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Questa Baseline and Premining Ground-Water Quality Investigation 15

Methods of Phase II and III Well Installation and Development and Results of Well Logging, Hydraulic Testing, and Water-Level Measurements in the Red River Valley, New Mexico, 2002–04

Scientific Investigations Report 2006–5246

U.S. Department of the Interior
U.S. Geological Survey

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Prepared in cooperation with the New Mexico Environment Department

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U.S. Geological Survey

U.S. Department of the Interior
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Suggested citation:
Blanchard, P.J., Bartolino, J.R., Donohoe, L.C., McAda, D.P., Naus, C.A., and Morin, R.H., 2007, Questa baseline and pre-mining ground-water quality investigation 15.—Methods of phase II and III well installation and development and results of well logging, hydraulic testing and water-level measurements in the Red River Valley, New Mexico, 2002–04: U.S. Geological Survey Scientific Investigations Report 2006–5246, 56 p.

Front cover: Jeffery Eman (left) and Arthur Clark (right), U.S. Geological Survey, Lakewood, Colorado, drilling shallow well near bank of Red River. Photograph taken by Cheryl Naus, U.S. Geological Survey, Albuquerque, New Mexico.

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
	Flow Rate	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
foot squared per minute (ft^2/min)	0.09290	meter squared per minute (m^2/min)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ton	0.9072	megagram

Ohm-meters (ohm-m) can be converted to microsiemens per centimeter (μS/cm) by the equation

$$(1/\text{ohm-m}) \times 0.0001 = \mu S/cm.$$

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32)/1.8.$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Questa Baseline and Pre-Mining Ground-Water Quality Investigation 15.—Methods of Phase II and III Well Installation and Development and Results of Well Logging, Hydraulic Testing, and Water-Level Measurements in the Red River Valley, New Mexico, 2002–04

By Paul J. Blanchard, James R. Bartolino, Lisa C. Donohoe, Douglas P. McAda, Cheryl A. Naus, and Roger H. Morin

Abstract

In April 2001, the U.S. Geological Survey and the New Mexico Environment Department began a cooperative study to infer the pre-mining ground-water chemistry at the Molycorp molybdenum mine site in the Red River Valley of north-central New Mexico. This report is one in a series of reports that can be used to determine pre-mining ground-water conditions at the mine site.

Weathering of hydrothermally altered bedrock in the study area has resulted in steep, highly erosive, and sparsely vegetated scar areas that are clearly visible from the ground and in aerial photographs. Runoff from intense summer rainfall over tributary drainages containing scar areas can transport large quantities of sediment and form debris fans where these tributaries join the Red River.

Twenty-nine observation wells were installed in three phases as part of this study in the Red River Valley and tributary drainages. Eight Phase II observation wells were drilled using an air-rotary/hammer rig. Three Phase II and 10 phase III small-diameter wells were installed using a direct-push rig. Lithologic logs were recorded for all eight Phase II drilled wells. Borehole geophysical logging (including natural gamma, induction, and single-detector neutron) was conducted in three Phase II wells.

Aquifer tests conducted during 2003 to estimate the hydraulic properties of debris-flow and Red River alluvial deposits in and near Straight Creek included a flow-meter survey, slug tests, and a pumping test. Results of a flow-meter survey in well SC–7A indicated that about 77 percent of the water entered the well from a 10-foot-thick zone near the top of the screened interval and about 23 percent of the water entered the well from a 15-foot-thick zone near the bottom of the screened interval. Slug tests, performed in 11 wells during June 3–5, 2003, indicated that the mean and median estimated hydraulic conductivities for debris-flow deposits were 15.25 and 15.35 feet per day, respectively, for bedrock were 0.12 and 0.08 feet per day, respectively, and for mixed debris flow and Red River alluvium were 73–207 (estimated range) and 80 feet per day. In general, bedrock has the smallest hydraulic conductivity, debris-flow material has the next highest hydraulic conductivity, and mixed debris flow and Red River alluvium has the largest hydraulic conductivity. A pumping test conducted December 3–4, 2003, using well AWWT–1 as the pumped well, and wells AWWT–2, SC–5A, SC–5B, SC–7A, and SC–8A as observation wells, indicated estimated transmissivity of 12,000 to 34,000 feet squared per day and estimated hydraulic conductivity of 230 to 340 feet per day.

Water-level measurements in wells SC–6A, SC–7A, SC–8A, and the Hottentot, Hansen, and La Bobita wells show that water levels typically rose rapidly during melting of the winter snowpack in the springtime and then generally declined during the rest of the year. The water-level rise in response to spring snowmelt occurred earlier and was smaller at larger distances from the Red River. Differences between the stage in the Red River and water levels in wells SC–8A and SC–9A, and the absence of water in well SC–9A at the time of well completion, indicate that the Red River has a poor hydraulic connection to the underlying ground-water system and the surface-water system is perched above the ground-water system at this site. Water levels in Phase III wells indicate that the Red River and the shallow ground-water system are connected hydraulically from near wells 4–1D and 4–1S downstream to near wells 2–1 and 2–2 but are poorly connected near the La Bobita well and well 1.

Introduction

In April 2001, the U.S. Geological Survey (USGS) and the New Mexico Environment Department began a cooperative study to infer the pre-mining ground-water chemistry at the Molycorp molybdenum mine site in the Red River Valley in north-central New Mexico (fig. 1). This study was prompted by the Water Quality Act, under the jurisdiction of the New Mexico Water Quality Control Commission that requires a mine operator to develop and complete an approved closure plan that prevents the exceedence of (1) standards set forth in New Mexico Water Quality Control Commission Regulations (§20.6.2.3103 New Mexico Administrative Code) or (2) natural background water-constituent concentrations.

The Molycorp molybdenum mine has operated intermittently since the 1920s; ground-water-level and water-quality data were not obtained prior to initiation of mining. To infer pre-mining ground-water chemistry, observation wells were installed in three phases in unmined areas that were judged to be analogs to the mine site. During Phase I wells were installed in the Straight Creek drainage (Naus and others, 2005) and during phases II and III wells were installed in five additional areas. The five areas were Hottentot Creek, Straight Creek, Hansen Creek, near La Bobita campground, and Capulin Canyon. The Hottentot Creek, Straight Creek, and Hansen Creek drainages (figs. 1, 2, 3, and 4) contain debris-flow deposits associated with scar areas. The La Bobita (fig. 4) drainage contains unconsolidated deposits in a non-scar area characterized by propylitic alteration. Capulin Canyon (figs. 1 and 5) contains shallow unconsolidated deposits overlying bedrock in a non-scar area. The existing ground-water conditions in these five analog areas were used to establish baseline ground-water conditions which, when combined with ground-water conditions in mined areas, can be used to infer pre-mining conditions at the mine site.

Field observations indicated that the analog areas have been disturbed to varying degrees by non-mining anthropogenic activities. These activities include exploration drilling, road construction, power and telephone line construction and maintenance, forest service construction and maintenance, and residential, commercial, and municipal development. The Straight Creek drainage basin was selected as the primary analog area because of similarities of terrain and geology to the mine site, its accessibility and potential for well installation, and minimal anthropogenic disturbance.

Purpose and Scope

The purpose of this report is to document and describe Phase II and Phase III well installation and development, present results of lithologic and geophysical logging, present results of hydraulic testing to determine aquifer characteristics, and present and discuss water-level measurements collected during the period March 2002 through June 2004. Because of the size and complexity of the study area, this report is one in a series of reports that can be used to determine pre-mining ground-water conditions at the mine site. The results of these studies can help guide decisionmakers in establishing appropriate remedial actions at the Molycorp mine.

Physical Description of Study Area

The Red River, a tributary to the Rio Grande, is located in north-central New Mexico (fig. 1). The area is a rugged mountainous terrain with steep slopes and V-shaped valleys. The main area of study within the Red River drainage basin extends west from the town of Red River to the USGS streamflow-gaging station near Questa (fig. 1) (station 08265000, Red River near Questa, New Mexico, referred to as the Questa gage). The area upstream from the Questa gage includes approximately 18 mi (miles) of the Red River and 108 mi^2 (square miles) of the Red River drainage basin. The mine site is located east of the Questa ranger station to the north of the Red River and New Mexico State Highway 38 (fig. 1). The mine site covers approximately 6 mi^2 (U.S. Department of Agriculture Forest Service, 2001) and includes three primary tributary drainages to the Red River—Capulin Canyon, Goat Hill Gulch, and Sulphur Gulch (fig. 1).

Hydrothermally altered bedrock is present in the Hottentot, Straight, Hansen, Little Hansen, Goat Hill, Sulphur, and Capulin drainages (fig. 1). Weathering of this bedrock has resulted in steep, highly erosive, and sparsely vegetated scar areas that are clearly visible from the ground and in aerial photographs.

Mining activities have produced extensive underground workings and an open pit of approximately 162 acres (Naus and others, 2005) in and adjacent to Sulphur Gulch. Waste-rock piles cover steep slopes on the north side of the Red River Valley between Capulin Canyon and Spring Gulch, a tributary valley of Sulphur Gulch.

Climate and Vegetation

The Red River drainage basin is located within a semi-arid desert that receives precipitation throughout the year and sustains moderate biodiversity. Between 1915 and 2002, the annual average temperature at the town of Red River was 4 °C, and the annual average precipitation and snowfall were approximately 20.5 and 146 in. (inch), respectively. The annual range of average daily temperatures at Red River was 18 °C (Western Regional Climate Center, 2003).

Climate and vegetation vary greatly within short distances, primarily because of differences in topography. Topography in the study area is steep, rising rapidly from the basin-floor elevation of approximately 7,450 ft (feet) at the Questa gage to ridge-crest elevations exceeding 10,500 ft. Orographic effects of mountainous topography lead to precipitation on the windward slopes and localized storms within the Red River drainage basin and tributary drainages. Precipitation from intense summer storms can cause soil mass wasting and debris flows in the scar areas that result in debris-flow deposits and debris fans at the mouths of many tributaries to the Red River (Kirk Vincent, USGS, written commun., 2003).

Dominant vegetation associations in the Red River Basin and the general elevation zones are piñon-juniper woodland

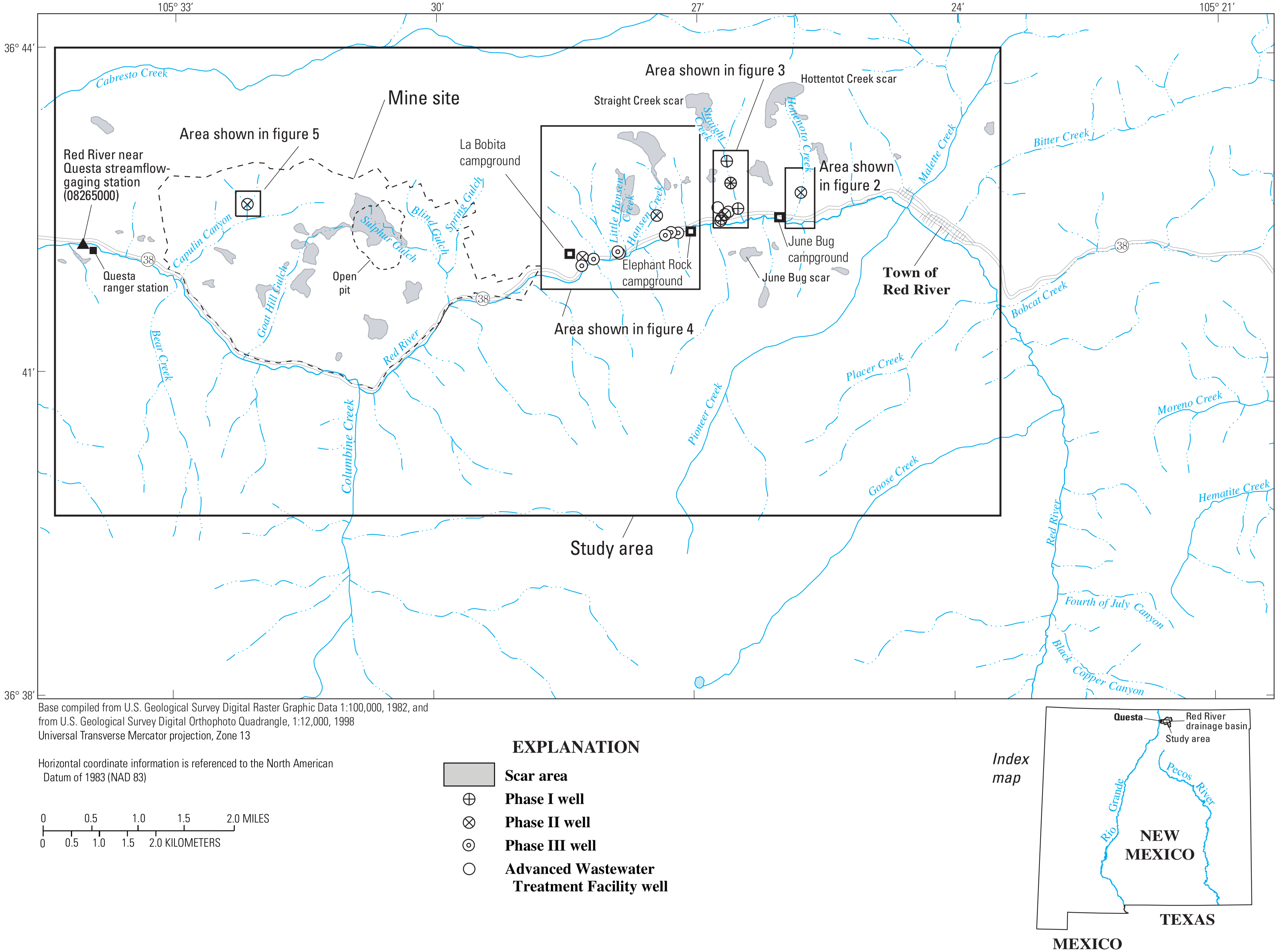
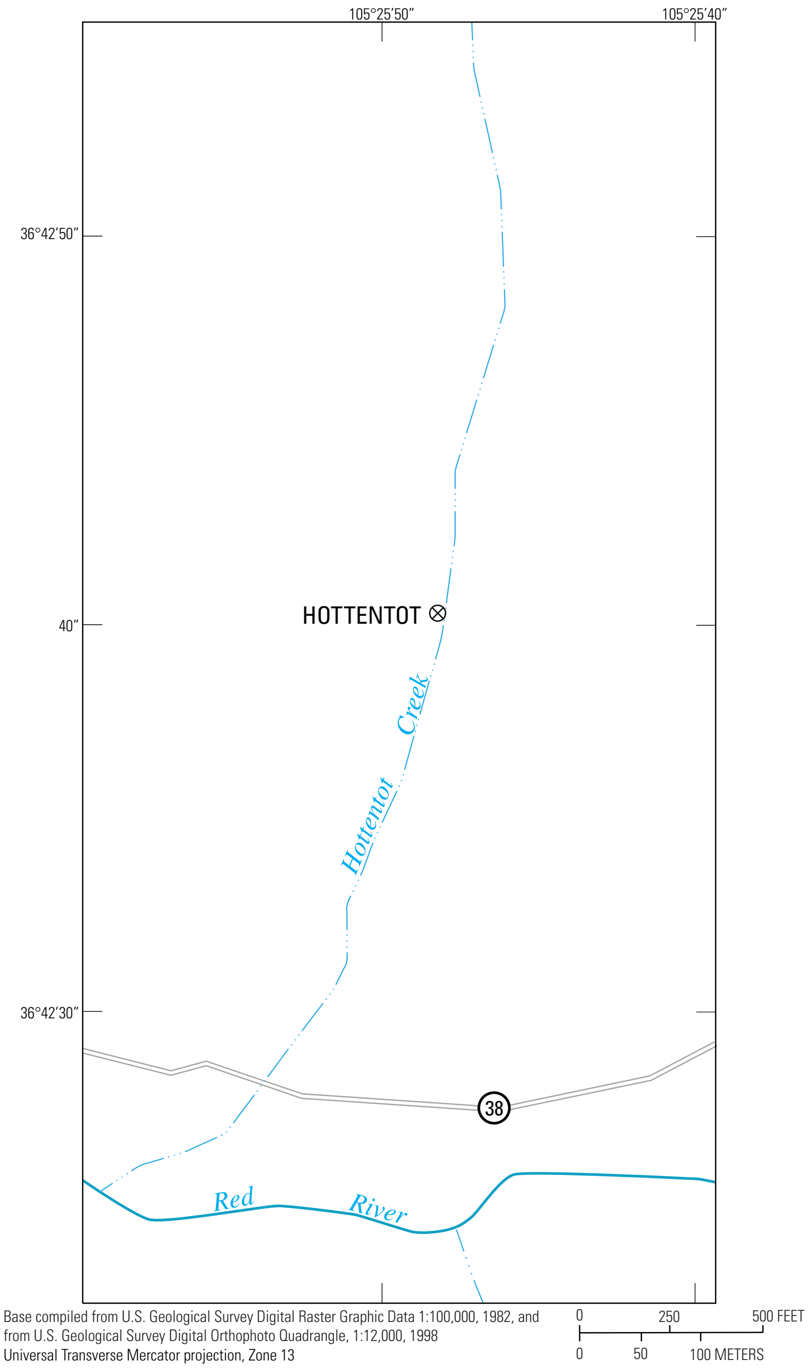


Figure 1. Location of study area in Red River Valley, north-central New Mexico, and features of study area.



Base compiled from U.S. Geological Survey Digital Raster Graphic Data 1:100,000, 1982, and from U.S. Geological Survey Digital Orthophoto Quadrangle, 1:12,000, 1998
Universal Transverse Mercator projection, Zone 13

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

EXPLANATION

HOTTENTOT ⊗ **Phase II well and name**

Figure 2. Location of Hottentot well.

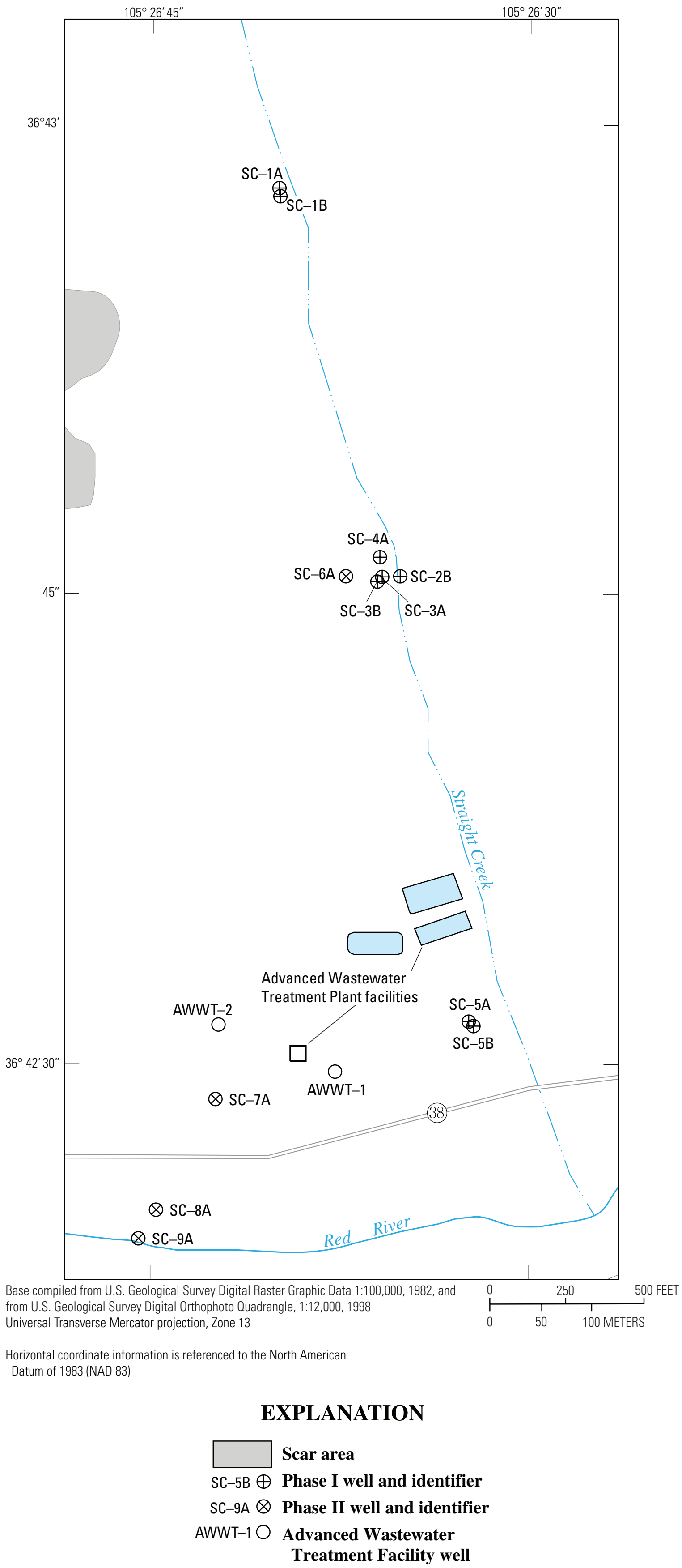
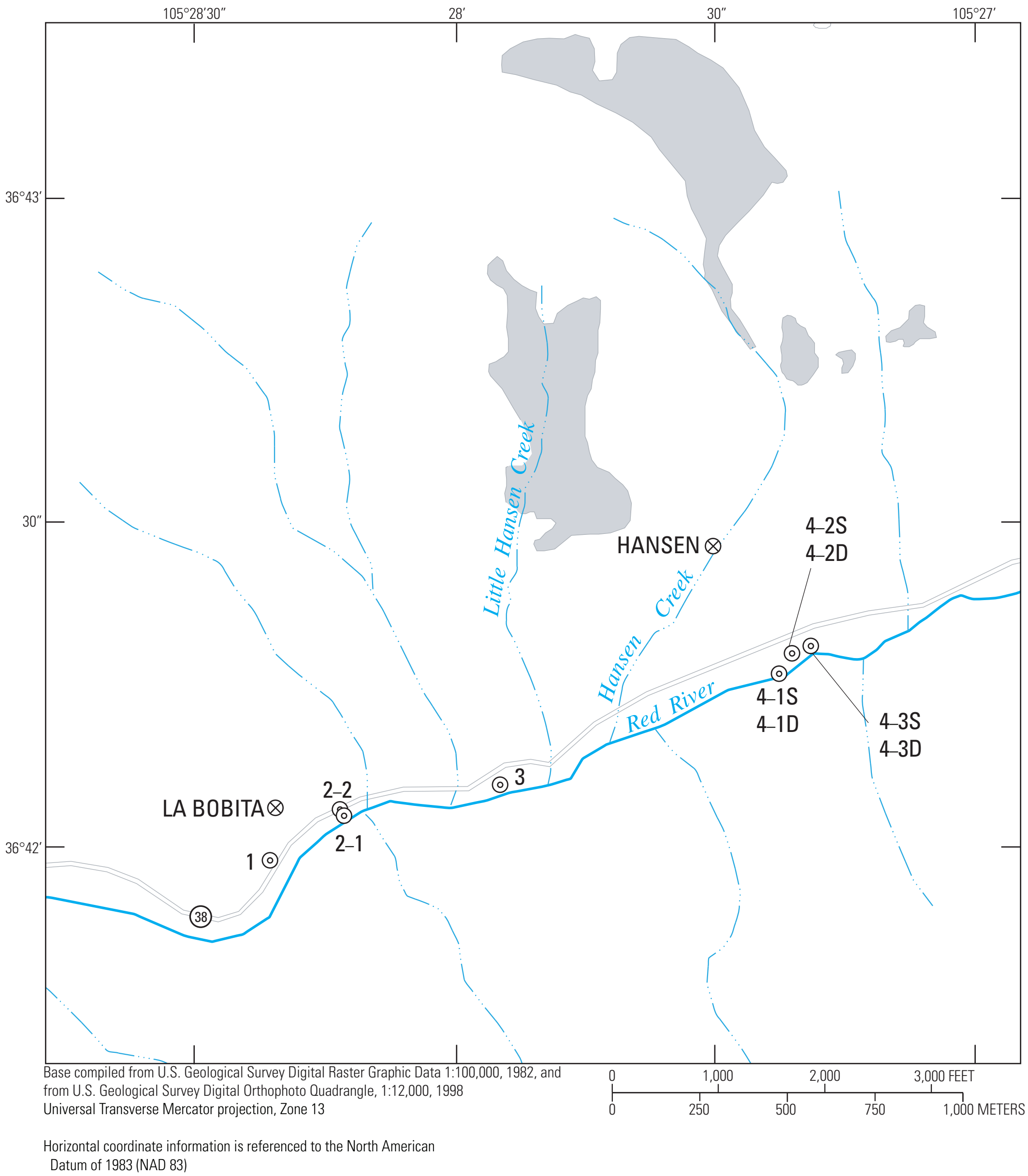


Figure 3. Location of Straight Creek and Advanced Wastewater Treatment Facility wells.



EXPLANATION

Scar area

LA BOBITA — **Phase II well and name**

2–1 — **Phase III well and identifier**

Figure 4. Location of La Bobita and Hansen Phase II wells and Phase III wells.

from 6,000 to 7,500 ft, mixed conifer woodland (primarily ponderosa and limber pine) from 7,500 to 9,000 ft, and spruce-fir woodland (primarily Douglas and white fir) from 9,000 to 12,000 ft (Knight, 1990; Larry Gough, USGS, oral commun., 2003).

Surface Water

The Red River originates at an altitude of about 12,000 ft, flows about 35 mi, and enters the Rio Grande at about 6,600 ft. The total Red River drainage-basin area is 190 mi^2; the drainage area upstream from the Questa gage is 108 mi^2. Snowmelt flows typically begin in late March and peak in late May to mid-June. Summer thunderstorms are prevalent in July and August and can cause localized flooding and debris-flow movement. Between 1930 and 2001, the mean annual discharge of the Red River at the Questa gage ranged from 12.8 to 103 ft^3/s (cubic feet per second), the average daily discharge ranged from 2.5 to 750 ft^3/s, and the average discharge was 46.1 ft^3/s (U.S. Geological Survey, 2004).

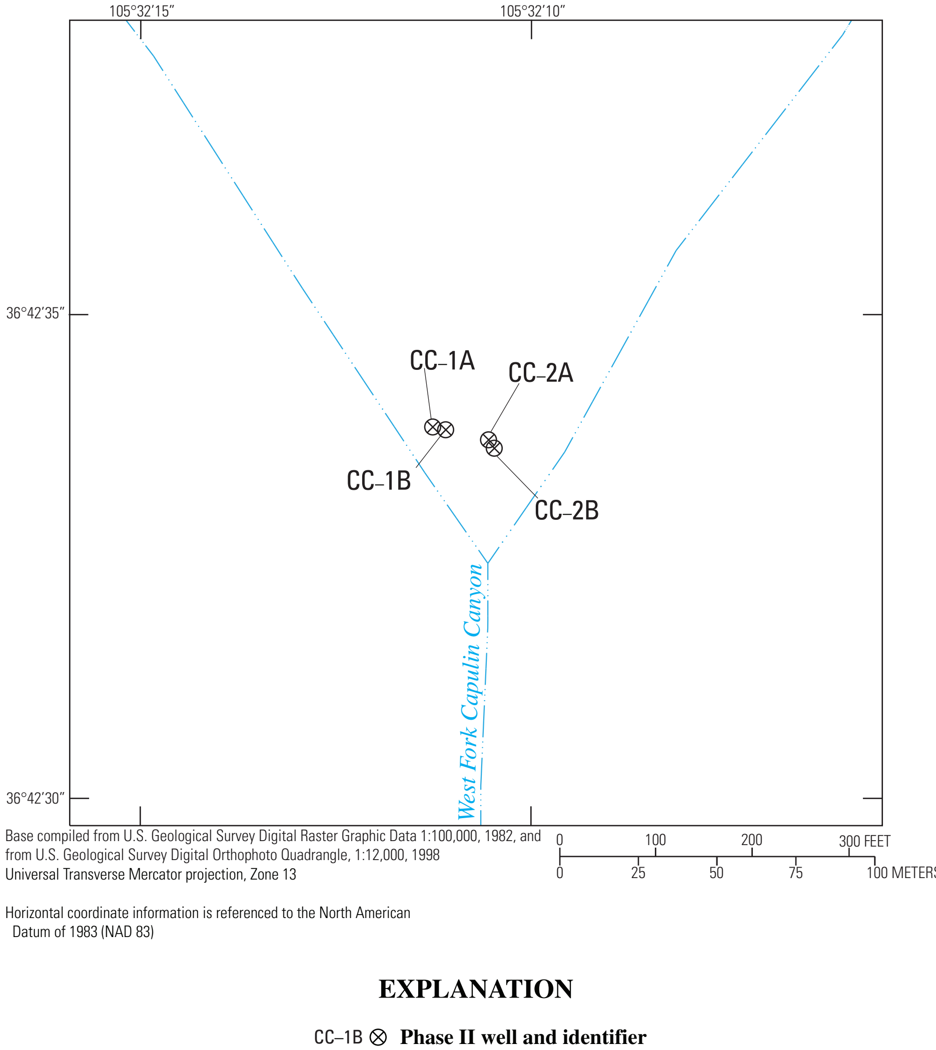


Figure 5. Location of Capulin Canyon Phase II wells.

Springs and shallow alluvial ground water discharge to the Red River, making the river a gaining stream over much of its length (Smolka and Tague, 1989). Between the town of Red River and the Questa gage, there are about 25 ephemeral seeps and springs along the banks of the Red River and approximately 20 intermittent seeps and springs in tributary drainages on the north side of the river (South Pass Resources, Inc., 1995; Steffen, Robertson, & Kirsten, 1995; Robertson Geo-Consultants, Inc., 2001). Flow from these springs and seeps affect the color and turbidity of the river. Aluminum hydroxide often precipitates downgradient from scar and mined areas on the north side of the Red River (Vail Engineering, Inc., 1989).

In the Straight Creek drainage, the West Fork of Straight Creek flows perennially through most of its reach. The East Fork of Straight Creek and Straight Creek downstream from the confluence of the West and East Forks flow ephemerally and intermittently; streamflow typically infiltrates the debris-flow deposits upstream from this confluence. Streamflow in Straight Creek discharges to the Red River only during periods of peak snowmelt runoff and following intense precipitation. The downstream reach of the Straight Creek natural streambed has been reworked to divert flow around the east side of the Advanced Wastewater Treatment (AWWT) Facility, which is operated by the town of Red River.

Hydrogeology

This section describes the generalized geology, geomorphology, and water-bearing units in the Red River Valley. Previous studies of the geology and mineralogy of the Red River Valley include those by Schilling (1956), Rehrig (1969), Lipman (1981), and Meyer and Leonardson (1990, 1997). The following discussion uses information from these sources, from Ludington and others (2005), and from USGS scientists participating in this study.

The Red River Valley is located along the southern edge of the Questa Caldera and contains complex structural features (Caine, 2003) and extensive zones of hydrothermal alteration. The geology of the basin consists of volcanic and intrusive rocks of Tertiary age, underlain by metamorphic rocks of

Precambrian age that were intruded by granitic stocks. The volcanic rocks are primarily intermediate to felsic in composition (andesite to rhyolite). Granites and porphyries that intruded the volcanic rocks were the apparent source of the hydrothermal fluids, rock alteration, and subsequent mineralization. Mineral deposits in the Red River Valley are considered climax-type deposits, which are associated with silica- and fluorine-rich rhyolite porphyry and granitic intrusives.

Ore deposits in the Red River Valley contain quartz, molybdenite, pyrite, fluorite, calcite, manganiferous calcite, dolomite, ankerite, and rhodochrosite. Lesser amounts of galena, sphalerite, chalcopyrite, magnetite, and hematite also are present. The hydrothermal alteration related to mineralization overprints an older, regional alteration of rock. In these areas, rocks can contain a mixture of quartz, pyrite, and illite clays replacing feldspar, chlorite, carbonates, and epidote. Minerals occurring in waste rock produced by mining activities include chlorite, gypsum, illite, illite-smectite, jarosite, kaolinite, and muscovite (Gale and Thompson, 2001).

Scar-area bedrock outcrops consist of andesitic volcanic and volcaniclastic rocks, rhyolitic tuff, quartz latite, and rhyolite porphyry. Most of the andesite and quartz latite has been hydrothermally altered and primarily contains plagioclase feldspar and chlorite. Rhyolite porphyry and tuff do not seem to have been substantially altered.

Runoff from intense summer rainfall over basins tributary to the Red River can transport large quantities of sediment down tributary drainages and form debris fans where these tributaries join the Red River. Where the tributary drainages contain scar areas, the debris fans are large, indicate evidence of active deposition, and contain poorly sorted coarse gravel and cobble to clay-size sediments. Sediment transported and deposited by the Red River (Red River alluvium), in contrast, generally consists of medium- to well-sorted sand and gravel that consist of a mix of the bedrock lithologies found in the entire Red River drainage basin. Large debris fans debouching from tributary drainages have caused aggradation of the Red River streambed in river reaches upstream from debris fans (Kirk Vincent, USGS, written commun., 2005).

Important water-bearing units in the Red River Valley include fractured bedrock, debris-flow deposits, and Red River alluvium. Bedrock constitutes the largest aquifer in the study area in terms of rock mass but contains only small amounts of ground water because the rock has low porosity and most of the water occurs in fractures. Debris-flow deposits, debris fans, and Red River alluvium are smaller in area, but they contain most of the ground water in the valley. Debris-flow deposits, debris fans, and the Red River alluvium typically are less than 1,000 ft wide and less than 200 ft thick (Kirk Vincent, USGS, written commun., 2003). The largest debris fans have caused the Red River to aggrade upstream from the fans during the Quaternary; water flowing in these shallow aquifers likely passes alternately through Red River alluvium and debris-flow deposits (Kirk Vincent, USGS, written commun., 2003).

Mining History

Molybdenite was discovered in Sulphur Gulch in 1914. Subsequently, underground mining operations took place between 1919 and 1958; by 1954 there were more than 35 mi of underground mine workings (Robertson Geoconsultants, 2000c; U.S. Environmental Protection Agency, 2000). Exploration of areas surrounding the mine was conducted following closure of the mine in 1958. By 1964, sufficient reserves had been identified to justify development of an open-pit mine in Sulphur Gulch and construction of a mill capable of processing 10,000 tons of ore per day. The first ore from the pit was delivered to the mill in December 1965 (Molycorp, Inc., 2004).

Overburden and waste rock from open-pit mining was deposited at several locations on the south-facing slopes north of the Red River between Capulin Canyon and Spring Gulch (Robertson Geoconsultants, 2000a, 2000c; URS, 2001). Beginning in 1964, tailings were transported by pipeline from the mine to the tailings facility near Questa. Water used in the mill operation was obtained from the Red River, the Red River alluvium, and from water collected during dewatering of the mine (URS, 2002). Approximately 328 million tons of waste rock were deposited at the tailings facility between 1964 and 1983 (Steffen Robertson & Kirsten, 1995; Slifer, 1996; Robertson GeoConsultants, Inc., 2000b, 2000c).

Molycorp ceased open-pit mining in 1983 and initiated a new phase of underground mining in Goat Hill Gulch. This change effectively stopped the dumping of waste rock in Capulin Canyon; along the north slope of the Red River; and in Goat Hill, Sulphur, and Spring Gulches. It also increased the volume of tailings slurry transported by pipeline to the tailings facility.

While the underground mine was inactive during 1992–95, ground water was not pumped from the underground mine workings, and the workings were allowed to partially reflood. The mine was dewatered and repaired when production resumed in late 1996, and mining of a new ore body began in 1998 (Molycorp, Inc., 2004).

Well-Numbering Systems

Two systems of numbering wells were used in this study—a study-specific system and a standardized New Mexico system. In the study-specific system, wells in Capulin Canyon and Straight Creek were assigned a two-letter abbreviation designating the drainage in which the wells were located (CC and SC), a sequence number, and a suffix of A if the well was completed in unconsolidated debris-flow or alluvial deposits, or a suffix of B if the well was completed in bedrock. The sequence number identifies a single well completed in either unconsolidated deposits or bedrock or a pair of wells where one well was completed in unconsolidated deposits and one well was completed in bedrock. For example, well SC–7A designates a well in Straight Creek completed in unconsolidated debris-flow or alluvial deposits, SC–2B designates a well in Straight Creek completed in bedrock, and wells SC–5A and SC–5B designate a well pair in Straight Creek completed in debris-flow/alluvial deposits and bedrock, respectively.

In the study-specific system, Phase III wells were assigned a general site area (areas 1 through 4) in a downstream-to-upstream direction along the Red River. In areas 1 and 3, only one well was drilled; each well was designated 1 and 3, respectively. In area 2, two wells were drilled at different distances from the Red River and were designated 2–1 and 2–2. In area 4, three pairs of deep (D) and shallow (S) wells were drilled and designated 4–1D and 4–1S, 4–2D and 4–2S, and 4–3D and 4–3S.

The standardized system of numbering wells in New Mexico also was used to designate the location of wells in this report. The system is based on the common division of public lands into sections (fig. 6). The well number, in addition to designating the well, locates the position to the nearest 10-acre tract in the land network. This number is divided into four segments. The first segment denotes the township (T.) north (N.) or south (S.) of the New Mexico base line, the second denotes the range (R.) east (E.) or west (W.) of the New Mexico principal meridian, and the third denotes the section. The fourth segment of the number consists of three digits that denote section subdivisions of 160-, 40-, and 10-acre tracts, respectively. Each section is divided into four 160-acre quarter sections. The first digit of the fourth segment denotes the quarter section and is numbered 1, 2, 3, or 4, for the northwest, northeast, southwest, and southeast quarters. Similarly, each 160-acre quarter section is further divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, each 40-acre tract is divided into four 10-acre tracts also numbered in the same manner, and the third digit denotes the 10-acre tract. Letters A, B, C, and so on are added sequentially to the fourth segment to designate the second, third, fourth, and succeeding wells in the same 10-acre tract. Well SC–1A, for example, is numbered 29N.14E.28.441 and, therefore, is in the NW¼ of the SE¼ of the SE¼ of section 28, township 29 north, range 14 east.

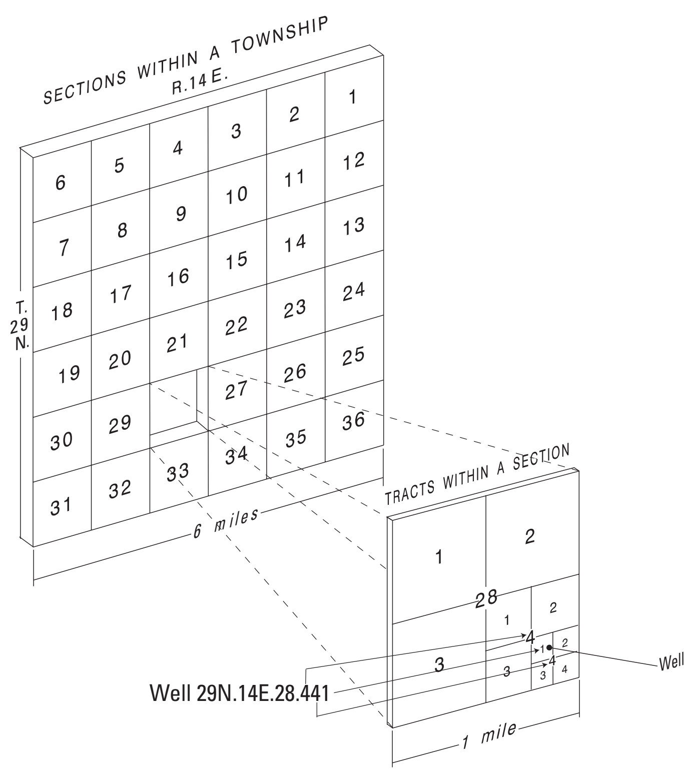


Figure 6. Well-numbering system in New Mexico.

Acknowledgments

The authors thank the study Advisory Committee for their contributions to the design and implementation of the study. Advisory committee members included Amigos Bravos, Molycorp, and the New Mexico Environment Department. Advice and cooperation from the U.S. Environmental Protection Agency Region 6 and the U.S. Forest Service are gratefully acknowledged. The authors thank Russell Church, Plant Supervisor, AWWT facility, the town of Red River, and the AWWT facility staff for providing access to their observation wells and assisting with field activity logistics. Assistance with data compilation and sample collection by Caroline Myer (USGS) is greatly appreciated.

Well Location, Installation, Construction, and Development

Twenty-nine observation wells were installed in three phases as part of this study in the Red River Valley and tributary drainages (figs. 2–5). Eight observation wells were installed in the Straight Creek analog site during Phase I (November 2001 through February 2002) (Naus and others, 2005). Eleven additional wells were installed in the Hottentot, Straight, Hansen, La Bobita, and Capulin drainages during Phase II (October 2002 through January 2003). Ten small-diameter wells were installed in the Red River alluvium north of the Red River during Phase III (December 2003). Two existing wells (AWWT–1 and AWWT–2) at the town of Red River Advanced Wastewater Treatment Facility also were included in the monitoring-well network.

Phase I wells (SC–1A and B, SC–2B, SC–3A and B, SC–4A, SC–5A and B) were located in the Straight Creek drainage basin along the assumed path of ground-water flow in debris-flow deposits from the upstream part of the basin to near the mouth of the basin where straight Creek flows into Red River (fig. 3) (Naus and others, 2005). Wells SC–2B, SC–3A, SC–3B, and SC–4A were located approximately midway between upgradient wells SC–1A and SC–1B and downgradient wells SC–5A and SC–5B.

During Phase II, well SC–6A was installed west of the middle cluster of wells in the Straight Creek drainage to monitor ground-water conditions where results of a geophysical cross-section survey indicated that the debris-flow deposits were the thickest. Wells SC–7A and SC–8A were installed in the Red River alluvial deposits west of Straight Creek in an area postulated to be a mixing zone of Straight Creek and Red River ground water (fig. 3). Well SC–7A was screened across an interval of approximately 90 ft to compare water chemistry at selected depths within this postulated mixing zone. Comparison of water chemistry in samples from wells SC–7A and SC–8A is anticipated to aid in characterizing the mixing of acidic water from the debris fan near the mouth of Straight Creek with near-neutral pH water in the Red River alluvium. Well SC–9A was installed on the north bank of the Red River to complete the series of wells in the Straight Creek drainage basin and to monitor conditions at the ground-water/Red River interface.

The Hottentot, Hansen, and La Bobita wells were installed in debris-flow deposits to monitor ground-water conditions at these analog sites. The Capulin Canyon wells were installed to monitor ground-water conditions at an analog site without debris-flow deposits.

Phase III wells were installed in unconsolidated material along an approximately 1-mi reach of the Red River west of Elephant Rock campground (fig. 1). These wells were installed to examine the interaction of the Red River and water in the Red River alluvium.

Well locations and altitudes, construction information, and initial ground-water-level measurements for Phase II and Phase III wells are listed in table 1. Latitudes, longitudes, and altitudes of Phase II wells were determined by Molycorp using a Trimble 5800 Real Time Kinematic Rover™ with a Trimble 5700 Global Positioning System (GPS) Total Station™ base; accuracy of the system is ± 0.016 ft horizontally and ± 0.1 ft vertically (B.M. Walker, Molycorp, written commun(s)., 2003).

Latitudes and longitudes for Phase III wells were determined using a Garmin eTrex® 12-parallel-channel GPS receiver; horizontal accuracy is ± 20 ft. The altitude of well AWWT–1 was estimated by using a hand-held site level and the altitude of the previously surveyed SC–7A well. The altitude of well AWWT–2 was determined from a USGS 7½-minute (1:24,000-scale) topographic map. Altitudes of Phase III wells 1, 2–1, 2–2, and 3 were determined by a level survey from the previously surveyed Phase II La Bobita well (fig. 4). Altitudes of Phase III wells—4–1D, 4–SD, 4–2D, 4–2S, 4–3D, and 4–3S—were determined by estimation of the altitude of well 4–1D from a USGS 7½-minute topographic map and a level survey from well 4–1D to the other five wells.

Phase II Drilled Wells

WDC Drilling Company (formerly THF Drilling Company) of Phoenix, Arizona, under direction of Souder, Miller and Associates (SMA) hydrogeologists and USGS hydrologists, drilled, constructed, and developed 8 of the 11 Phase II observation wells. These wells included the Hottentot well; Straight Creek wells SC–6A, SC–7A, and SC–8A; the Hansen well; the La Bobita well; and Capulin Canyon wells CC–1B and CC–2B. The locations of these wells are shown in figures 2–5, and information describing well location and construction is listed in table 1.

All eight wells were drilled using an Ingersoll Rand TH75E air-rotary/hammer rig equipped with a Stratex® casing-advance system and an onboard Ingersoll Rand air compressor (an auxiliary compressor provided additional air capacity as needed). Boreholes were drilled using a 9-in. diameter button bit. Boreholes were advanced to total well depth using the Stratex® system to temporarily case the holes to ensure that the holes did not collapse. The temporary casing was cleaned using phosphate-free detergent and tapwater prior to drilling each well.

Each of the eight wells was constructed using new, flush-threaded, 4-in. diameter, schedule-80 polyvinyl chloride (PVC) casing and factory-cut, 0.010-in. slot-size PVC screen with threaded end cap. The annulus of each well was filled with 10/20 silica sand from the bottom of the hole to a minimum of 2.5 ft above the top of the screen. A hydrated bentonite-pellet seal, typically from 4 to 8 ft thick, was installed above the 10/20 silica sand, and hydrated bentonite chips were installed above the seal to the land surface.

Each of the eight wells was developed until specific conductance, pH, and temperature stabilized. Stabilization criteria were: specific conductance, ±10 percent; pH, ±0.1 standard unit; and temperature, ±0.5º C. Each well was initially developed by mechanical surging for a minimum of 20 minutes. Wells CC–1B and CC–2B were further developed by additional surging and subsequent pumping. Wells SC–6A, SC–8A, and the Hottentot, Hansen, and La Bobita wells were further developed by mechanical surging and subsequent bailing; wells SC–6A, SC–8A, and the Hottentot well were further developed by pumping following bailing. Well SC–7A was further developed solely by pumping.

Phase II Small-Diameter Wells

Phase II small-diameter wells were installed using a Geoprobe Model 6610-DT. The Geoprobe (a direct-push rig) uses hydraulic pressure and supplementary hammering to advance the drill point and drill rod. Wells CC–1A and CC–2A were installed in Capulin Canyon (fig. 5) next to the air-rotary-drilled wells CC–1B and CC–2B, respectively. Well SC–9A (fig. 3) was installed at the mouth of the Straight Creek drainage near the upstream end of the Elephant Rock campground (fig. 1). Prior to installing the SC–9A well casing, three small-diameter, vertical holes were advanced to between 20 and 36 ft below land surface along the north bank of the Red River in an attempt to locate the water table. All three holes were dry. A fourth small-diameter hole (well SC–9A) was advanced

Table 1. Locations, altitudes, construction information, and initial water levels for phase II and III wells, Red River Valley, north-central New Mexico, 2002–04.

[NA, not available or not applicable; NGVD 29, National Geodetic Vertical Datum of 1929]

Well (figs. 2–5)	U.S. Geological Survey site identifier	Well location	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Land-surface altitude (feet above NGVD 29)	Date completed (month/day/year)	Bore-hole depth (feet below land surface)	Well depth (feet below land surface)	Screened interval (feet below land surface)	Date water level measured (month/day/year)	Initial water level (feet below land surface)	Initial water-level altitude (feet above NGVD 29)
					Phase II wells							
Hottentot	364240105255001	29N.14E.34.211	36°42’40.43”	105°25’50.19”	8,790.79	10/30/02	118.0	115.5	105–115	02/05/03	98.72	8,692.07
SC–6A[1]	364245105263901	29N.14E.33.221D	36°42’45.67”	105°26’39.33”	8,739.43	11/12/02	150.0	148.5	129–149	02/07/03	133.12	8,606.31
SC–7A[1]	364228105264301	29N.14E.33.241	36°42’28.25”	105°26’43.04”	8,506.86	12/07/02	196.0	195.5	107–195	02/04/03	108.08	8,398.78
SC–8A[1]	364225105264501	29N.14E.33.234	36°42’25.42”	105°26’45.66”	8,468.22	11/24/02	98.0	97.5	87–97	02/08/03	69.84	8,398.38
SC–9A	364224105264401	29N.14E.33.234A	36°42’24.30”	105°26’43.30”	8,444.19	11/13/02	20.9	20.9	16.4–20.9	02/08/03	Dry	Dry
Hansen	364228105273201	29N.14E.33.131	36°42’28.17”	105°27’32.09”	8,569.53	11/07/02	120.0	109.5	99–109	02/05/03	104.68	8,464.85
La Bobita	364204105282201	29N.14E.32.341	36°42’03.67”	105°28’22.29”	8,229.45	12/08/02	65.0	63.5	53–63	02/07/03	61.14	8,168.31
CC–1A	364234105321301	29N.13E.34.214A	36°42’33.96”	105°32’13.24”	8,880.23	11/13/02	12.5	12.5	7.5–12.5	02/04/03	3.40	8,876.83
CC–1B	364234105321302	29N.13E.34.214B	36°42’33.93”	105°32’13.08”	8,878.31	10/29/02	40.0	39.0	23.5–38.5	02/05/03	7.54	8,870.77
CC–2A	364234105321303	29N.13E.34.232A	36°42’33.83”	105°32’12.53”	8,876.02	11/13/02	17.0	16.0	11.0–16.0	04/10/03	4.42	8,871.60
CC–2B	364234105321201	29N.13E.34.232B	36°42’33.74”	105°32’12.45”	8,877.53	10/24/02	116.5	115.5	56.5 – 105.25	02/05/03	8.66	8,868.87
					Phase III wells							
Site 1[2]	364159105282101	29N.14E.32.314	36°41’58.70”	105°28’20.89”	8,187.30	12/03/03	26.02	25.82	20.82–25.82	12/17/03	19.88	8,167.42
Site 2–1[2]	364203105281201	29N.14E.32.341	36°42’02.81”	105°28’12.40”	8,207.92	12/03/03	15.97	14.06	9.06–14.06	12/17/03	7.18	8,200.74
Site 2–2[2]	364203105281301	29N.14E.32.341A	36°42’03.46”	105°28’12.86”	8,207.94	12/03/03	14.37	13.12	8.12–13.12	12/17/03	8.29	8,199.65
Site 3[2]	364206105275401	29N.14E.32.432	36°42’05.80”	105°27’54.43”	8,255.54	12/03/03	9.21	9.21	4.21–9.21	12/17/03	3.61	8,251.93
Site 4–1D[2]	364216105272201	29N.14E.33.312	36°42’16.27”	105°27’22.32”	8,398.00	12/04/03	39.50	36.67	31.67–36.67	12/18/03	7.10	8,390.90
Site 4–1S[2]	364216105272202	29N.14E.33.312A	36°42’16.27”	105°27’22.32”	8,398.10	12/04/03	19.05	19.04	14.04–19.04	12/18/03	7.14	8,390.96
Site 4–2D[2]	364218105272101	29N.14E.33.312B	36°42’18.14”	105°27’20.88”	8,401.95	12/04/03	38.10	38.10	33.10–38.10	12/18/03	10.05	8,391.90
Site 4–2S[2]	364218105272102	29N.14E.33.312C	36°42’18.14”	105°27’20.88”	8,402.32	12/04/03	19.5	18.95	13.95–18.95	12/18/03	10.47	8,391.85
Site 4–3D[2]	364219105271901	29N.14E.33.312D	36°42’18.83”	105°27’18.68”	8,397.86	12/04/03	38.52	38.49	33.49–38.49	12/17/03	11.06	8,386.80
Site 4–3S[2]	364219105271902	29N.14E.33.312E	36°42’18.83”	105°27’18.68”	8,398.00	12/04/03	19.5	18.90	13.90–18.90	12/17/03	11.25	8,386.75

[1] Latitude, longitude, and altitude data determined by Molycorp using a Trimble 5800 Real Time Kinematic Rover with Trimble 5700 Global Positioning System Total Station base; accuracy of the system is ±0.016 foot horizontally and ± 0.1 foot vertically. All other information for Straight Creek wells was measured at time of drilling and well installation.

[2] Latitude and longitude determined using a Garmin eTrex 12-parallel-channel GPS receiver; horizontal accuracy is ±20 ft.

under the Red River at an angle of 21.5 degrees from vertical to a total angular depth of 22.5 ft. The vertical depth below land surface of this well is 20.9 ft and the bottom of the well is about 1.3 ft beyond the bank of the river. Well SC–9A also was dry at the time of installation.

Each of the Phase II small-diameter wells (CC–1A, CC–2A, and SC–9A) was completed by installing a 5-ft long, 1-in. diameter schedule 40 PVC factory-cut, 0.010-in. slot-size screen with a bottom cap at the total depth of the hole and 1-in. diameter schedule 40 PVC casing above the slotted-screen section to approximately 2 ft above land surface. The annulus of each well was filled with 10/20 silica sand from total depth to within about 5 ft of land surface, above which the annulus was filled with 3/8-in. bentonite pellets to the land surface.

Wells CC–1A and CC–2A were surged for 15 and 50 minutes, respectively, and then purged until dry using a bailer or a peristaltic pump and dedicated tubing, after which the wells were allowed to recover. This purging and recovery sequence was conducted three times in each well. Well SC–9A was not developed because it was dry at the time of installation.

Phase III Small-Diameter Wells

Several facts, including well SC–9A being dry at completion, results of two synoptic tracer studies (McCleskey and others, 2003), and results of geomorphologic investigations (Kirk Vincent, USGS, written commun., 2005), suggested that from Straight Creek to about 1,500 ft upstream from Hansen Creek, surface water in the Red River and the underlying ground water in the Red River alluvium are hydraulically disconnected. In this area, ground water originating in debris-flow deposits likely flows into the Red River alluvial aquifer and remains in the subsurface hydraulically disconnected from the Red River. Ten small-diameter observation wells were installed along approximately a 1-mi reach of the Red River west of Elephant Rock campground to measure water levels to characterize ground-water flow along this reach of the Red River (fig. 4).

Ten Phase III wells were completed by installing a 5-ft long, 1-in. diameter schedule 40 PVC factory-cut, 0.010-in. slot-size screen with a bottom cap at total depth of the hole and 1-in. diameter schedule 40 PVC casing above the slotted-screen section to approximately 2 ft above land surface. The annulus of each well was filled with 10/20 silica sand from total depth to within about 5 ft of land surface, above which the annulus was filled with 3/8-in. bentonite pellets to the land surface. The wells were developed by pumping a minimum of three casing volumes of water from each well using a peristaltic pump and dedicated tubing. Specific conductance, pH, temperature, and turbidity were monitored during development.

Lithologic and Geophysical Well Logging

Lithologic logs were recorded for all eight Phase II air-rotary-drilled wells, and borehole geophysical logging was conducted in Phase II wells SC–6A, SC–7A, and SC–8A. Well-completion diagrams and lithologic logs for the Hottentot, Hansen, La Bobita, and Capulin (CC–1B and CC–2B) wells are shown in figure 7, and well-completion diagrams, lithologic logs, and geophysical logs for wells SC–6A, SC–7A, and SC–8A are shown in figure 8.

Lithologic Logging

Lithologic logs were constructed from examination of borehole cuttings from the Hottentot, Hansen, La Bobita, and Capulin (CC–1B and CC–2B) wells, and wells SC–6A, SC–7A, and SC–8A (Souder, Miller, and Associates, 2003). Borehole cuttings were collected from all eight wells from land surface to total depth. Cuttings were collected at 5-ft intervals from sampling cyclones and stored in 5-gal (gallon) plastic containers. Representative samples from each 5-ft interval were examined in the field using a hand lens (Souder, Miller, and Associates, 2003). The level of detail in field logging of samples was dictated by the condition of the sample (wet or dry, fine or coarse) and the time available for inspection. Ludington and others (2005) conducted detailed analyses of these samples.

Geophysical Logging

Natural gamma, induction, and single-detector neutron geophysical logging was conducted in wells SC–6A, SC–7A, and SC–8A (figs. 8A, 8B, and 8C) during February 2003, following well completion and development. Logging and log interpretation was conducted using information regarding geophysical logging applications in ground-water investigations by Keys (1986, 1990), Jorgensen (1991), Paillet and Crowder (1996), and Hearst and others (2000). In completed wells SC–6A, SC–7A, and SC–8A, the conditions in the annulus between the 4-in. PVC casing and the 9-in. diameter bore holes at the time of logging were not representative of the undisturbed aquifer material beyond the borehole, and these disturbed conditions substantially limited interpretations of these logs.

Two primary quality-control measures were used during the collection of geophysical log data. First, an accurate depth scale was ensured by verifying that the depth indicator on the log recorded a value within about 0.8 in. of zero when the probe was returned to the pre-logging measurement reference point. Second, nuclear logging was repeated in selected sections of the wells to verify the repeatability of the initial logging results.

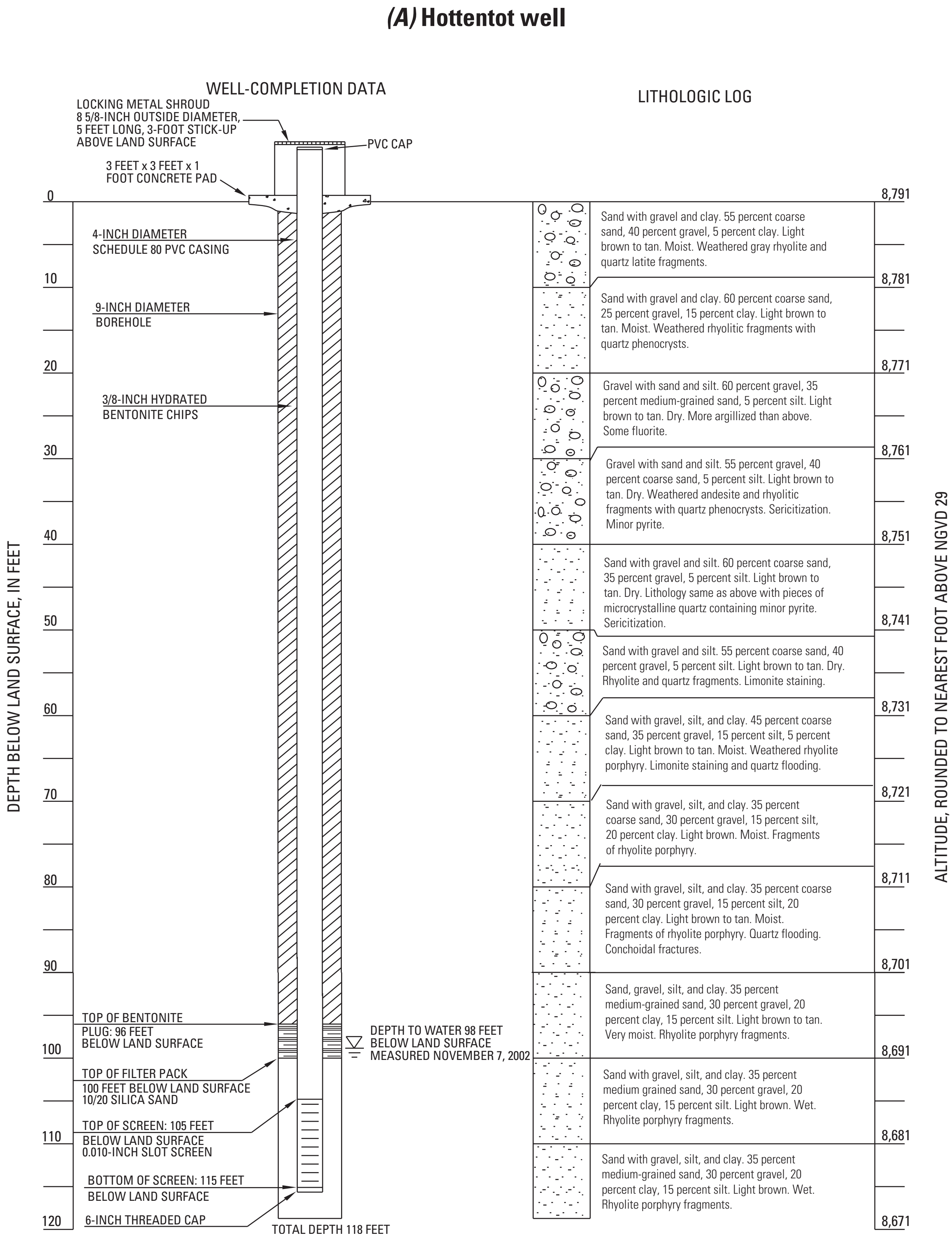


Figure 7A. Well-completion data and lithologic log for Hottentot well (modified from Souder, Miller, and Associates, 2003).

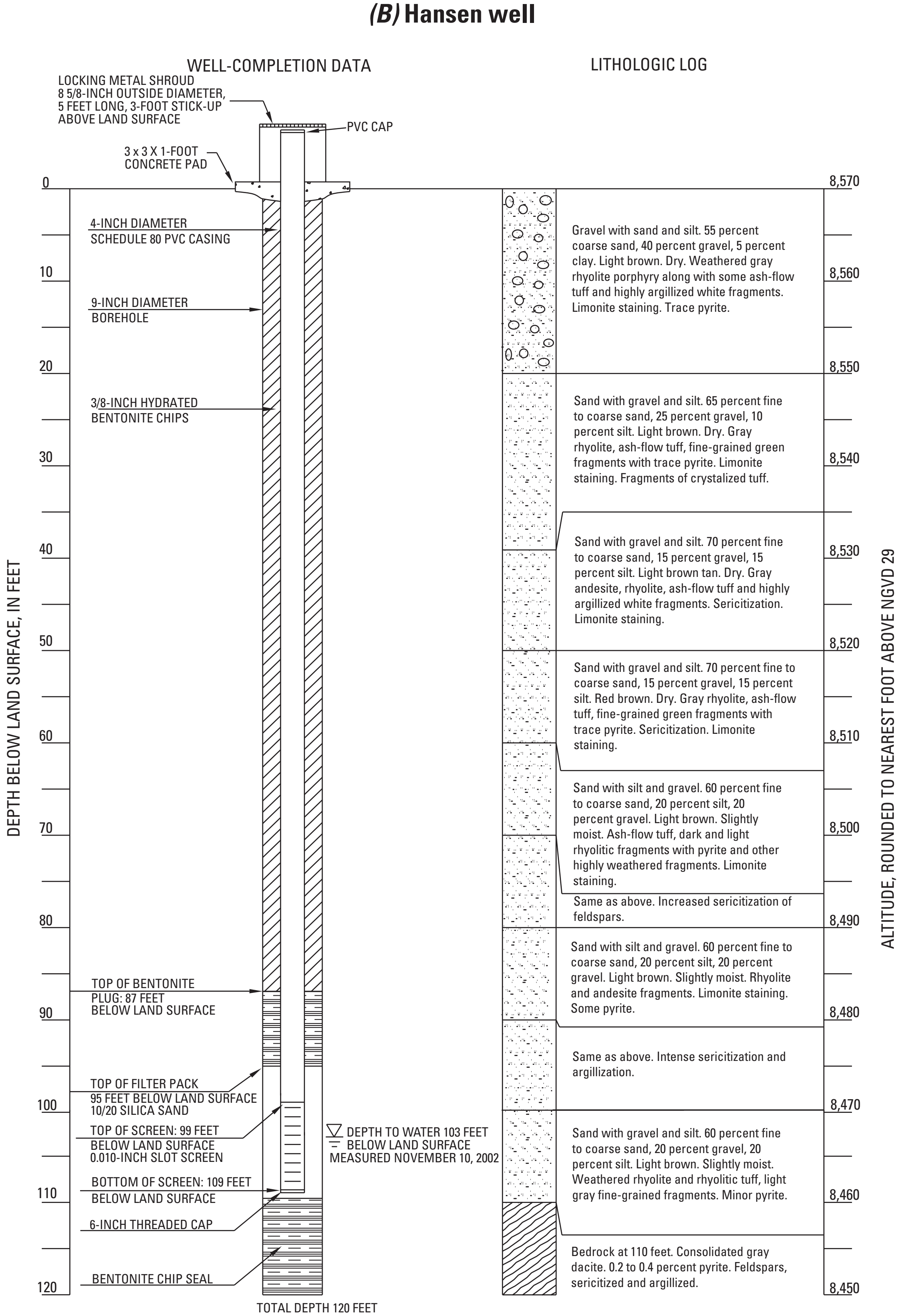


Figure 7*B*. Well-completion data and lithologic log for Hansen well (modified from Souder, Miller, and Associates, 2003).

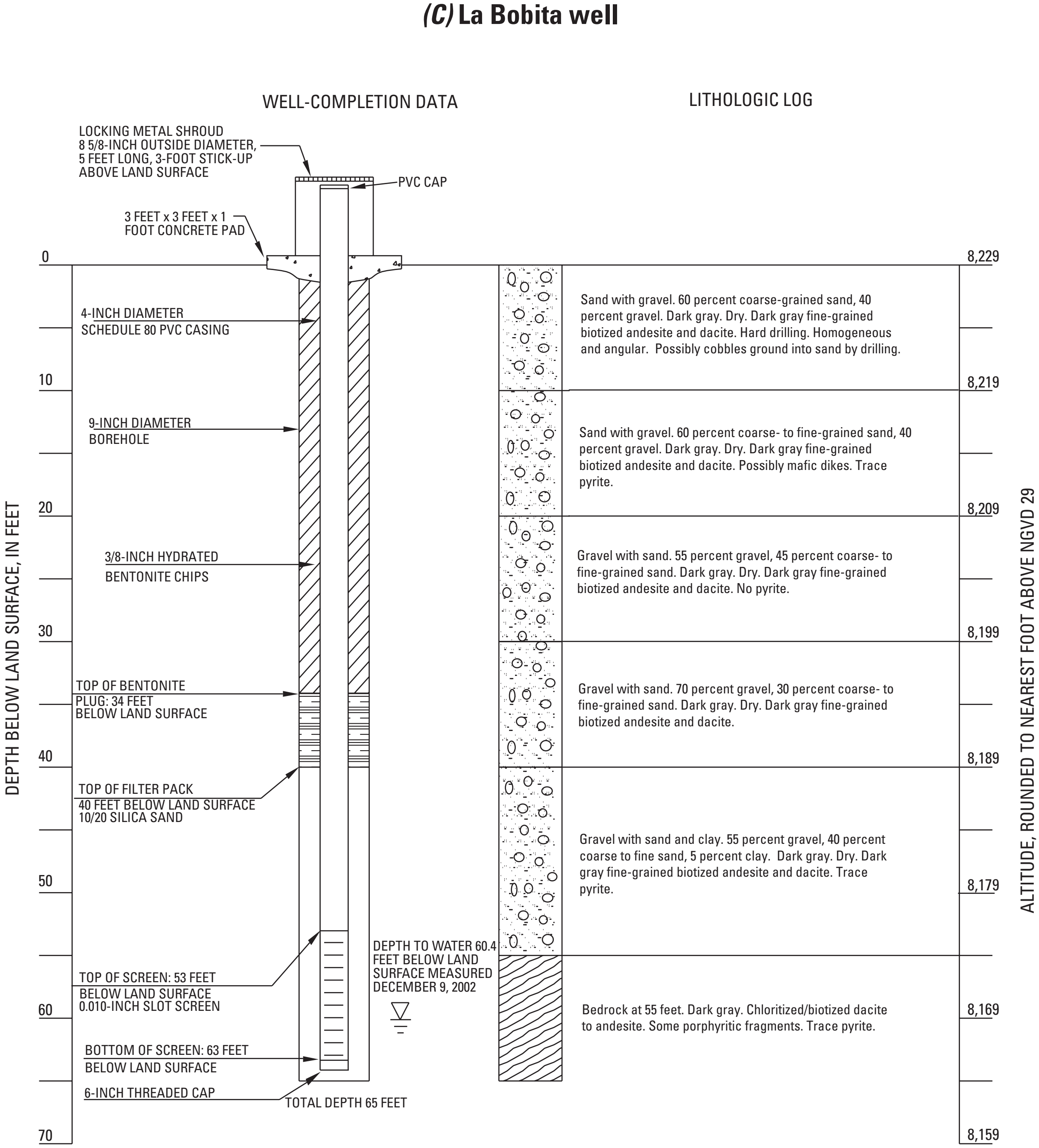


Figure 7*C*. Well-completion data and lithologic log for La Bobita well (modified from Souder, Miller, and Associates, 2003).

Natural gamma logs are used to estimate the proportion of clay minerals and (or) the proportion of unweathered mineral grains in the aquifer. The log measures the gamma activity produced by naturally occurring isotopes of uranium, potassium, and thorium in the formation beyond the borehole and, therefore, indicates variations in the lithology of aquifer materials. Log units are counts per second (cps). Well-casing and borehole fluid typically attenuate the flux of gamma particles from the undisturbed geologic material beyond the borehole to the detector in the logging tool resulting in reduced gamma counts. To minimize this attenuation, the log is run with the probe decentralized so that the probe is free to move within and lie against the side of the borehole or well that is not precisely plumb.

The induction log shows the bulk electrical resistivity of the aquifer material and the fluid in the aquifer material's pore spaces. Log units are ohm-meters. Resistivity values can vary depending on the electrical properties of the aquifer material, with the degree of saturation of the aquifer material, and with

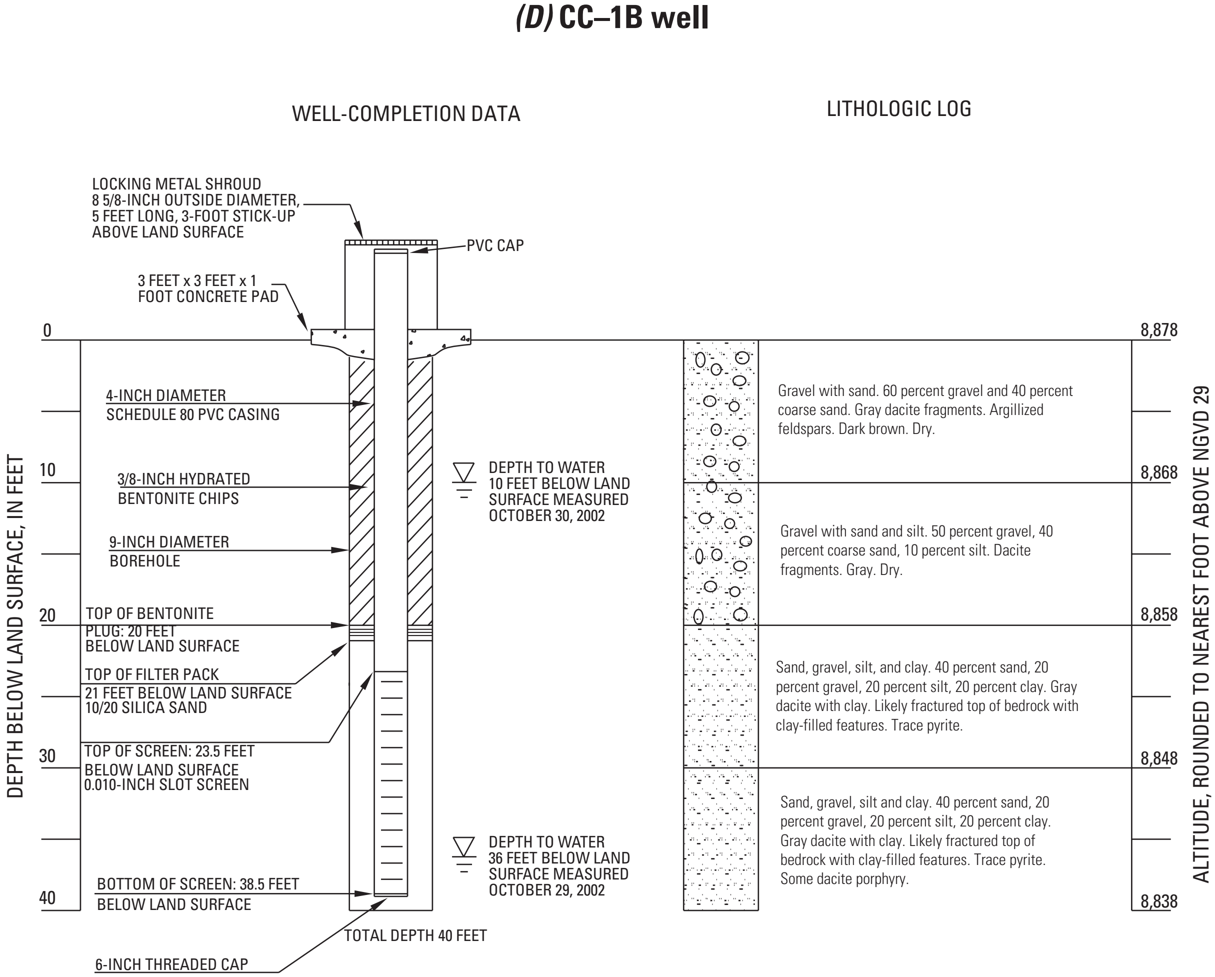


Figure 7*D*. Well-completion data and lithologic log for CC–1B well (modified from Souder, Miller, and Associates, 2003).

the electrical properties of the water filling pore spaces in the aquifer material.

Single-detector neutron logs provide an estimate of the degree of saturation of aquifer materials and, below the water table, the porosity of these materials. The single-detector neutron log generates a flux of neutrons and measures the rate at which those neutrons are scattered back to the detector. Neutrons generated by the logging tool are absorbed through collision with hydrogen atoms so the count rate is inversely proportional to the total amount of water within a radius of approximately 10 in. of the logging tool. To minimize the effects of casing and annulus materials on logging results in completed wells, the single-detector neutron log is run with the probe decentralized and free to move within and lie against the side of a casing that is not precisely plumb. Log units are counts per second. Typically, the response of the single-detector neutron log to fully saturated materials is less than about 2,000 cps, the response to partially saturated materials is about 2,000 to 3,500 cps, and the response to relatively dry materials is more than about 3,500 cps. Neutron logs in saturated formations respond to the total of effective (drainable) and noneffective (nondrainable and often containing geochemically bound water) porosity.

In completed wells SC–6A, SC–7A, and SC–8A, the conditions in the annulus between the 4-in. PVC casing and the 9-in. diameter boreholes inside the casing and the annulus at the time of logging were not representative of the undisturbed aquifer material beyond the borehole, and these disturbed conditions substantially affected the neutron counts in the saturated zone. Above the water table, however, the results of neutron logging provided some measure of the degree of saturation of the aquifer materials.

In well SC–6A, the gamma count decreased, the resistivity increased, and the neutron count was unusually high (greater than 4,000 cps) between top of the sand pack in the annulus at 122 ft and the top of the saturated zone, about 133 ft at the time logging was conducted (fig. 8*A*). The unusually high neutron count indicates that the deposits about 11 ft above the water table were dry. The lithologic log, however, indicates that the cuttings retrieved from this interval were wet (fig. 8*A*). This inconsistency between the lithologic log and the geophysical log interpretation indicates that the change in the

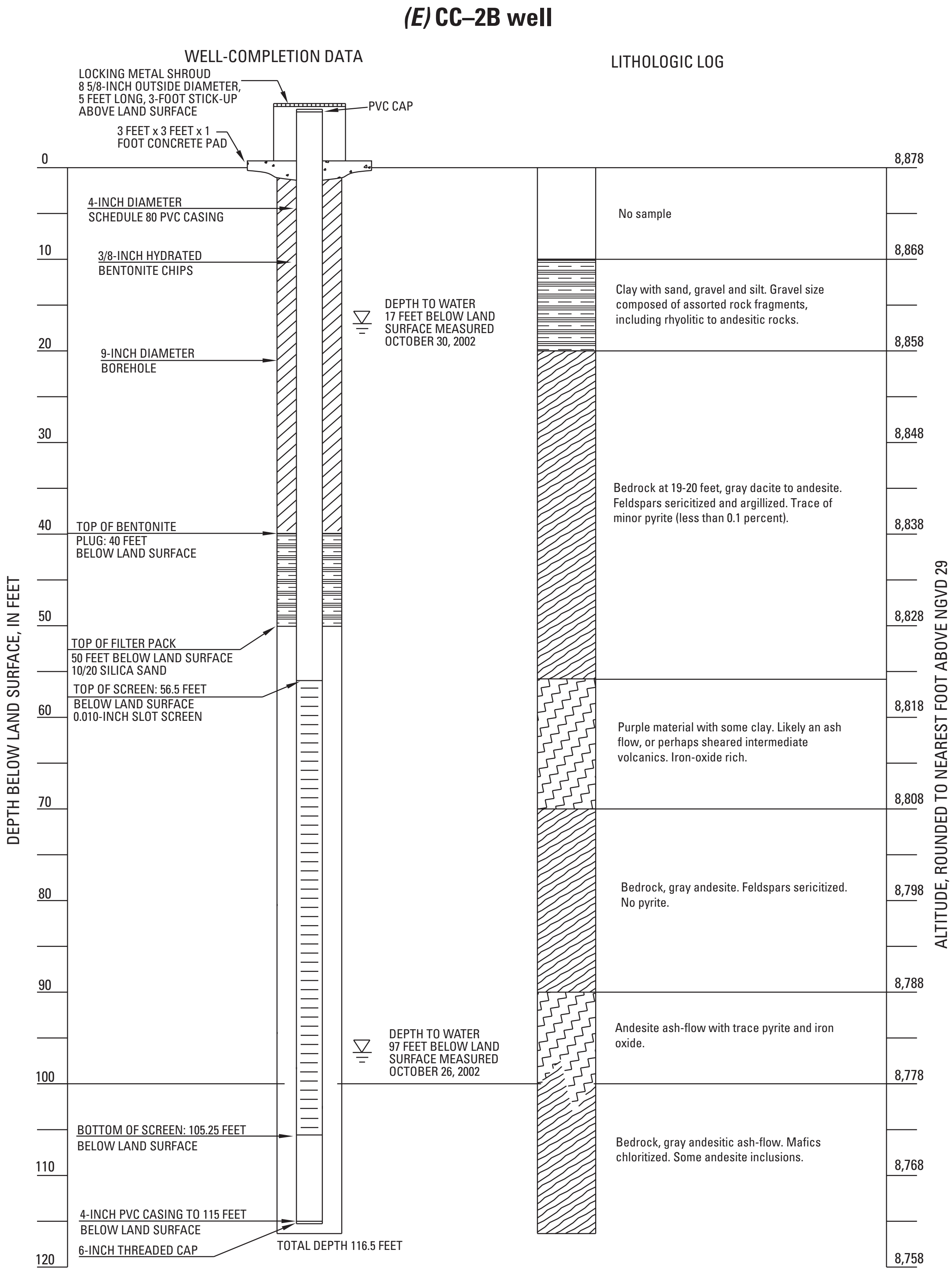


Figure 7*E*. Well-completion data and lithologic log for CC–2B well (modified from Souder, Miller, and Associates, 2003).

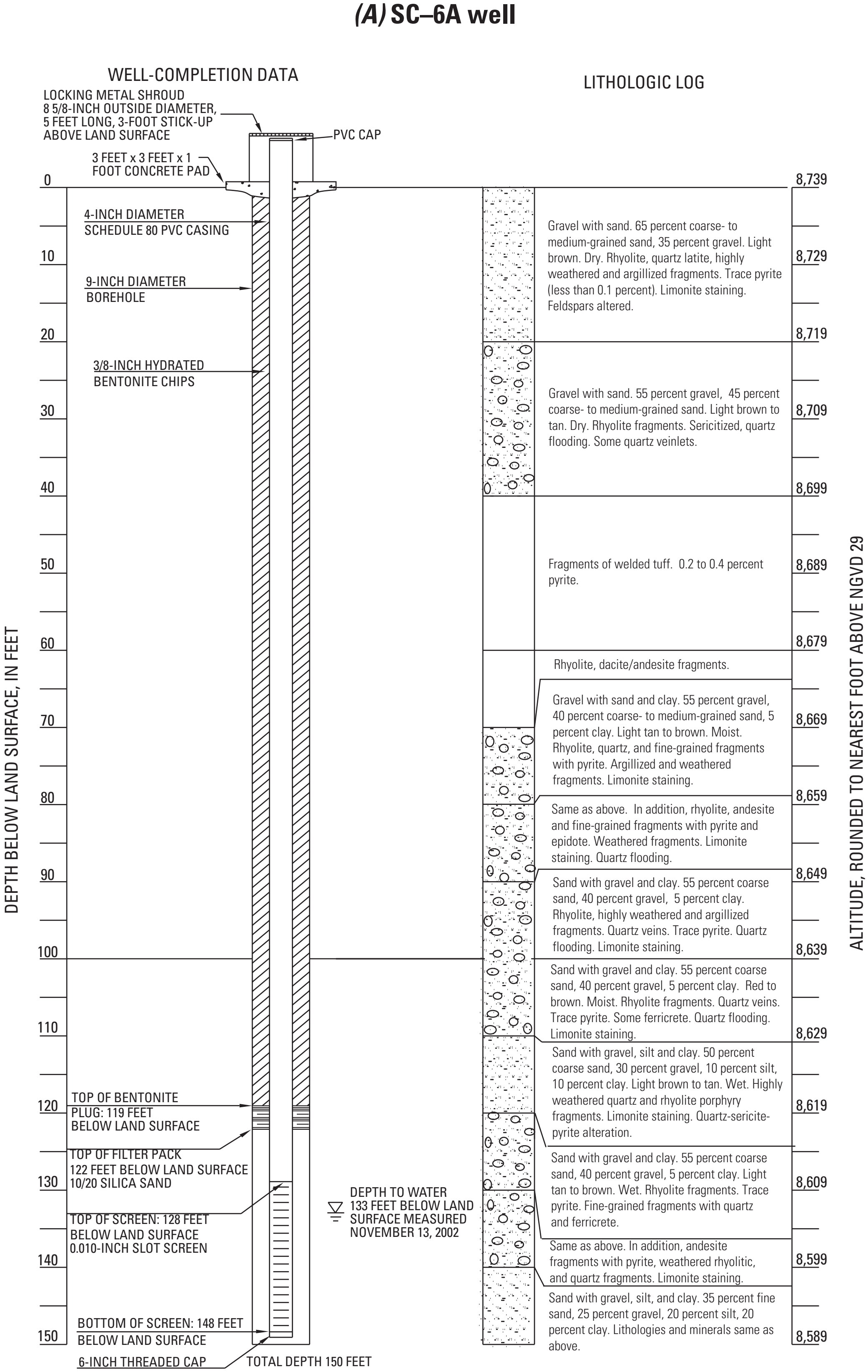


Figure 8*A*. Well-completion data, lithologic log, and geophysical log for SC–6A well. Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

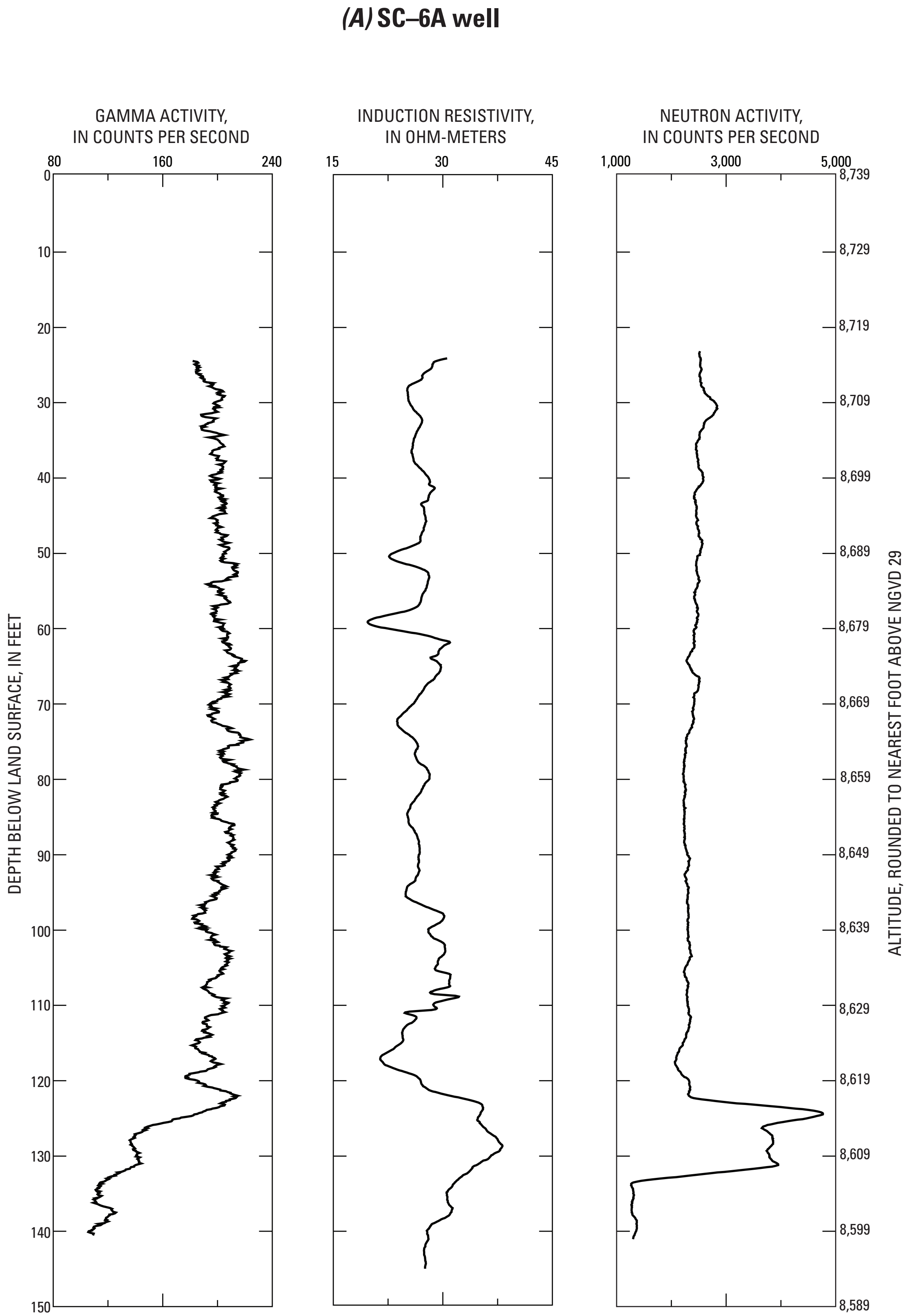


Figure 8*A*. Well-completion data, lithologic log, and geophysical log for SC–6A well.—Continued
Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

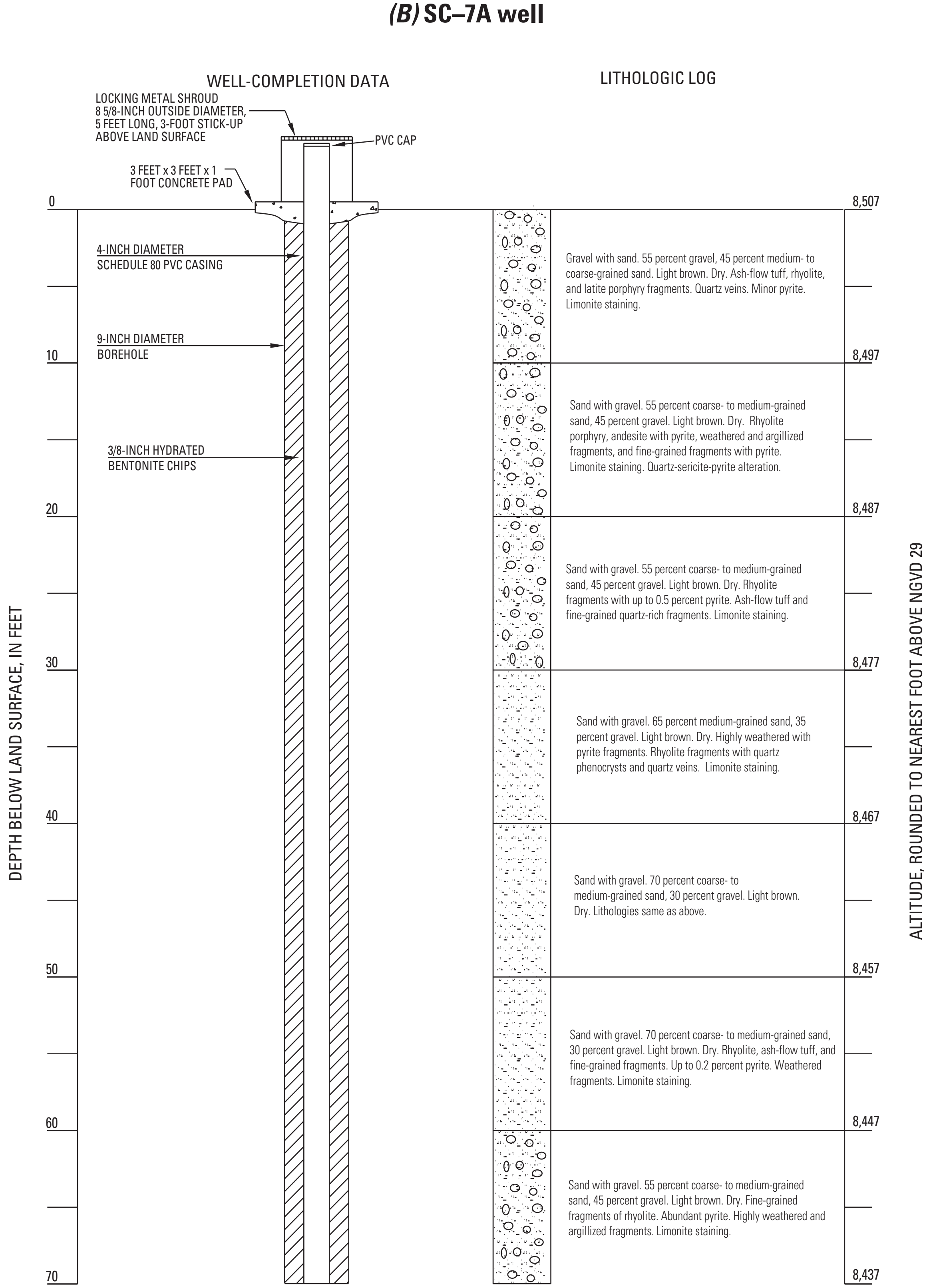


Figure 8*B*. Well-completion data, lithologic log, and geophysical logs for SC–7A well.—Continued
Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

(B) SC–7A well

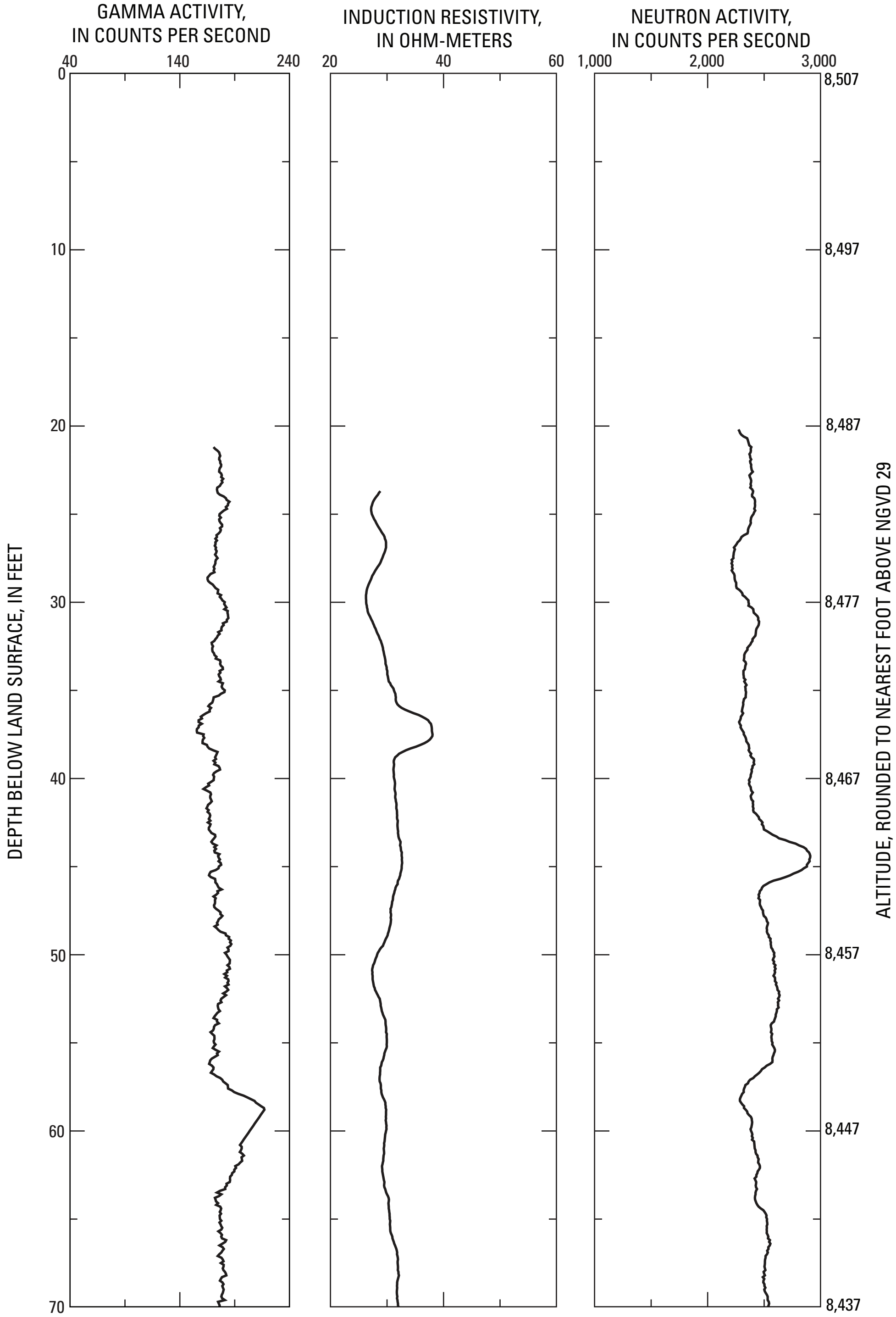


Figure 8*B*. Well-completion data, lithologic log, and geophysical logs for SC–7A well.—Continued
Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

(B) SC–7A well—Continued

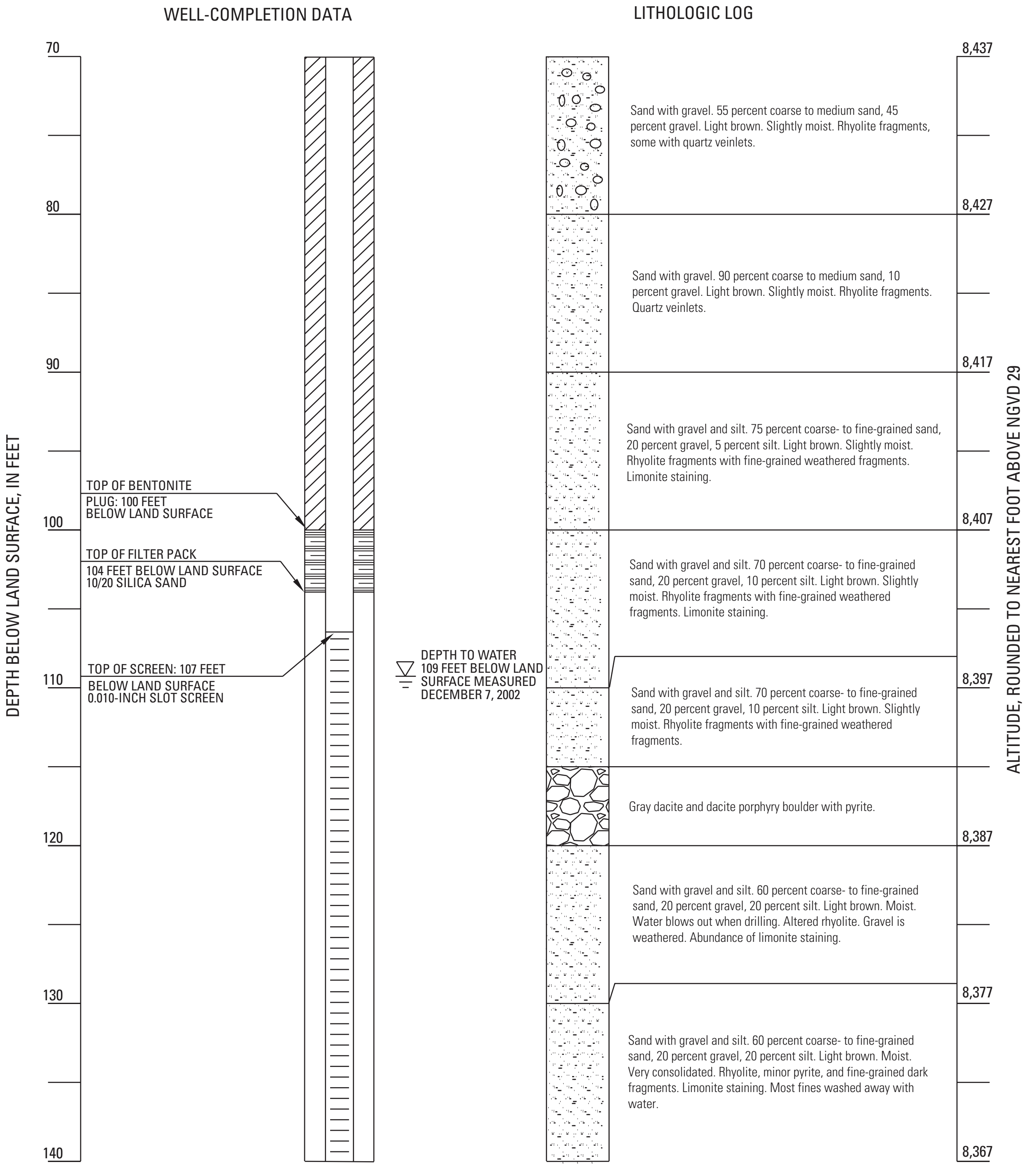


Figure 8*B*. Well-completion data, lithologic log, and geophysical logs for SC–7A well.—Continued
Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

(B) SC–7A well—Continued

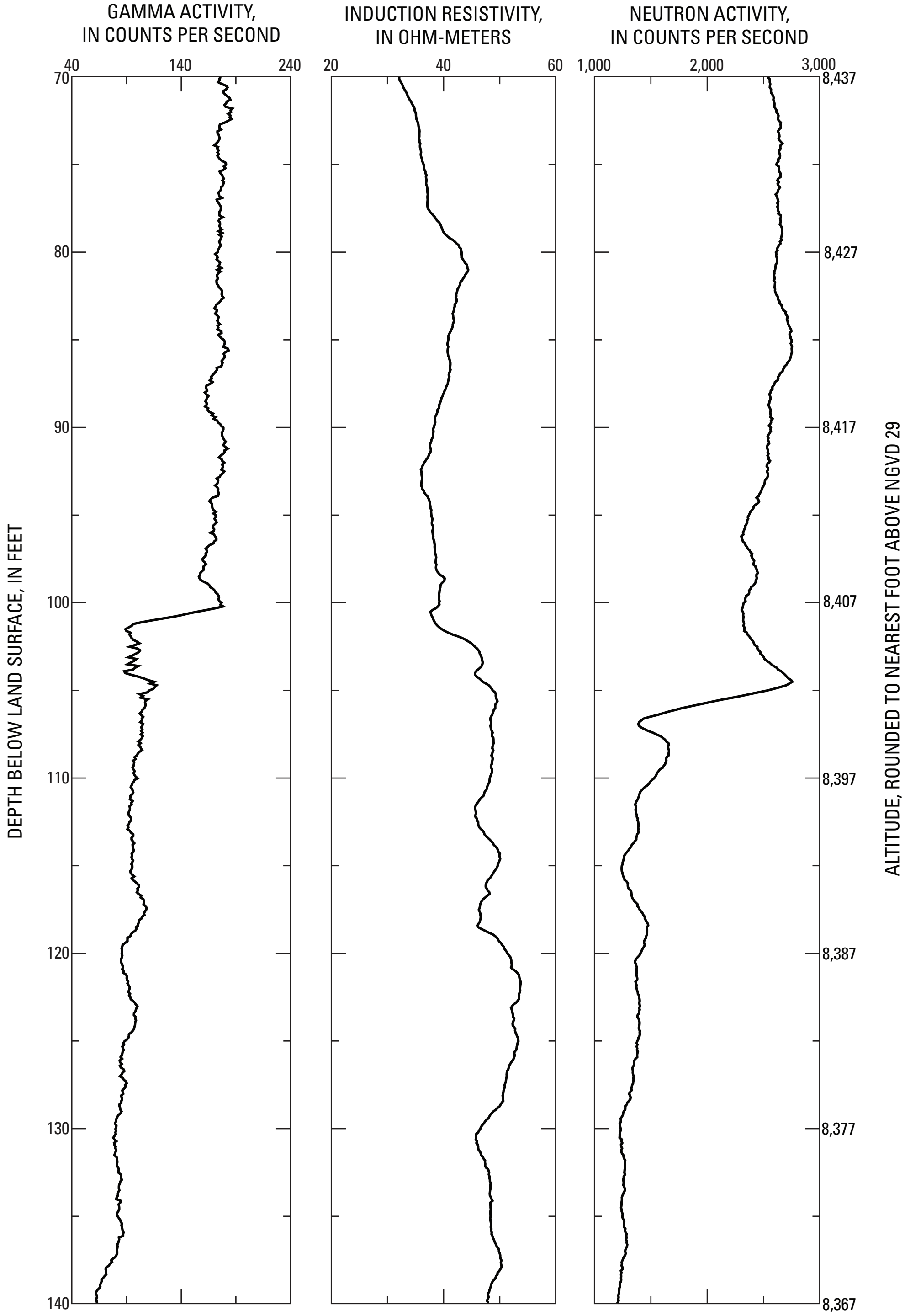


Figure 8*B*. Well-completion data, lithologic log, and geophysical logs for SC–7A well.—Continued
Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

(B) SC–7A well—Continued

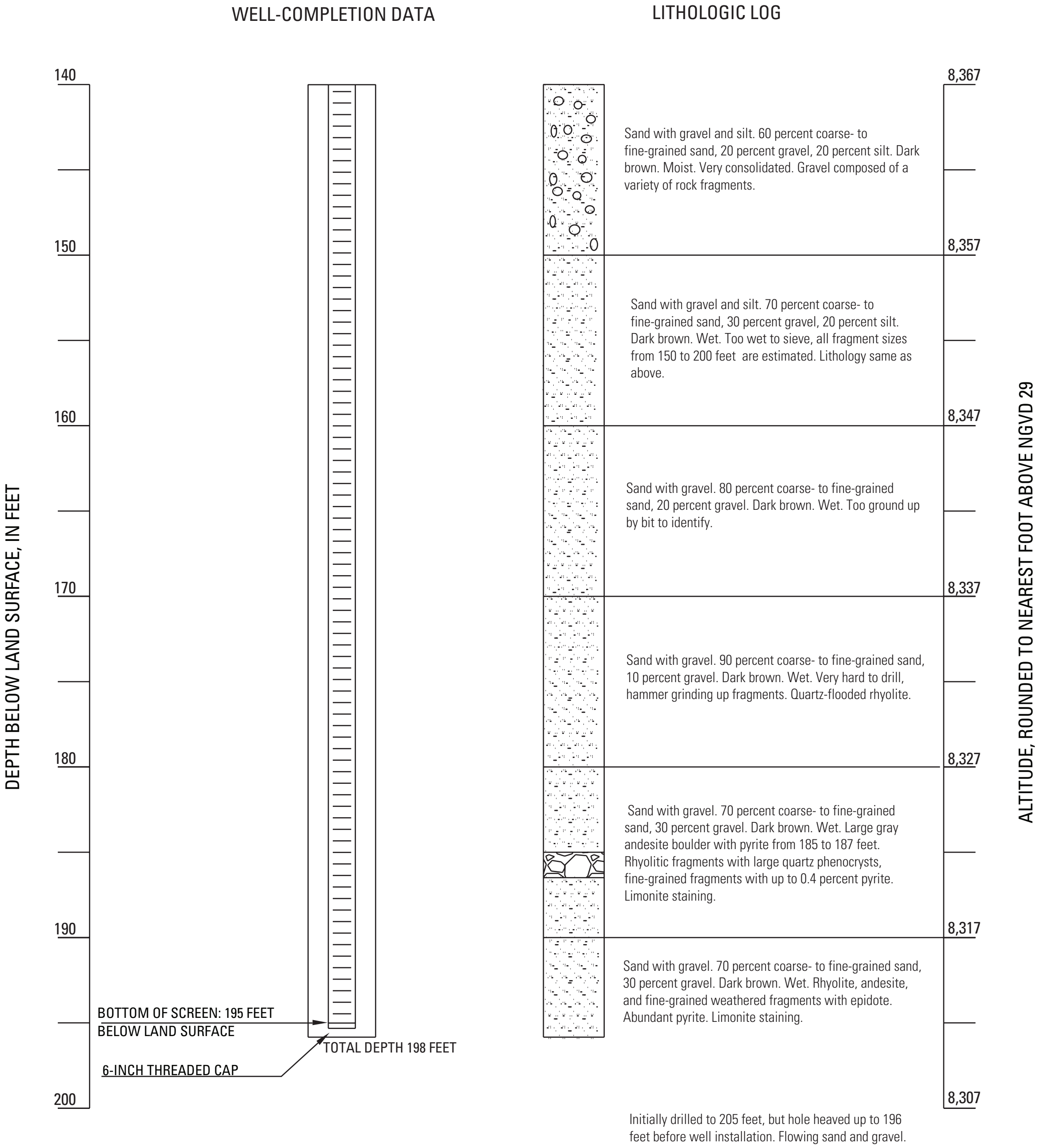


Figure 8*B*. Well-completion data, lithologic log, and geophysical logs for SC–7A well.—Continued
Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

(B) SC–7A well—Continued

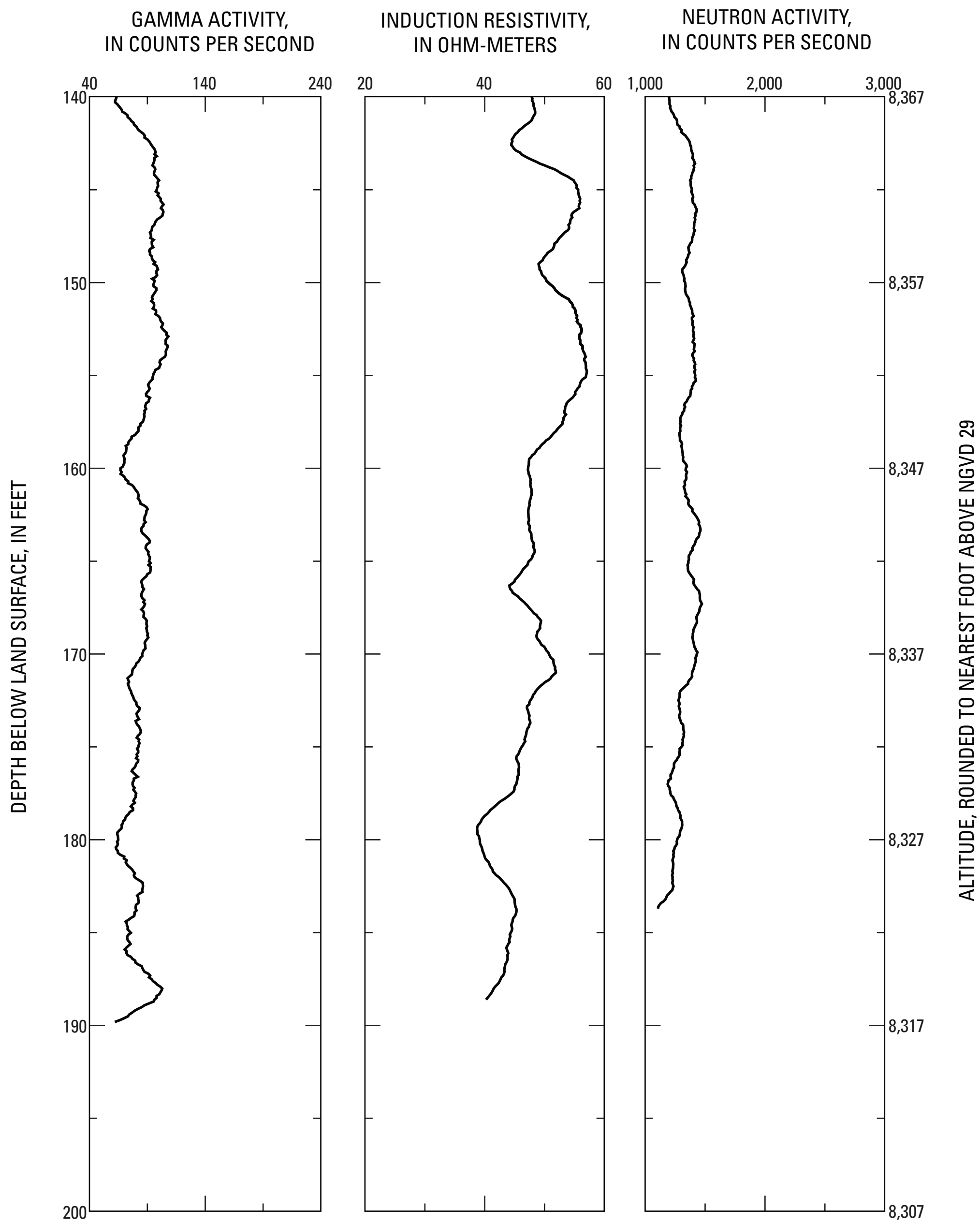


Figure 8*B*. Well-completion data, lithologic log, and geophysical logs for SC–7A well.—Continued
Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

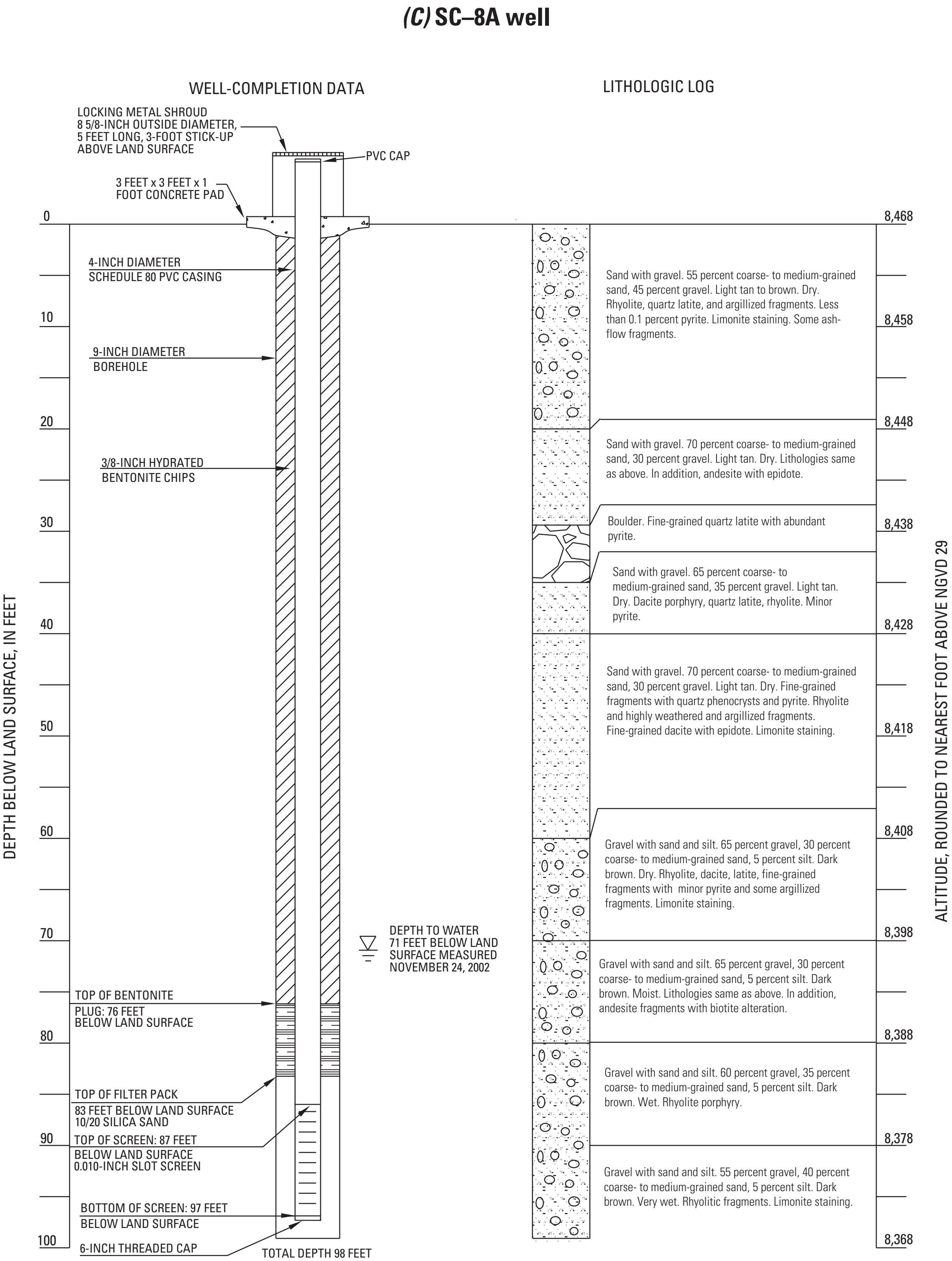


Figure 8*C*. Well-completion data, lithologic log, and geophysical logs for SC–8A well. Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

(C) SC–8A well

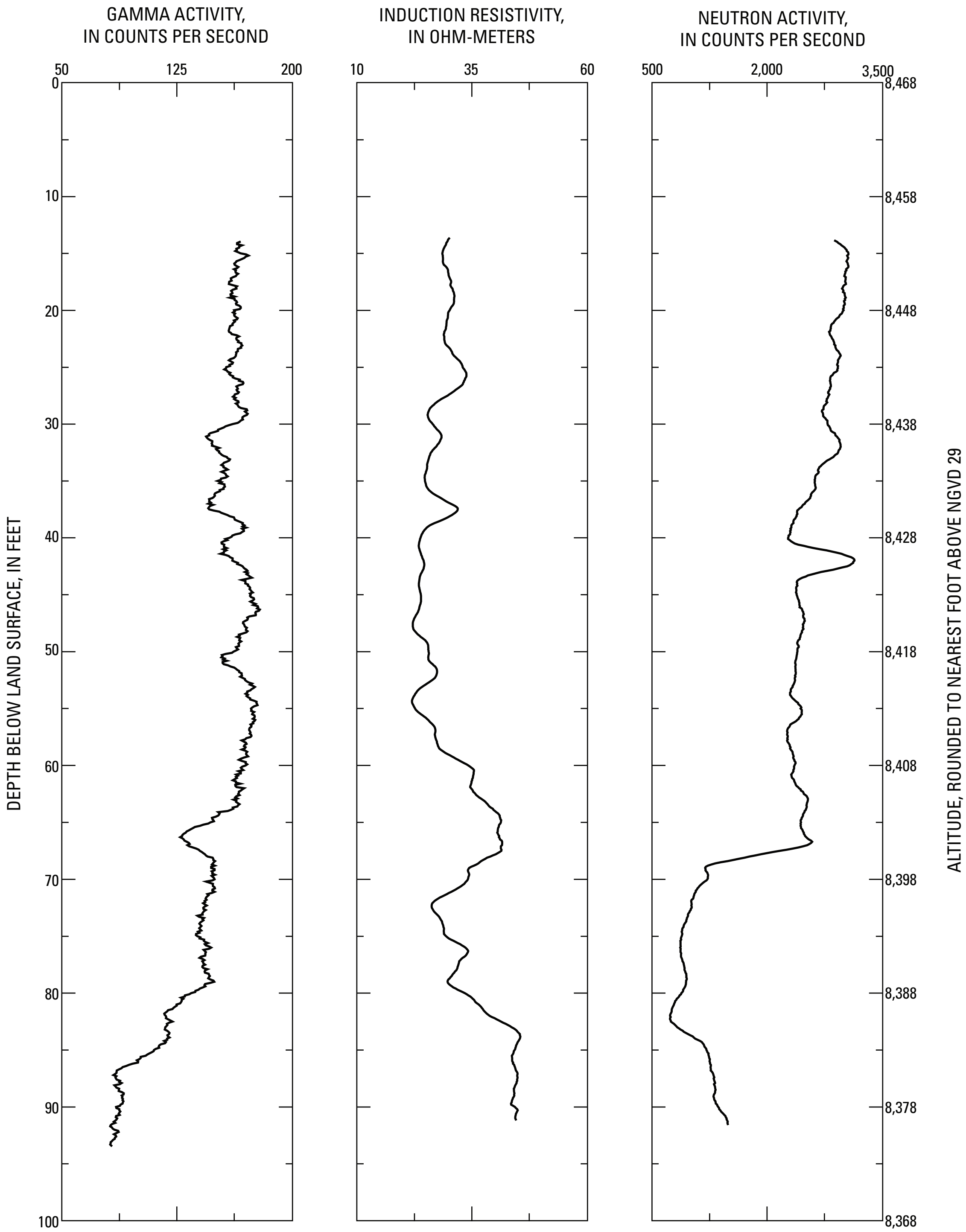


Figure 8*C*. Well-completion data, lithologic log, and geophysical logs for SC–8A well.—Continued
Well-completion data and lithologic log modified from Souder, Miller, and Associates (2003).

geophysical log may be related to geologic conditions rather than a lack of moisture.

In well SC–7A, resistivity measurements ranged from 30 to 40 ohm-meters, and neutron counts ranged from 2,000 to 3,000 cps from land surface to the water table, about 109 ft below land surface at the time logging was conducted. These values suggest that the deposits above the water table were dry to partially saturated (fig. 8*B*).

In well SC–8A, typical resistivity measurements of about 30 ohm-meters and typical neutron counts of about 2,000 to 3,000 cps above the water table, about 71 ft below land surface at the time logging was conducted, indicate that these deposits were partially saturated (fig. 8*C*) though the water content may not have been high enough to note on the lithologic log. A slight increase in resistivity and decrease in gamma activity from 60 to 69 ft corresponds to the presence of gravel-sized deposits described in the driller's log (fig. 8*C*). The increasing neutron count with depth in the screened interval (87.5 to 97 ft) indicates that porosity decreased with depth in this interval.

Hydraulic Testing to Determine Aquifer Characteristics

A flow-meter survey and several aquifer tests were conducted during 2003 to estimate the hydraulic properties of debris-flow deposits, bedrock, and Red River alluvial deposits in and near Straight Creek. A flow-meter survey was conducted in well SC–7A, slug tests were conducted in wells SC–1A, SC–1B, SC–2B, SC–3A, SC–3B, SC–4A, SC–5A, SC–5B, SC–6A, SC–7A, and SC–8A, and a pumping test was conducted at the mouth of the Straight Creek drainage in well AWWT–1. Wells AWWT–2, SC–5A, SC–5B, SC–7A and SC–8A were used to monitor ground-water levels during the pumping test.

Flow-Meter Survey in Well SC–7A

A flow-meter survey was conducted in well SC–7A on October 27, 2003, to determine the vertical distribution of flow to the well through the interval open to the aquifer. The SC–7A well screen extends from about 107 ft to about 195 ft below land surface and, at the time of the test, was entirely below the water level in the well.

Prior to the survey, a flow meter was lowered to about 150 ft, and a pump was lowered to about 10 ft below the static water level (about 114 ft below land surface). The well was pumped at a rate of 3.64 gal/min (gallons per minute); this pumping rate was constant throughout the test. Drawdown in the well reached steady state at 0.07 ft below the static water level. The flow meter was raised and lowered incrementally in the well to measure the vertical distribution of flow produced by the pumping. The flow rates indicated the relative contribution of water to the well from each increment (fig. 9).

Results of the flow-meter survey indicated that nearly all water entered well SC–7A from two zones—one approximately 10-ft-thick zone near the top of the screened interval (107–117 ft below land surface) and one approximately 15-ft-thick zone near the bottom of the screened interval (177–192 ft below land surface). About 77 percent of the water entered the well through the upper zone, and about 23 percent of the water entered the well through the lower zone (fig. 9); less than 1 percent of the water entered the well between these two zones. The lithologic log of well SC–7A (fig. 8*B*) indicates that boulders were present within both of these zones.

Slug Tests Conducted in Selected Phase I and II Drilled Wells

Slug tests were performed in wells SC–1A, SC–1B, SC–2B, SC–3A, SC–3B, SC–4A, SC–5A, SC–5B, SC–6A, SC–7A, and SC–8A during June 3–5, 2003. Water-level data were recorded during each slug test using a submersible pressure transducer connected to a data logger. The data logger was programmed to collect data in the early stages of slug tests at a rate of once every 0.125 second, and in the later stages of slug tests at a rate of once every 5 seconds. Water in the wells was displaced (raised or lowered) by means of a slug, a sealed 2-in. outside diameter, 5.5-ft long, schedule 80 PVC pipe filled with sand. Slug tests were performed using both slug-in and slug-out techniques.

The slug-in test procedure was as follows. The static water level in the well was measured using an electric tape shortly before introduction of the slug. The slug was lowered to just above the static water level in the well. Then, data logger recording was initiated shortly before the slug was rapidly and completely submerged below the static water level in the well.

The slug-out procedure, usually done following a slug-in test, was as follows. The water level in the well was measured using an electric tape to determine if the water level had returned to the static level, and then data logger recording was initiated shortly before the slug was rapidly and completely removed from the well.

All slug-test data except that from wells SC–7A and SC–8A were analyzed using the method of Bouwer and Rice (1976) as implemented in the AQTESOLV computer program (Duffield, 2000). Water levels in wells SC–7A and SC–8A exhibited oscillatory behavior (oscillations from above to below the static water level) during slug tests and, therefore, were analyzed using the method of van der Kamp (1976) as implemented in the van der Kamp spreadsheet developed by Halford and Kuniansky (2002). The van der Kamp (1976) method assumes that the well screen fully penetrates the saturated aquifer—a condition met for well SC–7A but not for well SC–8A. Thus, an estimated range of likely hydraulic-conductivity values is reported for well SC–8A. Analytical

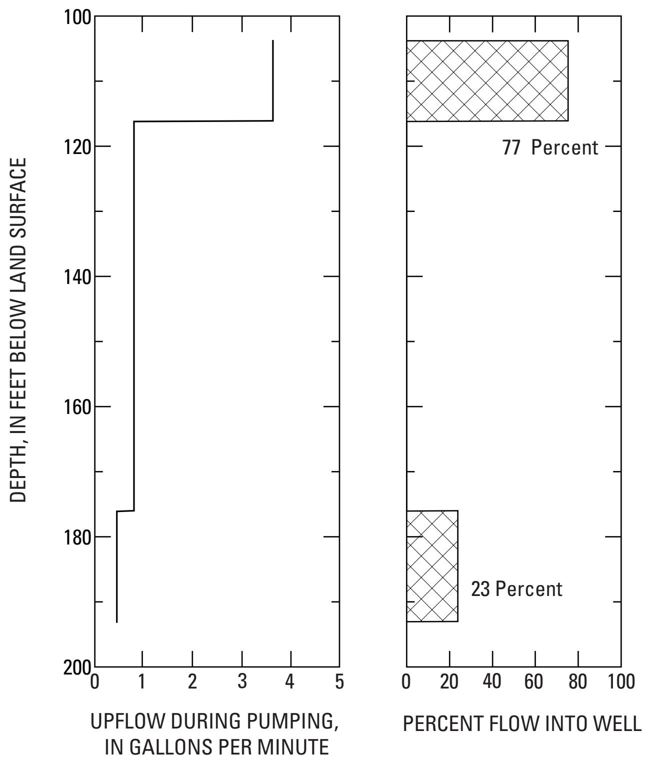


Figure 9. Vertical distribution of borehole flow measured during pumping and corresponding percentage of flow into well SC-7A.

solutions within both the AQTESOLV program and the van der Kamp spreadsheet were obtained by manually fitting straight-line segments to the data.

Because of the limited radius of investigation of a slug test (Halford and Kuniansky, 2002), the aquifer interval contributing water during a slug test was assumed to be the aquifer interval adjacent to the well screen. During installation, the SC–1A, SC–3A, SC–4A, SC–5A, and SC–6A well screens were placed primarily in Straight Creek debris-flow deposits, but some of these screens also penetrated bedrock. For consistency, hydraulic-conductivity values were estimated for that part of the each well's screen that was in debris-flow deposits. Hydraulic-conductivity values were estimated for a vertical-to-horizontal hydraulic-conductivity ratio of 0.01.

On the basis of the above variables, hydraulic-conductivity values were estimated for the wells (table 2). For the wells with screens in debris-flow deposits (wells SC–1A, SC–3A, SC–4A, and SC–6A), the mean and median estimated hydraulic conductivities were 15.25 and 15.35 ft/d (feet per day), respectively. For the wells with screens in bedrock (wells SC–1B, SC–2B, SC–3B, and SC–5B), the mean and median estimated hydraulic conductivities were 0.12 and 0.08 ft/d, respectively (table 2). For the wells with screens in mixed debris-flow deposits and Red River alluvium (wells SC–5A, SC–7A, and SC–8A), the mean and median estimated hydraulic conductivities were 73–207 (estimated range) and 80 ft/d. Although there is some overlap of the estimated hydraulic-conductivity values between the groups of wells, the mean and median values indicate that, in general, bedrock has the smallest hydraulic conductivity, debris-flow deposits have the next highest hydraulic conductivity, and mixed debris-flow deposits and Red River alluvium have the largest hydraulic conductivity.

Variations in hydraulic conductivity over short distances, such as between wells SC–3A, SC–4A, and SC–6A, are an indication of the heterogeneity of the debris-flow deposits. The variations in estimated hydraulic conductivity are consistent with field observations along Straight Creek such as the debris-flow deposits consist of massive beds with discontinuous layers of poorly sorted clay- to boulder-size material that may be interlayered with thin beds, generally less than a foot thick, of well-sorted sand and gravel. Thus, wells separated by short distances can exhibit very different hydraulic properties.

It is interesting to note that for the wells with screens in mixed debris-flow deposits and Red River alluvium, the largest hydraulic conductivity was estimated for the well (SC–8A)

Table 2. Estimated hydraulic-conductivity values for slug tests conducted June 3–5, 2003, for selected wells in Red River Valley, north-central New Mexico.

[e, estimated value—actual value probably is within the indicated range. The actual value is uncertain because the well screen did not fully penetrate the aquifer as assumed by the van der Kamp (1976) method]

Hydraulic conductivity, in feet per day					
Wells completed in debris-flow deposits					
SC–1A	SC–3A	SC–4A	SC–6A	Mean	Median
0.7	0.3	30	30	15.25	15.35
Wells completed in bedrock					
SC–1B	SC–2B	SC–3B	SC–5B	Mean	Median
0.06	0.1	0.005	0.3	0.12	0.08
Wells completed in mixed Red River alluvium and debris-flow deposits					
SC–5A	SC–7A	SC–8A		Mean	Median
40	80	e 100–500		e 73–207	80

closest to the axis of the Red River Valley. This may be an indication that debris-flow deposits near the central part of the Red River Valley (or farther away from the source of debris-flow material) are more likely to be reworked and sorted into hydraulically transmissive alluvial deposits than are the debris-flow deposits near margins of the valley.

Pumping Test Conducted at Mouth of Straight Creek Drainage

A pumping test was conducted to estimate the hydraulic properties of mixed debris-flow deposits and Red River alluvium at the mouth of the Straight Creek drainage. The aquifer test was conducted December 3–4, 2003, using well AWWT–1 as the pumped well, and wells AWWT–2, SC–5A, SC–5B, SC–7A, and SC–8A as observation wells. Well AWWT–2 is completed in bedrock that is horizontally adjacent to mixed debris flow and Red River alluvium, but water levels in the well did not show a measurable response to pumping (discussed later in this report); therefore, it was not used in the aquifer-test analysis. Well SC–5B is completed in bedrock; wells AWWT–1, SC–5A, SC–7A, and SC–8A are completed in mixed debris-flow deposits and Red River alluvium.

The pumping test was conducted as follows. Pressure transducers were installed in wells AWWT–1, AWWT–2, SC–7A, and SC–8A on November 22, 2003, to allow for measurement of pre-pumping water-level trends. Wells SC–5A and SC–5B had been equipped previously with pressure transducers. During the week of December 1, 2003, a submersible pump was installed in well AWWT–1. Pumping for the aquifer test began at 2:05 p.m. on December 3, 2003. The pumping rate was monitored using a totalizing flow meter located near the well head. The measured pumping rate ranged from 104.5 to 108.6 gal/min with a time-weighted average of 106 gal/min. The water from well AWWT–1 was pumped into a nearby unused sewage lagoon. Water levels measured by pressure transducers in the pumped well and in the observation wells were recorded by a data logger eight times per second for the first minute of the test, once a second for the next 9 minutes, and then the recording interval was increased over time to a maximum of 15 minutes. Barometric pressure also was recorded prior to and during the pumping test for use in correcting the water-level data for changes in barometric pressure.

Pre-pumping monitoring indicated that water levels were rising in all of the pumping-test wells from late November to about December 2, 2003, (fig. 10*A*). Water levels stopped rising on December 3, just prior to initiation of the pumping test, and began falling after initiation of pumping. Pre-pumping monitoring indicated that water-level variations in well AWWT–2 closely followed variations in barometric pressure and that the water-level variations caused by barometric-pressure changes masked any observable water-level change caused by pumping well AWWT–1 (fig. 10*B*). Other wells did not show a discernable relation between water-level and barometric-pressure changes.

The change in water-level trends just prior to initiation of the pumping test makes the corrections in drawdown measured during the test difficult for all but the pumping well. The drawdown in the pumping well was relatively large compared with the water-level-trend changes. But, drawdowns measured in the observation wells were relatively small compared to the changing water-level trends. Pre- and post-test water levels from wells AWWT–1, SC–5A, SC–5B, and SC–7A were used to correct for water-level trends not attributed to the test pumping. However, because of the changing trends in background water levels, corrected drawdown from the early part of the test was considered more reliable than corrected drawdown from the later part of the test. Therefore, the early part of the test was used in the test analysis.

Analysis of the pumping test water-level data from wells SC–5A and SC–7A using standard curve-matching techniques and type curves for non-steady radial flow (Theis, 1935) indicated that estimated transmissivity was 12,000 to 34,000 ft^2/d (feet squared per day), and estimated hydraulic conductivity was 230 to 340 ft/d (table 3). Pumping-test data from wells AWWT–2 and SC–8A were not analyzed because the water levels in these wells did not visibly respond to pumping. Data from well AWWT–1 was not analyzed because most of the drawdown in the well probably resulted from hydraulic head losses that occurred as ground-water flowed in through the well screen. The water-level response to pumping in well SC–5B was judged to be a pressure response and an indication of hydraulic connection between bedrock and the overlying mixed debris-flow deposits and Red River alluvium.

Water-Level Measurements

Periodic manual water-level measurements were made at each observation well using a steel or electric tape. Measurements were recorded to the nearest 0.01 ft and were repeated until the precision was within 0.02 ft.

Hydrographs of manually measured water-level altitudes in Phase II wells, except well SC-9A, are shown in figures 11–13. Streamflow and stage in the Red River also are shown in figure 11. The hydrographs of water levels in the Capulin Canyon wells (fig. 13) include measurements made by the USGS and the measurements made by URS, Denver, Colorado, a private consultant contracted by Molycorp.

The land-surface altitude was used to establish a datum for each observation well. A permanent measuring point for water-level measurement was established at each well, and the distance of this measuring point above land surface was determined. Description and distance above land surface of measuring points for Phase I and II wells are listed in table 4. Ground-water altitudes in observation wells were calculated by subtracting the depth to water below the permanent measuring point, minus the height of the permanent measur-

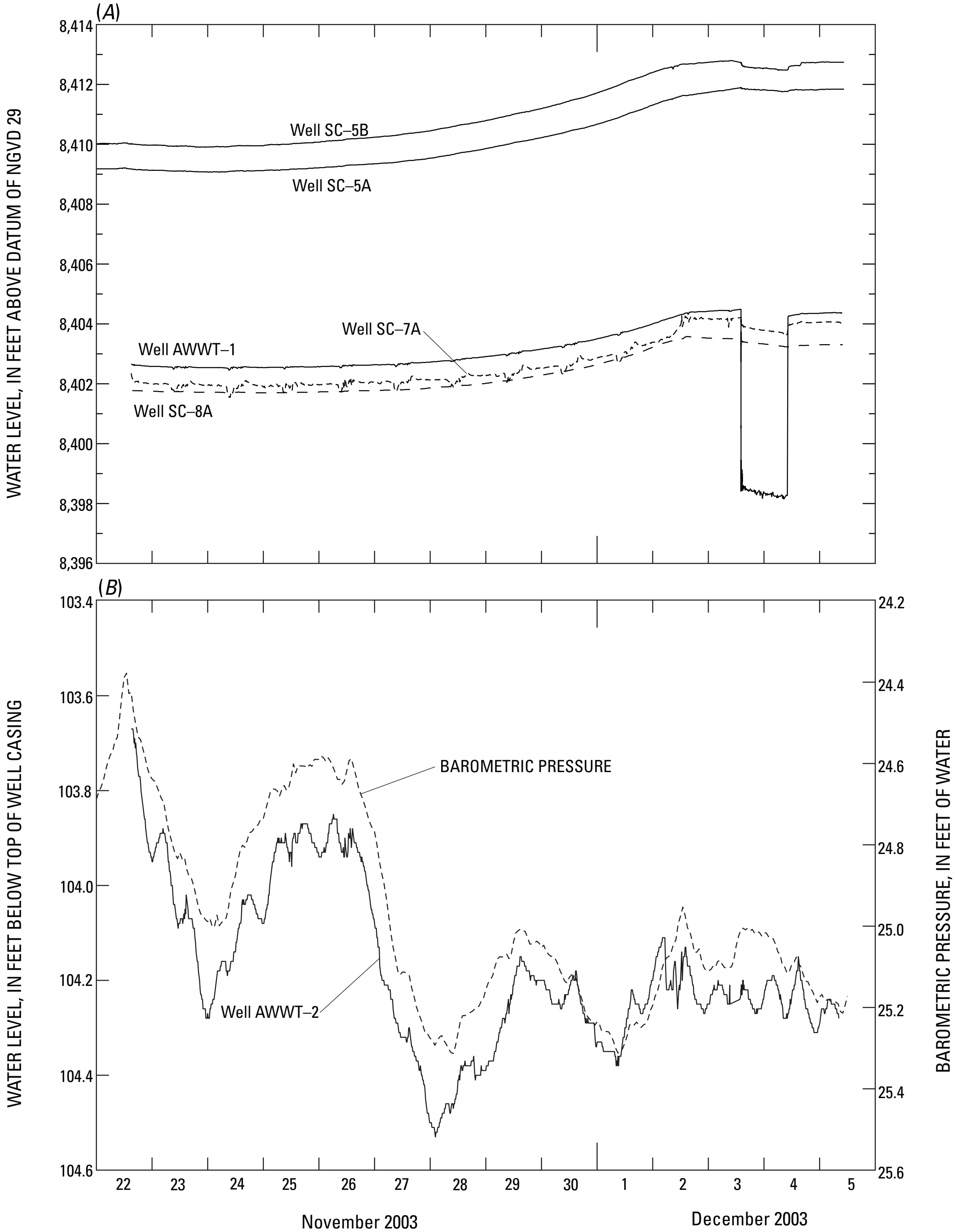


Figure 10. *(A)* Water levels in wells AWWT–1, SC–5A, SC–5B, SC–7A, and SC–8A before, during, and after pumping test and *(B)* comparison of water levels in well AWWT–2 to barometric pressure, November 22–December 5, 2003.

Table 3. Results of pumping test conducted December 3–4, 2003, in selected wells in Red River Valley, north-central New Mexico.

Well (fig. 3)	Estimated transmissivity (feet squared per day)	Estimated saturated thickness (feet)	Estimated hydraulic conductivity (feet per day)
SC–5A	12,000	52	230
SC–7A	34,000	99	340

ing point above land surface, from the land-surface altitude. Water-level altitudes for Phase I and II wells are listed in table 4. Water levels in Phase I wells included in table 4 have not been previously published. Naus and others (2005) discuss water levels measured in Phase I wells during 2002 and 2003.

Water levels in the Phase II drilled wells SC–6A, SC–7A, SC–8A, and the Hottentot, Hansen, and La Bobita wells typically rose rapidly during the melting of the winter snowpack in the springtime and then generally declined during the rest of the year. The Red River streamflow hydrograph (fig. 11*A*) indicates that most meltwater from the winter snowpack entered the river during April and May. Water levels in these wells were measured periodically and, therefore, may not coincide precisely with the beginning and ending of water-level rises in response to spring snowmelt. The duration of water-level rise, however, appears to be typically about 2 months, after which a slow water-level decline occurs during the following 10 months.

Wells SC–6A, SC–7A and SC–8A are completed in unconsolidated deposits; well SC6–A is completed in debris-flow deposits, and wells SC–7A and SC–8A are most likely completed in mixed debris-flow deposits and Red River alluvium. Wells SC–6A, SC–7A, and SC–8A are about 2,200, 400, and 100 ft north of the Red River, respectively.

In the Straight Creek drainage, the water-level rise in response to spring snowmelt occurred earlier and was smaller at greater distances from the Red River. The water level in well SC–6A rose 1.88 ft between February 7 and April 15, 2003, and 1.85 ft between February 20 and May 12, 2004 (fig. 11*B*); water levels in wells SC–7A and SC–8A rose 13.71 and 13.02 ft between April 17 and June 5, 2003, and 14.00 and 13.56 ft between March 26 and June 1, 2004, respectively (figs. 11*C* and 11*D*). The springtime increases in water levels in wells SC7–A and SC–8A were about eight times larger than those in well SC-6A (fig. 11). The magnitude of subsequent water-level declines in wells SC–6A, SC–7A and SC–8A during the following approximately 10 months were similarly related to distance from the Red River (fig. 11). The water level in well SC–6A declined 1.73 ft during the approximately 10 months between April 15, 2003, and February 20, 2004; water levels in wells SC–7A and SC–8A declined 12.71 and 12.05 ft, respectively, during the approximately 10 months between June 5, 2003, and March 26, 2004.

Well SC–9A is about 7 ft from the north bank of the Red River and about 100 ft south of well SC–8A (fig. 3). This well was dry at the time of construction but subsequently contained water. Three water levels in well SC–9A measured on March 26, May 12, and June 1, 2004, ranged from 12.02 to 25.58 ft above concurrently measured water levels in well SC–8A. On May 12, 2004, the stage of the Red River was 31.5 ft above the water level in well SC–8A and 16.2 ft higher than the water level in well SC–9A. This substantially higher stage in the Red River compared with water levels in wells SC–8A and SC–9A, and the absence of water in well SC–9A and nearby holes at the time of completion of well SC–9A, indicate that the Red River had a poor hydraulic connection to the underlying ground-water system and the surface-water system is perched above the ground-water system at this site.

The Hottentot well, completed in debris-flow deposits, is about 1,700 ft north of the Red River and about 0.75 mi upstream (east) from Straight Creek. The water level in the Hottentot well rose 1.69 ft between February 5 and May 12, 2003, and 2.80 ft between March 26 and May 12, 2004 (fig. 12*A*). The water level declined 0.77 ft during the approximately 10 months between May 12, 2003, and March 26, 2004.

The Hansen well is completed in debris-flow deposits and is about 1,500 ft north of the Red River and about 0.75 mi downstream (west) from Straight Creek. The water level in the Hansen well rose 3.96 ft between February 5 and April 17, 2003, and 2.83 ft between February 20 and May 11, 2004 (fig. 12*B*). The water level declined 3.79 ft during the approximately 10 months between measurements on April 17, 2003, and February 20, 2004.

The La Bobita well is completed in unconsolidated deposits not associated with debris-flow deposits. The well is about 600 ft northwest of the Red River and about 2 mi downstream (west) from Straight Creek. The water level in the La Bobita well rose 5.49 ft between February 7 and May 15, 2003, and 4.68 ft between March 26 and May 13, 2004 (fig. 12*C*). The water level declined 4.57 ft during the approximately 10 months between measurements on May 15, 2003, and March 26, 2004.

Wells in Capulin Canyon are about 1 mi northeast of the Red River. Wells CC–1A and CC–2A are completed in Capulin Canyon alluvium, well CC–1B is completed in bedrock or overlying regolith, and well CC–2B is completed in bedrock. The hydrographs for each of these four wells are similar (fig. 13). A seasonal high in water level occurs during spring snowmelt in April or May 2003, a seasonal low in July 2003, and then a second seasonal high in September 2003. The spring seasonal high occurs again in April 2004. The range in water levels at wells CC–1A and CC–2A (completed in alluvium) were about 1.8 times the range in wells CC–1B and CC–2B (completed in regolith or bedrock), respectively (fig. 13).

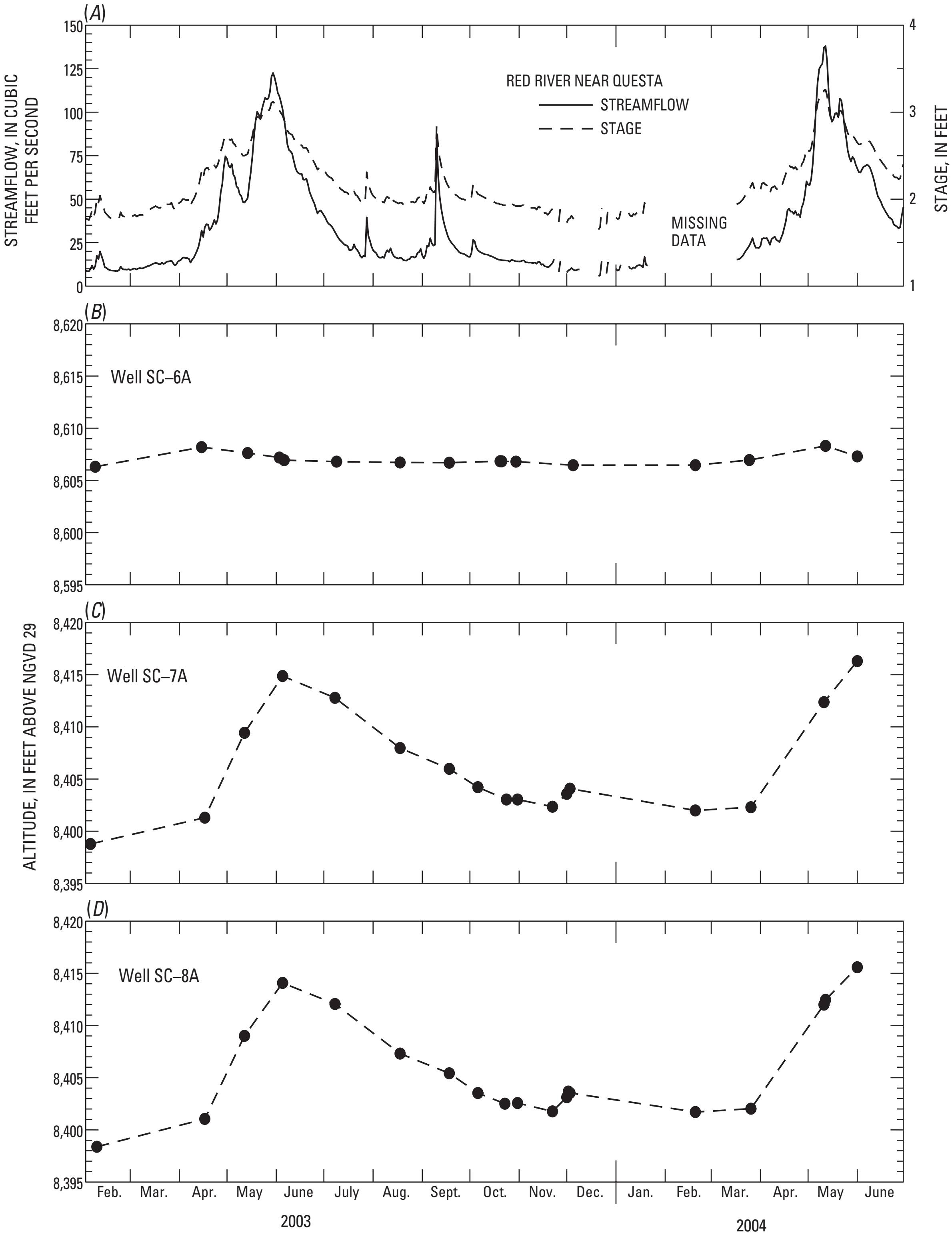


Figure 11. *(A)* Daily mean streamflow and stage of the Red River near Questa and *(B–D)* ground-water altitudes in wells SC–6A, SC–7A, and SC–8A, February 2003–June 2004.

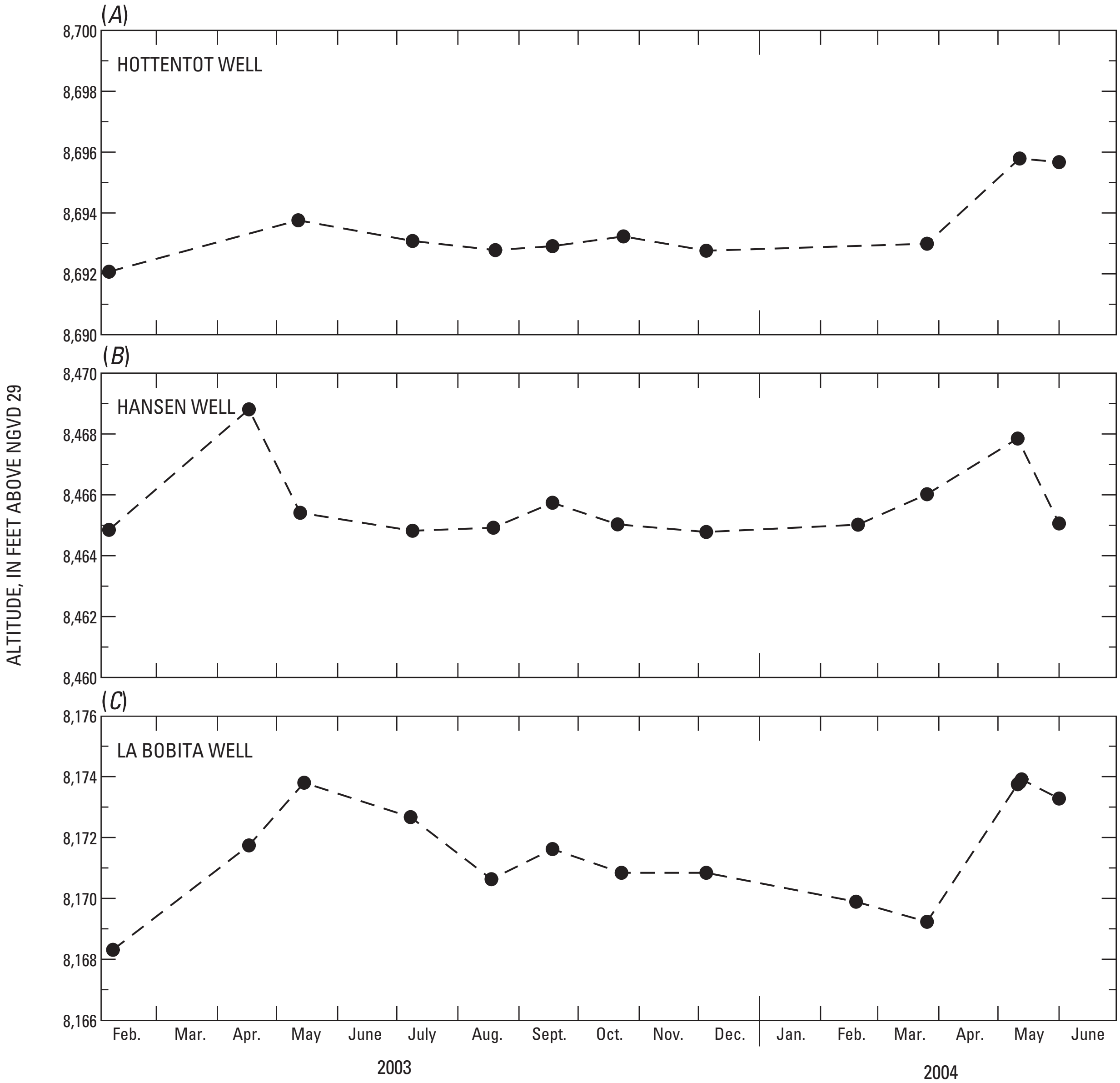


Figure 12. Ground-water altitudes in *(A)* Hottentot, *(B)* Hansen, and *(C)* La Bobita wells, February 2003–June 2004.

Phase III wells were installed in unconsolidated material along an approximately 1-mi reach of the Red River west of Elephant Rock campground (figs. 1 and 4). These wells were installed to examine the interaction of the Red River and water in the Red River alluvium. Water levels in these wells were measured in December 2003 and in February, March, May, and June 2004. The difference in altitude between the water level in these wells and the stage of the Red River also was determined from survey data collected in May and June 2004. Water-level altitudes in the Phase II La Bobita well and all Phase III wells and altitude of the stage of the Red River are listed in table 5; a comparison of water levels in the La Bobita well and Phase III wells with the stage of the Red River is shown in figure 14.

Well 1 was installed about 150 ft downstream (west) from a line approximately perpendicular to the Red River and connecting to the La Bobita well (fig. 4). Water levels measured in May and June 2004 in the La Bobita well ranged from 2.95 to 3.52 ft higher than concurrently measured water levels in well 1 (fig. 14, table 5). Considering the locations of these two wells, the relative water levels indicate that ground water is flowing toward the Red River. The stage of the Red River also was measured in May and June 2004 where a line approximately perpendicular to the bank of the river intersects the La Bobita well. Ground-water levels in the La Bobita well ranged from 7.1 to 6.7 ft lower and in well 1 ranged from 10.1 to 9.8 ft lower than the stage of the Red River (fig. 14, table 5). This indicates that, near these wells, the Red River is perched above the water table and may be disconnected from or have a poor hydraulic connection to the underlying ground water.

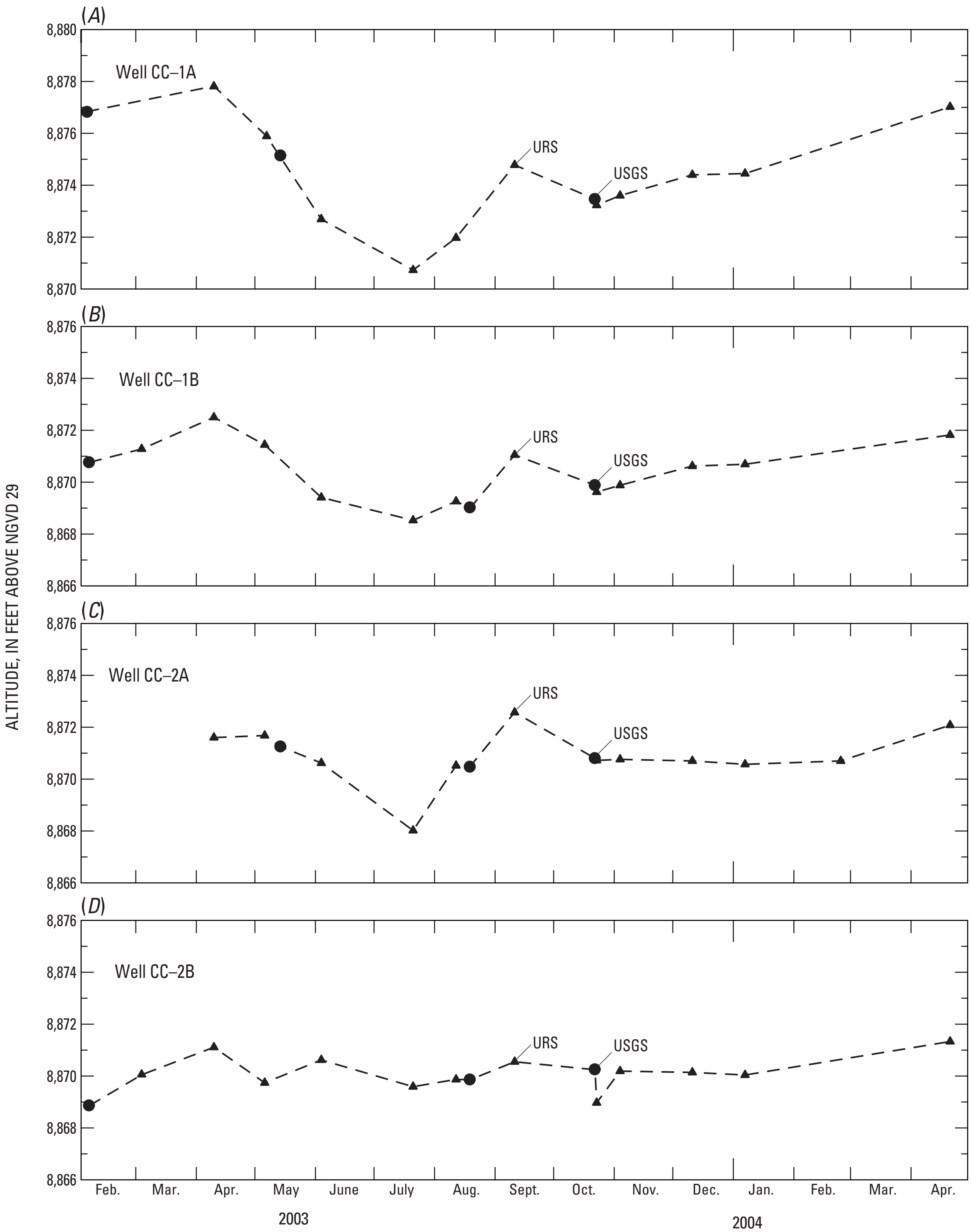


Figure 13. Ground-water altitudes in wells *(A)* CC–1A, *(B)* CC-1B, *(C)* CC–2A, and *(D)* CC–2B, February 2003–April 2004. Data collected by URS, Denver, Colorado, and U.S. Geological Survey (USGS) personnel.

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
				Phase I wells					
SC–1A	03/15/02	Top of casing	52.51	+0.12	52.39	2.88	49.51	8,904.44	8,854.94
SC–1A	03/18/02	Top of casing	52.51	+0.12	52.39	2.88	49.51	8,904.44	8,854.94
SC–1A	03/26/02	Access hole in cap	52.32	0.00	52.32	2.88	49.44	8,904.44	8,855.00
SC–1A	04/25/02	Access hole in cap	52.44	0.00	52.44	2.88	49.56	8,904.44	8,854.88
SC–1A	05/22/02	Access hole in cap	52.65	0.00	52.65	2.88	49.77	8,904.44	8,854.67
SC–1A	06/18/02	Access hole in cap	52.73	0.00	52.73	2.88	49.85	8,904.44	8,854.59
SC–1A	07/24/02	Access hole in cap	52.85	0.00	52.85	2.88	49.97	8,904.44	8,854.47
SC–1A	08/21/02	Access hole in cap	52.48	0.00	52.48	2.88	49.60	8,904.44	8,854.84
SC–1A	09/17/02	Access hole in cap	52.71	0.00	52.71	2.88	49.83	8,904.44	8,854.61
SC–1A	10/16/02	Access hole in cap	51.94	0.00	51.94	2.88	49.06	8,904.44	8,855.38
SC–1A	11/14/02	Access hole in cap	52.30	0.00	52.30	2.88	49.42	8,904.44	8,855.02
SC–1A	12/12/02	Access hole in cap	52.39	0.00	52.39	2.88	49.51	8,904.44	8,854.93
SC–1A	02/03/03	Access hole in cap	52.61	0.00	52.61	2.88	49.73	8,904.44	8,854.71
SC–1A	04/16/03	Access hole in cap	51.50	0.00	51.50	2.88	48.62	8,904.44	8,855.82
SC–1A	05/13/03	Access hole in cap	51.91	0.00	51.91	2.88	49.03	8,904.44	8,855.41
SC–1A	06/02/03	Access hole in cap	52.45	0.00	52.45	2.88	49.57	8,904.44	8,854.87
SC–1A	06/06/03	Access hole in cap	52.48	0.00	52.48	2.88	49.60	8,904.44	8,854.84
SC–1A	07/08/03	Access hole in cap	52.48	0.00	52.48	2.88	49.60	8,904.44	8,854.84
SC–1A	08/21/03	Access hole in cap	52.45	0.00	52.45	2.88	49.57	8,904.44	8,854.87
SC–1A	09/18/03	Access hole in cap	51.99	0.00	51.99	2.88	49.11	8,904.44	8,855.33
SC–1A	10/20/03	Access hole in cap	52.45	0.00	52.45	2.88	49.57	8,904.44	8,854.87
SC–1A	10/23/03	Access hole in cap	52.48	0.00	52.48	2.88	49.60	8,904.44	8,854.84
SC–1A	12/05/03	Access hole in cap	52.61	0.00	52.61	2.88	49.73	8,904.44	8,854.71
SC–1A	02/21/04	Access hole in cap	52.61	0.00	52.61	2.88	49.73	8,904.44	8,854.71
SC–1A	03/26/04	Access hole in cap	51.58	0.00	51.58	2.88	48.70	8,904.44	8,855.74
SC–1A	05/11/04	Access hole in cap	51.45	0.00	51.45	2.88	48.57	8,904.44	8,855.87
SC–1A	06/01/04	Access hole in cap	52.45	0.00	52.45	2.88	49.57	8,904.44	8,854.87
SC–1B	03/15/02	Top of casing	59.02	+0.12	58.90	3.15	55.75	8,901.88	8,846.13
SC–1B	03/18/02	Top of casing	59.01	+0.12	58.89	3.15	55.74	8,901.88	8,846.14
SC–1B	03/26/02	Access hole in cap	58.88	0.00	58.88	3.15	55.73	8,901.88	8,846.15

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
				Phase I wells—Continued					
SC–1B	04/25/02	Access hole in cap	59.00	0.00	59.00	3.15	55.85	8,901.88	8,846.03
SC–1B	05/22/02	Access hole in cap	59.12	0.00	59.12	3.15	55.97	8,901.88	8,845.91
SC–1B	06/18/02	Access hole in cap	59.66	0.00	59.66	3.15	56.51	8,901.88	8,845.37
SC–1B	07/24/02	Access hole in cap	59.29	0.00	59.29	3.15	56.14	8,901.88	8,845.74
SC–1B	08/21/02	Access hole in cap	59.00	0.00	59.00	3.15	55.85	8,901.88	8,846.03
SC–1B	09/17/02	Access hole in cap	59.25	0.00	59.25	3.15	56.10	8,901.88	8,845.78
SC–1B	10/16/02	Access hole in cap	58.37	0.00	58.37	3.15	55.22	8,901.88	8,846.66
SC–1B	11/14/02	Access hole in cap	58.78	0.00	58.78	3.15	55.63	8,901.88	8,846.25
SC–1B	12/12/02	Access hole in cap	58.83	0.00	58.83	3.15	55.68	8,901.88	8,846.20
SC–1B	02/03/03	Access hole in cap	58.87	0.00	58.87	3.15	55.72	8,901.88	8,846.16
SC–1B	04/16/03	Access hole in cap	57.38	0.00	57.38	3.15	54.23	8,901.88	8,847.65
SC–1B	05/13/03	Access hole in cap	58.09	0.00	58.09	3.15	54.94	8,901.88	8,846.94
SC–1B	06/02/03	Access hole in cap	58.63	0.00	58.63	3.15	55.48	8,901.88	8,846.40
SC–1B	06/06/03	Access hole in cap	58.60	0.00	58.60	3.15	55.45	8,901.88	8,846.43
SC–1B	07/08/03	Access hole in cap	58.54	0.00	58.54	3.15	55.39	8,901.88	8,846.49
SC–1B	08/21/03	Access hole in cap	58.58	0.00	58.58	3.15	55.43	8,901.88	8,846.45
SC–1B	09/18/03	Access hole in cap	57.99	0.00	57.99	3.15	54.84	8,901.88	8,847.04
SC–1B	10/20/03	Access hole in cap	58.34	0.00	58.34	3.15	55.19	8,901.88	8,846.69
SC–1B	12/05/03	Access hole in cap	58.49	0.00	58.49	3.15	55.34	8,901.88	8,846.54
SC–1B	02/21/04	Access hole in cap	58.42	0.00	58.42	3.15	55.27	8,901.88	8,846.61
SC–1B	03/26/04	Access hole in cap	57.53	0.00	57.53	3.15	54.38	8,901.88	8,847.50
SC–1B	05/11/04	Access hole in cap	57.11	0.00	57.11	3.15	53.96	8,901.88	8,847.92
SC–1B	06/01/04	Access hole in cap	58.03	0.00	58.03	3.15	54.88	8,901.88	8,847.00
SC–2B	03/15/02	Top of casing	70.95	+0.12	70.83	2.59	68.24	8,737.35	8,669.11
SC–2B	03/19/02	Top of casing	70.81	+0.12	70.69	2.59	68.09	8,737.35	8,669.26
SC–2B	03/25/02	Access hole in cap	70.66	0.00	70.66	2.59	68.07	8,737.35	8,669.28
SC–2B	04/25/02	Access hole in cap	71.05	0.00	71.05	2.59	68.46	8,737.35	8,668.89
SC–2B	05/23/02	Access hole in cap	71.23	0.00	71.23	2.59	68.64	8,737.35	8,668.71
SC–2B	06/25/02	Access hole in cap	71.44	0.00	71.44	2.59	68.85	8,737.35	8,668.50
SC–2B	07/25/02	Access hole in cap	71.72	0.00	71.72	2.59	69.13	8,737.35	8,668.22

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
				Phase I wells—Continued					
SC–2B	08/21/02	Access hole in cap	71.40	0.00	71.40	2.59	68.81	8,737.35	8,668.54
SC–2B	09/18/02	Access hole in cap	71.06	0.00	71.06	2.59	68.47	8,737.35	8,668.88
SC–2B	10/17/02	Access hole in cap	67.74	0.00	67.74	2.59	65.15	8,737.35	8,672.20
SC–2B	11/14/02	Access hole in cap	69.27	0.00	69.27	2.59	66.68	8,737.35	8,670.67
SC–2B	12/12/02	Access hole in cap	69.94	0.00	69.94	2.59	67.35	8,737.35	8,670.00
SC–2B	02/08/03	Access hole in cap	70.77	0.00	70.77	2.59	68.18	8,737.35	8,669.17
SC–2B	04/15/03	Access hole in cap	69.63	0.00	69.63	2.59	67.04	8,737.35	8,670.31
SC–2B	06/03/03	Top of casing	69.65	+0.12	69.53	2.59	66.94	8,737.35	8,670.41
SC–2B	06/06/03	Access hole in cap	69.75	0.00	69.75	2.59	67.16	8,737.35	8,670.19
SC–2B	07/09/03	Access hole in cap	70.62	0.00	70.62	2.59	68.03	8,737.35	8,669.32
SC–2B	08/22/03	Access hole in cap	71.09	0.00	71.09	2.59	68.50	8,737.35	8,668.85
SC–2B	09/18/03	Access hole in cap	69.96	0.00	69.96	2.59	67.37	8,737.35	8,669.98
SC–2B	10/20/03	Access hole in cap	70.08	0.00	70.08	2.59	67.49	8,737.35	8,669.86
SC–2B	12/05/03	Access hole in cap	70.79	0.00	70.79	2.59	68.20	8,737.35	8,669.15
SC–2B	02/20/04	Access hole in cap	71.41	0.00	71.41	2.59	68.82	8,737.35	8,668.53
SC–2B	03/25/04	Access hole in cap	68.44	0.00	68.44	2.59	65.85	8,737.35	8,671.50
SC–2B	05/12/04	Access hole in cap	68.38	0.00	68.38	1.59	66.79	8,737.35	8,670.56
SC–2B	06/01/04	Access hole in cap	69.08	0.00	69.08	2.59	66.49	8,737.35	8,670.86
SC–3A	03/15/02	Top of casing	70.53	+0.12	70.41	2.61	67.80	8,735.87	8,668.08
SC–3A	03/19/02	Top of casing	70.92	+0.12	70.80	2.61	68.19	8,735.87	8,667.69
SC–3A	03/25/02	Access hole in cap	71.53	0.00	71.53	2.61	68.92	8,735.87	8,666.95
SC–3A	04/24/02	Access hole in cap	71.95	0.00	71.95	2.61	69.34	8,735.87	8,666.53
SC–3A	05/23/02	Access hole in cap	72.03	0.00	72.03	2.61	69.42	8,735.87	8,666.45
SC–3A	06/19/02	Access hole in cap	72.38	0.00	72.38	2.61	69.77	8,735.87	8,666.10
SC–3A	07/25/02	Access hole in cap	72.64	0.00	72.64	2.61	70.03	8,735.87	8,665.84
SC–3A	08/21/02	Access hole in cap	72.52	0.00	72.52	2.61	69.91	8,735.87	8,665.96
SC–3A	09/18/02	Access hole in cap	72.28	0.00	72.28	2.61	69.67	8,735.87	8,666.20
SC–3A	10/17/02	Access hole in cap	68.92	0.00	68.92	2.61	66.31	8,735.87	8,669.56
SC–3A	11/14/02	Access hole in cap	70.27	0.00	70.27	2.61	67.66	8,735.87	8,668.21
SC–3A	12/12/02	Access hole in cap	70.54	0.00	70.54	2.61	67.93	8,735.87	8,667.94

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
				Phase I wells—Continued					
SC–3A	02/08/03	Access hole in cap	72.00	0.00	72.00	2.61	69.39	8,735.87	8,666.48
SC–3A	04/15/03	Access hole in cap	68.57	0.00	68.57	2.61	65.96	8,735.87	8,669.91
SC–3A	05/14/03	Access hole in cap	68.30	0.00	68.30	2.61	65.69	8,735.87	8,670.18
SC–3A	06/06/03	Top of casing	69.62	+0.12	69.50	2.61	66.89	8,735.87	8,668.98
SC–3A	07/09/03	Access hole in cap	70.99	0.00	70.99	2.61	68.38	8,735.87	8,667.49
SC–3A	08/21/03	Access hole in cap	71.67	0.00	71.67	2.61	69.06	8,735.87	8,666.81
SC–3A	09/18/03	Access hole in cap	71.25	0.00	71.25	2.61	68.64	8,735.87	8,667.23
SC–3A	10/20/03	Access hole in cap	70.48	0.00	70.48	2.61	67.87	8,735.87	8,668.00
SC–3A	10/21/03	Access hole in cap	70.50	0.00	70.50	2.61	67.89	8,735.87	8,667.98
SC–3A	12/05/03	Access hole in cap	71.56	0.00	71.56	2.61	68.95	8,735.87	8,666.92
SC–3A	12/05/03	Access hole in cap	71.56	0.00	71.56	2.61	68.95	8,735.87	8,666.92
SC–3A	02/20/04	Access hole in cap	72.24	0.00	72.24	2.61	69.63	8,735.87	8,666.24
SC–3A	03/25/04	Access hole in cap	70.85	0.00	70.85	2.61	68.24	8,735.87	8,667.63
SC–3A	05/12/04	Access hole in cap	67.12	0.00	67.12	1.61	65.51	8,735.87	8,670.36
SC–3A	06/01/04	Access hole in cap	68.77	0.00	68.77	2.61	66.16	8,735.87	8,669.71
SC–3B	03/15/02	Top of casing	156.33	0.00	156.32	2.50	153.82	8,735.38	8,581.56
SC–3B	03/19/02	Top of casing	156.34	0.00	156.34	2.50	153.84	8,735.38	8,581.54
SC–3B	03/26/02	Access hole in cap	156.32	0.00	156.32	2.50	153.82	8,735.38	8,581.56
SC–3B	04/25/02	Access hole in cap	156.06	0.00	156.06	2.50	153.56	8,735.38	8,581.82
SC–3B	06/25/02	Access hole in cap	156.31	0.00	156.31	2.50	153.81	8,735.38	8,581.57
SC–3B	07/25/02	Access hole in cap	156.25	0.00	156.25	2.50	153.75	8,735.38	8,581.63
SC–3B	08/21/02	Access hole in cap	156.31	0.00	156.31	2.50	153.81	8,735.38	8,581.57
SC–3B	09/18/02	Access hole in cap	156.16	0.00	156.16	2.50	153.66	8,735.38	8,581.72
SC–3B	10/17/02	Access hole in cap	155.40	0.00	155.40	2.50	152.90	8,735.38	8,582.48
SC–3B	11/14/02	Access hole in cap	155.40	0.00	155.40	2.50	152.90	8,735.38	8,582.48
SC–3B	12/12/02	Access hole in cap	155.28	0.00	155.28	2.50	152.78	8,735.38	8,582.60
SC–3B	02/08/03	Access hole in cap	155.52	0.00	155.52	2.50	153.02	8,735.38	8,582.36
SC–3B	04/15/03	Access hole in cap	154.83	0.00	154.83	2.50	152.33	8,735.38	8,583.05
SC–3B	05/14/03	Access hole in cap	154.51	0.00	154.51	2.50	152.01	8,735.38	8,583.37
SC–3B	06/03/03	Top of casing	154.64	0.00	154.64	2.50	152.14	8,735.38	8,583.24

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
				Phase I wells—Continued					
SC–3B	06/06/03	Access hole in cap	154.61	0.00	154.61	2.50	152.11	8,735.38	8,583.27
SC–3B	07/09/03	Access hole in cap	154.94	0.00	154.94	2.50	152.44	8,735.38	8,582.94
SC–3B	08/21/03	Access hole in cap	155.10	0.00	155.10	2.50	152.60	8,735.38	8,582.78
SC–3B	09/18/03	Access hole in cap	154.97	0.00	154.97	2.50	152.47	8,735.38	8,582.91
SC–3B	10/20/03	Access hole in cap	154.62	0.00	154.62	2.50	152.12	8,735.38	8,583.26
SC–3B	10/21/03	Access hole in cap	154.71	0.00	154.71	2.50	152.21	8,735.38	8,583.17
SC–3B	12/05/03	Access hole in cap	154.68	0.00	154.68	2.50	152.18	8,735.38	8,583.20
SC–3B	02/20/04	Access hole in cap	154.22	0.00	154.22	2.50	151.72	8,735.38	8,583.66
SC–3B	03/25/04	Access hole in cap	153.99	0.00	153.99	2.50	151.49	8,735.38	8,583.89
SC–3B	05/12/04	Access hole in cap	152.03	0.00	152.03	1.50	150.53	8,735.38	8,584.85
SC–3B	06/01/04	Access hole in cap	152.39	0.00	152.39	2.50	149.89	8,735.38	8,585.49
SC–4A	03/15/02	Top of casing	76.54	+0.12	76.42	2.21	74.22	8,745.70	8,671.49
SC–4A	03/19/02	Top of casing	76.96	+0.12	76.84	2.21	74.63	8,745.70	8,671.07
SC–4A	03/25/02	Access hole in cap	77.69	0.00	77.69	2.21	75.48	8,745.70	8,670.22
SC–4A	04/24/02	Access hole in cap	78.37	0.00	78.37	2.21	76.17	8,745.70	8,669.54
SC–4A	05/23/02	Access hole in cap	78.75	0.00	78.75	2.21	76.55	8,745.70	8,669.16
SC–4A	06/25/02	Access hole in cap	79.08	0.00	79.08	2.21	76.88	8,745.70	8,668.83
SC–4A	07/25/02	Access hole in cap	79.18	0.00	79.18	2.21	76.98	8,745.70	8,668.73
SC–4A	08/21/02	Access hole in cap	79.10	0.00	79.10	2.21	76.89	8,745.70	8,668.81
SC–4A	09/18/02	Access hole in cap	78.76	0.00	78.76	2.21	76.56	8,745.70	8,669.15
SC–4A	10/17/02	Access hole in cap	74.90	0.00	74.90	2.21	72.70	8,745.70	8,673.01
SC–4A	11/14/02	Access hole in cap	76.54	0.00	76.54	2.21	74.34	8,745.70	8,671.37
SC–4A	12/13/02	Access hole in cap	76.68	0.00	76.68	2.21	74.48	8,745.70	8,671.23
SC–4A	02/08/03	Access hole in cap	78.17	0.00	78.17	2.21	75.97	8,745.70	8,669.74
SC–4A	04/15/03	Access hole in cap	74.20	0.00	74.20	2.21	72.00	8,745.70	8,673.71
SC–4A	05/14/03	Access hole in cap	74.02	0.00	74.02	2.21	71.81	8,745.70	8,673.89
SC–4A	06/03/03	Top of casing	75.94	+0.12	75.82	2.21	73.61	8,745.70	8,672.09
SC–4A	06/05/03	Access hole in cap	76.15	0.00	76.15	2.21	73.95	8,745.70	8,671.76
SC–4A	06/06/03	Access hole in cap	76.23	0.00	76.23	2.21	74.03	8,745.70	8,671.68

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
Phase I wells—Continued									
SC–4A	07/09/03	Access hole in cap	77.77	0.00	77.77	2.21	75.56	8,745.70	8,670.14
SC–4A	08/21/03	Access hole in cap	78.34	0.00	78.34	2.21	76.14	8,745.70	8,669.57
SC–4A	09/18/03	Access hole in cap	77.91	0.00	77.91	2.21	75.70	8,745.70	8,670.00
SC–4A	10/20/03	Access hole in cap	77.02	0.00	77.02	2.21	74.81	8,745.70	8,670.89
SC–4A	10/21/03	Access hole in cap	77.03	0.00	77.03	2.21	74.83	8,745.70	8,670.88
SC–4A	12/05/03	Access hole in cap	78.17	0.00	78.17	2.21	75.97	8,745.70	8,669.74
SC–4A	02/20/04	Access hole in cap	78.79	0.00	78.79	2.21	76.58	8,745.70	8,669.12
SC–4A	05/12/04	Access hole in cap	73.28	0.00	73.28	2.21	71.08	8,745.70	8,674.63
SC–4A	05/12/04	Access hole in cap	73.28	0.00	73.28	2.21	71.08	8,745.70	8,674.63
SC–5A	03/15/02	Top of casing	154.41	+0.12	154.29	2.63	151.66	8,559.29	8,407.64
SC–5A	03/19/02	Top of casing	154.49	+0.12	154.37	2.63	151.74	8,559.29	8,407.55
SC–5A	03/27/02	Access hole in cap	154.35	0.00	154.35	2.63	151.72	8,559.29	8,407.57
SC–5A	04/26/02	Access hole in cap	151.55	0.00	151.55	2.63	148.92	8,559.29	8,410.37
SC–5A	05/23/02	Access hole in cap	150.43	0.00	150.43	2.63	147.80	8,559.29	8,411.49
SC–5A	06/26/02	Access hole in cap	152.03	0.00	152.03	2.63	149.40	8,559.29	8,409.89
SC–5A	07/23/02	Access hole in cap	153.91	0.00	153.91	2.63	151.28	8,559.29	8,408.01
SC–5A	08/22/02	Access hole in cap	156.29	0.00	156.29	2.63	153.66	8,559.29	8,405.63
SC–5A	09/17/02	Access hole in cap	157.00	0.00	157.00	2.63	154.37	8,559.29	8,404.92
SC–5A	10/16/02	Access hole in cap	157.55	0.00	157.55	2.63	154.92	8,559.29	8,404.37
SC–5A	11/14/02	Access hole in cap	157.98	0.00	157.98	2.63	155.35	8,559.29	8,403.94
SC–5A	12/13/02	Access hole in cap	157.31	0.00	157.31	2.63	154.68	8,559.29	8,404.61
SC–5A	02/08/03	Access hole in cap	156.39	0.00	156.39	2.63	153.76	8,559.29	8,405.53
SC–5A	04/15/03	Access hole in cap	154.78	0.00	154.78	2.63	152.15	8,559.29	8,407.14
SC–5A	05/13/03	Access hole in cap	145.06	0.00	145.06	2.63	142.43	8,559.29	8,416.86
SC–5A	06/04/03	Top of casing	138.13	+0.12	138.01	2.63	135.38	8,559.29	8,423.91
SC–5A	06/05/03	Access hole in cap	137.98	0.00	137.98	2.63	135.35	8,559.29	8,423.94
SC–5A	06/06/03	Access hole in cap	137.97	0.00	137.97	2.63	135.34	8,559.29	8,423.95
SC–5A	07/08/03	Access hole in cap	140.18	0.00	140.18	2.63	137.55	8,559.29	8,421.74
SC–5A	08/20/03	Access hole in cap	146.42	0.00	146.42	2.63	143.79	8,559.29	8,415.50
SC–5A	09/18/03	Access hole in cap	148.53	0.00	148.53	2.63	145.90	8,559.29	8,413.39

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
Phase I wells—Continued									
SC–5A	10/20/03	Access hole in cap	151.38	0.00	151.38	2.63	148.75	8,559.29	8,410.54
SC–5A	11/22/03	Access hole in cap	152.74	0.00	152.74	2.63	150.11	8,559.29	8,409.18
SC–5A	12/01/03	Access hole in cap	150.77	0.00	150.77	2.63	148.14	8,559.29	8,411.15
SC–5A	12/02/03	Access hole in cap	150.22	0.00	150.22	2.63	147.59	8,559.29	8,411.70
SC–5A	12/03/03	Access hole in cap	149.96	0.00	149.96	2.63	147.33	8,559.29	8,411.96
SC–5A	03/25/04	Access hole in cap	153.14	0.00	153.14	2.63	150.51	8,559.29	8,408.78
SC–5A	05/12/04	Access hole in cap	141.60	0.00	141.60	2.63	138.97	8,559.29	8,420.32
SC–5A	06/04/04	Access hole in cap	136.83	0.00	136.83	2.63	134.20	8,559.29	8,425.09
SC–5B	03/19/02	Top of casing	153.27	0.00	153.27	3.00	150.27	8,558.02	8,407.75
SC–5B	03/27/02	Access hole in cap	152.66	0.00	152.66	3.00	149.66	8,558.02	8,408.36
SC–5B	04/26/02	Access hole in cap	149.01	0.00	149.01	3.00	146.01	8,558.02	8,412.01
SC–5B	05/23/02	Access hole in cap	148.78	0.00	148.78	3.00	145.78	8,558.02	8,412.24
SC–5B	06/26/02	Access hole in cap	150.38	0.00	150.38	3.00	147.38	8,558.02	8,410.64
SC–5B	07/23/02	Access hole in cap	152.22	0.00	152.22	3.00	149.22	8,558.02	8,408.80
SC–5B	08/22/02	Access hole in cap	155.65	0.00	155.65	3.00	152.65	8,558.02	8,405.37
SC–5B	09/17/02	Access hole in cap	156.08	0.00	156.08	3.00	153.08	8,558.02	8,404.94
SC–5B	10/16/02	Access hole in cap	155.81	0.00	155.81	3.00	152.81	8,558.02	8,405.21
SC–5B	11/14/02	Access hole in cap	156.33	0.00	156.33	3.00	153.33	8,558.02	8,404.69
SC–5B	12/13/02	Access hole in cap	155.49	0.00	155.49	3.00	152.49	8,558.02	8,405.53
SC–5B	02/08/03	Access hole in cap	154.72	0.00	154.72	3.00	151.72	8,558.02	8,406.30
SC–5B	04/15/03	Access hole in cap	153.00	0.00	153.00	3.00	150.00	8,558.02	8,408.02
SC–5B	05/13/03	Access hole in cap	143.52	0.00	143.52	3.00	140.52	8,558.02	8,417.50
SC–5B	06/04/03	Top of casing	136.28	0.00	136.28	3.00	133.28	8,558.02	8,424.74
SC–5B	06/05/03	Access hole in cap	136.37	0.00	136.37	3.00	133.37	8,558.02	8,424.65
SC–5B	06/06/03	Access hole in cap	136.17	0.00	136.17	3.00	133.17	8,558.02	8,424.85
SC–5B	07/08/03	Access hole in cap	138.42	0.00	138.42	3.00	135.42	8,558.02	8,422.60
SC–5B	08/20/03	Access hole in cap	144.80	0.00	144.80	3.00	141.80	8,558.02	8,416.22
SC–5B	09/18/03	Access hole in cap	146.89	0.00	146.89	3.00	143.89	8,558.02	8,414.13
SC–5B	10/20/03	Access hole in cap	149.78	0.00	149.78	3.00	146.78	8,558.02	8,411.24
SC–5B	10/24/03	Access hole in cap	150.91	0.00	150.91	3.00	147.91	8,558.02	8,410.11

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
Phase I wells—Continued									
SC–5B	11/22/03	Access hole in cap	151.00	0.00	151.00	3.00	148.00	8,558.02	8,410.02
SC–5B	12/01/03	Access hole in cap	148.89	0.00	148.89	3.00	145.89	8,558.02	8,412.13
SC–5B	12/02/03	Access hole in cap	148.36	0.00	148.36	3.00	145.36	8,558.02	8,412.66
SC–5B	12/03/03	Access hole in cap	148.26	0.00	148.26	3.00	145.26	8,558.02	8,412.76
SC–5B	03/25/04	Access hole in cap	151.52	0.00	151.52	3.00	148.52	8,558.02	8,409.50
SC–5B	05/12/04	Access hole in cap	139.78	0.00	139.78	3.00	136.78	8,558.02	8,421.24
SC–5B	06/01/04	Access hole in cap	135.21	0.00	135.21	3.00	132.21	8,558.02	8,425.81
Phase II wells									
Hottentot	02/05/03	Access hole in cap	100.10	0.00	100.10	1.38	98.72	8,790.79	8,692.07
Hottentot	05/12/03	Access hole in cap	98.41	0.00	98.41	1.38	97.03	8,790.79	8,693.76
Hottentot	07/09/03	Access hole in cap	99.09	0.00	99.09	1.38	97.71	8,790.79	8,693.08
Hottentot	08/20/03	Access hole in cap	99.39	0.00	99.39	1.38	98.01	8,790.79	8,692.78
Hottentot	09/18/03	Access hole in cap	99.26	0.00	99.26	1.38	97.88	8,790.79	8,692.91
Hottentot	10/24/03	Access hole in cap	98.94	0.00	98.94	1.38	97.56	8,790.79	8,693.23
Hottentot	12/05/03	Access hole in cap	99.41	0.00	99.41	1.38	98.03	8,790.79	8,692.76
Hottentot	03/26/04	Access hole in cap	99.18	0.00	99.18	1.38	97.80	8,790.79	8,692.99
Hottentot	05/12/04	Access hole in cap	96.38	0.00	96.38	1.38	95.00	8,790.79	8,695.79
Hottentot	06/01/04	Access hole in cap	96.50	0.00	96.50	1.38	95.12	8,790.79	8,695.67
SC–6A	02/07/03	Access hole in cap	136.20	0.00	136.20	3.08	133.12	8,739.43	8,606.31
SC–6A	04/15/03	Access hole in cap	134.32	0.00	134.32	3.08	131.24	8,739.43	8,608.19
SC–6A	05/14/03	Access hole in cap	134.89	0.00	134.89	3.08	131.81	8,739.43	8,607.62
SC–6A	06/03/03	Top of casing	135.45	+0.12	135.33	3.08	132.25	8,739.43	8,607.18
SC–6A	06/06/03	Access hole in cap	135.57	0.00	135.57	3.08	132.49	8,739.43	8,606.94
SC–6A	07/09/03	Access hole in cap	135.71	0.00	135.71	3.08	132.63	8,739.43	8,606.80
SC–6A	08/18/03	Access hole in cap	135.79	0.00	135.79	3.08	132.71	8,739.43	8,606.72
SC–6A	09/18/03	Access hole in cap	135.81	0.00	135.81	3.08	132.73	8,739.43	8,606.70
SC–6A	10/20/03	Access hole in cap	135.67	0.00	135.67	3.08	132.59	8,739.43	8,606.84
SC–6A	10/21/03	Access hole in cap	135.68	0.00	135.68	3.08	132.60	8,739.43	8,606.83
SC–6A	10/30/03	Access hole in cap	135.71	0.00	135.71	3.08	132.63	8,739.43	8,606.80
SC–6A	12/05/03	Access hole in cap	136.05	0.00	136.05	3.08	132.97	8,739.43	8,606.46

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
Phase II wells—Continued									
SC–6A	02/20/04	Access hole in cap	136.05	0.00	136.05	3.08	132.97	8,739.43	8,606.46
SC–6A	03/25/04	Access hole in cap	135.56	0.00	135.56	3.08	132.48	8,739.43	8,606.95
SC–6A	05/12/04	Access hole in cap	134.20	0.00	134.20	3.08	131.12	8,739.43	8,608.31
SC–6A	06/01/04	Access hole in cap	135.21	0.00	135.21	3.08	132.13	8,739.43	8,607.30
SC–7A	02/04/03	Access hole in cap	111.71	0.00	111.71	3.63	108.08	8,506.86	8,398.78
SC–7A	04/17/03	Access hole in cap	109.19	0.00	109.19	3.63	105.56	8,506.86	8,401.30
SC–7A	05/12/03	Access hole in cap	101.06	0.00	101.06	3.63	97.43	8,506.86	8,409.43
SC–7A	06/05/03	Top of casing	95.60	+0.12	95.48	3.63	91.85	8,506.86	8,415.01
SC–7A	07/08/03	Access hole in cap	97.71	0.00	97.71	3.63	94.08	8,506.86	8,412.78
SC–7A	08/18/03	Access hole in cap	102.52	0.00	102.52	3.63	98.89	8,506.86	8,407.97
SC–7A	09/18/03	Access hole in cap	104.51	0.00	104.51	3.63	100.88	8,506.86	8,405.98
SC–7A	10/06/03	Access hole in cap	106.27	0.00	106.27	3.63	102.64	8,506.86	8,404.22
SC–7A	10/24/03	Access hole in cap	107.45	0.00	107.45	3.63	103.82	8,506.86	8,403.04
SC–7A	10/31/03	Access hole in cap	107.45	0.00	107.45	3.63	103.82	8,506.86	8,403.04
SC–7A	11/22/03	Access hole in cap	108.14	0.00	108.14	3.63	104.51	8,506.86	8,402.35
SC–7A	12/01/03	Top of casing	106.89	-0.02	106.91	3.63	103.28	8,506.86	8,403.58
SC–7A	12/03/03	Top of casing	106.39	-0.02	106.41	3.63	102.78	8,506.86	8,404.08
SC–7A	02/20/04	Top of casing	108.48	-0.02	108.50	3.63	104.87	8,506.86	8,401.99
SC–7A	03/26/04	Top of casing	108.17	-0.02	108.19	3.63	104.56	8,506.86	8,402.30
SC–7A	05/11/04	Top of casing	98.10	-0.02	98.12	3.63	94.49	8,506.86	8,412.37
SC–7A	06/01/04	Top of casing	94.17	-0.02	94.19	3.63	90.56	8,506.86	8,416.30
SC–8A	02/08/03	Access hole in cap	73.01	0.00	73.01	3.17	69.84	8,468.22	8,398.38
SC–8A	04/17/03	Access hole in cap	70.34	0.00	70.34	3.17	67.17	8,468.22	8,401.05
SC–8A	05/12/03	Access hole in cap	62.38	0.00	62.38	3.17	59.21	8,468.22	8,409.01
SC–8A	06/05/03	Top of casing	57.44	+0.12	57.32	3.17	54.15	8,468.22	8,414.07
SC–8A	07/08/03	Top of casing	59.46	+0.12	59.34	3.17	56.17	8,468.22	8,412.05
SC–8A	08/18/03	Access hole in cap	64.08	0.00	64.08	3.17	60.91	8,468.22	8,407.31
SC–8A	09/18/03	Access hole in cap	65.97	0.00	65.97	3.17	62.80	8,468.22	8,405.42
SC–8A	10/06/03	Access hole in cap	67.86	0.00	67.86	3.17	64.69	8,468.22	8,403.53
SC–8A	10/23/03	Access hole in cap	68.88	0.00	68.88	3.17	65.71	8,468.22	8,402.51

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/ day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
Phase II wells—Continued									
SC–8A	10/31/03	Access hole in cap	68.82	0.00	68.82	3.17	65.65	8,468.22	8,402.57
SC–8A	11/22/03	Access hole in cap	69.62	0.00	69.62	3.17	66.45	8,468.22	8,401.77
SC–8A	12/01/03	Top of casing	68.39	+0.12	68.27	3.17	65.10	8,468.22	8,403.12
SC–8A	12/02/03	Top of casing	67.85	+0.12	67.73	3.17	64.56	8,468.22	8,403.66
SC–8A	12/03/03	Top of casing	67.98	+0.12	67.86	3.17	64.69	8,468.22	8,403.53
SC–8A	02/20/04	Top of casing	69.81	+0.12	69.69	3.17	66.52	8,468.22	8,401.70
SC–8A	03/26/04	Top of casing	69.49	+0.12	69.37	3.17	66.20	8,468.22	8,402.02
SC–8A	05/11/04	Top of casing	59.52	+0.12	59.40	3.17	56.23	8,468.22	8,411.99
SC–8A	05/12/04	Top of casing	59.06	+0.12	58.94	3.17	55.77	8,468.22	8,412.45
SC–8A	06/01/04	Top of casing	55.93	+0.12	55.81	3.17	52.64	8,468.22	8,415.58
SC–9A	03/26/04	Top of casing	[2]19.76	0.00	[3]18.38	1.79	[3]16.59	8444.19	8,427.60
SC–9A	05/12/04	Top of casing	[2]19.64	0.00	[3]18.26	1.79	[3]16.47	8444.19	8,427.72
SC–9A	06/01/04	Top of casing	[2]19.76	0.00	[3]18.38	1.79	[3]16.59	8444.19	8,427.60
Hansen	02/05/03	Access hole in cap	107.91	0.00	107.91	3.23	104.68	8,569.53	8,464.85
Hansen	04/17/03	Top of casing	103.93	-0.02	103.95	3.23	100.72	8,569.53	8,468.81
Hansen	05/13/03	Access hole in cap	107.35	0.00	107.35	3.23	104.12	8,569.53	8,465.41
Hansen	07/09/03	Top of casing	107.92	-0.02	107.94	3.23	104.71	8,569.53	8,464.82
Hansen	08/19/03	Access hole in cap	107.84	0.00	107.84	3.23	104.61	8,569.53	8,464.92
Hansen	09/18/03	Top of casing	107.00	-0.02	107.02	3.23	103.79	8,569.53	8,465.74
Hansen	10/21/03	Access hole in cap	107.73	0.00	107.73	3.23	104.50	8,569.53	8,465.03
Hansen	12/05/03	Top of casing	107.96	-0.02	107.98	3.23	104.75	8,569.53	8,464.78
Hansen	02/20/04	Top of casing	107.72	-0.02	107.74	3.23	104.51	8,569.53	8,465.02
Hansen	03/26/04	Top of casing	106.70	-0.02	106.72	3.23	103.49	8,569.53	8,466.04
Hansen	05/11/04	Top of casing	104.89	-0.02	104.91	3.23	101.68	8,569.53	8,467.85
Hansen	06/01/04	Top of casing	107.68	-0.02	107.70	3.23	104.47	8,569.53	8,465.06
La Bobita	02/07/03	Access hole in cap	64.37	0.00	64.37	3.23	61.14	8,229.45	8,168.31
La Bobita	04/17/03	Top of casing	60.92	-0.02	60.94	3.23	57.71	8,229.45	8,171.74
La Bobita	05/15/03	Access hole in cap	58.88	0.00	58.88	3.23	55.65	8,229.45	8,173.80
La Bobita	07/08/03	Top of casing	59.99	-0.02	60.01	3.23	56.78	8,229.45	8,172.67
La Bobita	08/18/03	Access hole in cap	62.05	0.00	62.05	3.23	58.82	8,229.45	8,170.63

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
Phase II wells—Continued									
La Bobita	09/18/03	Top of casing	61.04	-0.02	61.06	3.23	57.83	8,229.45	8,171.62
La Bobita	10/23/03	Access hole in cap	61.84	0.00	61.84	3.23	58.61	8,229.45	8,170.84
La Bobita	12/05/03	Top of casing	61.82	-0.02	61.84	3.23	58.61	8,229.45	8,170.84
La Bobita	02/19/04	Top of casing	62.77	-0.02	62.79	3.23	59.56	8,229.45	8,169.89
La Bobita	03/26/04	Top of casing	63.43	-0.02	63.45	3.23	60.22	8,229.45	8,169.23
La Bobita	05/11/04	Top of casing	58.91	-0.02	58.93	3.23	55.70	8,229.45	8,173.75
La Bobita	05/12/04	Top of casing	58.85	-0.02	58.87	3.23	55.64	8,229.45	8,173.81
La Bobita	05/13/04	Top of casing	58.75	-0.02	58.77	3.23	55.54	8,229.45	8,173.91
La Bobita	06/02/04	Top of casing	59.38	-0.02	59.40	3.23	56.17	8,229.45	8,173.28
CC–1A	02/04/03	Top of casing	5.90	0.00	5.90	2.50	3.40	8,880.23	8,876.83
CC–1A	04/10/03	Top of casing	4.92	0.00	4.92	2.50	2.42	8,880.23	8,877.81
CC–1A	05/07/03	Top of casing	6.84	0.00	6.84	2.50	4.34	8,880.23	8,875.89
CC–1A	05/14/03	Top of casing	7.58	0.00	7.58	2.50	5.08	8,880.23	8,875.15
CC–1A	06/04/03	Top of casing	10.04	0.00	10.04	2.50	7.54	8,880.23	8,872.69
CC–1A	07/21/03	Top of casing	12.00	0.00	12.00	2.50	9.50	8,880.23	8,870.73
CC–1A	08/12/03	Top of casing	10.76	0.00	10.76	2.50	8.26	8,880.23	8,871.97
CC–1A	09/11/03	Top of casing	7.95	0.00	7.95	2.50	5.45	8,880.23	8,874.78
CC–1A	10/22/03	Top of casing	9.26	0.00	9.26	2.50	6.76	8,880.23	8,873.47
CC–1A	10/23/03	Top of casing	9.50	0.00	9.50	2.50	7.00	8,880.23	8,873.23
CC–1A	11/04/03	Top of casing	9.13	0.00	9.13	2.50	6.63	8,880.23	8,873.60
CC–1A	12/11/03	Top of casing	8.33	0.00	8.33	2.50	5.83	8,880.23	8,874.40
CC–1A	01/07/04	Top of casing	8.28	0.00	8.28	2.50	5.78	8,880.23	8,874.45
CC–1A	04/21/04	Top of casing	5.71	0.00	5.71	2.50	3.21	8,880.23	8,877.02
CC–1B	02/05/03	Access hole in cap	10.50	0.00	10.50	2.96	7.54	8,878.31	8,870.77
CC–1B	03/04/03	Access hole in cap	9.99	0	9.99	2.96	7.03	8,878.31	8,871.28
CC–1B	04/10/03	Access hole in cap	8.77	0	8.77	2.96	5.81	8,878.31	8,872.50
CC–1B	05/06/03	Access hole in cap	9.83	0	9.83	2.96	6.87	8,878.31	8,871.44
CC–1B	06/04/03	Access hole in cap	11.86	0.00	11.86	2.96	8.90	8,878.31	8,869.41
CC–1B	07/21/03	Access hole in cap	12.74	0.00	12.74	2.96	9.78	8,878.31	8,868.53
CC–1B	08/12/03	Access hole in cap	12.01	0.00	12.01	2.96	9.05	8,878.31	8,869.26

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
Phase II wells—Continued									
CC–1B	08/19/03	Access hole in cap	12.24	0.00	12.24	2.96	9.28	8,878.31	8,869.03
CC–1B	09/11/03	Access hole in cap	10.22	0.00	10.22	2.96	7.26	8,878.31	8,871.05
CC–1B	10/22/03	Access hole in cap	11.38	0.00	11.38	2.96	8.42	8,878.31	8,869.89
CC–1B	10/23/03	Access hole in cap	11.65	0.00	11.65	2.96	8.69	8,878.31	8,869.62
CC–1B	11/04/03	Access hole in cap	11.39	0.00	11.39	2.96	8.43	8,878.31	8,869.88
CC–1B	12/11/03	Access hole in cap	10.65	0.00	10.65	2.96	7.69	8,878.31	8,870.62
CC–1B	01/07/04	Access hole in cap	10.58	0.00	10.58	2.96	7.62	8,878.31	8,870.69
CC–1B	04/21/04	Access hole in cap	9.45	0.00	9.45	2.96	6.49	8,878.31	8,871.82
CC–2A	04/10/03	Top of casing	8.42	0.00	8.42	4.00	4.42	8,876.02	8,871.60
CC–2A	05/06/03	Top of casing	8.34	0.00	8.34	4.00	4.34	8,876.02	8,871.68
CC–2A	05/14/03	Top of casing	8.76	0.00	8.76	4.00	4.76	8,876.02	8,871.26
CC–2A	06/04/03	Top of casing	9.40	0.00	9.40	4.00	5.40	8,876.02	8,870.62
CC–2A	07/21/03	Top of casing	12.00	0.00	12.00	4.00	8.00	8,876.02	8,868.02
CC–2A	08/12/03	Top of casing	9.50	0.00	9.50	4.00	5.50	8,876.02	8,870.52
CC–2A	08/19/03	Top of casing	9.54	0.00	9.54	4.00	5.54	8,876.02	8,870.48
CC–2A	09/11/03	Top of casing	7.45	0	7.45	4.00	3.45	8,876.02	8,872.57
CC–2A	10/22/03	Top of casing	9.21	0.00	9.21	4.00	5.21	8,876.02	8,870.81
CC–2A	10/23/03	Top of casing	9.30	0.00	9.30	4.00	5.30	8,876.02	8,870.72
CC–2A	11/04/03	Top of casing	9.26	0.00	9.26	4.00	5.26	8,876.02	8,870.76
CC–2A	12/11/03	Top of casing	9.32	0.00	9.32	4.00	5.32	8,876.02	8,870.70
CC–2A	01/07/04	Top of casing	9.45	0.00	9.45	4.00	5.45	8,876.02	8,870.57
CC–2A	02/25/04	Top of casing	9.32	0.00	9.32	4.00	5.32	8,876.02	8,870.70
CC–2A	04/21/04	Top of casing	7.94	0.00	7.94	4.00	3.94	8,876.02	8,872.08
CC–2B	02/05/03	Access hole in cap	10.87	0.00	10.87	2.21	8.66	8,877.53	8,868.87
CC–2B	03/04/03	Access hole in cap	9.68	0.00	9.68	2.21	7.47	8,877.53	8,870.06
CC–2B	04/10/03	Access hole in cap	8.63	0.00	8.63	2.21	6.42	8,877.53	8,871.11
CC–2B	05/06/03	Access hole in cap	10.00	0.00	10.00	2.21	7.79	8,877.53	8,869.74
CC–2B	06/04/03	Access hole in cap	9.12	0.00	9.12	2.21	6.91	8,877.53	8,870.62
CC–2B	07/21/03	Access hole in cap	10.15	0.00	10.15	2.21	7.94	8,877.53	8,869.59
CC–2B	08/12/03	Access hole in cap	9.87	0.00	9.87	2.21	7.66	8,877.53	8,869.87

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
				Phase II wells—Continued					
CC–2B	08/19/03	Access hole in cap	9.87	0.00	9.87	2.21	7.66	8,877.53	8,869.87
CC–2B	09/11/03	Access hole in cap	9.19	0.00	9.19	2.21	6.98	8,877.53	8,870.55
CC–2B	10/22/03	Access hole in cap	9.48	0.00	9.48	2.21	7.27	8,877.53	8,870.26
CC–2B	10/23/03	Access hole in cap	10.77	0.00	10.77	2.21	8.56	8,877.53	8,868.97
CC–2B	11/04/03	Access hole in cap	9.55	0.00	9.55	2.21	7.34	8,877.53	8,870.19
CC–2B	12/11/03	Access hole in cap	9.60	0.00	9.60	2.21	7.39	8,877.53	8,870.14
CC–2B	01/07/04	Access hole in cap	9.70	0.00	9.70	2.21	7.49	8,877.53	8,870.04
CC–2B	04/21/04	Access hole in cap	8.41	0.00	8.41	2.21	6.20	8,877.53	8,871.33
				Existing Advanced Wastewater Treatment Facility wells					
AWWT–1	03/27/02	Top of casing	124.68	0.00	124.68	0.50	124.18	8,523.00	8,398.82
AWWT–1	04/26/02	Top of casing	121.95	0.00	121.95	0.50	121.45	8,523.00	8,401.55
AWWT–1	05/23/02	Top of casing	121.26	0.00	121.26	0.50	120.76	8,523.00	8,402.24
AWWT–1	06/26/02	Top of casing	123.20	0.00	123.20	0.50	122.70	8,523.00	8,400.30
AWWT–1	07/26/02	Top of casing	125.10	0.00	125.10	0.50	124.60	8,523.00	8,398.40
AWWT–1	08/22/02	Top of casing	127.22	0.00	127.22	0.50	126.72	8,523.00	8,396.28
AWWT–1	09/17/02	Top of casing	128.40	0.00	128.40	0.50	127.90	8,523.00	8,395.10
AWWT–1	10/17/02	Top of casing	128.29	0.00	128.29	0.50	127.79	8,523.00	8,395.21
AWWT–1	12/11/02	Top of casing	128.42	0.00	128.42	0.50	127.92	8,523.00	8,395.08
AWWT–1	02/04/03	Top of casing	127.30	0.00	127.30	0.50	126.80	8,523.00	8,396.20
AWWT–1	04/17/03	Top of casing	124.85	0.00	124.85	0.50	124.35	8,523.00	8,398.65
AWWT–1	05/12/03	Top of casing	116.54	0.00	116.54	0.50	116.04	8,523.00	8,406.96
AWWT–1	07/08/03	Top of casing	113.02	0.00	113.02	0.50	112.52	8,523.00	8,410.48
AWWT–1	08/21/03	Top of casing	118.37	0.00	118.37	0.50	117.87	8,523.00	8,405.13
AWWT–1	09/18/03	Top of casing	120.04	0.00	120.04	0.50	119.54	8,523.00	8,403.46
AWWT–1	10/06/03	Top of casing	121.77	0.00	121.77	0.50	121.27	8,523.00	8,401.73
AWWT–1	10/24/03	Top of casing	123.50	0.00	123.50	0.50	123.00	8,523.00	8,400.00
AWWT–1	10/31/03	Top of casing	123.00	0.00	123.00	0.50	122.50	8,523.00	8,400.50
AWWT–1	11/22/03	Top of casing	123.70	0.00	123.70	0.50	123.20	8,523.00	8,456.80
AWWT–1	12/01/03	Top of casing	122.57	0.00	122.57	0.50	122.07	8,523.00	8,400.93
AWWT–1	12/03/03	Top of casing	121.98	0.00	121.98	0.50	121.48	8,523.00	8,401.52

Table 4. Altitude of water levels in Phase I and II wells and existing Advanced Wastewater Treatment Facility wells, Red River Valley, north-central New Mexico, 2002–04.—Continued

[Shaded rows indicate water-level measurements obtained by URS, Denver, Colorado. NGVD 29, National Geodetic Vertical Datum of 1929]

Well identification (figs. 2–5)	Date (month/day/year)	Measuring point (permanent measuring point if no correction)	Depth to water (feet below measuring point)	Measuring point correction (feet)[1]	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Land surface altitude (feet above NGVD 29)	Altitude of water level (feet above NGVD 29)
Existing Advanced Wastewater Treatment Facility wells—Continued									
AWWT–1	02/20/04	Top of casing	124.04	0.00	124.04	0.50	123.54	8,523.00	8,399.46
AWWT–1	03/26/04	Top of casing	123.86	0.00	123.86	0.50	123.36	8,523.00	8,399.64
AWWT–1	05/11/04	Top of casing	113.61	0.00	113.61	0.50	113.11	8,523.00	8,409.89
AWWT–1	06/01/04	Top of casing	109.61	0.00	109.61	0.50	109.11	8,523.00	8,413.89
AWWT–2	12/13/02	Top of casing	108.64	0.00	108.64	1.17	107.47	8,560.00	8,452.53
AWWT–2	10/06/03	Top of casing	100.90	0.00	100.90	1.17	99.73	8,560.00	8,460.27
AWWT–2	10/24/03	Access hole in cap	102.94	+0.03	102.91	1.17	101.74	8,560.00	8,458.26
AWWT–2	10/31/03	Access hole in cap	103.89	+0.03	103.86	1.17	102.69	8,560.00	8,457.31
AWWT–2	11/22/03	Access hole in cap	103.68	+0.03	103.65	1.17	102.48	8,560.00	8,457.52
AWWT–2	12/01/03	Top of casing	104.36	0.00	104.36	1.17	103.19	8,560.00	8,456.81
AWWT–2	12/02/03	Top of casing	104.28	0.00	104.28	1.17	103.11	8,560.00	8,456.89
AWWT–2	12/03/03	Top of casing	104.39	0.00	104.39	1.17	103.22	8,560.00	8,456.78

[1]Measuring point correction is distance of measuring point at time of measurement, in feet above (+) or below (-) permanent measuring point.

[2]Depth is measured along the well bore. Well bore was angled 21.5 degrees from vertical.

[3]Calculated vertical distance from measuring point or land surface to water.

Wells 2–1 and 2–2 were installed about 450 ft upstream (east) from a line from the Red River to the La Bobita well (fig. 4). Well 2–1 is adjacent to the north bank of the Red River, and well 2–2 is about 100 ft farther north of the Red River. Wells 2–1 and 2–2 were advanced to 15.97 and 14.37 ft below land surface, respectively, at which depth a semiconsolidated deposit (possibly ferricrete) was encountered and no further advancement was achieved.

Ground-water levels in wells 2–1 and 2–2 ranged from 30.35 to 35.11 ft higher than concurrently measured water levels in well 1 (table 5). The land surface at wells 2–1 and 2–2 is about 20.6 ft higher than at well 1 (table 5). The substantially higher water levels in wells 2–1 and 2–2 relative to those measured concurrently in the La Bobita well and well 1 indicate that the underlying semiconsolidated deposits encountered at total depths of wells 2–1 and 2–2 are substantially less permeable than the overlying alluvium. Therefore, ground water near wells 2–1 and 2–2 is perched by the semiconsolidated deposits encountered during drilling. Water in wells 2–1 and 2–2 may be disconnected from or have a poor hydraulic connection to ground water present at the La Bobita well and well 1.

Ground-water levels were measured in wells 2–1 and 2–2 in May and June 2004. The stage of the Red River also was measured where a line approximately perpendicular to the bank of the river intersects wells 2–1 and 2–2. Ground-water levels in well 2–1 ranged from about 0.2 to 0.7 ft higher than the stage of the Red River (fig. 14, table 5). Ground-water levels in well 2–2 ranged from about 0.4 to 0.1 ft lower than the stage of the Red River (fig. 14, table 5). Ground-water levels in well 2–1 were 0.59 and 0.80 ft higher than those in well 2–2. Differences of less than 1 ft between water levels in wells 2–1, 2–2, and the stage of the Red River indicate that there is a substantial hydraulic connection between the ground-water system penetrated by the wells and the Red River surface-water system.

Well 3 was installed about 1,600 ft upstream (east) from wells 2–1 and 2–2 (fig. 4). Ground-water levels measured in well 3 in May and June 2004 ranged from 0.5 to 1.1 ft higher than the stage of the Red River where a line approximately perpendicular to the bank of the river intersects well 3. These water-level measurements indicate that the Red River and the underlying ground water are hydraulically connected and that ground water has a gradient toward the Red River.

Table 5. Altitude of water levels in La Bobita and Phase III wells and concurrent altitude of stage of Red River, north-central New Mexico, 2003–04.

[Permanent measuring point for Phase III wells is top of the 1-inch PVC casing (TOC); NGVD 29, National Geodetic Vertical Datum of 1929; --, no data]

Well identification (fig. 4)	Date (month/day/year)	Land-surface altitude (feet above NGVD 29)	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Water-level altitude (feet above NGVD 29)	Altitude of Red River stage (feet above NGVD 29)	Water-level altitude in well minus altitude of Red River stage (feet)
La Bobita	12/05/03	8,229.45	61.84	3.23	58.61	8,170.84	--	--
La Bobita	02/19/04	8,229.45	62.79	3.23	59.56	8,169.89	--	--
La Bobita	03/26/04	8,229.45	63.45	3.23	60.22	8,169.23	--	--
La Bobita	05/11/04	8,229.45	58.93	3.23	55.70	8,173.75	--	--
La Bobita	05/12/04	8,229.45	58.87	3.23	55.64	8,173.81	--	--
La Bobita	05/13/04	8,229.45	58.77	3.23	55.54	8,173.91	8,181.02	-7.1
La Bobita	06/02/04	8,229.45	59.40	3.23	56.17	8,173.28	8,180.03	-6.7
Well 1	12/17/03	8,187.30	21.88	2.00	19.88	8,167.42	--	--
Well 1	02/19/04	8,187.30	22.93	2.00	20.93	8,166.37	--	--
Well 1	03/26/04	8,187.30	23.45	2.00	21.45	8,165.85	--	--
Well 1	05/12/04	8,187.30	18.44	2.00	16.44	8,170.86	--	--
Well 1	05/13/04	8,187.30	18.34	2.00	16.34	8,170.96	8,181.02	-10.1
Well 1	06/02/04	8,187.30	19.09	2.00	17.09	8,170.21	8,180.03	-9.8
Well 2–1	12/17/03	8,207.92	9.18	2.00	7.18	8,200.74	--	--
Well 2–1	02/20/04	8,207.92	9.09	2.00	7.09	8,200.83	--	--
Well 2–1	03/26/04	8,207.92	8.96	2.00	6.96	8,200.96	--	--
Well 2–1	05/12/04	8,207.92	8.01	2.00	6.01	8,201.91	--	--
Well 2–1	05/13/04	8,207.92	8.02	2.00	6.02	8,201.90	8,201.71	.2
Well 2–1	06/02/04	8,207.92	8.41	2.00	6.41	8,201.51	8,200.78	.7
Well 2–2	12/17/03	8,207.94	10.29	2.00	8.29	8,199.65	--	--
Well 2–2	02/20/04	8,207.94	10.33	2.00	8.33	8,199.61	--	--
Well 2–2	03/26/04	8,207.94	10.20	2.00	8.20	8,199.74	--	--
Well 2–2	05/12/04	8,207.94	8.71	2.00	6.71	8,201.23	--	--
Well 2–2	05/13/04	8,207.94	8.63	2.00	6.63	8,201.31	8,201.71	-.4
Well 2–2	06/02/04	8,207.94	9.23	2.00	7.23	8,200.71	8,200.78	-.1
Well 3	12/17/03	8,255.54	5.61	2.00	3.61	8,251.93	--	--
Well 3	02/20/04	8,255.54	5.62	2.00	3.62	8,251.92	--	--
Well 3	03/26/04	8,255.54	5.30	2.00	3.30	8,252.24	--	--
Well 3	05/11/04	8,255.54	4.10	2.00	2.10	8,253.44	--	--
Well 3	05/13/04	8,255.54	4.13	2.00	2.13	8,253.41	8,252.88	.5
Well 3	06/02/04	8,255.54	4.54	2.00	2.54	8,253.00	8,251.87	1.1

Table 5. Altitude of water levels in La Bobita and Phase III wells and concurrent altitude of stage of Red River, north-central New Mexico, 2003–04.—Continued

[Permanent measuring point for Phase III wells is top of the 1-inch PVC casing (TOC); NGVD 29, National Geodetic Vertical Datum of 1929; --, no data]

Well identification (fig. 4)	Date (month/day/year)	Land-surface altitude (feet above NGVD 29)	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Water-level altitude (feet above NGVD 29)	Altitude of Red River stage (feet above NGVD 29)	Water-level altitude in well minus altitude of Red River stage (feet)
Well 4–1D	12/18/03	8,398.00	9.10	2.00	7.10	8,390.90	--	--
Well 4–1D	02/19/04	8,398.00	9.70	2.00	7.70	8,390.30	--	--
Well 4–1D	03/26/04	8,398.00	8.70	2.00	6.70	8,391.30	--	--
Well 4–1D	05/11/04	8,398.00	6.38	2.00	4.38	8,393.62	--	--
Well 4–1D	05/13/04	8,398.00	6.58	2.00	4.58	8,393.42	8,392.96	0.5
Well 4–1D	06/02/04	8,398.00	6.69	2.00	4.69	8,393.31	8,391.64	1.7
Well 4–1S	12/18/03	8,398.10	9.09	1.95	7.14	8,390.96	--	--
Well 4–1S	02/19/04	8,398.10	9.79	1.95	7.84	8,390.26	--	--
Well 4–1S	03/26/04	8,398.10	8.68	1.95	6.73	8,391.37	--	--
Well 4–1S	05/11/04	8,398.10	6.49	1.95	4.54	8,393.56	--	--
Well 4–1S	05/13/04	8,398.10	6.61	1.95	4.66	8,393.44	8,392.96	.5
Well 4–1S	06/02/04	8,398.10	6.77	1.95	4.82	8,393.28	8,391.64	1.6
Well 4–2D	12/18/03	8,401.95	12.10	2.05	10.05	8,391.90	--	--
Well 4–2D	02/19/04	8,401.95	13.04	2.05	10.99	8,390.96	--	--
Well 4–2D	03/26/04	8,401.95	11.50	2.05	9.45	8,392.50	--	--
Well 4–2D	05/11/04	8,401.95	7.71	2.05	5.66	8,396.29	--	--
Well 4–2D	05/13/04	8,401.95	8.11	2.05	6.06	8,395.89	8,394.99	.9
Well 4–2D	06/02/04	8,401.95	7.83	2.05	5.78	8,396.17	8,395.27	.9
Well 4–2D	06/03/04	8,401.95	7.83	2.05	5.78	8,396.17	8,394.99	1.2
Well 4–2S	12/18/03	8,402.32	12.47	2.00	10.47	8,391.85	--	--
Well 4–2S	02/19/04	8,402.32	13.41	2.00	11.41	8,390.91	--	--
Well 4–2S	03/26/04	8,402.32	11.89	2.00	9.89	8,392.43	--	--
Well 4–2S	05/11/04	8,402.32	8.40	2.00	6.40	8,395.92	--	--
Well 4–2S	05/13/04	8,402.32	8.70	2.00	6.70	8,395.62	8,394.99	.6
Well 4–2S	06/02/04	8,402.32	8.57	2.00	6.57	8,395.75	8,395.27	.5
Well 4–2S	06/03/04	8,402.32	8.55	2.00	6.55	8,395.77	8,394.99	.8

Table 5. Altitude of water levels in La Bobita and Phase III wells and concurrent altitude of stage of Red River, north-central New Mexico, 2003–04.—Continued

[Permanent measuring point for Phase III wells is top of the 1-inch PVC casing (TOC); NGVD 29, National Geodetic Vertical Datum of 1929; --, no data]

Well identification (fig. 4)	Date (month/day/year)	Land-surface altitude (feet above NGVD 29)	Depth to water (feet below permanent measuring point)	Measuring point height above land surface (feet)	Depth to water (feet below land surface)	Water-level altitude (feet above NGVD 29)	Altitude of Red River stage (feet above NGVD 29)	Water-level altitude in well minus altitude of Red River stage (feet)
Well 4–3D	12/17/03	8,397.86	12.99	1.93	11.06	8,386.80	--	--
Well 4–3D	02/19/04	8,397.86	14.10	1.93	12.17	8,385.69	--	--
Well 4–3D	03/26/04	8,397.86	12.20	1.93	10.27	8,387.59	--	--
Well 4–3D	05/11/04	8,397.86	7.18	1.93	5.25	8,392.61	--	--
Well 4–3D	05/13/04	8,397.86	7.05	1.93	5.12	8,392.74	8,391.77	1.0
Well 4–3D	06/02/04	8,397.86	7.23	1.93	5.30	8,392.56	8,390.80	1.8
Well 4–3D	06/03/04	8,397.86	7.22	1.93	5.29	8,392.57	8,390.80	1.8
Well 4–3S	12/17/03	8,398.00	13.25	2.00	11.25	8,386.75	--	--
Well 4–3S	02/19/04	8,398.00	14.38	2.00	12.38	8,385.62	--	--
Well 4–3S	03/26/04	8,398.00	12.47	2.00	10.47	8,387.53	--	--
Well 4–3S	05/11/04	8,398.00	7.37	2.00	5.37	8,392.63	--	--
Well 4–3S	05/13/04	8,398.00	8.07	2.00	6.07	8,391.93	8,391.77	.2
Well 4–3S	06/02/04	8,398.00	7.44	2.00	5.44	8,392.56	8,390.80	1.8
Well 4–3S	06/03/04	8,398.00	7.45	2.00	5.45	8,392.55	8,390.80	1.8

Wells 4–1D, 4–1S, 4–2D, 4–2S, 4–3D and 4–3S were installed between about 3,000 and 3,500 ft upstream (east) from well 3 (fig. 4). Within each of these three pairs of wells, the deeper well (designated with the letter D) was completed at depths ranging from 36.67 to 38.49 ft below land surface; the shallower well (designated with the letter S) was completed at depths ranging from 18.90 to 19.04 ft below land surface.

Ground-water levels measured in all six wells in May and June 2004 ranged from 0.2 to 1.0 ft higher in May 2004 and 0.8 to 1.8 ft higher in June 2004 than the stage of the Red River where lines approximately perpendicular to the bank of the river intersect each of the three pairs of wells. These water-level measurements indicate that the Red River and the underlying ground water are hydraulically connected and that ground water has a gradient toward the Red River.

From December 12, 2003 through June 2, 2004, ground-water levels in well 4–1S ranged from 0.07 ft higher to 0.06 ft lower than concurrently measured water levels in well 4–1D (table 5). During the same period, ground-water levels in well 4–2S ranged from 0.05 to 0.42 ft lower than concurrently measured water levels in well 4–2D, and water levels in well 4–3S ranged from 0.02 ft higher to 0.81 ft lower than concurrently measured water levels in well 4–3D (table 5). At the well 4–1 pair, the differences in concurrently measured water levels indicate neither a substantial upward nor a substantial downward vertical component of ground-water flow. At the well 4–2 pair, the differences in concurrently measured water levels indicate that an upward vertical component was present and was greater during the spring snowmelt in May and June. At the well 4–3 pair, the differences in concurrently measured water levels indicate that neither a substantial upward nor a substantial downward vertical component of ground-water flow was present except on May 13, 2004, when an upward gradient was present and was about 10 times larger than during any other of the concurrent measurements.

Within the reach of the Red River adjacent to the La Bobita well and the Phase III wells, the Red River and the shallow ground-water system appear to be hydraulically connected from the upstream part of this reach near wells 4–1D and 4–1S downstream to near wells 2–1 and 2–2. Between wells 2–1 and 2–2 and the La Bobita well and well 1, however, the nature of this connection changes, and these systems are no longer hydraulically connected or are poorly connected near the La Bobita well and well 1.

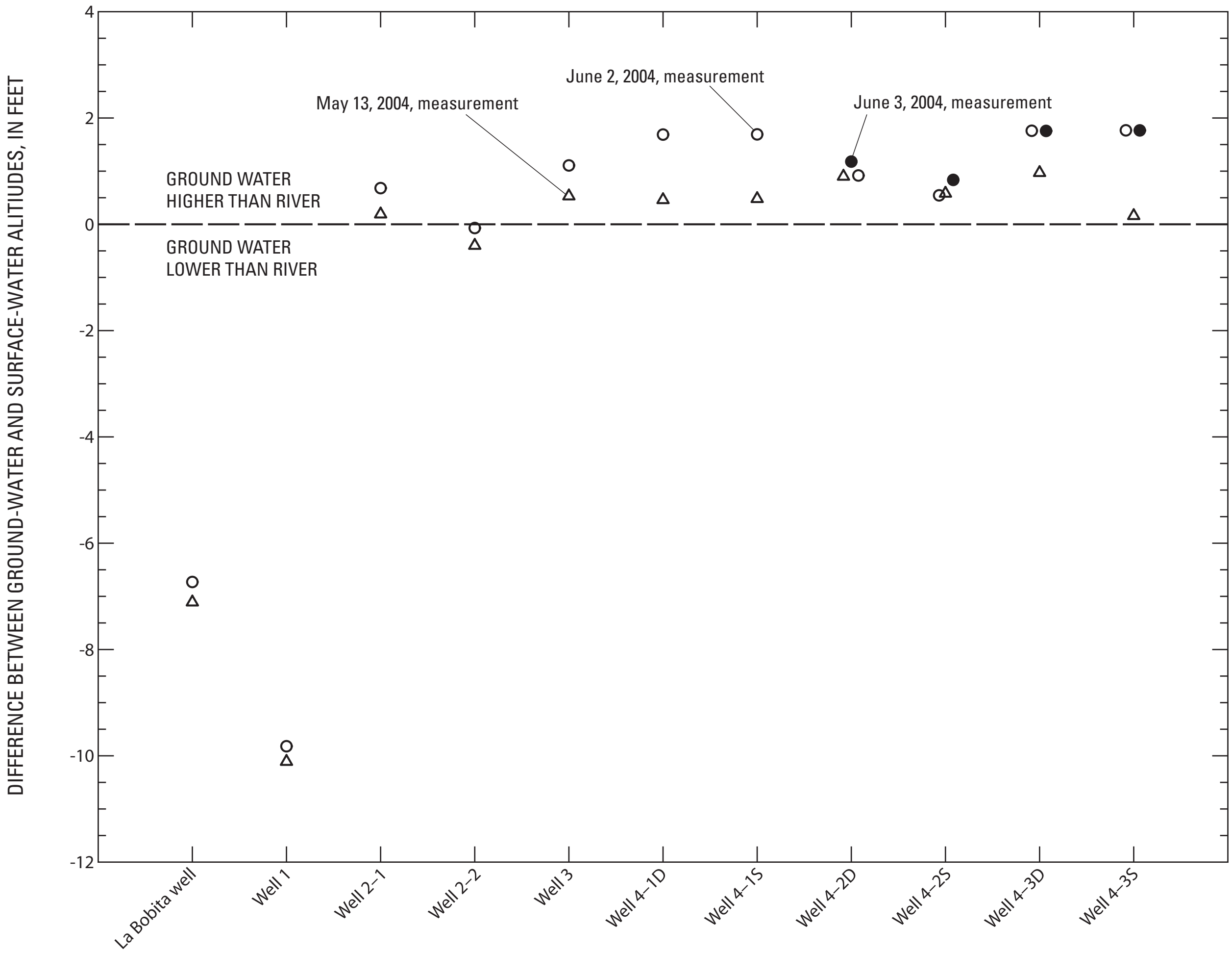


Figure 14. Difference between ground-water altitudes in La Bobita and Phase III wells and altitude of water in Red River, May 13 and June 2–3, 2004.

Summary

In April 2001, the U.S. Geological Survey (USGS) and the New Mexico Environment Department began a cooperative study to infer the pre-mining ground-water chemistry at the Molycorp molybdenum mine site in the Red River Valley, north-central New Mexico. The Molycorp molybdenum mine has operated intermittently since the 1920s; ground-water-level and water-quality data were not obtained prior to initiation of mining. To infer pre-mining ground-water chemistry, wells were drilled in five unmined areas geologically analogous to the mined area—Hottentot Creek, Straight Creek, Hansen Creek, near La Bobita campground, and Capulin Canyon.

The purpose of this report is to document and describe Phase II and Phase III well installation and development, present results of lithologic and geophysical logging, present results of hydraulic testing to determine aquifer characteristics, and present and discuss water-level measurements collected during the period March 2002 to June 2004. This report is one in a series of reports that can be used to determine pre-mining ground-water conditions at the mine site.

The main area of study within the Red River drainage basin extends west from the town of Red River to the USGS streamflow-gaging station near Questa (Questa gage). The area upstream from the Questa gage includes approximately 18 mi of the Red River and 108 mi^2 of the Red River drainage basin. Weathering of hydrothermally altered bedrock in the study area has resulted in steep, highly erosive, and sparsely vegetated scar areas that are clearly visible from the ground and in aerial photographs. Runoff from intense summer rainfall over basins tributary to the Red River can transport large quantities of sediment down tributary drainages and form debris fans where these tributaries join the Red River. Where the tributary drainages contain scar areas, the debris fans are large and indicate evidence of active deposition. Large debris fans debouching from tributary drainages have caused aggradation of the Red River streambed in river reaches upstream from debris fans.

Important water-bearing units in the Red River Valley include fractured bedrock, debris-flow deposits, and Red River alluvium. Debris-flow deposits, debris fans, and Red River alluvium are smaller in area but contain most of the ground water in the valley. Debris-flow deposits, debris fans, and the Red River alluvium typically are less than 1,000 ft wide and less than 200 ft thick.

Twenty-nine observation wells were installed in three phases as part of this study in the Red River Valley and tributary drainages. Phase I wells (SC–1A and B, SC–2B, SC–3A and B, SC–4A, SC–5A and B) were located in the Straight Creek drainage basin along the assumed path of ground-water flow in debris-flow deposits from the upstream part of the basin to near the mouth of the basin, where Straight Creek flows into Red River. Phase II well SC–6A was installed in the Straight Creek drainage, wells SC–7A and SC–8A were installed in Red River alluvial deposits west of Straight Creek, and well SC–9A was installed on the north bank of Red River to complete the series of wells in the Straight Creek drainage basin. Phase II wells also were installed in the Hottentot, Hansen, and La Bobita drainages and in Capulin Canyon. Phase III wells were installed in unconsolidated material along an approximately 1-mi reach of the Red River west of Elephant Rock campground.

Eight Phase II observation wells (Hottentot, SC–6A, SC–7A, SC–8A, Hansen, La Bobita, CC–1B and CC–2B) were drilled using an air-rotary/hammer rig equipped with a casing-advance system. The casing-advance system temporarily cased the holes ensuring that the holes did not collapse. Each well was constructed using flush-threaded, 4-in. diameter, schedule-80 polyvinyl chloride (PVC) casing and factory-cut, 0.010-in. slot size PVC screen. Three Phase II small-diameter wells were installed using a direct-push rig. Wells CC–1A and CC–2A were installed in Capulin Canyon next to the air-rotary-drilled wells CC–1B and CC–2B, respectively. Well SC–9A was installed at the mouth of the Straight Creek and was advanced under the Red River at an angle of 21.5 degrees from vertical to a total angular depth of 22.5 ft. The Phase II small-diameter wells (CC–1A, CC–2A, and SC–9A) were constructed of 1-in. diameter schedule 40 PVC with a 5-ft long screen at the total depth of the hole.

Ten Phase III small-diameter observation wells were installed using a direct-push rig along an approximately 1-mi reach of the Red River west of Elephant Rock. Each well was constructed of 1-in. diameter schedule 40 PVC casing and a 5-ft screen at the total depth of the hole.

Lithologic logs were recorded for all eight Phase II drilled wells. Borehole geophysical logging was conducted in Phase II wells SC–6A, SC–7A, and SC–8A. Lithologic logs were constructed from examination of borehole cuttings. Cuttings were collected at 5-ft intervals from land surface to total depth. Natural gamma, induction, and single-detector neutron geophysical logging were conducted in wells SC–6A, SC–7A, and SC–8A during February 2003 following well completion and development.

In well SC–6A, the geophysical logs indicate that the deposits about 11 ft above the water table were dry. The lithologic log, however, indicates that the cuttings retrieved from this interval were wet. This inconsistency between the lithologic log and the geophysical log interpretation indicates that the change in the geophysical log may be related to geologic conditions rather than a lack of moisture. For well SC–7A, geophysical logs suggest that the deposits above the water table were dry to partially saturated. For well SC-8A, geophysical logs indicate that deposits were partially saturated at about 70 ft below land surface. Induction and gamma logs from 60 to 69 ft correspond to the presence of gravel-sized deposits described in the driller's log. The neutron log indicates that porosity decreases with depth over the screened interval.

Aquifer tests conducted during 2003 to estimate the hydraulic properties of debris-flow deposits and Red River alluvial deposits in and near Straight Creek included a flow-meter survey, slug tests, and a pumping test. A flow-meter survey was conducted in well SC–7A on October 27, 2003, using a flow meter that was lowered to about 150 ft and a pump that was lowered to about 10 ft below the static water level. The well was pumped at a rate of 3.64 gal/min, and drawdown in the well reached steady state at 0.07 ft below the static water level. Results of the flow-meter survey indicated that about 77 percent of the water entered the well from a 10-ft-thick zone near the top of the screened interval and about 23 percent of the water entered the well from a 15-ft-thick zone near the bottom of the screened interval.

Slug tests were performed in wells SC–1A, SC–1B, SC–2B, SC–3A, SC–3B, SC–4A, SC–5A, SC–5B, SC–6A, SC–7A, and SC–8A during June 3–5, 2003. Water-level data were recorded during each slug test using a submersible pressure transducer connected to a data logger. For wells with screens in debris-flow deposits (wells SC–1A, SC–3A, SC–4A, and SC–6A), the mean and median estimated hydraulic conductivities were 15.25 and 15.35 ft/d, respectively. For wells with screens in bedrock (wells SC–1B, SC–2B, SC–3B, and SC–5B), the mean and median estimated hydraulic conductivities were 0.12 and 0.08 ft/d, respectively. For wells with screens in mixed debris-flow deposits and Red River alluvium (wells SC–5A, SC–7A, and SC–8A), the mean and median estimated hydraulic conductivities were 73–207 (estimated range) and 80 ft/d. In general, bedrock has the smallest hydraulic conductivity, debris-flow deposits have the next highest hydraulic conductivity, and the mixed debris-flow deposits and Red River alluvium have the largest hydraulic conductivity.

A pumping test was conducted December 3–4, 2003, on well AWWT–1 as the pumped well and wells AWWT–2, SC–5A, SC–5B, SC–7A, and SC–8A as observation wells. The time-weighted average pumping rate was 106 gal/min. Analysis of the pumping test water-level data indicated estimated transmissivity of 12,000 to 34,000 ft^2/d and estimated hydraulic conductivity of 230 to 340 ft/d.

Water-level measurements in wells SC–6A, SC–7A, SC–8A, and the Hottentot, Hansen, and La Bobita wells show that water levels typically rose rapidly during the time of melting of the winter snowpack in the spring and then generally declined during the rest of the year. The duration of water-level rise, however, appears to be typically about 2 months, after which a slow water-level decline occurs during the following 10 months. In the Straight Creek drainage, the water-level rise in response to spring snowmelt occurred earlier and was smaller at greater distances from the Red River. The spring increases in water levels in wells SC7–A and SC–8A were about eight times larger than those in well SC–6A.

Well SC–9A was dry at the time of construction but subsequently contained water. Differences between the stage in the Red River and water levels in wells SC–8A and SC–9A, and the absence of water in well SC–9A at its time of completion, indicate that the Red River had a poor hydraulic connection to the underlying ground-water system and the surface-water system is perched above the ground-water system at this site.

Water levels in Phase III wells indicate that the Red River and the shallow ground-water system appear to be hydraulically connected from near wells 4–1D and 4–1S downstream to near wells 2–1 and 2–2. Between wells 2–1 and 2–2 and the La Bobita well and well 1, however, the nature of this connection changes, and these systems are no longer hydraulically connected or are poorly connected in the vicinity of the La Bobita well and well 1.

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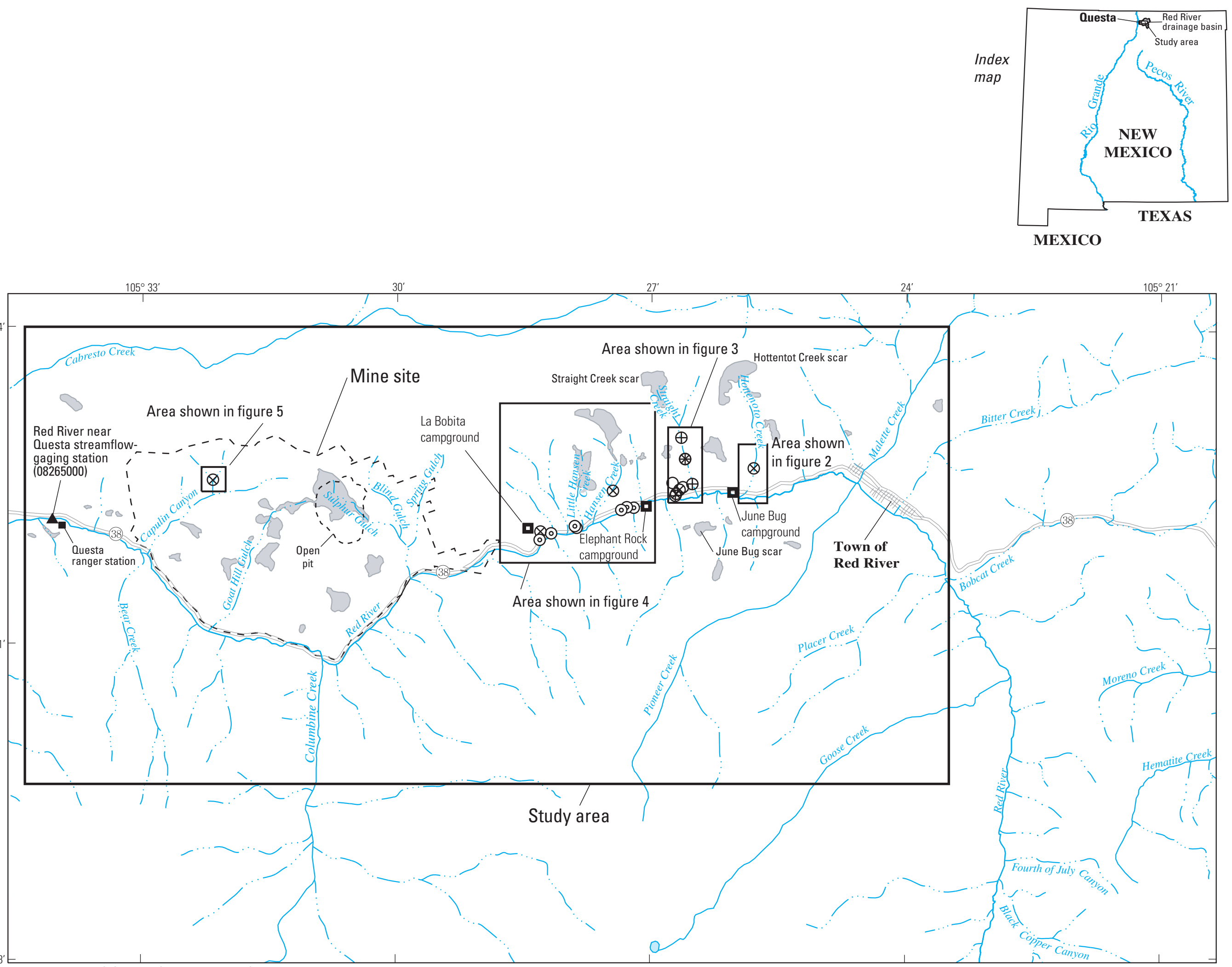

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Universal Transverse Mercator projection, Zone 13

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