Middle
1N/5W-27D4		250	225-245	Middle
1N/5W-28J2	1,512	455	430-450	Middle
1N/5W-28J3		355	330-350	Middle
1N/5W-29Q1	1,540	995	975-995	Consolidated deposits
1N/5W-29Q2		775	755-775	Lower
1N/5W-29Q3		660	640-660	Lower
1N/5W-29Q4		550	530-550	Middle
1N/5W-29Q5		320	300-320	Middle
1N/5W-34D1	1,460	990	970-990	Consolidated deposits
1N/5W-34D2		780	760-780	Lower
1N/5W-34D3		610	590-610	Middle
1N/5W-34D4		492	472-492	Middle
1N/5W-35B1	1,405	935	910-930	Lower
1N/5W-35B2		815	790-810	Lower
1N/5W-35B3		690	650-670	Middle
1N/5/W-35B4		395	370-390	Middle
1S/5W-11F1	1,244	950	930-950	Consolidated deposits
1S/5W-11F2		714	694-714	Lower
1S/5W-11F3		442	422-442	Middle
1S/5W-11F4		330	310-330	Middle
1S/4W-8E1	1,110	995	970-990	Consolidated deposits
1S/4W-8E2		775	750-770	Lower
1S/4W-8E3		602	577-597	Lower
1S/4W-8E4		340	310-330	Middle
1S/4W-20H1	990	958	918-938	Consolidated deposits
1S/4W-20H2		638	598-618	Lower
1S/4W-20H3		530	490-510	Middle
1S/4W-20H4		310	270-290	Upper
1S/4W-20H5		190	150-170	River-channel deposits

Table 1. Well-construction data, Rialto-Colton basin, San Bernardino County, California—Continued

State well No.	Altitude of land surface	Well depth	Perforated interval	Water-bearing unit perforated
Other observation well				
1N/5W-29P2	1,540	348	300-348	Middle
Production wells				
1N/5W-17G1	1,865	204	54-204	Middle
1N/5W-17K1	1,851	325	80-120, 176-208, 212-224	Middle
1N/5W-17K2	1,860	300	61-220	Middle
1N/5W-19A1	1,812	167	--	--
1N/5W-20N1	1,665	455	150-428	Middle
1N/5W-27D1	1,535	960	650-865, 890-958	Middle, lower
1N/5W-28J1	1,508	741	440-495, 530-555, 608-623, 690-709, 720-730, 750-773	Middle, lower
1N/5W-30L1	1,577	1,200	321-624	Middle, lower
1N/5W-31A1	1,525	460	330-380	Middle
1N/5W-32A1	1,497	1,010	--	--
1N/5W-34B1	1,453	807	--	--
1N/5W-34B2	1,445	1,022	588-750, 780-818, 850-870, 965-1,000	Lower, consolidated deposits
1N/5W-34M1	1,417	887	525-860	Middle, lower
1S/5W-2C1	1,340	907	384-420, 588-594, 609-614, 630-662, 696-720, 750-774, 832-844, 850-888	Middle, lower
1S/5W-2E1	1,312	1,010	430-840	Middle, lower
1S/5W-2G1	1,305	1,000	440-830, 930-970	Middle, lower, consolidated deposits
1S/5W-2K1	1,289	828	310-787	Middle, lower, consolidated deposits
1S/5W-3A1	1,350	890	355-425, 432-545, 554-564, 572-577, 600-637, 644-652, 664-688, 716-722, 726-758, 804-878	Middle, lower
1S/5W-3A2	1,360	970	460-950	Middle, lower
1S/5W-3N2	1,301	540	300-540	Middle, lower
1S/5W-4D2	1,397	553	366-380, 402-445, 530-533	Middle
1S/5W-5A2	1,406	543	--	--
1S/5W-5A3	1,407	842	240-525, 620-842	Middle, lower
1S/5W-12L1	1,175	590	292-388, 390-464	Middle
1S/5W-12N1	1,173	688	183-187, 195-200, 211-220, 228-237, 258-270, 280-409, 447-450, 520-524, 539-549, 600-613, 623-630	Middle, lower
1S/4W-17R1	1,014.52	209	188-209	Middle
1S/4W-18B1	1,121	600	201-216, 267-326	Upper, middle
1S/4W-18F1	1,098	903	194-778	Middle, lower, consolidated deposits
1S/4W-18G1	1,097	556	244-344, 356-436, 500-514, 522-534	Middle, lower
1S/4W-18M1	1,103	706	250-310, 344-434, 534-634	Middle, lower
1S/4W-21J1	962	150	--	River-channel deposits
1S/4W-21K1	975.78	1,020	200-260, 280-930	Upper, middle, lower, consolidated deposits
1S/4W-21K11	963	--	--	--
1S/4W-21L1	956	432	101-125,126-145, 167-194, 227-242, 264-270, 372-409	River-channel deposits, upper, middle
1S/4W-21L3	958	245	165-240	Upper
1S/4W-21N1	963	689	96-180, 283-312, 337-360, 416-435, 437-457, 530-542, 552-602, 620-635, 645-670	River-channel deposits, upper, middle, lower
1S/4W-27L1	992	420	165-280	Upper
1S/4W-27M1	1,000	1,014	160-850	Upper, middle, lower, consolidated deposits
1S/4W-28K2	947	186	18-114, 164-170	River-channel deposits, upper

Table 2. Chemical analyses of samples from cluster wells, selected production wells, a spring, and surface-water sites, Rialto-

[Constituents are in milligrams per liter except where noted. Specific conductance, pH, and alkalinity: L, laboratory values. °C, degrees
Perforated interval: depths of topmost and bottommost perforations, in feet below land surface datum. Water-bearing unit perforated:

State well No.	Date of sample	Well depth	Perforated interval	Water-bearing unit perforated	Specific conductance (µS/cm)	pH (Standard units)	Temperature, water (°C)	Calcium	Magnesium
				Cluster sites					
1N/5W-21K1	03-10-92	1,000	960-980	4	273	7.8	19.5	17	1.3
	10-24-92				258	8.3	20.0	14	1.4
	06-30-93				251	8.2	20.0	16	1.6
1N/5W-21K2	03-10-92	780	740-770	4	303	7.7	20.0	34	3.2
	10-25-92				343	7.3	20.0	24	3.3
	07-01-93				323	7.4	20.5	26	2.8
1N/5W-21K3	03-11-92	475	435-455	3	474	7.9	20.0	23	9.1
	10-23-92				442	7.7	19.0	36	11
	02-16-93				412	7.5	17.0	53	9.3
	06-30-93				392	7.7	18.5	53	9.1
	03-16-94				366	7.9	19.0	43	7.8
1N/5W-21K4	02-16-93	600	575-595	3	308	7.8	18.0	41	7.1
	07-01-93				312	7.9	20.0	41	6.9
	03-16-94				313	8.0	21.0	34	7.2
1N/5W-22N1	03-03-92	1,000	960-980	4	210	9.1	17.5	3.2	.35
	06-30-92				177	8.9	20.0	4.1	.22
	11-12-92				186	8.9	19.0	5.8	.37
	02-05-93				190	8.7	17.5	6.8	.27
	06-29-93				203	8.6	22.0	6.8	.23
	10-09-93				187	8.4	20.0	6.7	.25
1N/5W-22N2	02-28-92	760	720-740	4	310	7.8	19.0	29	4.2
	11-12-92				378	7.7	19.0	24	3.6
	02-04-93				323	7.7	18.0	23	3.9
	06-29-93				340	7.8	18.5	29	3.8
	10-08-93				300	7.6	19.5	30	4.0
1N/5W-22N3	06-26-92	455	415-435	3	302	8.0	20.5	33	5.4
	11-11-92				572	7.8	19.0	10	3.2
	02-04-93				342	7.6	18.0	29	4.6
	06-30-93				318	7.7	19.0	37	5.4
	10-15-93				310	7.7	17.5	24	4.1
1N/5W-22N4	01-27-93	600	575-595	3	395	7.6(L)	21.0	45	13
	06-30-93				327	7.6	20.0	33	9.1
	10-07-93				326	7.6	17.0	27	8.1
1N/5W-22N5	01-27-93	380	340-360	3	653	7.5(L)	19.5	24	7.6
	06-30-93				617(L)	7.5	18.5	63	11
	10-08-93				607	7.3	16.5	69	12
1N/5W-26L1	09-01-93	358	322-352	3	608	7.7	19.5	72	11
	03-16-94				580	7.7	22.5	65	9.6
1N/5W-27D2	09-01-93	478	450-470	3	601	7.7	22.0	72	12
	06-10-94				582	7.6	20.0	75	13
1N/5W-28J2	11-04-94	455	430-450	3	455	8.4	20.0	61	8.4
1N/5W-29Q1	05-06-94	995	975-995	5	371	8.0	20.0	47	7.8
	11-01-94				379	7.9	20.5	49	8.2
1N/5W-29Q2	06-22-94	775	755-775	4	327	8.0	21.0	41	4.9
	11-01-94				352	7.6	20.0	34	4.5
1N/5W-29Q3	06-23-94	660	640-660	4	349	8.0	20.5	35	4.7
	11-02-94				398	7.7	17.0	21	3.7
1N/5W-29Q4	06-24-94	550	530-550	3	406	7.8	20.5	6.6	3.8

Celsius; µS/cm, microsiemens per centimeter (at 25 degrees Celsius; µg/L, microgram per liter. <, less than value shown; --, no data. 1, river-channel deposits; 2, upper; 3, middle; 4, lower; 5, consolidated deposits. Location of wells shown in figure 5]

Sodium	Potassim	Alkalinity as $CaCO_3$	Sulfate	Chloride	Fluoride	Silica	Solids, sum of constituents	Nitrite plus nitrate as N	Boron (µg/L)	Iron (µg/L)	Manganese (µg/L)
Cluster sites—Continued											
43	2.6	110	19	5.3	0.4	20	182	0.40	20	21	<1
37	2.7	106	16	3.3	.2	21	162	.36	30	7	<1
37	2.5	122	15	3.0	.3	21	171	.35	20	8	<1
31	1.9	130	18	4.4	.2	27	210	.37	10	110	28
43	2.0	136	21	3.8	.1	27	234	.52	10	72	96
38	2.1	140	16	3.2	.8	29	202	--	20	93	39
64	5.9	160	28	26	.4	23	296	3.7	90	<3	45
30	4.9	159	23	9.9	.3	25	256	4.6	60	4	6
14	2.9	157	18	5.8	.3	26	249	5.7	20	4	<1
11	2.8	167	23	4.6	.3	25	252	5.2	20	<3	4
11	2.4	140	23	5.1	.3	26	223	3.5	20	<3	<1
11	1.6	138	13	2.9	.3	27	189	.53	20	10	5
11	1.7	141	13	2.6	.3	27	191	.55	10	<3	<1
20	1.6	139	14	2.8	.3	29	197	.97	20	7	<1
43	1.4	74	23	5.5	.5	15	140	.26	30	130	<1
35	1.0	65	19	2.9	.3	15	118	.25	20	21	<1
33	1.3	67	18	2.7	.4	15	118	.25	20	130	4
36	1.3	74	18	2.7	.3	18	131	.32	20	45	1
34	1.3	81	17	2.5	.2	16	129	.25	20	9	<1
35	0.9	73	18	2.5	.3	17	126	.23	10	10	<1
35	2.7	130	25	5.6	.3	25	213	.42	20	38	59
52	3.0	138	38	7.6	.3	25	255	.27	40	300	52
38	2.9	120	26	4.3	.2	29	217	.38	30	220	140
29	2.5	146	18	3.0	.2	26	203	.30	20	4	<1
28	2.0	130	18	2.5	.2	27	195	.29	10	9	4
19	1.9	137	16	3.2	.4	26	201	1.2	10	31	42
100	3.1	151	43	30	.3	28	353	1.6	30	670	160
39	2.2	136	20	7.6	.3	27	238	2.6	20	43	19
19	2.3	138	14	4.0	.3	25	202	1.6	20	20	19
37	1.1	127(L)	20	4.1	.3	28	[1]172	1.5	10	73	61
66	4.7	152(L)	31	14	.3	28	320	.38	60	--	--
21	2.1	136	17	2.9	.3	26	197	.34	20	22	9
31	1.7	151	19	2.8	.3	28	219	.35	20	130	43
120	4.8	95(L)	88	110	.2	14	432	.52	290	1,900	210
32	3.8	109	47	96	.3	20	347	1.2	90	9	61
15	2.6	103	49	92	.3	21	345	1.9	80	20	24
21	2.9	104	41	80	.3	21	327	3.3	10	<3	6
15	2.5	106(L)	42	66	.3	21	321	6.6	20	4	<1
16	2.8	107	35	75	.2	24	308	1.3	20	3	11
13	2.6	99	49	82	.2	24	328	1.9	10	<3	<1
17	3.1	167	16	18	.3	23	283	6.9	30	7	43
19	1.8	169(L)	16	6.9	.3	35	[1]230	1.1	20	6	18
15	1.9	155	15	6.8	.3	34	228	1.1	<10	<3	1
18	2.2	133	17	4.3	.3	26	205	1.7	30	9	50
32	2.4	145(L)	18	4.0	.3	27	214	1.4	20	8	74
32	2.5	135	25	4.6	.3	27	[1]240	2.7	30	30	36
59	2.7	150	29	4.7	.2	28	[1]254	2.6	<10	39	74
94	2.7	208	29	4.5	.5	28	322	2.5	70	1,300	280

Table 2. *Chemical analyses of samples from cluster wells, selected production wells, a spring, and surface-water sites, Rialto-*

State well No.	Date of sample	Well depth	Perforated interval	Water-bearing unit perforated	Specific conductance (µS/cm)	pH (Standard units)	Temperature, water (°C)	Calcium	Magnesium
				Cluster sites—Continued					
1N/5W-29Q4	11-03-94				382	7.6	20.0	15	3.3
1N/5W-34D1	03-05-93	990	970-990	5	368	7.6	19.0	43	11
	07-02-93				384	7.5	20.5	41	11
	03-15-94				370	7.7	21.0	41	11
	10-28-94				367	7.7	20.5	42	11
1N/5W-34D2	08-27-92	780	760-780	4	298	7.7	20.5	23	8.9
	07-02-93				324	8.0	19.5	44	5.5
	03-14-94				294	7.9	20.0	35	8.5
	10-27-94				328	8.0	20.5	46	6.0
1N/5W-34D3	08-27-92	610	590-610	3	323	7.9	19.0	41	11
	03-04-93				340	7.8	19.0	39	5.2
	07-02-93				306	8.1	20.0	30	8.0
	03-14-94				314	8.0	20.5	46	5.4
	10-27-94				316	8.2	24.0	46	5.7
1N/5W-34D4	08-28-92	492	472-492	3	339	7.9	19.0	46	5.8
	03-04-93				339	7.7	19.5	49	5.5
	07-02-93				334	7.9	20.5	49	5.6
	03-15-94				334	7.9	18.0	50	5.6
	10-26-94				337	8.0	21.0	50	5.8
1N/5W-35B1	12-21-92	935	910-930	4	215	9.6	19.0	.74	.11
	06-16-93				201	9.6	23.0	1.1	.11
	04-01-94				203	9.8	20.0	1.3	.12
1N/5W-35B2	12-22-92	815	790-810	4	221	9.4	20.5	1.5	.35
	06-16-93				197	9.5	23.0	1.3	.011
	04-02-94				188	9.8	18.0	1.4	.08
1N/5W-35B3	12-20-92	690	650-670	3	248	8.0	18.5	11	.99
	06-17-93				229	8.1	22.5	15	.78
	04-01-94				223	8.2	19.5	17	.76
1N/5W-35B4	12-21-92	395	370-390	3	352	7.4	17.0	22	3.8
	06-28-93				376	7.6	19.5	26	4.1
	04-01-94				318	8.0	19.5	46	4.3
1S/5W-11F1	08-25-92	950	930-950	5	422	9.3	21.5	2.5	.55
	02-06-93				484	8.8	20.0	3.7	.65
	11-06-93				417	8.9	23.5	3.0	.45
1S/5W-11F2	08-26-92	714	694-714	4	378	7.8	--	19	3.2
	02-07-93				375	7.8	20.0	21	3.3
	11-05-93				339	7.7	21.5	27	4.0
1S/5W-11F3	08-25-92	442	422-442	3	306	7.7	--	37	6.6
	01-26-93				297	7.8(L)	24.0	40	6.8
	11-10-93				292	7.8	20.0	41	7.1
1S/5W-11F4	08-24-92	330	310-330	3	321	7.7	--	27	5.9
	02-07-93				316	7.6	19.0	35	6.5
	10-19-93				304	7.8	21.0	40	7.5
1S/4W-8E1	12-09-92	995	970-990	5	570	8.5	23.5	5.8	.57
	06-23-93				545	8.7	25.0	6.5	.45
	04-03-94				535	8.7	22.0	6.4	.37
1S/4W-8E2	12-09-92	775	750-770	4	365	8.6	22.5	3.0	.58
	06-23-93				329	8.7	25.5	3.5	.41
	04-03-94				315	8.8	21.5	3.5	.38

See footnotes at end of table.

Sodium	Potassim	Alkalinity as $CaCO_3$	Sulfate	Chloride	Fluoride	Silica	Solids, sum of constit-uents	Nitrite plus nitrate as N	Boron (µg/L)	Iron (µg/L)	Manganese (µg/L)
					Cluster sites—Continued						
64	2.7	140	26	3.8	0.3	26	251	2.6	10	31	99
19	1.7	152	15	7.5	.3	32	227	1.4	20	150	16
17	1.5	160	15	6.1	.4	32	226	1.4	10	<3	<1
16	1.5	162	15	6.1	.4	32	220	--	20	<3	<1
17	1.4	156	15	6.3	.4	33	226	1.3	<10	20	<1
28	1.9	133(L)	17	5.7	.4	28	[1]184	.75	<10	54	70
11	2.4	141	17	2.9	.3	22	194	.60	20	<3	24
14	2.3	136	13	3.7	.3	28	197	.85	20	19	2
12	2.5	132	14	4.5	.3	25	199	1.0	20	<3	8
18	1.8	142	18	7.4	.4	32	221	1.4	<10	6	9
26	2.8	126	18	3.2	.3	24	211	.56	20	420	53
20	2.5	130	14	3.7	.3	28	199	.77	20	8	9
10	2.4	147	16	2.5	.4	23	200	.60	20	<3	<1
10	2.5	135	17	2.7	.3	23	193	.52	20	<3	2
15	2.2	154	16	6.0	.4	23	215	1.2	<10	19	47
12	2.4	166	12	4.7	.3	23	216	1.2	20	59	13
11	2.4	155	12	4.5	.3	22	206	1.2	20	<3	2
9.7	2.2	137	12	4.2	.4	23	196	1.4	10	<3	<1
10	2.3	144	13	4.4	.4	23	202	1.3	20	6	7
43	0.70	60(L)	32	5.2	1	16	136	<.05	40	120	6
42	.50	64	28	3.0	1	18	135	.24	50	62	3
41	.50	74	26	3.3	1.1	19	138	.055	40	17	1
46	1.3	61(L)	31	5.1	.9	16	127	.098	60	370	28
43	.80	63(L)	26	3.6	.8	17	[1]118	.086	50	56	3
37	.50	62	24	3.4	.9	18	124	.10	40	36	<1
41	1.8	98(L)	22	3.3	.5	19	[1]144	.28	30	110	36
34	1.5	103	17	2.1	.7	20	154	<.05	30	10	2
30	1.5	95	17	2.3	.6	21	149	.26	20	6	<1
54	2.6	143(L)	24	3.1	.2	23	[1]240	1.3	10	360	59
43	2.7	142	21	1.4	.2	25	209	--	10	72	39
14	2.1	145	19	3.4	.3	25	207	1.0	20	7	<1
89	1.7	130	40	27	1.3	19	280	<.05	4,600	160	45
99	1.8	137	48	33	6	20	318	.076	3,600	130	28
83	1.2	132	33	17	11	18	256	<.05	2,700	260	5
59	3.3	154(L)	23	9.3	.3	22	[1]231	.93	50	30	58
57	3.4	160(L)	20	8.1	.1	27	[1]223	.88	60	16	17
46	3.1	155(L)	15	6.2	.2	24	[1]216	.97	30	5	1
20	2.0	134	7.7	5.5	.3	28	188	--	20	7	48
13	1.3	138(L)	8.5	5.0	.3	27	191	1.2	10	84	15
13	1.3	139(L)	8.6	4.3	.3	28	[1]192	1.3	20	4	<1
39	2.1	156	9.8	6.1	.4	31	229	1.1	<10	190	75
22	1.6	149	9.6	5.1	.3	33	218	1.3	20	31	13
15	1.1	134	9.0	4.5	.3	32	190	--	20	4	1
130	2.1	220	9.4	33	4.6	19	341	.052	890	92	17
130	1.7	285	6.0	31	4.9	19	374	<.05	930	43	11
120	1.2	209	2.9	31	4.9	20	314	<.05	880	46	10
83	2.1	152	17	9.1	2.1	19	237	.079	150	340	28
76	1.6	164	6.2	5.9	2.0	19	219	<.05	130	52	9
69	1.4	152	4.2	5.2	2.1	20	201	<.05	120	120	10

Table 2. Chemical analyses of samples from cluster wells, selected production wells, a spring, and surface-water sites, Rialto-

State well No.	Date of sample	Well depth	Perforated interval	Water-bearing unit perforated	Specific conductance (μS/cm)	pH (Standard units)	Temperature, water (°C)	Calcium	Magnesium
				Cluster sites—Continued					
1S/4W-8E3	12-09-92	602	577-597	4	446	8.1	22.5	6.0	0.94
	06-24-93				398	8.2	25.0	3.6	.71
	04-03-94				431	8.2	20.5	6.9	.70
1S/4W-8E4	12-09-92	340	310-330	3	433	7.2	22.0	26	4.2
	06-24-93				369	7.5	23.0	41	5.6
	04-03-94				390	7.7	19.0	40	5.2
1S/4W-20H1	06-08-93	958	918-938	5	884	8.7	24.0	3.6	.50
	04-02-94				755	8.7	21.5	3.3	.25
1S/4W-20H2	06-10-93	638	598-618	4	311	8.5	23.0	3.0	.97
	04-02-94				256	8.8	21.5	2.3	.26
1S/4W-20H3	06-10-93	530	490-510	3	420	7.6	22.5	46	5.4
	04-02-94				396	7.8	20.0	54	5.4
1S/4W-20H4	06-10-93	310	270-290	2	1,010	7.2	23.0	84	14
	04-02-94				918	7.2	20.5	110	17
1S/4W-20H5	06-09-93	190	150-170	1	1,040	7.3	22.0	100	18
	04-02-94				1,130	7.3	20.0	140	23
				Production wells					
1N/5W-17K2	07-14-92	300	61-220	3	318	7.6	17.0	48	7.5
	07-18-95				298	7.7	16.5	41	6.5
1N/5W-23P4[2]	07-01-92	647	200-630	--	346	8.1	17.0	53	6.9
1N/5W-26A3[2]	12-01-94	407	--	--	298	7.9	20.5	43	7.0
1N/5W-27D1	02-04-93	960	650-865, 890-958	3, 4	369	7.8	21.0	55	5.7
	03-16-94				352	7.8	20.0	50	6.1
	10-11-94				372	7.9	--	53	6.1
1N/5W-31A1	07-15-92	460	330-380	3	415	7.7	19.5	63	8.1
1N/5W-32A1	07-15-92	1,010	--	--	333	8.0	20.0	49	6.0
1N/5W-34B2	03-04-92	1,022	588-750, 780-818, 850-870, 965-1,000	4, 5	330	7.7	19.0	46	9.1
	10-11-94				366	7.8	--	49	7.5
1N/5W-34M1	10-11-94	887	525-860	3, 4	320	8.0	--	45	5.6
1S/5W-2G1	03-23-92	1,000	440-830, 930-970	3, 4, 5	300	7.9	19.0	43	6.6
1S/5W-3A2	12-01-94	970	460-950	3, 4	318	7.7	21.0	42	7.2
1S/5W-3N2[3]	06-24-92	552	312-552	3, 4	378	7.9	21.5	54	7.6
1S/5W-5A3	07-15-92	842	240-525, 620-842	3, 4	393	7.9	19.5	61	7.4
1S/5W-10H2[3]	06-24-92	818	440-750	3, 4 ,5	469	8.0	22.0	69	6.6
1S/5W-12L1	07-01-92	590	292-464	3	319	8.0	19.5	48	5.5
1S/4W-8F134	06-29-92	932	457-550, 647-690, 747-762, 844-911	--	339	7.8	20.0	66	12

See footnotes at end of table.

Sodium	Potassim	Alkalinity as $CaCO_3$	Sulfate	Chloride	Fluoride	Silica	Solids, sum of constit-uents	Nitrite plus nitrate as N	Boron (µg/L)	Iron (µg/L)	Manganese (µg/L)
					Cluster sites—Continued						
100	2.2	182	13	16	2.4	19	293	0.06	290	260	44
86	1.7	174	4.7	14	2.2	19	244	<.05	280	440	54
91	1.6	193	10	14	1.6	21	271	<.05	270	52	40
63	3.4	178	29	6.8	.3	27	295	2.4	40	160	52
33	3.1	159(L)	23	4.0	.3	25	279	2.5	20	44	58
37	3.1	160	23	3.8	.3	28	265	2.5	20	36	30
160	1.6	167(L)	31	120	4.4	16	[1]440	<.05	830	36	5
150	.4	170	21	110	4.7	16	409	.077	790	28	3
64	1.9	107(L)	25	7.3	.8	14	[1]242	<.05	120	560	48
55	1.2	93	17	7.8	.9	13	156	<.05	100	10	1
30	3.4	155(L)	27	18	.3	24	[1]256	1.4	40	26	14
18	2.5	151	23	16	.3	25	241	1.3	40	<3	<1
91	5.5	244(L)	210	26	.4	28	[1]626	3.0	310	51	29
64	4.9	236	200	25	.5	27	607	3.0	330	<3	1
70	5.7	245(L)	190	45	.6	25	[1]622	3.7	330	9	6
68	5.6	261	240	55	.6	27	740	5.2	340	<3	5
					Production wells—Continued						
9.8	2.3	142	23	2.4	.4	--	185	1.4	20	<3	<1
8.0	2.1	154	18	2.7	.4	18	[1]176	.75	20	<3	<1
10	1.8	149	24	3.2	.4	20	214	1.1	10	<3	<1
8.7	1.6	128	16	2.2	.4	21	181	1.0	10	<3	<1
11	2.2	144	11	12	.2	26	227	3.8	10	<3	<1
11	2.1	144(L)	16	8.3	.3	25	206	2.1	20	5	<1
11	2.3	147(L)	15	10	.3	25	[1]228	2.9	20	4	<1
12	2.0	153	31	5.8	.3	19	265	7.2	20	10	3
12	1.6	136	20	4.4	.3	24	206	1.6	10	3	<1
12	<.10	148(L)	14	6.4	.40	25	[1]199	2.4	10	<3	<1
11	2.0	153(L)	13	6.2	.3	26	207	3.4	10	<3	<1
10	1.9	133	13	4.7	.3	23	190	1.5	10	3	<1
10	1.8	135(L)	16	4.5	.3	23	189	.56	10	4	1
12	1.9	134	13	4.9	.3	25	193	1.4	20	<3	<1
14	1.5	146	19	7.3	.2	25	242	5.7	10	3	<1
11	2.2	168	25	5.2	.3	23	256	4.5	10	<3	<1
22	2.2	164	32	11	.3	24	286	4.6	40	4	<1
11	1.7	140	20	3.5	.3	23	204	1.4	10	<3	<1
12	2.8	185	42	4.5	.3	21	276	.74	10	11	7

Table 2. Chemical analyses of samples from cluster wells, selected production wells, a spring, and surface-water sites, Rialto-

State well No.	Date of sample	Well depth	Perforated interval	Water-bearing unit perforated	Specific conductance (µS/cm)	pH (Standard units)	Temperature, water (°C)	Calcium	Magnesium
Production wells—Continued									
1S/4W-18G1	06-29-92	556	244-344, 356-436, 500-514, 522-534	3, 4	422	7.9	20.5	59	9.9
1S/4W-21K1	06-29-92	1,020	200-260, 280-930	2, 3, 4, 5	776	7.8	21.5	79	13
Observation well and other cluster site									
1N/5W-29P2	03-04-94	348	300-348	3	503	7.6	--	74	11
1S/4W-22D2[4]	04-19-95	157	--	2	1,080	7.6	21.0	170	20
1S/4W-22D4[4]	04-03-95	574	555-574	3	478	8.2	23.5	31	2.2
1S/4W-22D5[4]	04-07-95	655	350-655	3	1,120	8.0	21.0	120	9.7
Spring									
1N/6W-12FS1	08-23-95	--	--	--	534	7.9	--	63	20
Surface-water sites									
Lytle Creek near Fontana (11062001)	10-06-93	--	--	--	325	8.4	--	52	7.5
Santa Ana River at E street (11059300)	10-06-93	--	--	--	843	7.7	--	65	12
Imported water at Linden Ponds	10-24-92	--	--	--	743	8.0	19.5	25	17
	02-04-93	--	--	--	570	7.8	16.5	21	12
	06-29-93	--	--	--	610	7.8	20.0	25	14

[1] Residue on evaporation at 180 °C.

[2] Well located in Lytle basin.

[3] Well located in Chino basin.

[4] Well located in Bunker Hill basin.

Sodium	Potassim	Alkalinity as $CaCO_3$	Sulfate	Chloride	Fluoride	Silica	Solids, sum of constit-uents	Nitrite plus nitrate as N	Boron (µg/L)	Iron (µg/L)	Manganese (µg/L)
Production wells—Continued											
15	2.1	152	33	6.4	0.3	27	270	5.9	20	<3	<1
70	3.4	226	110	49	.7	23	487	.64	160	14	9
Observation well and other cluster site—Continued											
14	3.6	207(L)	20	17	.2	25	[1]296	3.1	30	1,000	98
47	3.3	260	290	27	.5	21	[1]760	<.05	280	1,200	160
64	1.9	130	17	51	3.2	20	[1]281	<.05	940	300	15
110	9.3	130	350	73	.3	9.3	[1]796	<.05	300	940	96
Spring—Continued											
16	3.2	155(L)	110	8.5	0.2	28	[1]330	0.35	20	<3	4
Surface-water sites—Continued											
6.7	2.5	144(L)	21	1.3	.3	14	[1]1863	0.27	<10	<3	<1
77	4.8	178	73	81	.9	28	483	5.2	350	25	10
92	3.7	78	85	120	<.1	14	407	.57	280	13	1
72	3.3	61	72	92	.1	15	327	.58	230	20	3
58	3.5	95	69	71	.1	16	319	.96	260	14	2

Table 3. Summary of isotopes in samples from cluster wells, selected production wells, a spring, and surface-water sites, Rialto-Colton basin, San Bernardino County, California

[Water-bearing unit perforated: 1, river-channel deposits; 2, upper; 3, middle; 4, lower; 5, consolidated deposits. Location of wells and sites shown in figure 5. <, actual value less than value shown; --, no data]

State well No.	Date of sample	Water-bearing unit perforated	Delta deuterium (permil)	Delta oxygen-18 (permil)	Tritium, total (tritium units)	Carbon 13/12 (ratio permil)	Carbon-14 (percent modern carbon)	Uncorrected carbon-14 age (years before present)
				Cluster sites				
1N/5W-21K1	03-10-92	4	-60.5	-9.15	<0.1	--	--	--
	10-24-92		-60.0	-9.20	--	--	--	--
	06-30-93		-61.0	-9.29	--	--	--	--
1N/5W-21K2	03-10-92	4	-59.5	-9.20	.1	--	--	--
	10-25-92		-60.5	-9.25	--	--	--	--
	07-01-93		-58.9	-9.31	--	--	--	--
1N/5W-21K3	03-11-92	3	-55.5	-8.50	5.1	--	--	--
	10-23-92		-54.5	-8.55	--	--	--	--
	02-16-93		-53.5	-8.13	--	--	--	--
	06-30-93		-53.3	-8.40	--	--	--	--
	03-16-94		-56.6	-8.76	--	--	--	--
1N/5W-21K4	02-16-93	3	-62.0	-9.46	--	--	--	--
	07-01-93		-62.5	-9.50	--	--	--	--
	03-16-94		-60.5	-9.20	--	--	--	--
1N/5W-22N1	03-03-92	4	-63.0	-9.65	<.1	--	--	--
	06-30-92		-63.5	-9.60	--	--	--	--
	11-12-92		-62.4	-9.63	<.1	--	--	--
	02-05-93		-62.4	-9.81	--	--	--	--
	06-29-93		-63.4	-9.82	--	--	--	--
	10-09-93		-63.9	-9.67	--	-13.70	64.2	3,663
1N/5W-22N2	02-28-92	4	-63.0	-9.65	.4	--	--	--
	11-12-92		-63.3	-9.62	.1	--	--	--
	02-04-93		-64.3	-9.71	--	--	--	--
	06-29-93		-63.8	-9.79	--	--	--	--
	10-08-93		-64.3	-9.81	--	-12.00	81.3	1,771
1N/5W-22N3	06-26-92	3	-61.0	-9.20	.3	--	--	--
	11-11-92		-61.6	-9.10	.6	--	--	--
	02-04-93		-60.3	-9.09	--	--	--	--
	06-30-93		-60.5	-9.25	--	--	--	--
	10-15-93		-60.8	-9.24	.5	-12.00	83.5	1,490
1N/5W-22N4	01-27-93	3	-62.3	-9.66	.4	--	--	--
	06-30-93		-64.8	-9.76	--	--	--	--
	10-07-93		-64.7	-9.72	--	-12.40	82.3	1,610
1N/5W-22N5	01-27-93	3	-63.8	-8.57	4.8	--	--	--
	06-30-93		-68.4	-9.27	--	--	--	--
	10-08-93		-66.1	-9.05	7.0	-11.3	--	--
1N/5W-26L1	09-01-93	3	-67.3	-9.26	7.0	--	--	--
	03-16-94		-66.5	-9.11	--	--	--	--
1N/5W-27D2	09-01-93	3	-65.3	-9.17	6.1	--	--	--
	06-10-94		-65.8	-8.82	--	--	--	--
1N/5W-28J2	11-04-94	3	-52.5	-7.99	--	--	--	--
1N/5W-29Q1	05-06-94	5	-44.9	-7.31	--	--	--	--
	11-01-94		-45.8	-7.23	--	-12.90	85.97	1,246
1N/5W-29Q2	06-22-94	4	-54.0	-8.30	--	--	--	--
	11-01-94		-54.1	-8.41	--	-12.90	80.55	1,782

Table 3. Summary of isotopes in samples from cluster wells, selected production wells, a spring, and surface-water sites, Rialto-Colton basin, San Bernardino County, California—Continued

State well No.	Date of sample	Water-bearing unit perforated	Delta deuterium (permil)	Delta oxygen-18 (permil)	Tritium, total (tritium units)	Carbon 13/12 (ratio permil)	Carbon-14 (percent modern carbon)	Uncorrected carbon-14 age (years before present)
			Cluster sites—Continued					
1N/5W-29Q3	06-23-94	4	-57.5	-8.83	--	--	--	--
	11-02-94		-58.2	-8.81	--	-12.30	81.33	1,711
1N/5W-29Q4	06-24-94	3	-58.7	-9.02	--	--	--	--
	11-03-94		-59.6	-9.06	--	-11.90	82.01	1,540
1N/5W-34D1	03-05-93	5	-45.9	-7.51	--	--	--	--
	07-02-93		-46.3	-7.58	--	-12.5	83.0	1,540
	03-15-94		-46.1	-7.44	--	--	--	--
	10-28-94		-47.2	-7.38	--	--	--	--
1N/5W-34D2	08-27-92	4	-53.5	-8.40	--	--	--	--
	03-05-93		-56.5	-8.81	--	--	--	--
	07-02-93		--	--	--	-13.0	79.9	1,854
	03-14-94		-52.8	-8.26	--	--	--	--
	10-27-94		-56.7	-8.59	--	--	--	--
1N/5W-34D3	03-04-93	3	-63.4	-9.58	--	--	--	-
	07-02-93		--	--	--	-11.3	84.0	1,441
	03-14-94		-61.8	-9.45	--	--	--	--
	10-27-94		-62.9	-9.43	--	--	--	--
1N/5W-34D4	08-28-92	3	-56.5	-8.85	<0.1	--	--	--
	07-02-93		-57.4	-8.70	--	-11.8	78.6	1,990
	03-15-94		-55.8	-8.63	--	--	--	--
	10-26-94		-56.1	-8.62	--	--	--	--
1N/5W-35B1	12-21-92	4	-67.5	-9.93	--	--	--	--
	06-16-93		-65.9	-9.90	--	--	--	--
	04-01-94		-66.6	-9.80	--	-16.5	11.6	17,807
1N/5W-35B2	12-22-92	4	-64.4	-9.84	--	--	--	--
	06-16-93		-66.2	-9.94	--	--	--	--
	04-02-94		-66.3	-9.87	<.1	-15.5	12.1	17,458
1N/5W-35B3	12-20-92	3	-64.1	-9.86	--	--	--	--
	06-17-93		-66.0	-9.83	--	--	--	--
	04-01-94		-66.5	-9.80	<.01	-13.7	66.8	3,335
1N/5W-35B4	12-21-92	3	-66.2	-9.96	--	--	--	--
	06-28-93		-65.3	-10.04	1.2	--	--	--
	04-01-94		-65.4	-9.87	--	-11.0	82.9	1,550
1S/5W-11F1	08-25-92	5	-60.5	-9.25	--	-	--	--
	02-06-93		-60.2	-9.21	--		--	--
	11-06-93		-60.8	-9.27	.5	-12.7	24.5	11,627
1S/5W-11F2	08-26-92	4	-48.0	-7.65	--	--	--	--
	02-07-93		-49.2	-7.69	--	--	--	--
	11-05-93		--	--	<.1	-13.90	67.6	3,236
1S/5W-11F3	08-25-92	3	-51.0	-7.90	--	--	--	--
	01-26-93		-50.6	-7.97	--	--	--	--
	11-10-93		-49.6	-7.87	<.1	-13.60	79.9	1,854
1S/5W-11F4	08-24-92	3	-51.0	-8.05	.1	--	--	--
	02-07-93		-51.2	-7.96	--	--	--	--
	10-19-93		-50.1	-7.98	<.1	-13.80	74.0	2,489
1S/4W-8E1	12-09-92	5	-66.5	-9.84	--	--	--	--
	06-23-93		-66.8	-9.88	--	--	--	--
	04-03-94		-65.3	-9.74	--	-11.4	2.3	31,184

Table 3. Summary of isotopes in samples from cluster wells, selected production wells, a spring, and surface-water sites, Rialto-Colton basin, San Bernardino County, California—Continued

State well No.	Date of sample	Water-bearing unit perforated	Delta deuterium (permil)	Delta oxygen-18 (permil)	Tritium, total (tritium units)	Carbon 13/12 (ratio permil)	Carbon-14 (percent modern carbon)	Uncorrected carbon-14 age (years before present)
			Cluster sites—Continued					
1S/4W-8E2	12-09-92	4	-61.0	-9.51	--	--	--	--
	06-24-93		-62.8	-9.51	--	--	--	--
	04-03-94		-62.0	-9.47	--	-22.6	4.4	25,821
1S/4W-8E3	12-09-92	4	-61.7	-9.26	--	--	--	--
	06-24-93		-60.1	-9.30	--	--	--	--
	04-03-94		-61.8	-9.24	--	-18.3	8.9	19,998
1S/4W-8E4	12-09-92	3	-60.7	-9.34	--	--	--	--
	06-24-93		-61.9	-9.41	<0.01	--	--	--
	04-03-94		-62.4	-9.34	--	-12.3	80.1	1,834
1S/4W-20H1	06-08-93	5	-64.5	-9.18	--	--	--	--
	04-02-94		-65.8	-9.18	<.01	-13.0	.77	39,914
1S/4W-20H2	06-10-93	4	-62.2	-9.46	--	--	--	--
	04-02-94		-62.3	-9.42	<.01	-16.80	11.69	17,736
1S/4W-20H3	06-10-93	3	-60.3	-9.07	--	--	--	--
	04-02-94		-60.0	-9.03	<.01	-13.60	77.52	2,107
1S/4W-20H4	06-10-93	2	-52.0	-7.86	4.6	--	--	--
	04-02-94		-50.9	-7.75	--	--	--	--
1S/4W-20H5	06-09-93	1	-53.7	-8.13	5.9	--	--	--
	04-02-94		-54.3	-8.05	--	--	--	--
			Production wells					
1N/5W-17K2	07-14-92	3	-65.0	-10.00	--	--	--	--
	07-18-95		-62.4	-9.55	--	-12.70	99.21	66
1N/5W-23P4[1]	07-01-92	--	-67.5	-10.00	--	--	--	--
1N/5W-26A3[1]	12-01-94	--	-66.4	-10.07	--	--	--	--
1N/5W-27D1	02-04-93	3, 4	-54.9	-8.46	--	--	--	--
	03-16-94		-57.6	-8.87	--	--	--	--
	10-11-94		-56.8	-8.48	--	--	--	--
1N/5W-31A1	07-15-92	3	-51.0	-7.95	--	--	--	--
1N/5W-32A1	07-15-92	--	-52.5	-8.35	--	--	--	--
1N/5W-34B2	03-04-92	4, 5	-56.5	-8.75	0.7	--	--	--
	10-11-94		-56.0	-8.44	--	--	--	--

Table 3. Summary of isotopes in samples from cluster wells, selected production wells, a spring, and surface-water sites, Rialto-Colton basin, San Bernardino County, California—Continued

State well No.	Date of sample	Water-bearing unit perforated	Delta deuterium (permil)	Delta oxygen-18 (permil)	Tritium, total (tritium units)	Carbon 13/12 (ratio permil)	Carbon-14 (percent modern carbon)	Uncorrected carbon-14 age (years before present)
Production wells—Continued								
1N/5W-34M1	10-11-94	3, 4	-56.2	-8.64	--	--	--	--
1S/5W-2G1	03-23-92	3, 4, 5	-60.5	-9.25	--	--	--	--
1S/5W-3A2	12-01-94	3, 4	-53.8	-8.34	-	--	--	--
1S/5W-3N2[2]	06-24-92	3, 4	-59.5	-9.00	--	--	--	--
1S/5W-5A3	07-15-92	3, 4	-56.0	-8.65	--	--	--	--
1S/5W-10H2[2]	06-24-92	3, 4 ,5	-55.0	-8.65	0.5	--	--	--
1S/5W-12L1	07-01-92	3	-60.0	-9.05	<.1	--	--	--
1S/4W-8F13[3]	06-29-92	--	-60.5	-9.10	3.5	--	--	--
1S/4W-18G1	06-29-92	3, 4	-61.5	-9.20	.3	--	--	--
1S/4W-21K1	06-29-92	2, 3, 4, 5	-59.5	-8.80	2.7	--	--	--
Observation well and other cluster site								
1N/5W-29P2	03-04-94	3	-52.9	-8.17	2.5		--	--
1S/4W-22D2	04-19-95	2	-52.0	-7.97	2.1	-7.50	--	--
1S/4W-22D4	04-03-95	3	-62.0	-8.69	<.1	-5.40	46.9	6,259
1S/4W-22D5	04-07-95	3	-55.4	-8.29	4.3	-14.40	86.3	1,480
Spring								
1N/5W-12FS1	08-23-95	--	-49.5	-7.65	4.4	-9.50	77.39	2,128
Surface-water sites								
Lytle Creek near Fontana (11062001)	10-06-93	--	-72.5	-10.64	5.3	--	--	--
Santa Ana River at E Street (11059300)	10-06-93	--	-56.0	-8.45	5.0	--	--	--
Imported water at Linden ponds	10-24-92	--	-64.5	-8.10	5.4	--	--	--
	02-04-93	--	-63.5	-8.74	--	--	--	--
	06-29-93	--	-61.8	-8.54	--	--	--	--

Table 4. Estimated ungaged runoff, in acre-feet, in the San Gabriel Mountains and the Badlands, Rialto-Colton basin, San Bernardino County, California, 1945-95

Year	San Gabriel Mountains	Badlands	Year	San Gabriel Mountains	Badlands
1945	1,733	88	1971	940	32
1946	1,857	44	1972	756	2
1947	1,433	7	1973	1,626	125
1948	771	8	1974	1,267	31
1949	651	4	1975	866	26
1950	556	6	1976	866	41
1951	473	6	1977	825	38
1952	2,114	176	1978	7,192	370
1953	756	3	1979	2,862	295
1954	1,024	78	1980	6,622	728
1955	763	10	1981	954	40
1956	704	17	1982	2,174	143
1957	747	6	1983	5,900	519
1958	3,118	114	1984	1290	59
1959	943	5	1985	896	29
1960	590	3	1986	1,487	75
1961	444	19	1987	763	5
1962	1,073	29	1988	869	0
1963	667	4	1989	636	0
1964	496	4	1990	455	0
1965	1,877	170	1991	931	14
1966	2,339	280	1992	2,451	61
1967	2,523	65	1993	6,251	985
1968	974	26	1994	266	78
1969	8,039	716	1995	2,872	641
1970	1,193	56			

Table 5. Surface-water inflow to the Rialto-Colton basin, San Bernardino County, California, 1945-95

[Measured and estimated annual discharge for gaged streams. Values in acre-feet are accurate to no more than three significant figures; greater precision is shown for computation purposes only. Asterisk (*) indicates estimated values. Measured data from U.S. Geological Survey (J.A. Huff, written commun., 1992). --, no data; (), data available but are included in another measurement]

Station No.	Station name	1945	1946	1947	1948	1949	1950
11065801	Warm Creek near Colton (combined discharge)	62,630	57,250	47,280	42,800	37,150	31,440
11060400	Warm Creek near San Bernardino	--	--	--	--	--	--
11059300	Santa Ana River at E Street	*14,740	*14,503	*21,149	2,010	2,150	1,680
11066050	Santa Ana River at Colton	--	--	--	--	--	--
11065000	Lytle Creek at Colton	--	--	--	--	--	--
	Total inflow	77,370	71,753	68,429	44,810	39,300	33,120

Station No.	Station name	1951	1952	1953	1954	1955	1956
11065801	Warm Creek near Colton (combined discharge)	27,020	35,220	24,540	24,920	19,830	19,830
11060400	Warm Creek near San Bernardino	--	--	--	--	--	--
11059300	Santa Ana River at E Street	3,870	14,580	1,380	*54,963	*11,859	*13,598
11066050	Santa Ana River at Colton	--	--	--	--	--	--
11065000	Lytle Creek at Colton	--	--	--	--	--	--
	Total inflow	30,890	49,800	25,920	79,883	31,689	33,428

Station No.	Station name	1957	1958	1959	1960	1961	1962
11065801	Warm Creek near Colton (combined discharge)	19,350	25,230	16,060	14,090	14,560	--
11060400	Warm Creek near San Bernardino	--	--	--	--	--	--
11059300	Santa Ana River at E Street	*13,562	*27,160	*12,858	*14,021	*15,804	--
11066050	Santa Ana River at Colton	--	--	--	--	--	16,560
11065000	Lytle Creek at Colton	--	()	()	()	()	()
	Total inflow	32,912	52,390	28,918	28,111	30,364	16,560

Station No.	Station name	1963	1964	1965	1966	1967	1968
11065801	Warm Creek near Colton (combined discharge)	--	--	--	--	--	--
11060400	Warm Creek near San Bernardino	--	--	()	858	479	146
11059300	Santa Ana River at E Street	--	--	--	*49,742	14,060	11,910
11066050	Santa Ana River at Colton	15,780	15,100	55,340	--	--	--
11065000	Lytle Creek at Colton	()	()	()	6,870	2,240	477
	Total inflow	15,780	15,100	55,340	57,470	16,779	12,533

Station No.	Station name	1969	1970	1971	1972	1973	1974
11065801	Warm Creek near Colton (combined discharge)	--	--	--	--	--	--
11060400	Warm Creek near San Bernardino	3,950	844	944	*593	*14,268	*3,617
11059300	Santa Ana River at E Street	246,700	17,340	15,230	12,020	30,900	25,490
11066050	Santa Ana River at Colton	--	--	--	--	--	--
11065000	Lytle Creek at Colton	47,690	1,820	1,220	176	5,900	1,050
	Total inflow	298,340	20,004	17,394	12,789	51,068	30,157

Table 5. Surface-water inflow to the Rialto-Colton basin, San Bernardino County, California, 1945-95—*Continued*

Station No.	Station name	1975	1976	1977	1978	1979	1980
11065801	Warm Creek near Colton (combined discharge)	--	--	--	--	--	--
11060400	Warm Creek near San Bernardino	1,330	1,760	1,630	51,820	3,100	19,460
11059300	Santa Ana River at E Street	19,410	24,000	24,550	153,000	55,630	320,300
11066050	Santa Ana River at Colton	--	--	--	--	--	--
11065000	Lytle Creek at Colton	130	1,060	635	37,360	2,750	29,990
	Total inflow	20,870	26,820	26,815	242,180	61,480	369,750

Station No.	Station name	1981	1982	1983	1984	1985	1986
11065801	Warm Creek near Colton (combined discharge)	--	--	--	--	--	--
11060400	Warm Creek near San Bernardino	7,940	13,920	24,640	19,550	19,150	18,590
11059300	Santa Ana River at E Street	27,150	61,260	248,770	44,040	41,280	56,410
11066050	Santa Ana River at Colton	--	--	--	--	--	--
11065000	Lytle Creek at Colton	1,200	3,010	*13,100	*3,117	1,390	4,660
	Total inflow	36,290	78,190	286,510	66,707	61,820	79,660

Station No.	Station name	1987	1988	1989	1990	1991
11065801	Warm Creek near Colton (combined discharge)	--	--	--	--	--
11060400	Warm Creek near San Bernardino	14,500	11,530	9,340	6,780	5,350
11059300	Santa Ana River at E Street	34,700	32,830	30,030	30,290	49,310
11066050	Santa Ana River at Colton	--	--	--	--	--
11065000	Lytle Creek at Colton	1,730	1,910	1,020	1,550	4,160
	Total inflow	50,930	46,270	40,390	38,620	58,820

Station No.	Station name	1992	1993	1994	1995
11065801	Warm Creek near Colton (combined discharge)	--		--	--
11060400	Warm Creek near San Bernardino	5,910	5,690	2,610	6,820
11059300	Santa Ana River at E Street	56,630	206,900	35,830	153,400
11066050	Santa Ana River at Colton	--		--	--
11065000	Lytle Creek at Colton	*8,866	18,640	841	7,940
	Total inflow	71,406	231,230	39,281	168,160

Table 6. Static water levels for selected wells perforated in the *river-channel deposits and upper water-bearing unit*, spring 1993, and middle and lower water-bearing units, spring 1994, Rialto-Colton basin, San Bernardino County, California

[Static water levels for middle and lower water-bearing units correspond to water-level contours in figures 15 and 16. Altitude of water level in feet above sea level]

State well no.	Date	Altitude of water level
River-channel deposits and upper water-bearing unit		
1S/4W-22D2	03-10-93	964.97
1S/4W-21J1	05-16-93	945.04
1S/4W-21K11	04-12-93	944.15
1S/4W-20H4	06-10-93	897.45
1S/4W-27L1	04-19-93	919.47
1S/4W-28K2	05-11-93	888.02
1S/4W-29H1	04-22-93	873.58
Middle water-bearing unit		
1N/5W-17K1	04-01-94	1,796
1N/5W-21K3	03-16-94	1,275.33
1N/5W-22N3	03-28-94	1,270.35
1N/5W-26L1	03-10-94	1,171.46
1N/5W-27D2	03-28-94	1,159.74
1N/5W-28J2	01-07-94	1,097.54
1N/5W-29Q4	06-21-94	1,047.16
1N/5W-34D4	03-14-94	1,031.80
1N/5W-35B4	04-01-94	1,152.86
1S/5W-11F4	03-30-94	1,011.11
1S/5W-12L1	04-01-94	964
1S/4W-8E4	04-03-94	918.28
1S/4W-17R1	04-19-94	909.99
1S/4W-20H3	03-24-94	904.50
Lower water-bearing unit		
1N/5W-21K1	03-10-94	1,280.14
1N/5W-22N1	03-28-94	1,270.41
1N/5W-29Q2	05-05-94	1,045.34
1N/5W-34B2	04-01-94	1,038
1N/5W-34D2	03-14-94	1,031.61
1N/5W-35B2	04-01-94	1,143.86
1S/5W-11F2	03-30-94	1,019.94
1S/4W-8E2	04-03-94	922.89
1S/4W-20H2	04-02-94	900.53

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