USGS
science for a changing world

Prepared in cooperation with the U.S. Army Fort Irwin National Training Center

Summary of Hydrologic Testing, Wellbore-Flow Data, and Expanded Water-Level and Water-Quality Data, 2011–15, Fort Irwin National Training Center, San Bernardino County, California

Scientific Investigations Report 2019–5091

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

Front cover. Aquifer testing with temporary pump installation. Photograph taken by Christopher Kohel, 2017.

Back cover. Slug testing set up using compressed nitrogen. Photograph taken by Joseph M. Nawikas, 2011.

Summary of Hydrologic Testing, Wellbore-Flow Data, and Expanded Water-Level and Water-Quality Data, 2011–15, Fort Irwin National Training Center, San Bernardino County, California

By Joseph M. Nawikas, Jill N. Densmore, David R. O'Leary, David C. Buesch, and John A. Izbicki

Prepared in cooperation with the U.S. Army Fort Irwin National Training Center

Scientific Investigations Report 2019–5091

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

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2019

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit https://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit https://store.usgs.gov.

Suggested citation:
Nawikas, J.M., Densmore, J.N., O'Leary, D.R., Buesch, D.C., and Izbicki, J.A., 2019, Summary of hydrologic testing, wellbore-flow data, and expanded water-level and water-quality data, 2011–15, Fort Irwin National Training Center, San Bernardino County, California: U.S. Geological Survey Scientific Investigations Report 2019–5091, 161 p., https://doi.org/10.3133/sir20195091.

ISSN 2328-0328 (online)

Acknowledgments

This study was funded by the U.S. Army, Fort Irwin National Training Center. The authors thank the following personnel at the National Training Center: Justine Dishart, Muhammed Bari, Chris Woodruff, and Miles Hubbard for access assistance, and the personnel at Range Operations for providing downrange access and for helping to ensure field personnel safety.

The U.S. Geological Survey Western Research Drilling Unit is acknowledged for borehole drilling, well construction, and other field assistance. The authors also thank Brian Twining and Amanda Garcia (U.S. Geological Survey) for their reviews of an earlier draft that provided insightful comments and suggestions that greatly improved the quality of the report.

Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

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)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
cubic mile (mi^3)	4.168	cubic kilometer (km^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
acre-foot per day (acre-ft/d)	0.01427	cubic meter per second (m^3/s)
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per minute (ft/min)	0.3048	meter per minute (m/min)
foot per hour (ft/h)	0.3048	meter per hour (m/h)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile ($[ft^3/s]/mi^2$)	0.01093	cubic meter per second per square kilometer ($[m^3/s]/km^2$)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gpm)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)

Multiply	By	To obtain
	Mass	
pound (lb)	0.4536	kilogram (kg)
	Pressure	
atmosphere, standard (atm)	101.3	kilopascal (kPa)
Bar	100	kilopascal (kPa)
inch of mercury at 60 °F (in Hg)	3.377	kilopascal (kPa)
pound-force per square inch (lbf/in^2)	6.895	kilopascal (kPa)
pound per square foot (lb/ft^2)	0.04788	kilopascal (kPa)
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)
	Specific capacity	
gallon per minute per foot (gpm/ft)	0.2070	liter per second per meter ([L/s]/m)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Hydraulic gradient	
foot per foot (ft/ft)	1	meter per meter (m/m)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

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

$$°F = (1.8 \times °C) + 32.$$

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

$$°C = (°F - 32) / 1.8.$$

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Elevation, as used in this report, refers to distance above the vertical datum NAVD 88.

Water-level measurements in this report are given in feet with reference to land-surface datum (lsd). Land-surface datum is a datum plane that is approximately at land surface at each well.

Supplemental Information

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of water-quality constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Activities for radioactive constituents in water are given in picocuries per liter (pCi/L).

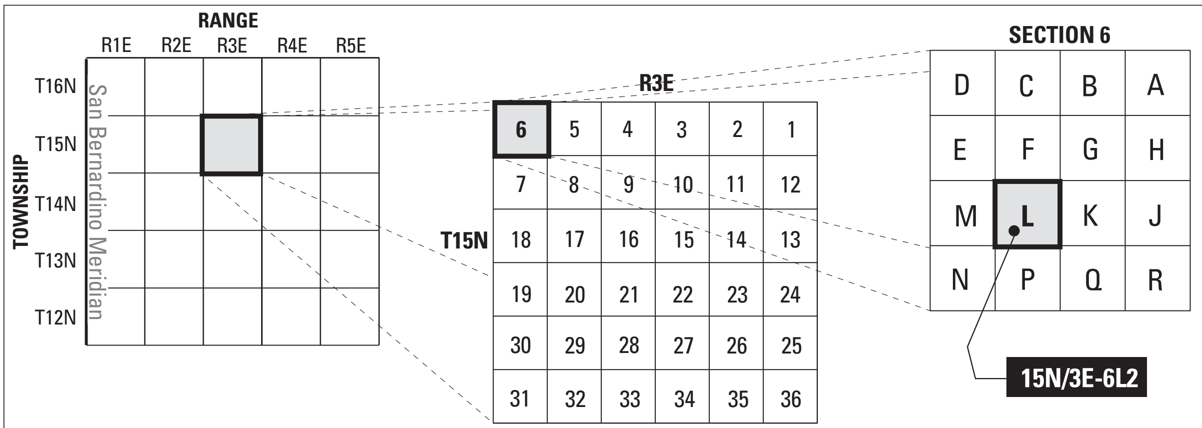
Results for measurements of stable isotopes of an element (with symbol E) in water, solids, and dissolved constituents commonly are expressed as the relative difference in the ratio of the number of the less abundant isotope (iE) to the number of the more abundant isotope of a sample with respect to a measurement standard.

Abbreviations

bls	below land surface
BD	bulk discharge
CDWR	California Department of Water Resources
EM	electromagnetic
GFM	Geologic Framework Model
HG	hydrogeologic
HGU	hydrogeologic unit
K	hydraulic conductivity
K_h	horizontal hydraulic conductivity
K_v	vertical saturated hydraulic conductivity
LG	lithostratigraphic-geophysical
LGU	lithostratigraphic-geophysical unit
MCL	maximum contaminant level
NTC	(Fort Irwin) National Training Center
NWIS	National Water Information System (USGS)
PVC	polyvinyl chloride
RMS	residual standard error
TDS	total dissolved solids
USGS	U.S. Geological Survey

Well-Numbering and Naming System

Wells are assigned a state well number (station name) by the California Department of Water Resources according to the location in the rectangular township and range grid system for the subdivision of public lands. Station names consist of the township number, north or south; the range number, east or west; and the section number. Each section is divided into sixteen 40-acre tracts lettered consecutively (except "I" and "O"), beginning with "A" in the northeast corner of the section and progressing in a sinusoidal manner to "R" in the southeast corner. Within the 40-acre tract, numbers are assigned sequentially in the order the wells are inventoried. The next letter within the station name refers to the base line and meridian. California has three base lines and meridians—Humboldt (H), Mount Diablo (M), and San Bernardino (S). Wells in the study area are referenced to the San Bernardino and Mount Diablo base line and meridian (S and M). Well numbers consist of 15 characters and follow the format 015N003E06L002S. In this report, wells are abbreviated and written as 15N/03E-06L2S. Wells are abbreviated in figures by their section number, tract letter, and sequence number (for example, 6L2). In addition to a station name assigned by the California Department of Water Resources, wells were assigned a common name derived from the basin in which they were installed and a sequence number. Wells were also assigned a unique 15-digit site identification number in the U.S. Geological Survey National Water Information System database.



Well-numbering diagram (Note: maps in this report use abbreviated well numbers such as **"6L2".**)

Summary of Hydrologic Testing, Wellbore-Flow Data, and Expanded Water-Level and Water-Quality Data, 2011–15, Fort Irwin Training Center, San Bernardino County, California

By Joseph M. Nawikas, Jill N. Densmore, David R. O'Leary, David C. Buesch, and John A. Izbicki

Abstract

In view of the U.S. Army's historical reliance and plans to increase demands on groundwater to supply its operations at Fort Irwin National Training Center (NTC), California, coupled with the continuing water-level declines in some developed groundwater basins as a result of pumping, the U.S. Geological Survey (USGS), in cooperation with the U.S. Army, evaluated the water resources, including water quality and potential groundwater supply, of undeveloped basins in the NTC. Previous work in the three developed groundwater basins—Langford, Bicycle, and Irwin—provided information to support water-resources management of those basins. During 2009–12, the USGS installed 41 wells at the NTC; 34 wells were at 14 single- or multiple-well monitoring sites, and 7 wells were long-screen test wells. The majority of the wells were installed in previously undeveloped or minimally developed groundwater basins (Cronise, Red Pass, the Central Corridor area, Superior, Goldstone, and Nelson Basins). During 2012–15, the USGS tested hydrologic properties at 32 wells in 8 basins to help characterize the aquifer system. This report presents data and analyses from core samples; slug tests and single-well aquifer tests; coupled measurements of wellbore flow, water levels, and water-quality constituents; and results from two-dimensional numerical modeling. This information provides a basis for developing and constraining basin-scale hydrogeologic framework and groundwater-flow models to further evaluate water resources in each groundwater basin.

Core samples were tested for vertical saturated hydraulic conductivity, physical properties, and particle-size distribution. Vertical saturated hydraulic conductivities of the cores ranged from less than 0.00001 to 18.13 feet per day, and porosities ranged from 0.15 to 0.56. These physical properties and particle-size analyses indicate the high degree of heterogeneity of the hydrogeologic deposits penetrated by the boreholes. Horizontal hydraulic conductivities estimated from slug tests in 22 monitoring wells in 6 basins (Cronise, Central Corridor area, Goldstone, Langford, Bicycle, and Nelson Basins) ranged from less than 0.1 to 40 feet per day. Results of the aquifer tests at six test wells in the Goldstone, Nelson, and Superior Basins indicate hydraulic conductivities ranged from 0.37 to 66 feet per day; associated transmissivity values ranged from 130 to 28,000 feet squared per day. Wellbore-flow data, collected from the six test wells under unpumped and pumped conditions, generally showed downward movement of water. Flow data collected under unpumped conditions indicate groundwater entered the well through the upper part of the screened interval and exited to aquifer zones in the lower part of the screened interval at rates ranging from 1 to 3 gallons per minute. Flow data collected under pumping conditions show increased flow downward in the test wells, indicating higher yields from deeper aquifers.

Water levels, measured periodically between 2011 and 2015, remained stable during this period in the majority of the wells measured since 2011, except at two monitoring sites in developed basins (Bicycle and Langford). Vertical hydraulic gradients were generally low throughout the NTC, but ranged from –0.0003 to 0.27 during the summer of 2015. Multiple-well monitoring sites in Bicycle, Central Corridor area, Cronise, Goldstone, Nelson, and Superior Basins, had downward vertical gradients.

Groundwater in wells in Nelson and Superior Basins, and wells BLA5, CCT1, and GOLD2 #2, was characterized as sodium-bicarbonate water, whereas groundwater from the remaining wells in Goldstone Basin was characterized as sodium-chloride water and Cronise Basin, and well LL04 was characterized by sodium-sulfate water. Total dissolved solids (TDS) ranged from 285 to 13,400 milligrams per liter (mg/L) TDS and chloride concentrations ranged from 19 to 1,030 mg/L chloride, with lowest concentrations of each in groundwater from Superior and Nelson Basins and highest concentrations in Cronise Basin. Nitrate plus nitrite as nitrogen ranged from less than 0.040 mg/L in groundwater from Cronise and Goldstone Basins to about 20 mg/L in Nelson Basin. Groundwater from wells in Nelson Basin was isotopically light, whereas groundwater samples from wells CRTH1, CRTH2, and LL04 were isotopically heavier and plotted along an evaporative trend line. No measurable tritium was detected in groundwater from 13 wells sampled in 2015, indicating that groundwater was recharged prior to 1952. Measured carbon-14 (^{14}C) activities in groundwater from four wells sampled in 2015 ranged from about 7.9 to 23.5 percent modern carbon and had apparent (uncorrected) ages of 11,970–20,980 years. Arsenic concentrations were above the maximum contaminant level of 10 micrograms per liter in groundwater from all wells, except those in Goldstone Basin and the two deepest wells in Langford Basin (LL04); likewise, fluoride concentrations were above the California maximum contaminant level of 2 mg/L in groundwater from most wells, except those in Goldstone and Superior Basins, the middle well in Langford Basin, middle and deep wells in two locations in Cronise Basin, and two wells in Nelson Basin.

Wellbore flow was simulated for each well by using an integrated-flow analysis tool, AnalyzeHOLE, to evaluate aquifer properties and heterogeneity. Horizontal layers in the model (hydrogeologic units) were defined by lithostratigraphic-geophysical units, interpreted from lithologic and geophysical logs for each well, and were adjusted during calibration. The saturated hydraulic conductivities derived from the calibrated simulations ranged from less than 0.01 to 60 feet per day in Nelson, Goldstone, and Superior Basins.

Introduction

The U.S. Army Fort Irwin National Training Center (NTC) is approximately 35 miles (mi) north-northeast of Barstow, California; covers approximately 1,177 square miles (mi^2); and contains 10 groundwater basins (fig. 1; California Department of Water Resources, 2003), 3 of which have been subdivided on the basis of additional hydrologic testing. Historically, the NTC has relied on groundwater pumped from three developed groundwater basins (Irwin, Langford, and Bicycle) to supply water for base operations. These basins are proximal to the cantonment areas where all base housing and substantial infrastructure are located. Extraction of groundwater at the NTC began as early as 1941 in Irwin Basin. Since the 1990s, reduced pumping in the Irwin Basin and artificial recharge by infiltration of wastewater from Irwin, Bicycle, and Langford Basins have caused water levels to stabilize or recover in much of the Irwin Basin (Voronin and others, 2013). Water levels have declined as a result of pumping in Bicycle and Langford Basins, however. Continued groundwater extraction and artificial recharge by infiltration have resulted in two unintended consequences: (1) land subsidence and earth fissuring in Bicycle Basin, presumably as a result of water-level declines, differential compaction, and tectonic forces, and (2) increased total dissolved solids (TDS) and nitrate concentrations in Irwin Basin as a result of infiltration of treated wastewater (Densmore and Londquist, 1997; Densmore, 2003). The U.S. Geological Survey (USGS) has been investigating groundwater-related concerns of the U.S. Army at Fort Irwin since the early 1990s. One issue of concern is the effect of planned expansion of training and infrastructure at the NTC on groundwater resources. In 2010, the USGS, in cooperation with the U.S. Army, began investigations of groundwater resources focused primarily on undeveloped basins in the NTC. In addition to collecting hydrologic data from undeveloped basins, this investigation and report included a compilation of existing hydrologic and drilling data collected during 2004 and 2009 from the developed basins.

The goals of the study reported here were the evaluation of the long-term availability and quality of water resources in generally undeveloped basins in the NTC; consequently, the USGS completed multiple-well monitoring sites and test wells in Bicycle, Langford, Cronise, Red Pass, the Central Corridor area, Superior, Goldstone, and Nelson Basins (fig. 2). As part of these studies, the USGS completed 41 wells during 2009–12. Kjos and others (2014) described the site construction, data-collection methods, lithologic and borehole-geophysical logs, water-levels, and water-quality data associated with the installation of 34 monitoring wells (2-in. diameter) at single-well and multiple-well monitoring sites at 14 locations and of 7 test wells (8-in. diameter) in the NTC. During 2012–15, hydrologic properties were estimated for these wells to characterize the aquifer system and provide input for the development of groundwater-flow models.

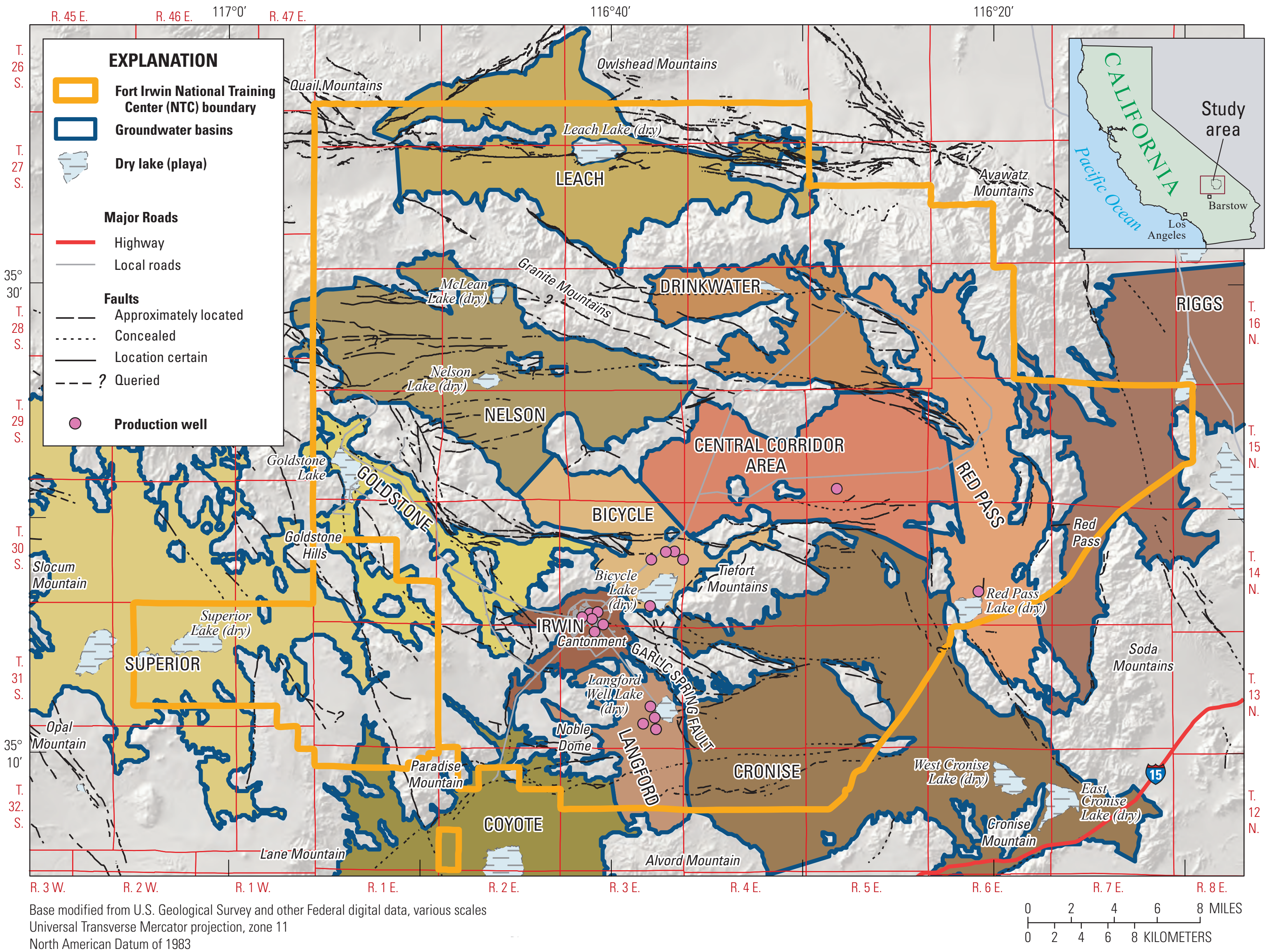


Figure 1. Study area, production wells, and groundwater basins at Fort Irwin National Training Center, California.

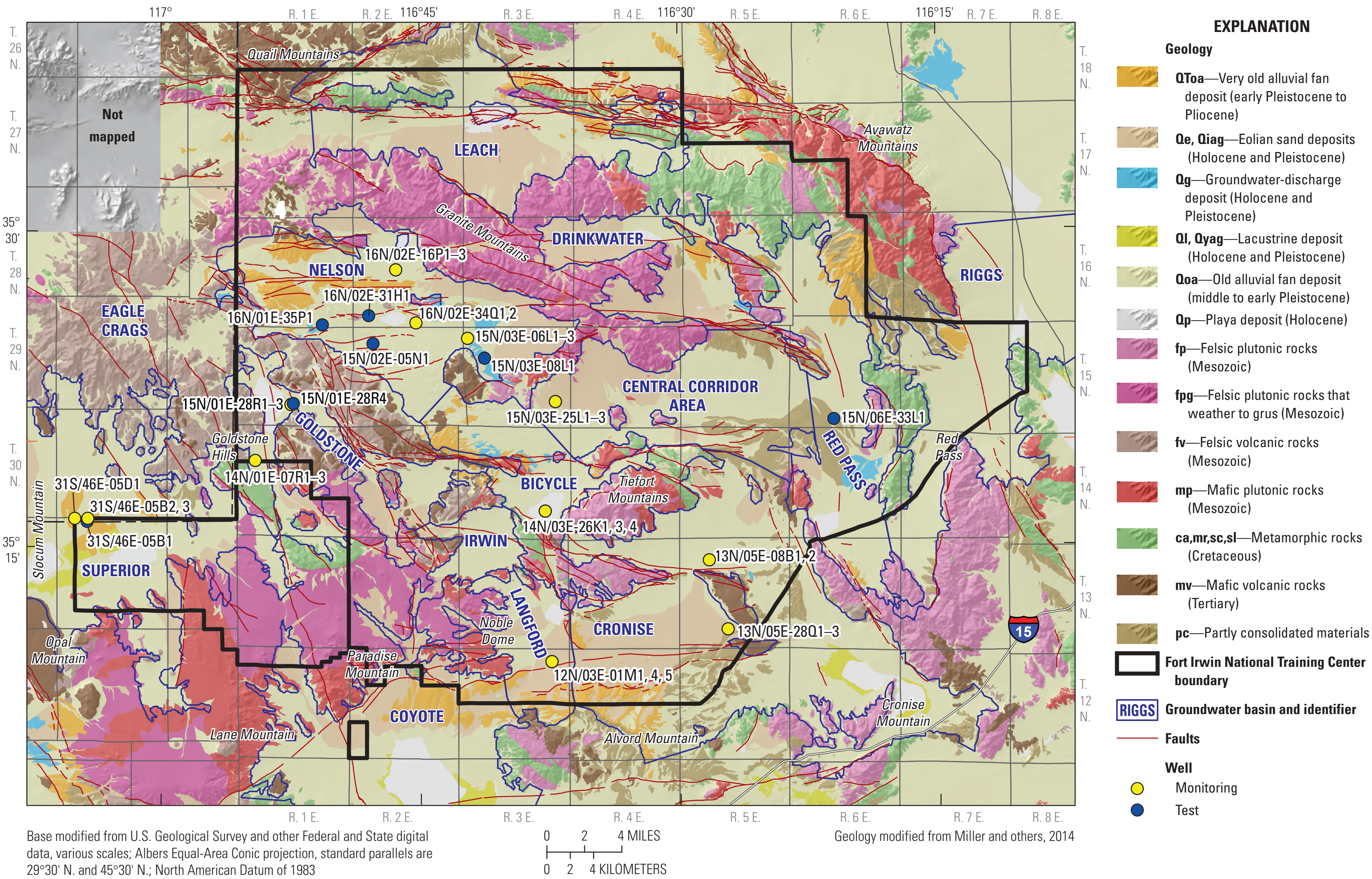


Figure 2. Generalized geology, groundwater basins, and locations of multiple-well monitoring sites and test wells at Fort Irwin National Training Center, California.

Purpose and Scope

The purpose of this report is to present hydrologic testing data collected from multiple-well monitoring sites and test wells in six undeveloped basins proximal to the cantonment area of the NTC and supplemental data collected in two previously developed basins. This report describes estimates of aquifer properties and aquifer conditions, including vertical gradients between or within aquifers, as indicated by ambient (unpumped) wellbore-flow logs in test wells, and vertical differences in water-level and water-quality data at multiple-well monitoring sites. Hydrogeologic data from boreholes in basins at the NTC, first described by Kjos and others (2014), were used to aid analysis of the hydrologic testing data. This report includes a description of the methods and procedures used for slug and aquifer testing; wellbore-flow measurement; and collection, analysis, and wellbore modeling of depth-dependent data and wellbore flow in long-screened test wells. Data presented in this report are to be used as input for the development of groundwater-flow models to further evaluate groundwater resources in each basin. The scope of this report is limited to the basins and subbasins in which wells were constructed, which include Bicycle, Nelson, Langford, Superior, Goldstone, Cronise, Red Pass, and the Central Corridor area (fig. 2).

Geologic Setting

The NTC is in the Mojave Desert region of southern California, a region typified by a wide variety of rock types and faults. The basement rocks and surrounding mountains chiefly consist of Mesozoic and older crystalline rocks but include lesser amounts of metamorphic and sedimentary rocks. The basin fill deposits consist of mainly Miocene to Pliocene volcanic and sedimentary rocks, poorly consolidated to consolidated Quaternary–Tertiary deposits, and Quaternary deposits (Miller and others, 2014). The western part of the NTC is along the eastern and southern edges of the Eagle Crags volcanic field (19–12 mega-annums, Ma, in age), which includes thick accumulations of lava flows, pyroclastic rocks, and volcaniclastic-tuffaceous sandstone and conglomerate (Sabin, 1994). Figure 2 shows the generalized surficial geologic map of the Fort Irwin area, as mapped by Miller and others (2014); however, only the units germane to this study are presented in figure 2.

The NTC area includes numerous faults that are part of the eastern California shear zone, a generally northeast–southwest-trending structural zone in the eastern part of the NTC. Faulting began in this area about 10 Ma (Schermer and others, 1996). The period of faulting in the NTC area ranges from Miocene to Holocene. Faulting at the NTC affects groundwater level and movement. Some faults could form barriers to groundwater flow. Although many of the faults do not cut Holocene deposits, some faults indicate Holocene activity (Miller and others, 2014).

Geologic mapping by Miller and others (2014) identified 20 geologic units across the NTC. Ongoing unpublished mapping by Buesch and Miller (U.S. Geological Survey, written commun., 2016) in the western part of the NTC has further refined the classification of surficial geologic units to 32 units (fig. 3). These units represent variations in rock types, and although few of these units have documented hydraulic properties, the variations in properties such as composition, grain size, sorting, porosity, and fracture characteristics can be used to help constrain estimates of hydraulic properties of these units. The geologic units by Buesch and Miller (U.S. Geological Survey, written commun., 2016; modified from Miller and others, 2014), together with the distribution of faults, provided first-order approximations of rocks and structural features that might have hydrogeologic importance; they are to be incorporated into a geologic framework model (GFM) for numerical groundwater modeling.

The 32 map units presented in figure 3 are divided into 4 main categories. These categories are (1) 14 Holocene units of varying lithology (this group is collectively referred to as Qu) and 3 early Pleistocene to Pliocene units that include alluvial fan deposits (QToa), playa deposits (QTp), and young basaltic lava flows (QTb); (2) 7 Miocene rock units that include basalt and basaltic andesite lava flows (Tba), flows of dacite to rhyolite (Tf), domes of dacite to rhyolite (Td), 2 types of volcanic and tuffaceous sedimentary rocks (Tv and Tts), fine-grained sandstone (Ts), and conglomerate and coarse-grained sandstone (Tc); (3) Mesozoic plutonic (fp, fpg, mp) and metavolcanic (mv) rocks; and (4) Cretaceous metaphoric (mr), carbonate (ca), schistose (sc), and siliciclastic (sl) rocks. Although 32 map units currently are used in the GFM (fig. 3), this report only focuses on the units identified from boreholes drilled in Nelson, Goldstone, and Superior Basins (fig. 2).

No geochronologic data were available from any of the boreholes drilled as part of this study; therefore, for the purpose of this report, tentative assignments of age, such as undivided Quaternary (Qu), early Pleistocene to Pliocene (QT), and Tertiary (T, most likely Miocene), were assigned according to lithologic features, descriptions of borehole cuttings, and geophysical properties. Volcanic-rich sedimentary rocks (identified with GFM unit symbol Tv) are the most abundant rocks penetrated in the boreholes of Nelson Basin. For the purpose of this study, and to further understand the hydrostratigraphy of major basins at the NTC, the volcanic-rich sedimentary rocks (Tv) were subdivided into six lithostratigraphic-geophysical units (LGUs) to reflect the different properties of the volcanic-rich sedimentary rocks (Tv). A similar classification has been applied to the volcanic-rich sedimentary rocks from boreholes in Goldstone Basin; however, the volcanic-rich sedimentary rocks (Tv) should not be considered laterally continuous across basin boundaries. Details of the lithostratigraphic-geophysical units are discussed later in this report.

Era	Period	Epoch	GF symbol	GF unit description[1]	Nelson Basin		Goldstone Basin		Superior Basin	
					LG unit	HG unit	LG unit	HG unit	LG unit	HG unit
Cenozoic	Quaternary	Holocene	Qac	Active stream channel	Qu+QToa(N)$_{LG}$	Qu+QToa(N)$_{HG}$	–	–	–	–
			Qap	Active playa			–	–	–	–
			Qag	Active groundwater discharge deposits			–	–	–	–
			Qya	Young alluvial fan and valley axis deposits			–	–	–	–
			Qye	Young eolian deposits			–	–	–	–
			Qae	Mixed alluvial fan and eolian deposits			–	–	–	–
			Qyg	Young groundwater discharge deposits			–	–	–	–
			Qyl	Young lacustrine deposits			–	–	–	–
			Qyp	Young playa deposits			–	–	–	–
			Qia	Intermediate alluvial fan and valley axis deposits			–	–	–	–
			Qie	Intermediate eolian deposits			–	–	–	–
			Qig	Intermediate groundwater discharge deposits			–	–	–	–
			Qil	Intermediate lacustrine deposits			–	–	–	–
			Qoa	Old alluvial fan deposits			–	–	–	–
		Pleistocene to Pliocene	QToa	Conglomerate and sandstone			QToa(G)$_{LG}$	QToa(G)$_{HG}$	QToa(S)$_{LG}$	QToa(S)$_{HG}$
			QTp	Playa and groundwater discharge deposits			–	–	–	–
	Tertiary		QTb	Young basalt	–	–	–	–	QTb(S)$_{LG}$	QTb(S)$_{HG}$
		Miocene	Tts	Tuffaceous sedimentary rocks	Tts(N)$_{LG}$	Tts(N)$_{HG}$	–	–	–	–
			Ts	Shale, siltstone, and fine sandstone	Ts(N)$_{LG}$	Ts(N)$_{HG}$	–	–	–	–
			Tv	Volcanic-rich strata	Tv1(N)$_{LG}$	Tv1(N)$_{HG}$	Tv1(G)$_{LG}$	Tv1(G)$_{HG}$	Tv(S)$_{LG}$	Tv(S)$_{HG}$
					Tv2(N)$_{LG}$	Tv2(N)$_{HG}$	Tv2(G)$_{LG}$	Tv2(G)$_{HG}$		
					Tv3(N)$_{LG}$	Tv3(N)$_{HG}$	Tv_vb(G)$_{LG}$	Tv_vb-1(G)$_{HG}$		
								Tv_vb-2(G)$_{HG}$		
					Tv4(N)$_{LG}$		Tv3(G)$_{LG}$	Tv3(G)$_{HG}$		
						Tv4(N)$_{HG}$				
					Tv5(N)$_{LG}$	Tv5-1(N)$_{HG}$	Tv4(G)$_{LG}$	Tv4(G)$_{HG}$		
						Tv5-2(N)$_{HG}$				
					Tv6(N)$_{LG}$	Tv6(N)$_{HG}$	Tv5(G)$_{LG}$	Tv5(G)$_{HG}$		
			Tc	Conglomerate and coarse sandstone	Tc(N)$_{LG}$	Tc(N)$_{HG}$	Tc(G)$_{LG}$	Tc(G)$_{HG}$	–	–
			Td	Domes of dacite to rhyolite	–	–	–	–	–	–
			Tf	Flows of dacite to rhyolite	–	–	–	–	–	–
			Tba	Basalt and basaltic andesitic flows	Tba(N)$_{LG}$	Tba(N)$_{HG}$	Tba(G)$_{LG}$	Tba(G)$_{HG}$	–	–
Mesozoic			fp	Felsic plutonic rocks	–	–	–	–	–	–
			fpg	Felsic plutonic rocks that weather to grus	–	–	–	–	–	–
			mp	Mafic plutonic rocks	–	–	–	–	–	–
			mv	Metavolcanic rocks	–	–	–	–	–	–
Paleozoic to Cretaceous			mr	Metamorphic rocks	mr(N)$_{LG}$	mr(N)$_{HG}$	–	–	–	–
			ca	Carbonate rocks	–	–	–	–	–	–
			sc	Schistose rocks	–	–	–	–	–	–
			sl	Siliciclastic rocks	–	–	–	–	–	–

[1]David Buesch and David Miller, written commun., 2016.

[GF, Geologic Framework Model; HG, Hydrogeologic; LG, Lithostratigraphic-geophysical]

Figure 3. Geologic-framework (GF), lithostratigraphic-geophysical (LG), and hydrogeologic units identified from boreholes, Fort Irwin National Training Center, California.

Hydrogeologic Setting

The NTC includes 10 groundwater basins: Bicycle Valley, Langford Valley (subbasins, Irwin and Langford Well Lake), Superior Valley Basin, Goldstone Valley, Cronise Valley, Red Pass Valley, Avawatz Valley (locally called Drinkwater), Leach Valley, Coyote Lake Valley, and Riggs Valley (California Department of Water Resources, 2003). Most of the basin boundaries are the same as those defined by the California Department of Water Resources (CDWR), except for Bicycle Valley, Langford Valley, and Red Pass Valley, which were subdivided as described later. For simplicity, in this report the word “valley” was dropped from the CDWR basin name (figs. 1, 2); thus, the basins are referred to as Superior, Goldstone, Cronise, Drinkwater, Leach, Coyote, and Riggs Basins. California Department of Water Resources (2003) subdivided Langford Valley Basin into two subbasins: Irwin and Langford Well Lake Basins; Langford Well Lake is referred to as Langford Basin in this report. For the purpose of this study, additional subdivisions were based on groundwater divides; Bicycle Valley Basin was subdivided into Bicycle and Nelson subbasins, referred to as Bicycle and Nelson Basins in this report; likewise, Red Pass Valley Basin was subdivided into the Central Corridor area and Red Pass subbasin, referred to as Central Corridor area and Red Pass Basin in this report.

Typical of desert regions, natural recharge is mainly limited to precipitation runoff and infiltration along ephemeral washes and near the base of the surrounding hills during winter rains and short summer thunderstorms (Densmore and Londquist, 1997). No perennial streams are present on the NTC (Mendez and Christensen, 1997). Limited local precipitation data were available for the basins; historical records for the NTC from the Goldstone ECHO 2, California, weather station (043498) in Goldstone Basin from December 01, 1973, to July 31, 2006, indicate an average annual precipitation of 5.80 inches (Western Region Climate Center, 2009), although this average can vary greatly from year to year. Because of similar climatic conditions across the basins, similar average precipitation values are expected for all basins at the NTC. As of 2015, wells in Bicycle, Langford, and Irwin Basins (fig. 1) provided all potable groundwater required for operation of the NTC.

Bicycle Valley Basin contains the Nelson and Bicycle Basins and has a drainage area of approximately 140 mi^2 (California Department of Water Resources, 2003). Bicycle Basin drainage area covers 37 mi^2, and the floor of Bicycle Basin covers an area of approximately 10.5 mi^2 (Densmore and others, 2018) and is bounded to the northwest and northeast by low-lying unnamed granitic and volcanic hills and to the east by the Tiefort Mountains (fig. 1). To the south, low-lying hills separate Bicycle Basin from Irwin Basin (California Department of Water Resources, 2003). Bicycle Lake (dry), a playa, is in the southern part of the basin (fig. 1). The floor of Bicycle Basin ranges in elevation from approximately 2,350 feet (ft) at the playa to about 2,600 ft at the base of Tiefort Mountain. Surface runoff drains internally to Bicycle Lake; however, underflow moves from Bicycle Basin to the east of Bicycle Lake through fractured rock in the faulted area along the southeastern edge of the playa (Diane Rewis, U.S. Geological Survey, written commun., 2010).

Nelson Basin has a drainage area of approximately 103 mi^2 and is bounded to the north and east by the Granite Mountains, to the southwest by Tertiary volcanic highlands, and to the south-southeast by low-lying granitic and volcanic hills separating it from the Central Corridor area and Bicycle Basin, respectively (fig. 2). A drainage divide forms a part of the eastern boundary (Jennings and others, 1962). The basin elevation ranges from approximately 3,050 ft above NAVD 88 at Nelson Lake (dry), to approximately 3,400 ft above NAVD 88 in the southwest part of the basin. Surface runoff from the Tertiary volcanic highlands and Granite Mountains drains internally to the Nelson Lake (dry) and McLean Lake (dry) playas in the central and northern part of the basin, respectively, and along an ephemeral wash that terminates at Bicycle Lake (dry) in the southeastern part of Bicycle Basin (fig. 2).

Langford Valley Basin has a total surface area of 46.6 mi^2, shared between Langford Basin (30.2 mi^2) and Irwin Basin (16.4 mi^2; California Department of Water Resources, 2003). Langford Basin is bounded to the northeast by low-lying hills at the base of the Tiefort Mountains, which formed along the Garlic Spring fault, to the northwest by low-lying hills separating it from Irwin Basin, to the west by Noble Dome, and to the south by Alvord Mountain (fig. 1). To the east, the low-lying hills form a drainage divide that separates Langford Basin from Cronise Basin. Langford Well Lake (dry), a playa (fig. 1), is in the northeastern part of the basin. The basin ranges in elevation from approximately 2,160 ft at Langford Well Lake to approximately 2,800 ft at the base of Alvord Mountain. Surface runoff drains to Langford Well Lake, but the low permeability of the playa sediments impedes groundwater recharge; thus, most runoff is lost to evaporation. Groundwater flows from Irwin Basin to Langford Basin beneath an unnamed wash paralleling the Garlic Spring fault (Densmore and Londquist, 1997; fig. 2). Groundwater underflow moves through a heavily faulted zone out of the Langford Basin to Cronise Basin, beneath the low-lying drainage divide east of the Langford Well Lake (Voronin and others, 2013).

The Superior Basin has a surface area of approximately 188 mi^2 (California Department of Water Resources, 2003). The basin is bounded to the north by Eagle Crags, to the east and southeast by low-lying hills dividing Superior Basin from Goldstone Basin and Coyote Basin, to the south by Lane Mountain and Opal Mountain, and to the west by Slocum Mountain (figs. 1, 2; California Department of Water Resources, 2003). The elevation of the basin ranges from approximately 2,990 ft at Superior Lake (dry), a playa, to approximately 3,400 ft at the base of Eagle Crags. Superior Lake (dry) is the easternmost of three playas in the south-central part of the basin where surface runoff drains internally (fig. 1).

Goldstone Basin has a surface area of approximately 44 mi^2 (California Department of Water Resources, 2003). The basin is bounded to the west and southwest by consolidated nonwater-bearing metamorphic and volcanic rocks of the Goldstone Hills and to the north, east, and south by Tertiary volcanic hills and plutonic rocks (figs. 1, 2). The elevation ranges from approximately 2,800 ft in the southeastern part of the basin to approximately 3,025 ft at Goldstone Lake (dry), a playa, to approximately 3,700 ft in the southwestern part of the basin. Surface runoff drains internally to Goldstone Lake in the northern part of the basin and exits the basin eastwardly to Bicycle Lake in the southern part of Bicycle Basin (fig. 1).

Cronise Basin has a surface area of approximately 198 mi^2 (California Department of Water Resources, 2003). The basin is bounded to the west by low-lying hills separating Cronise Basin from Langford Basin, to the east and northeast by the Soda Mountains, and to the north-northwest by Tiefort Mountains (fig. 1). The basin extends south beyond the edge of the NTC to a low point at the eastward extension of the Alvord and Cronise Mountains near West and East Cronise Lakes (dry), playas (fig. 1). The elevation ranges from 1,065 ft at West Cronise Lake to 2,500 ft in the northern part of the basin. Surface runoff drains internally to West and East Cronise Lakes in the southeastern part of the basin (fig. 1). The heavily faulted, low-lying drainage divide east of Langford Well Lake allows subsurface underflow into the basin (Voronin and others, 2013).

The Red Pass Valley Basin, containing the Central Corridor area and Red Pass Basin, has a surface area of approximately 151 mi^2 (California Department of Water Resources, 2003). The Red Pass Basin has an area of approximately 73 mi^2 and is bounded to the north by the Avawatz Mountains, to the east by low-lying hills that separate Red Pass Basin from Riggs Basin, to the south by the Soda Mountains, and to the west-southwest by low-lying hills that separate Red Pass Basin from Cronise Basin (fig. 1; California Department of Water Resources, 2003). A low rise to the northwest separates Red Pass Basin from the Central Corridor area, which has an area of approximately 77 mi^2 and is bounded to the north by the Granite Mountains and to the south by the Tiefort Mountains and low-lying hills that separate the Central Corridor area from Cronise Basin. Surface runoff flows from the Granite Mountains through the Central Corridor area to Red Pass Basin from the west and from the Avawatz Mountains in the north. Red Pass, a narrow canyon, cuts through the low-lying hills separating Red Pass Basin from Riggs Basin to the east and allows most of the surface runoff from the northern part of the basin to exit to Riggs Basin (California Department of Water Resources, 2003). The basin elevation ranges from approximately 1,600 ft at Red Pass to approximately 2,600 ft at the base of the Avawatz Mountains. Red Pass Lake (dry), a playa (fig. 1), is in the southern part of the Red Pass Basin. Red Pass Lake is approximately 1,850 ft elevation and is separated from the northern part of the basin by a small rise acting as a partial barrier to surface-water drainage from the north. The southern part of the basin is drained internally to Red Pass Lake. The northern part of Red Pass Basin is drained externally, primarily through Red Pass to the east into Riggs Basin; some of the surface runoff reaches Red Pass Lake, presumably during high-flow events.

Methods of Study

Descriptions and hydraulic characterization of aquifer materials and the overlying unsaturated zone in basins of the NTC were determined from data collected as part of drilling and well construction, geophysical logging, flowmeter surveys, slug tests and aquifer tests, and the results from associated analyses. All wells discussed in this report were drilled and constructed by the USGS Western Region Research Drilling Unit using standard mud-rotary techniques. Table 1 provides a summary of these sites. A detailed description of sites, construction and data-collection methods, lithologic logs, borehole-geophysical logs, water-level, and water-quality data associated with the installation of 34 single-well and multiple-well monitoring sites at 14 locations and 7 test wells (8-in. diameter) at the NTC is provided in Kjos and others (2014).

Drilling and Collection of Cores and Cuttings

Drill cores were collected at the time of drilling from discrete depths within each of the boreholes. Cores were described and tested for vertical hydraulic conductivity and physical properties including bulk density, porosity, volumetric water content, and saturation. Methods of testing are presented later in this report; results from these tests will be used for calibration purposes in future numerical modeling. Drill cuttings also were collected during drilling by the following two methods: (1) “sieved” samples were collected throughout a 20-ft interval from the returning drilling fluid, and (2) “shaker” samples were collected as grab samples every 10 ft (Kjos and others, 2014). Sieved samples represent a composite of finer grained material from the entire 20-ft drilling interval, whereas shaker samples represent the coarser grained material at discrete points.

Borehole Geophysical Logs

Borehole geophysical logs for each multiple-well monitoring site and test well were collected from uncased fluid-filled boreholes after drilling and prior to well installation to provide information on the lithologic units and water-quality characteristics of the groundwater encountered during drilling. Five types of geophysical logs were collected in all boreholes: caliper, gamma, resistivity, sonic velocity, and spontaneous potential. These data were collected at 0.1-ft intervals and represent an almost continuous recording of properties along the borehole. Details regarding borehole geophysical logging are presented by Kjos and others (2014).

Table 1. Well-construction data and type of hydrologic testing for single- and multiple-well monitoring sites and test wells, Fort Irwin National Training Center, California.

[Elevations were interpolated from a topographic map. Well locations shown on figure 2. All wells were constructed with schedule-80 polyvinyl chloride (PVC) casing and slotted screens, except RDPS, which was constructed with steel casing and slotted screens. All monitoring wells have screen slot size of 1.5 inches (in.) long by 0.02 in. wide; all test wells have screen slot size of 1.6 in. long by 0.03 in. wide. The borehole annulus was filled with #3 Monterey sand (6.7 millimeters, U.S. No. 3). Type and purpose of well: MWMS, multiple-well monitoring site; SWMS, single-well monitoring site (or test well). Type of seal: G, grout; GC, grout and bentonite chips; GP, grout and bentonite pellets; ID, inner diameter; P, bentonite pellets; GPC, grout and portland cement. **Abbreviations**: A, aquifer test; ft bls, feet below land surface; mm/dd/yyyy, month/day/year; NAVD88, North American Vertical Datum of 1988; S, slug test; W, wellbore flow; #, number; =, equal; —, no data]

Common name	State well number	Short well number	U.S. Geological Survey site identifier	Depth of well (ft bls)	Sand-pack interval[1] (ft bls)	Seal interval (ft bls)	Type of seal	Perforated interval (ft bls)	Type of hydrologic testing
LL04: MWMS well drilled Feb. 3, 2011, at 2,410 ft above land surface; ID = 1.94 in.									
LL04 #1	12N/03E-01M1S	1M1	350929116372301	970	925–1,019	515–925	G	950–970	S
[2]LL04 #2	12N/03E-01M2S	1M2	350929116372302	490	445–515	371–445	G	470–490	—
[2]LL04 #3	12N/03E-01M3S	1M3	350929116372303	350	305–371	0–305	GC	330–350	—
LL04B: MWMS well drilled Mar. 1, 2011, at 2,410 ft above land surface; ID = 1.94 in.									
LL04B #1	12N/03E-01M4S	1M4	350929116372201	490	446–520	366–446	G	470–490	S
LL04B #2	12N/03E-01M5S	1M5	350929116372202	350	307–366	0–307	G	330–350	—
CRTH2: MWMS well drilled Aug. 11, 2011, at 1,432 ft above land surface; ID = 1.94 in.									
CRTH2 #1	13N/05E-08B1S	8B1	351416116281501	940	883–965	306–883	GP	920–940	S
CRTH2 #2	13N/05E-08B2S	8B2	351416116281502	290	249–306	0–249	G	270–290	S
CRTH1: MWMS well drilled June 10, 2011, at 1,577 ft above land surface; ID = 1.94 in.									
CRTH1 #1	13N/05E-28Q1S	28Q1	351100116271001	1,260	1,182–1,301	736–1,182	G	1,240–1,260	S
CRTH1 #2	13N/05E-28Q2S	28Q2	351100116271002	720	679–736	268–679	G	700–720	—
CRTH1 #3	13N/05E-28Q3S	28Q3	351100116271003	255	219–268 151–205	205–219 0–151	P GP	235–255 175–195	S
GOLD2: MWMS well drilled Mar. 9, 2012, at 3,107 ft above land surface; ID = 1.94 in.									
GOLD2 #1	14N/01E-07R1S	7R1	351904116543101	440	400–451	362–400	GP	420–440	S
GOLD2 #2	14N/01E-07R2S	7R2	351904116543102	350	308–362	258–308	GP	330–350	S
GOLD2 #3	14N/01E-07R3S	7R3	351904116543103	240	196–258	0–196	GP	220–240	S
BLA5: MWMS well drilled Mar. 19, 2011, at 2,345 ft above land surface; ID = 1.94 in.									
BLA5 #1	14N/03E-26K1S	26K1	351638116374301	360	299–349	349–370 280–299	P P	320–340	S
[3]BLA5 #2	14N/03E-26K2S	26K2	351638116374302	210	240–280	220–240	P	190–210	—
BLA5 #3	14N/03E-26K3S	26K3	351638116374303	210	171–220	0–171	GP	190–210	S
BLA5B: SWMS well drilled Mar. 22, 2011, at 2,345 ft above land surface; ID = 1.94 in.									
BLA5B #1	14N/03E-26K4S	26K4	351638116374304	270	238–280	0–238	GP	250–270	S
GOLD1: MWMS well drilled June 30, 2011, at 3,058 ft above land surface; ID = 1.94 in.									
GOLD1 #1	15N/01E-28R1S	28R1	352144116522601	670	631–684	595–631	GP	650–670	S
GOLD1 #2	15N/01E-28R2S	28R2	352144116522602	580	534–595	392–534	GP	560–580	S
GOLD1 #3	15N/01E-28R3S	28R3	352144116522603	370	328–392	0–328	GP	350–370	S
GOLD1-T: SWTS well drilled Mar. 5, 2012, at 3,064 ft above land surface; ID = 7.63 in.									
GOLD1-T #1	15N/01E-28R4S	28R4	352145116522401	680	208–700	0–208	GP	620–680 300–420 260–280	A, W

Table 1. Well-construction data and type of hydrologic testing for single- and multiple-well monitoring sites and test wells, Fort Irwin National Training Center, California.—Continued

[Elevations were interpolated from a topographic map. Well locations shown on figure 2. All wells were constructed with schedule-80 polyvinyl chloride (PVC) casing and slotted screens, except RDPS, which was constructed with steel casing and slotted screens. All monitoring wells have screen slot size of 1.5 inches (in.) long by 0.02 in. wide; all test wells have screen slot size of 1.6 in. long by 0.03 in. wide. The borehole annulus was filled with #3 Monterey sand (6.7 millimeters, U.S. No. 3). Type and purpose of well: MWMS, multiple-well monitoring site; SWMS, single-well monitoring site (or test well). Type of seal: G, grout; GC, grout and bentonite chips; GP, grout and bentonite pellets; ID, inner diameter; P, bentonite pellets; GPC, grout and portland cement. **Abbreviations**: A, aquifer test; ft bls, feet below land surface; mm/dd/yyyy, month/day/year; NAVD88, North American Vertical Datum of 1988; S, slug test; W, wellbore flow; #, number; =, equal; —, no data]

Common name	State well number	Short well number	U.S. Geological Survey site identifier	Depth of well (ft bls)	Sand-pack interval[1] (ft bls)	Seal interval (ft bls)	Type of seal	Perforated interval (ft bls)	Type of hydrologic testing
NELT6: SWTS well drilled Feb. 23, 2012, at 3,139 ft above land surface; ID = 7.63 in.									
NELT6 #1	15N/02E-05N1S	5N1	352436116474001	840	355–903	0–355	GP	760–840 500–560 400–460	A, W
NELT2: MWMS well drilled Sept. 6, 2011, at 3,054 ft above land surface; ID = 1.94 in.									
NELT2 #1	15N/03E-06L1S	6L1	352450116421101	800	738–840	545–738	G	760–800	S
NELT2 #2	15N/03E-06L2S	6L2	352450116421102	530	490–545	313–490	G	510–530	S
NELT2 #3	15N/03E-06L3S	6L3	352450116421103	300	245–313	0–245	GP	280–300	S
NELT4: SWTS well drilled Dec. 14, 2011, at 2,990 ft above land surface; ID = 7.63 in.									
NELT4 #1	15N/03E-08L1S	8L1	352354116411201	580	280–618	618–885 — 0–280	G — GP	560–580 500–520 320–480	A, W
CCT1: MWMS well drilled Aug. 8, 2011, at 2,688 ft above land surface; ID = 1.94 in.									
CCT1 #1	15N/03E-25L1S	25L1	352149116370701	895	850–903	769–850	G	875–895	S
CCT1 #2	15N/03E-25L2S	25L2	352149116370702	750	716–769	686–716	P	730–750	S
CCT1 #3	15N/03E-25L3S	25L3	352149116370703	665	625–686	0–625	GP	645–665	S
RDPS: SWTS well drilled Apr. 23, 2009, at 2,102 ft above land surface; ID = 6.00 in.									
RDPS #1	15N/06E-33L1S	33L1	352058116205901	740	388–739	739–1,000 0–388	G GPC	520–700 420–440	—
NELT5: SWTS well drilled Feb. 20, 2012, at 3,243 ft above land surface; ID = 7.63 in.									
NELT5 #1	16N/01E-35P1S	35P1	352530116503601	840	437–905	0–437	GP	820–840 640–780 480–520	A, W
NELT7: MWMS well drilled Dec. 14, 2011, at 3,172 ft above land surface; ID = 1.94 in.									
NELT7 #1	16N/02E-16P1S	16P1	352806116462101	800	750–865	661–750	G	780–800	S
NELT7 #2	16N/02E-16P2S	16P2	352806116462102	640	592–661	421–592	GP	620–640	S
NELT7 #3	16N/02E-16P3S	16P3	352806116462103	400	348–421	0–348	GP	380–400	S
NELT3: SWTS well drilled July 25, 2011, at 3,097 ft above land surface; ID = 7.63 in.									
NELT3 #1	16N/02E-31H1S	31H1	352556116475501	740	204–800	0–204	GP	720–740 540–580 360–460 260–300	A, W
NELT1: MWMS well drilled July 10, 2011, at 3,074 ft above land surface; ID = 1.94 in.									
NELT1 #1	16N/02E-34Q1S	34Q1	352535116451001	760	715–803	321–715	G	740–760	S
NELT1 #2	16N/02E-34Q2S	34Q2	352535116451002	300	258–321	0–258	GP	280–300	S

Table 1. Well-construction data and type of hydrologic testing for single- and multiple-well monitoring sites and test wells, Fort Irwin National Training Center, California.—Continued

[Elevations were interpolated from a topographic map. Well locations shown on figure 2. All wells were constructed with schedule-80 polyvinyl chloride (PVC) casing and slotted screens, except RDPS, which was constructed with steel casing and slotted screens. All monitoring wells have screen slot size of 1.5 inches (in.) long by 0.02 in. wide; all test wells have screen slot size of 1.6 in. long by 0.03 in. wide. The borehole annulus was filled with #3 Monterey sand (6.7 millimeters, U.S. No. 3). Type and purpose of well: MWMS, multiple-well monitoring site; SWMS, single-well monitoring site (or test well). Type of seal: G, grout; GC, grout and bentonite chips; GP, grout and bentonite pellets; ID, inner diameter; P, bentonite pellets; GPC, grout and portland cement. **Abbreviations**: A, aquifer test; ft bls, feet below land surface; mm/dd/yyyy, month/day/year; NAVD88, North American Vertical Datum of 1988; S, slug test; W, wellbore flow; #, number; =, equal; —, no data]

Common name	State well number	Short well number	U.S. Geological Survey site identifier	Depth of well (ft bls)	Sand-pack interval[1] (ft bls)	Seal interval (ft bls)	Type of seal	Perforated interval (ft bls)	Type of hydrologic testing
SBTW: SWTS well drilled Dec. 7, 2009, at 3,041 ft above land surface; ID = 7.63 in.									
SBTW #1	31S/46E-05B1M	5B1	351619117041301	400	118–600	0–118	G	220–380 140–200	A, W
SBMW: MWMS well drilled Feb. 23, 2010, at 3,044 ft above land surface; ID = 1.94 in.									
SBMW #1	31S/46E-05B2M	5B2	351620117041101	290	259–298	160–259	G	270–290	—
SBMW #2	31S/46E-05B3M	5B3	351620117041102	150	105–160	0–105	G	130–150	—
SBMC: SWMS well drilled Nov. 17, 2009, at 3,041 ft above land surface; ID = 1.94 in.									
SBMC #1	31S/46E-05D1M	5D1	351619117045701	200	160–218	218–280 0–160	G	180–200	—

[1]The bottom of the sand-pack interval is at the bottom of the borehole, which is deeper than the depth of the well shown in this table.

[2]Wells failed because of a grout manufacturing defect, sealed and abandoned; replaced by site LL04B.

[3]Well placed at wrong depth, sealed and abandoned; replaced by site BLA5B.

Descriptions of Borehole Stratigraphy

The GFM described in the "Geologic Setting" section provides a basis for tying together the stratigraphy encountered in the boreholes of 14 single- or multiple-well monitoring sites. Drill cuttings, cores, and geophysical logs were analyzed further to describe the stratigraphy in each of these boreholes. This detailed lithostratigraphic-geophysical (LG) relation was later used to establish hydrogeologic (HG) units for future modeling of the Nelson, Goldstone, and Superior Basins. Details related to borehole stratigraphy are described in the next section. Refinement of HG units is described later in this report.

Measurement of Properties in Core

A total of 29 cores were collected at discrete depths ranging from 55 to 1,298 ft below land surface (bls) from 12 boreholes during drilling (table 2). These cores were sent to the USGS Hydrologic Research Laboratory in Sacramento, California, to be tested for vertical saturated hydraulic conductivity, physical properties (including bulk density, volumetric water content, residual saturation, total and effective porosity, which are not shown in table 2), and particle size analysis. Laboratory values for one-directional (vertical) saturated flow were calculated using the Tri-Flex Permeability System in accordance with the American Society of Testing and Materials (ASTM) D5084. Physical properties were determined using core weights with vacuum saturation, relative humidity (RH) and 105 degrees Celsius (°C) oven drying in accordance with standard methods of soil analysis (Dane and Topp, 2002) and USGS –YMP-HP-229 (D. Soeder, USGS, written commun., 1993). Particle-size was analyzed using sieving and hydrometer in accordance with ASTM C136 and USGS-YMP-HP-263 (Bill Guertal and Mohammad Nash, USGS, written commun., 1993). In this method, 53 microns is the size-class boundary between sand and silt for the particle-size analysis. Laboratory tests of cores indicate vertical saturated hydraulic conductivities (K_v) ranged from less than 0.00001 to 18.13 feet per day (ft/d) and total porosities ranged from 0.15 to 0.56 (table 2). Physical properties and particle-size analyses indicate the high degree of heterogeneity of the hydrogeologic deposits in the boreholes. Results of other physical properties tested, including bulk density, water content, saturation, and particle size, are presented in appendix 1.

Table 2. Estimated vertical hydraulic conductivity and total porosity of core samples collected from boreholes at Fort Irwin National Training Center, California.

[Analyses by U.S. Geological Survey-California Water Science Center Hydrologic Research Laboratory, Sacramento, California. Site information shown in table 1. **Abbreviations**: ft bls, feet below land surface datum; ft/day, feet per day; n/a, not available]

Sample identifier	Sample depth (ft bls)	Saturated vertical hydraulic conductivity (ft/day)	Porosity
CRTH2			
CRTH2-1C-3 R1	100	0.0306	0.36
CRTH1			
CRTH1-1C-3 R1	380	0.00001	0.49
CRTH1-2C-3	600	0.00002	0.39
CRTH1-3C-2	860	0.0001	0.32
CRTH1-4C-3	1,298	0.00002	0.27
GOLD2			
GOLD2-1C-2	100	18.13	0.31
GOLD2-2C-2	219	9.35	0.41
GOLD2-3C-2	400	n/a	0.15
BLA5			
BLA5-13C-3	55	0.0130	0.50
GOLD1			
GOLD1-1C-2	200	0.0510	0.40
GOLD1-2C-2	500	0.0233	0.33
NELT6			
NELT6-1C-2	280	0.00005	0.32
NELT6-2C-2	560	0.0254	0.28
NELT6-3C-2	900	0.0066	0.28
NELT2			
NELT2-1C-3	200	0.4950	0.39
NELT2-2C-2	400	0.4790	0.56
NELT4			
NELT4-1C-2	200	0.1210	0.41
NELT4-2C-2	500	0.0754	0.30
CCT1			
CCT1-1C-3	200	1.24	0.39
CCT1-2C-2	300	0.0004	0.36
CCT1-3C-3	500	0.6296	0.38
NELT7			
NELT7-1C-2	280	0.0011	0.37
NELT7-2C-2	520	n/a	0.37
NELT3			
NELT3-1C-3	260	0.1952	0.33
NELT3-2C-2	460	n/a	0.40
NELT3-3C-2	660	0.0060	0.31
NELT1			
NELT1-1C-2	200	0.00002	0.29
NELT1-2C-2	420	0.0281	0.32
NELT1-3C-2	800	0.0024	0.29

Descriptions of Cuttings and Core

Drill cuttings and core material were described using two different methods, previously described in the "Drilling and Collection of Cores and Cuttings" section. During drilling of boreholes, cuttings were examined and described using generalized grain-size descriptions and techniques as defined by Kjos and others, 2014. Following drilling, more detailed examinations of cores and selected cuttings were done to establish the characteristics of the borehole; this resulted in more detailed lithologic descriptions. Lithologic descriptions were coupled with geophysical interpretations to establish the lithostratigraphic-geophysical relations described in the next section. Lithologic descriptions of cuttings and core material were based on examinations of the following features: (1) The rock types of cutting fragments, including plutonic or metamorphic rocks, volcanic rocks—basalt versus andesite, dacite, and rhyolite (and porphyritic or aphanitic types)—tuffaceous sedimentary rocks, and lithic-rich sedimentary rocks; (2) individual grains to determine how surfaces were formed with respect to weathering, cementation, or potentially fractured during the drilling process; and (3) indications of cementation, including calcite rinds and coatings of sedimentary matrix material cemented to edges of individual grains.

Lithostratigraphic-Geophysical Units

Lithologic descriptions of core and cutting material, coupled with borehole geophysical data, were used to interpret the GFM stratigraphy unit(s) at each borehole site (fig. 3). These coupled data sets, referred to as lithostratigraphic-geophysical (LG) data, provide valuable insight into the complexities (and variability) of the materials at the borehole sites. Correlations in the data were seen at various scales and were used to interpret "beds," "sequences," "cycles," and GFM units. The interpretation of beds, sequences, and cycles using lithostratigraphic-geophysical data also enabled description of homogeneity and heterogeneity of properties across a range of thicknesses.

The LG data were grouped into a series of lithostratigraphic-geophysical units (LGUs) equivalent to the GFM units. The LG data were instrumental in dividing the volcanic-rich sedimentary rocks (GFM unit Tv) into six subunits (effectively lithofacies): Tv1, Tv2, Tv3, Tv4, Tv5, and Tv6. These subunits can be correlated across Nelson Basin (fig. 3), and similar correlations were found in volcanic-rich sedimentary rocks across Goldstone Basin; however, volcanic-rich sedimentary rock subunits may not directly correlate among Nelson, Goldstone, and Superior Basins. For clarity, subunits of volcanic-rich sedimentary rocks identified in Nelson and Goldstone Basins have been labeled Tv1-6(N) and Tv1-5(G), respectively. The LGU subunits of volcanic-rich sedimentary rocks should not be seen as laterally continuous units outside of specified basin boundaries. The GFM volcanic-rich sedimentary rock unit (Tv) is undifferentiated in Superior Basin, where it was labeled Tv(S).

Well Construction

All wells at the 14 multiple-well monitoring sites were constructed of flush-threaded 2-inch (in.) diameter, schedule 80 polyvinyl chloride (PVC) pipe (fig. 2). The screened interval of the monitoring wells is 20 ft in length, except in wells 15N/03E-06L1S (NELT2 #1) and 13N/05E-28Q3S (CRTH1 #3), which have screened intervals of 40 ft (table 1). Well 13N/05E-28Q3S (CRTH1 #3) has two 20-ft screened intervals (175–195 and 235–255 ft bls), separated by a 40-ft section of unscreened PVC. The borehole diameter along the screened interval ranges from about 6.8 to 10 in., depending on the site and depth of the well. Each multiple-well monitoring site consists of a single borehole containing two or three individual monitoring wells that are perforated at different intervals. One exception is well 14N/03E-26K4S (BLA5-B #1), which is a single-well monitoring site.

Adjacent to and extending above and below the screened intervals, the boreholes were packed with #3 Monterey sand, medium aquarium Monterey sand, and (or) gravel, depending if it was a monitoring site or test well. Larger aggregate and screen openings were typically used for test wells, described later, to allow for greater flow. Gravel-packed intervals in each borehole were isolated by pumping bentonite grout (30 percent solids), time-release bentonite pellets, and (or) bentonite chips into the annular space. In the multiple-well monitoring sites, this method was repeated for each well. Bentonite grout was tremied from land surface to seal the top of the gravel pack above the shallowest screened interval.

The test wells were constructed of flush-threaded 8-in. diameter, schedule 80 PVC pipe, except well 15N/06E-33L1S (RDPS #1), which is 6-in. diameter steel casing (fig. 2). Most test wells were screened intermittently over a 200-ft length, where screened intervals ranging from 20 to 160 ft were separated by sections of blank PVC or steel casing (table 1). The exception is 31S/46E-05B1M (SBTW #1), which has a screened interval of 220 ft. This is not a continuous section of screen in all cases, however, but rather multiple screened intervals. The reader is referred to table 1 for specific screened intervals for test well sites. The borehole diameter along the screened intervals of test wells varies from about 13 to 15 in., depending on the site and depth of the well. Bentonite grout was tremied from land surface to seal the top of the gravel pack above the first screened interval. The wells were developed using air-lifting and surging techniques until no drilling mud was visible in the discharge and several water-quality parameters (conductance, pH, temperature) had stabilized. See Kjos and others (2014) for additional information regarding drilling and well construction. Well construction information is summarized in table 1.

Hydrologic Testing

Slug Tests

Slug tests were completed following methods of Cunningham and Schalk (2011) and modified to use compressed nitrogen for water-level (or head) displacement within the 2-in. diameter monitoring wells, as described by Greene and Shapiro (1995). Test procedures for slug testing follow. Water levels were manually measured for each well before testing (table 3). A test adapter was connected to the top of the monitoring well that allowed for the pressurization and venting of the gas. Water-level measurements during each test were collected and recorded using a 30 pounds per square inch (psi) vented pressure transducer. Calibration of transducers was completed by the USGS Hydrologic Instrumentation Facility (HIF) prior to use. The pressure transducer was placed in the well at a depth ranging from 33 to 40 ft below the static water level, and the data logger was set to record at 1-second intervals. Following placement of the transducer, sufficient time, approximately 5–20 minutes for most wells, was allotted for observation of static water-level conditions and to ensure that the water level in the well had stabilized to atmospheric pressure.

At the onset of testing, a 2-in. diameter ball valve on the adapter was closed, sealing the well. Compressed nitrogen was then used to pressurize the column of air above the water surface, effectively dropping the water level in the well. Sufficient time was allowed until the observed pressure (that is, head) inside the well stabilized. Pressures were selected according to the desired amount of initial head displacement. Tests were completed at several pressures, including 5, 7.5, 10, and 15 psi, producing theoretical head displacements of approximately 11.5, 17.3, 23.1, and 34.6 ft, respectively. Once static conditions were achieved, the recovery phase of the test was initiated by opening the 2-in. diameter ball valve to instantly vent the well. Adequate time was allowed for recovery of the water level to static conditions before initiating additional tests. Recovery times for individual tests ranged from approximately 90 to 2,100 seconds. This process typically was repeated several times per well.

Table 3. Slug test results from single- and multiple-well monitoring sites, 2011 and 2012, Fort Irwin National Training Center, California.

[All wells were constructed with 2-inch, schedule-80 polyvinyl chloride (PVC) casing and slotted screens. Only those wells with completed slug tests are presented. ‘Static water level -before’ and ‘-after’ refers to water levels collected prior to slug testing and water levels collected after slug testing was completed. ‘Water-level change’ represents the difference in water levels collected before and after the period of slug testing. Residual standard error (RMS) is the fitting error between measured and simulated recovery. **Abbreviations**: ft bls, feet below land surface; ft, feet; ft/d, feet per day; k_h, horizontal hydraulic conductivity; MF, dampening coefficient (dimensionless); mm/dd/yyyy, month/day/year; NT, not tested; nc, not calculated; NC, results not conclusive; psi, pounds per square inch; —, no data; <, less than]

Common name	State well number	Number of tests	Date of test (mm/dd/yyyy)	Static water level before (ft bls)	Static water level after (ft bls)	Water level change (ft)	Pressures applied (psi)	Top of screen (ft bls)	Bottom of screen (ft bls)	Hydraulic conductivity (k_h) (ft/d)	RMS (ft)	Dampening coefficient (MF)
						LL04						
LL04 #1	12N/03E-01M1S	1	10/31/2011	296.30	297.49	[1]1.19	5	950	970	<0.1	nc	4.35
						LL04B						
LL04B #1	12N/03E-01M4S	3	11/03/2011	295.28	295.11	–0.17	5, 5, 10	470	490	4.9	0.37	2.38
LL04B #2	12N/03E-01M5S	—	—	—	—	—	—	—	—	NT	—	—
						CRTH2						
CRTH2 #1	13N/05E-08B1S	4	03/04/2012	56.68	56.59	–0.09	5, 5, 10, 10	920	940	40.0	0.54	5.14
CRTH2 #2	13N/05E-08B2S	—	—	—	—	—	—	—	—	NC	—	—
						CRTH1						
CRTH1 #1	13N/05E-28Q1S	2	03/04/2012	205.62	205.22	–0.40	5, 5	1,240	1,260	0.3	0.47	5.54
CRTH1 #2	13N/05E-28Q2S	—	—	—	—	—	—	—	—	NT	—	—
CRTH1 #3	13N/05E-28Q3S	3	03/04/2012	160.40	160.46	0.06	5, 5, 10	235	255	1.0	0.62	1.03
CRTH1 #3	13N/05E-28Q3S	3	03/04/2012	160.40	160.46	0.06	5, 5, 10	175	195	1.0	0.62	1.03
						GOLD2						
GOLD2 #1	14N/01E-07R1S	3	03/27/2012	247.29	247.11	–0.18	5, 5, 7.5	420	440	0.5	0.51	2.43
GOLD2 #2	14N/01E-07R2S	3	03/27/2012	247.35	247.30	–0.05	5, 5, 10	330	350	9.2	0.60	1.65
GOLD2 #3	14N/01E-07R3S	—	—	—	—	—	—	—	—	NC	—	—
						BLA5						
BLA5 #1	14N/03E-26K1S	3	10/28/2011	186.08	186.10	0.02	5, 5, 10	320	340	6.8	0.26	1.97
BLA5 #3	14N/03E-26K3S	—	—	—	—	—	—	—	—	NC	—	—
						BLA5B						
BLA5B #1	14N/03E-26K4S	3	10/25/2011	185.93	185.97	0.04	5, 5, 10	250	270	28.0	0.22	1.51
						GOLD1						
GOLD1 #1	15N/01E-28R1S	4	10/24/2011	171.15	171.10	–0.05	5, 10, 10, 15	650	670	31.0	0.91	3.79
GOLD1 #2	15N/01E-28R2S	3	10/25/2011	171.16	171.09	–0.07	5, 10, 10	560	580	1.0	0.24	3.57
GOLD1 #3	15N/01E-28R3S	4	10/25/2011	171.16	171.16	0.00	5, 10, 10, 15	350	370	26.0	0.40	1.87

Table 3. Slug test results from single- and multiple-well monitoring sites, 2011 and 2012, Fort Irwin National Training Center, California.—Continued

[All wells were constructed with 2-inch, schedule-80 polyvinyl chloride (PVC) casing and slotted screens. Only those wells with completed slug tests are presented. 'Static water level -before' and '-after' refers to water levels collected prior to slug testing and water levels collected after slug testing was completed. 'Water-level change' represents the difference in water levels collected before and after the period of slug testing. Residual standard error (RMS) is the fitting error between measured and simulated recovery. **Abbreviations**: ft bls, feet below land surface; ft, feet; ft/d, feet per day; k_h, horizontal hydraulic conductivity; MF, dampening coefficient (dimensionless); mm/dd/yyyy, month/day/year; NT, not tested; nc, not calculated; NC, results not conclusive; psi, pounds per square inch; —, no data; <, less than]

Common name	State well number	Number of tests	Date of test (mm/dd/yyyy)	Static water level before (ft bls)	Static water level after (ft bls)	Water level change (ft)	Pressures applied (psi)	Top of screen (ft bls)	Bottom of screen (ft bls)	Hydraulic conductivity (k_h) (ft/d)	RMS (ft)	Dampening coefficient (MF)
NELT2												
NELT2 #1	15N/03E-06L1S	3	11/02/2011	216.94	216.83	–0.11	5, 5, 10	760	800	4.5	0.42	4.17
NELT2 #2	15N/03E-06L2S	—	—	—	—	—	—	—	—	NC	—	—
NELT2 #3	15N/03E-06L3S	3	11/02/2011	216.63	216.65	0.02	5, 5, 10	280	300	2.6	0.57	1.54
CCT1												
CCT1 #1	15N/03E-25L1S	3	03/05/2012	527.19	527.11	–0.08	5, 5, 7.5	875	895	3.3	0.18	3.21
CCT1 #2	15N/03E-25L2S	2	03/05/2012	527.14	527.10	–0.04	5, 5	730	750	1.1	0.13	2.61
CCT1 #3	15N/03E-25L3S	3	03/06/2012	526.88	526.78	–0.10	5, 5, 7.5	645	665	7.6	0.13	2.01
NELT7												
NELT7 #1	16N/02E-16P1S	3	03/05/2012	293.82	293.70	–0.12	5, 5, 10	780	800	7.3	0.36	3.79
NELT7 #2	16N/02E-16P2S	3	03/05/2012	293.77	293.76	–0.01	5, 5, 10	620	640	2.8	0.33	3.06
NELT7 #3	16N/02E-16P3S	3	03/05/2012	279.82	279.60	–0.22	5, 5, 10	380	400	6.0	0.48	1.81
NELT1												
NELT1 #1	16N/02E-34Q1S	3	10/26/2011	207.52	207.50	–0.02	5, 5, 10	740	760	5.0	0.36	4.07
NELT1 #2	16N/02E-34Q2S	3	11/01/2011	202.99	202.97	–0.02	5, 5, 10	280	300	14.0	0.34	1.63

[1]The large change in static water level recorded is thought to be in connection with fine-grained material observed during drilling and the low hydraulic conductivity that was calculated (0.04 ft/day) or is possibly the product of screen fouling as part of well construction.

Hydrographs showing the recorded events are included in appendix 2. Each hydrograph includes plots of (1) the measured water levels; (2) the initial static water level; and (3) the calculated, or theoretical, head displacements for the different pressures applied.

Computations were completed using a spreadsheet-based aquifer-test analysis program developed by the USGS (Halford and Kuniansky, 2002). Data were analyzed using methods developed by Butler and Garnett (2000) for formations of high hydraulic conductivity, based on the water-level response to the slug test. The spreadsheet created by Halford and Kuniansky (2002) allowed for multiple tests, up to 20, to be entered and simultaneously compared to type curves. The type curve (that is, pre-plotted solutions of horizontal hydraulic conductivity, K_h) can be automatically or manually fit to match the observed response by adjusting the dimensionless dampening coefficient (γ), the horizontal hydraulic conductivity, or both. The accuracy of the fit between the type curve and the measured response curve is characterized best by the residual standard error (RMS). For detailed descriptions of these parameters, the reader is referred to Halford and Kuniansky (2002).

Between one and four slug tests were done at each monitoring well. Tests were manually examined to detect errors, and tests containing errors were removed. The measured response from individual tests was fairly consistent in each respective well, regardless of the pressure applied. Results of each test were simultaneously plotted and used to select the best-fit type curve. Type curves were selected by the best visual fit to the recovery curve and by finding a curve match with the lowest RMS (appendix 3).

The following assumptions were made for the analysis of the data. The volume of water that was induced by gas pressurization was injected into, or discharged from, the well instantaneously at time zero ($t = 0$). The wells were of finite diameter and fully penetrated the aquifer. The aquifers were assumed to be confined, homogeneous, isotropic, and of uniform thickness. The flow in each aquifer was assumed to be horizontal and radially symmetric. The aquifer was assumed to respond over the entire screened interval. Thus, for these calculations, the aquifer thickness was assumed to be equal to the length of the screened interval of the monitoring well. Calculations also accounted for borehole and well-casing diameter. As part of the analysis of test results for this report, it was assumed that each well was in the center of the annular space and the internal diameter of the well casing used in calculations was 1.94 in. Horizontal hydraulic conductivities, derived from slug tests, were estimated for the aquifer material adjacent to the screened interval, which may not be representative of hydraulic conditions of the overall aquifer system. Butler and Garnett (2000) describe in more detail the analytical method and underlying assumptions.

Aquifer Tests

For all tests, a submersible pump was used to stress the surrounding aquifer at pumping rates ranging from 16 to 350 gallons per minute (gpm; table 4). Based on individual well construction, the pump intake was situated at depths ranging from approximately 200 ft to 460 ft bls to ensure the pump intake was within blank casing and not adjacent to a screened interval. A sonic flow meter, which measures the velocity of a fluid with ultrasound to calculate flow, was attached to the discharge pipe to measure the discharge during the test. Changes in water level were measured by pressure transducer. Hydrographs showing the recorded events are included in appendix 4. An optimal constant flow rate was determined for each well according to historical well data and the drawdown constraint that prevented drawdown below the pump intake. Test durations varied from 9 hours 1 minute (541 minutes) in well 15N/02E-05N1S (NELT6 #1) to 26 hours 20 minutes (1,580 minutes) in well 16N/01E-35P1S (NELT5 #1; table 4). The test duration of NELT6 #1 was limited because of a combination of site conditions (low specific capacity) and timing of military operations. Discharge rates and associated drawdown for each well tested are listed in table 4. After drawdown leveled-off, or as time permitted, the pump was turned off, allowing the well to recover to the original static level. Water-level recovery was continuously monitored (and analyzed) at each of the wells tested.

The Cooper-Jacob method (Cooper and Jacob, 1946), commonly referred to as the straight-line method, is a simplification of the Theis (1935) solution for flow through a fully penetrating well in a confined aquifer of infinite extent. Although the user of this method assumes that the aquifer is infinitely large, homogeneous, isotropic, confined, and unconsolidated, it is a reasonable first-order approximation of the transmissivity of the aquifer or aquifers near a well. Although these aquifers may be only partially confined, the Cooper-Jacob method has been used to estimate transmissivity for single-well aquifer tests in unconfined aquifers. The use of this method for unconfined aquifers can overestimate unconfined aquifer transmissivities (Halford and others 2006).

Table 4. Aquifer-test data for test wells, 2012 and 2015, Fort Irwin National Training Center, California.

[All wells are constructed of 8”, schedule-80 polyvinyl chloride (PVC) casing and slotted screens, except site RDPS, which is constructed with steel casing and slotted screens. All wells constructed between December 2009 and March 2012 for monitoring purposes only. **Abbreviations**: CJ, Cooper-Jacobs; CJR, Cooper-Jacob Recovery; ft bls, feet below land surface datum; ft, feet; ft/d, feet per day; ft^2/day, square feet per day; gpm, gallons per minute; gpm/ft, gallons per minute per foot; hh:mm, hours:minutes; mm/dd/yyyy, month/day/year]

Common name	State well number	Well depth (ft bls)	Screen intervals (ft bls)	Date of test (mm/dd/yyyy)	Pumping duration (hh:mm)	Static water level (ft bls)	Pumping water level (ft bls)	Drawdown (ft)	Method of analysis	Discharge rate (gpm)	Hydraulic conductivity (ft/d)	Transmissivity (ft^2/day)	Specific capacity (gpm/ft)
GOLD1-T #1	15N/01E-28R4S	680	260–280, 300–420, 620–680	03/21/2012	21:57	170.56	202.19	31.6	CJ	270	66	28,000	9.5
GOLD1-T #1	15N/01E-28R4S	680	260–280, 300–420, 620–680	03/21/2012	21:57	170.56	202.19	31.6	CJR	270	58	25,000	9.5
NELT6 #1	15N/02E-05N1S	840	480–520,640–780, 820–840	03/27/2012	09:01	299.59	399.44	99.9	CJ	12.9	1.0	440	0.2
NELT6 #1	15N/02E-05N1S	840	480–520, 640–780, 820–840	03/27/2012	09:01	299.59	399.44	99.9	CJR	12.9	0.55	220	0.2
NELT4 #1	15N/03E-08L1S	580	320–480, 500–520, 560–580	02/09/2012	22:12	158.86	235.28	76.4	CJ	350	8.3	2,200	4.6
NELT4 #1	15N/03E-08L1S	580	320–480, 500–520, 560–580	02/09/2012	22:12	158.86	235.28	76.4	CJR	350	15	3,900	4.6
NELT5 #1	16N/01E-35P1S	840	480–520, 640–780, 820–840	02/29/2012	26:20	394.23	500.34	106.1	CJ	100	0.37	130	0.7
NELT5 #1	16N/01E-35P1S	840	480–520, 640–780, 820–840	02/29/2012	26:20	394.23	500.34	106.1	CJR	100	0.39	140	0.7
NELT3 #1	16N/02E-31H1S	740	260–300, 360–460, 540–580, 720–740	02/13/2015	24:47	208.26	212.29	4.0	CJ	85	25	12,000	21.1
NELT3 #1	16N/02E-31H1S	740	260–300, 360–460, 540–580, 720–740	02/13/2015	24:47	208.26	212.29	4.0	CJR	85	6.8	3,300	21.1
SBTW #1	31S/46E-05B1M	400	140–200, 220–380	02/24/2015	24:28	119.36	124.91	5.6	CJ	111	13	3,000	20.0
SBTW #1	31S/46E-05B1M	400	140–200, 220–380	02/24/2015	24:28	119.36	124.91	5.6	CJR	111	19	4,500	20.0

Using the Cooper-Jacob method, the transmissivities were estimated by fitting a straight line to late-time drawdown and recovery data (appendix 5). The Cooper-Jacob method is only valid when the well function argument, u, is less than or equal to 0.01:

$$u = (r^2S) / (4Tt) \text{ [dimensionless]} \quad (1)$$

where

- r is the distance (ft) to observation well,
- S is the storage coefficient of the aquifer (dimensionless),
- T is the aquifer transmissivity (foot squared per day, ft^2/d), and
- t is the time (days) since the onset of pumping (Lohman, 1972).

For example, for the estimated aquifer transmissivity, T, assuming an r of 1 ft and S of 0.001, the criterion of a value of u less than or equal to 0.01 was met after the first second of pumping. The absence of deviation in the straight-line portion of the curve indicates no meaningful boundary effects during the majority of testing, except for wells 15N/03E-08L1S (NELT4 #1) and 16N/01E-35P1S (NELT5 #1; appendix 5). Although not entirely obvious in the hydrograph, the normalized drawdown data from NELT4 #1 show a decrease in slope after approximately 4.5 hours of pumping, indicating more permeable deposits are present nearby. The drawdown data from NELT5 #1 show an increase in slope after approximately 7 hours, indicating possible boundary conditions, such as nearby mapped faults. Hydrographs showing observed drawdown data for all wells tested are included in appendix 5. Wellbore storage effects can affect the initial period of the drawdown and recovery phase of a test, when water pumped from the well is derived from the wellbore and not from the aquifer or when there is a delay in recovery caused by water filling the wellbore. To eliminate the influence of these effects on this test, the first 10–15 minutes of the tests were not included in these analyses.

Wellbore-Flow Logs

Wellbore-flow logs were collected under unpumped and pumped conditions from six test wells (table 1; fig. 2) in the Goldstone, Nelson, and Superior Basins to determine vertical distribution of flow. Data were collected under unpumped conditions using an electromagnetic (EM) flow meter following methods described by Paillet (2000). Data collected under pumping conditions were obtained using either an EM flow meter, as described by Paillet (2000), or the ”tracer-pulse method” following methods described by Izbicki and others (1999). The choice of equipment and methods used for the collection of pumped flow data were based on the timing of field operations, equipment availability, and site-specific conditions.

Utilizing Faraday’s Law, the EM flowmeter measures the voltage generated by an electrical conductor (water) passing through the inside of a hollow, cylindrical section of the flowmeter that is surrounded by electromagnets (Young and Pearson, 1995; Paillet, 2000). The EM flowmeter has no moving parts and a large dynamic range, capable of measuring velocities ranging from less than 0.3 to 259 feet per minute (ft/min; Newhouse and others, 2005). In addition to wellbore flow, the EM flowmeter records fluid resistivity, fluid temperature, and formational natural gamma information during logging. These fluid-property logs provide information on well yield and water quality at discrete intervals in the well and can aid in the interpretation of the wellbore-flow logs; the formational natural gamma can provide geologic information as well as confirm geologic data collected as part of drilling and well construction.

The tracer-pulse method allows for collection of pumped wellbore-flow data in wells with limited access (that is, narrow casing or large pump diameter), where the EM flowmeter cannot otherwise be deployed. Fluid resistivity, fluid temperature, and formational natural gamma are not collected with the tracer-pulse method; however, the work of Clark and others (2012) shows that wellbore-flow data collected using the EM flowmeter and the tracer-pulse techniques compared favorably.

Unpumped Flow Logs

Wellbore flow in a long-screened well can exist under unpumped conditions as a result of vertical differences in water pressure (head) in the aquifer(s) along screened interval(s) of a well (Izbicki, 2004). To measure wellbore flow under unpumped conditions, fluid-velocity data were collected using an EM flow meter. Unpumped wellbore-flow data were collected in the downward direction at three trolling speeds (5, 10, and 15 ft/min) in each well. For calibration purposes, data were collected from an unscreened section of the well, where no flow was present (below the water table and above the uppermost screened interval) and were plotted to ensure the tool response increased proportionately with tool speed (appendix 6). The average tool response in counts per second in the measured section was related to the trolling speed in ft/min using linear regression to develop an equation to estimate unpumped velocity in the well in ft/min. Velocity data, in ft/min, were converted to gpm using the internal cross-sectional area, in square foot (ft^2), of the well. The data collected from the screened intervals were then plotted by depth to show vertical changes and variability in wellbore flow.

Pumped Flow Logs

Pumped flow logs show cumulative flow of water toward pump intake in a well and identify depth intervals where water enters the well during pumping (Izbicki and others, 2015). For data collection under pumped conditions, a temporary submersible pump, having a capacity ranging from 50 to 350 gpm, was installed in the test well. Instantaneous and cumulative discharge data were measured at the surface using a sonic flowmeter and confirmed using physical discharge measurements. To determine the relative contribution of flow from screened intervals, flow data in the wellbore were collected under pumped conditions using either an EM flowmeter or the “tracer-pulse method.”

An EM flowmeter was used to collect a continuous-flow profile at sites 16N/02E-31H1S (NELT3 #1) and 31S/46E-05B1M (SBTW #1; shown in the “Wellbore-Flow Data” section; table 1). Pumped wellbore-flow data were collected in the downward direction at three trolling speeds (5, 10 and 15 ft/min) in each well. Centralizers were attached to the flowmeter, but diverters were not used to allow passage of the tool beyond the temporary pump. Data were calibrated using methods of Izbicki and others (2015) and data collected throughout the well at the three trolling rates (appendix 7). To determine the linearity of the tool response at different trolling speeds, two regression equations were developed comparing the tool response (in counts per second) for trolling speeds of 5 and 10 ft/min and for trolling speeds of 5 and 15 ft/min. For a linear tool response, the regression lines should have a slope of 1:1, and the difference between the intercepts of the two regression equations would be the tool response at 5 ft/min. For all wells measured, the EM flowmeter data indicated some non-linearity, and the tool response (in counts per second) increased at a non-linear rate with increased trolling speed. Therefore, the difference between the two regression lines at a given tool response was used to develop another regression equation that was then used to estimate pumped flow in the well in ft/min and, ultimately, in gpm, following methods of Izbicki and others (2015; appendix 7).

The tracer-pulse method was used at test wells 15N/01E-28R4S (GOLD1-T #1), 15N/02E-05N1S (NELT6 #1), 15N/03E-08L1S (NELT4 #1) and 16N/01E-35P1S (NELT5 #1) and involved injecting dye at different depths in a wellbore and timing the arrival of the dye at the surface discharge, following methods of Izbicki and others (1999). The data from these injection tests (the dye arrival times) were used to calculate the contribution to wellbore flow between each dye-injection point; the results from each injection point were compiled to create the wellbore-velocity profile (shown in the “Wellbore-Flow Data” section). Flow calculated using the dye method provides average discharge along a section of the wellbore between the injected points. As noted, continuous profiles of fluid resistivity and fluid temperature are not collected as part of the tracer-pulse method.

Groundwater-Data Collection

Groundwater levels were measured, and groundwater quality was sampled periodically as part of this study. Water levels have been measured manually in Fort Irwin wells since 2011 and recorded to within 0.01 ft using a calibrated electric or steel tape, following methods of Cunningham and Schalk (2011). Figure 2 shows the location of the monitoring sites and test wells. Continuous water-level data were also collected using pressure transducers during slug and short-term aquifer tests, as described in following sections.

Groundwater-quality samples were processed by USGS personnel following the protocols established by the USGS National Field Manual (NFM; U.S. Geological Survey, variously dated). The sample collection, field-handling procedures, analytical methods, and quality-control data are briefly described here. More detailed descriptions can be found in Kjos and others (2014).

All 2-in. diameter multiple-well monitoring sites were sampled using either a Bennett or Keck sample pump with Teflon tubing. Test wells, which had multiple perforated intervals, were sampled for bulk discharge (contributions from all the perforated intervals) and depth-dependent samples (contributions of cumulative flow toward pump intake). Bulk-discharge samples were collected from test wells at the well head using a submersible pump with steel conductor pipe.

Samples for inorganic constituents were analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado. Stable isotope ratios of hydrogen (δ^2H) and oxygen ($\delta^{18}O$) in water (H_2O) were analyzed by mass spectrometry at the USGS Reston Stable Isotope Laboratory (Révész and Coplen (2008a, b). Samples for tritium were analyzed by electrolytic enrichment and liquid scintillation (Thatcher and others, 1977) at the USGS Tritium Laboratory, Menlo Park, California. Samples for $\delta^{13}C$ and ^{14}C were analyzed by mass spectrometry and by accelerator mass spectrometry, respectively, at the National Ocean Sciences Accelerator Mass Spectrometry Facility at the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts. For further information regarding sampling procedures and list of analytes, see Kjos and others (2014).

All data described in this section are available in the USGS National Water Information System (NWIS) database (http://waterdata.usgs.gov/nwis/). Users of the data presented in this report are encouraged to access information through the USGS NWIS Web page (NWISWeb) at http://waterdata.usgs.gov/nwis/. The NWISWeb interfaces to USGS database of site information and groundwater, surface-water, and water-quality data collected throughout the United States. Data can be retrieved by category and geographic area, and the retrieval can be selectively refined by filters to constrain results to a specific location or parameter field. The NWISWeb outputs include water-level and water-quality graphs, site maps, and data tables (in HTML and ASCII format) and can be used to develop site-selection lists. All manual water-level measurements and the daily maximum, minimum, and median values for all water-level time-series data for sites presented in this report are available through the USGS NWISWeb. In digital copies of this report, the site-identification numbers presented in the tables are hyperlinked directly to the data through NWISWeb. Formal requests for specific data may be directed to the U.S. Geological Survey California Water Science Center, Public Information Officer in Sacramento, California.

Numerical Modeling

Wellbore flow was simulated in each of the test wells using an integrated wellbore-flow analysis tool, AnalyzeHOLE (Halford, 2009), to help evaluate the effect of aquifer heterogeneity on groundwater movement and travel times. AnalyzeHOLE simulates wellbore flow using an axisymmetric, radial geometry in a two-dimensional MODFLOW model (Harbaugh and others, 2000). Hydraulic conductivities are distributed by depth and iteratively estimated by minimizing differences between simulated and measured flows and drawdowns. Hydraulic conductivity can vary within a lithology, but variance was limited by using regularization within model runs. Transmissivity of the simulated system also can be constrained to estimates from aquifer tests (Halford, 2009).

Hydrologic Testing (Horizontal Hydraulic Conductivity and Aquifer Transmissivity)

To determine aquifer characteristics, hydrologic tests, including slug tests at single- and multiple-well monitoring sites, and aquifer tests at selected test wells, were completed at sites in Langford, Cronise, Goldstone, Bicycle, Nelson, Central Corridor area, and Superior Basins. Slug tests were completed using a pneumatic displacement method to estimate the horizontal hydraulic conductivity. Single-well aquifer (pumping) tests were completed at selected test wells to estimate the aquifer transmissivity. These hydrologic tests were used to constrain wellbore-flow modeling described later in this report.

Slug Tests

Horizontal hydraulic conductivity (K_h) estimates were obtained by completing slug tests at single- and multiple-well monitoring sites (table 1). Between October 2011 and March 2012, slug tests were completed on 22 monitoring wells at 12 sites throughout 6 basins (fig. 2). Wells tested and associated results are listed in table 3.

Changes in static water level were calculated by subtracting the water level at the end of the test from the initial water level at the beginning. Positive values indicated a decrease in static water level, whereas negative values indicated an increase in water level. Changes to static water level following the testing period generally varied between an increase in water level of –0.22 ft in well 16N/02E-16P3S (NELT7 #3) and a decrease in water level of 0.06 ft in well 13N/05E-28Q3S (CRTH1 #3; table 3). It is assumed that for the short duration of the test, these small changes in static water level were negligible. Exceptions were an increase in static water level of –0.40 ft observed in monitoring well 13N/5E-28Q1S (CRTH1 #1) and a decrease of 1.19 ft observed in 12N/03E-01M1S (LL04 #1) during the respective testing periods. The observed increase in well 13N/5E-28Q1 (CRTH1 #1, –0.40 ft) was the result of pressure-transducer slippage during the testing period, verified by manual-tape down measurements. The large decrease in static water level recorded in well 12N/03E-01M1 (LL04 #1, 1.19 ft) is thought to be related to fine-grained material at this perforated interval and the low hydraulic conductivity that was calculated (0.04 ft/day), or it is possibly the product of screen fouling irregularities during well construction. Water-level recovery was very slow following both tests (greater than 3 hours); however, it is assumed that the well would have fully recovered with additional time.

Throughout the period of data collection, four wells at the multiple-well monitoring sites yielded anomalous results compared to other wells in the study area: 14N/03E-26K3S (BLA5 #3), 13N/05E-08B2S (CRTH2 #2), 14N/01E-07R3S (GOLD2 #3), and 15N/03E-06L2S (NELT2 #2). The water level in well 14N/03E-26K3S (BLA5 #3) was too close to the top of the screened interval to allow for adequate pressurization of the well casing. Monitoring wells 13N/05E-08B2S (CRTH2 #2) and 15N/03E-06L2S (NELT2 #2) did not equalize to static conditions despite a long period of pressurization. The pressure in monitoring well 14N/01E-07R3S (GOLD2 #3) steadily increased during pressurization, indicating little or no hydraulic communication with the formation. All three of these wells are perforated in fine-grained sediment and could not be completely developed.

Thus, these results were likely influenced by possible screen fouling related to fine-grained materials or compromised well construction (possible intrusion of bentonite grout). Slug-test results from all four of these wells were inconclusive and are not presented in this report; only those wells with consistent results, showing little to no interference, are presented. Hydrographs documenting these irregular results are provided in appendix 2.

At the time of aquifer testing, monitoring wells 12N/03E-01M5S (LL04B #2) and 13N/05E-28Q2S (CRTH1 #2) were not available for slug testing because these wells were not fully developed. Because of time constraints and the remote location, slug tests were not done on multiple-well monitoring sites in Superior Basin, including wells 31S/46E-05B2M (SBMW #1), 31S/46E-05B3M (SBMW #2), and 31S/46E-05D1M (SBCM #1).

Between one and four slug tests were carried out at each well, as time allowed. For most wells tested, the initial head displacement was consistent with estimates of theoretical head displacement, based on pressures applied, and ranged from 10.5 to 36.3 ft of displacement (appendix 2). Test durations that ranged between 90 and 2,100 seconds were used to measure the water-level response to slug tests. The observed water-level recovery curves were plotted simultaneously and matched to simulated type curves (appendix 3). In general, the analytical method developed by Butler and Garnett (2000) yielded favorable type curves that were matched to slug-test response data for each monitoring well tested.

The calculated horizontal hydraulic conductivity (K_h), static water level (before and after), number of tests with pressures applied, and RMS for each well tested are presented in table 3. In general, the estimated values of horizontal hydraulic conductivity from slug tests correlated with the ranges of values published in literature for the lithology adjacent to the screened interval, as recorded during borehole drilling and geophysical logging. Slug-test results for the 22 monitoring wells successfully tested indicate that horizontal hydraulic conductivity ranged from less than 0.1 ft/d at well 12N/03E-01M1S (LL04 #1) to 40 ft/d at well 13N/05E-08B1S (CRTH2 #1). The RMS for these tests ranged from 0.13 ft at well 15N/03E-25L2, 3 (CCT1 #2, #3) to 0.91 ft at well 15N/01E-28R1S (GOLD1 #1).

Aquifer Tests

To determine aquifer characteristics and estimate values of transmissivity (T), single-well aquifer tests were completed at selected test well sites in the Goldstone, Nelson, and Superior Basins (table 1; fig. 1). Between March 2012 and February 2015, aquifer tests were completed at six test wells throughout the northern and western extents of the NTC (fig. 2). Wells tested and aquifer characteristics results are listed in table 4.

The calculated horizontal hydraulic conductivity (K_h), transmissivity, static and pumping water levels, and method of analysis are presented in table 4. The horizontal hydraulic conductivity and transmissivities were calculated in spreadsheets developed by Halford and Kuniansky (2002). For the six wells tested, hydraulic conductivity ranged from 0.37 to 66 ft/d, transmissivity values ranged from 130 to 28,000 ft^2/d, and specific capacity ranged from 0.2 to 21.1 gallons per minute per foot (gpm/ft). Test results from well 16N/02E-31H1S (NELT3 #1) collected in February 2015 show a clear change in slope associated with the Cooper-Jacob analysis of drawdown and recovery data (appendix 5), indicating a higher hydraulic conductivity boundary condition such as a leaky fault, fracture zone, or a potentially delayed yield. Additional aquifer testing was done at well 16N/02E-31H1S (NELT3 #1) in 2017 to further assess these conditions (Christopher Kohel, USGS, written commun., 2018).

Wellbore-Flow Data

Wellbore-flow data were collected from the six test well sites (table 1) under unpumped and pumped conditions (figs. 4–9 and 10–15, respectively). Borehole geophysical data presented by Kjos and others (2014), including short-normal (16-in.) and long-normal (64-in.) resistivity logs, are also presented in this report to show relations among different aquifer materials and changes in wellbore flow along perforated sections of the well. In addition to flow logs, depth-dependent water-quality data were collected under pumping conditions from the test wells to determine changes in the concentration of selected water-quality constituents by depth, following methods of Izbicki and others (2015). In figures 4–9, presenting unpumped flow data, negative values represent downward flow in the well, and positive values represent upward flow, whereas near-zero values (within the ±1 sigma, σ, precision of the EM flow tool) represent no flow. Depth of core samples and vertical hydraulic conductivity results collected from core samples are shown in red in the lithologic log descriptions on figures 10–14.

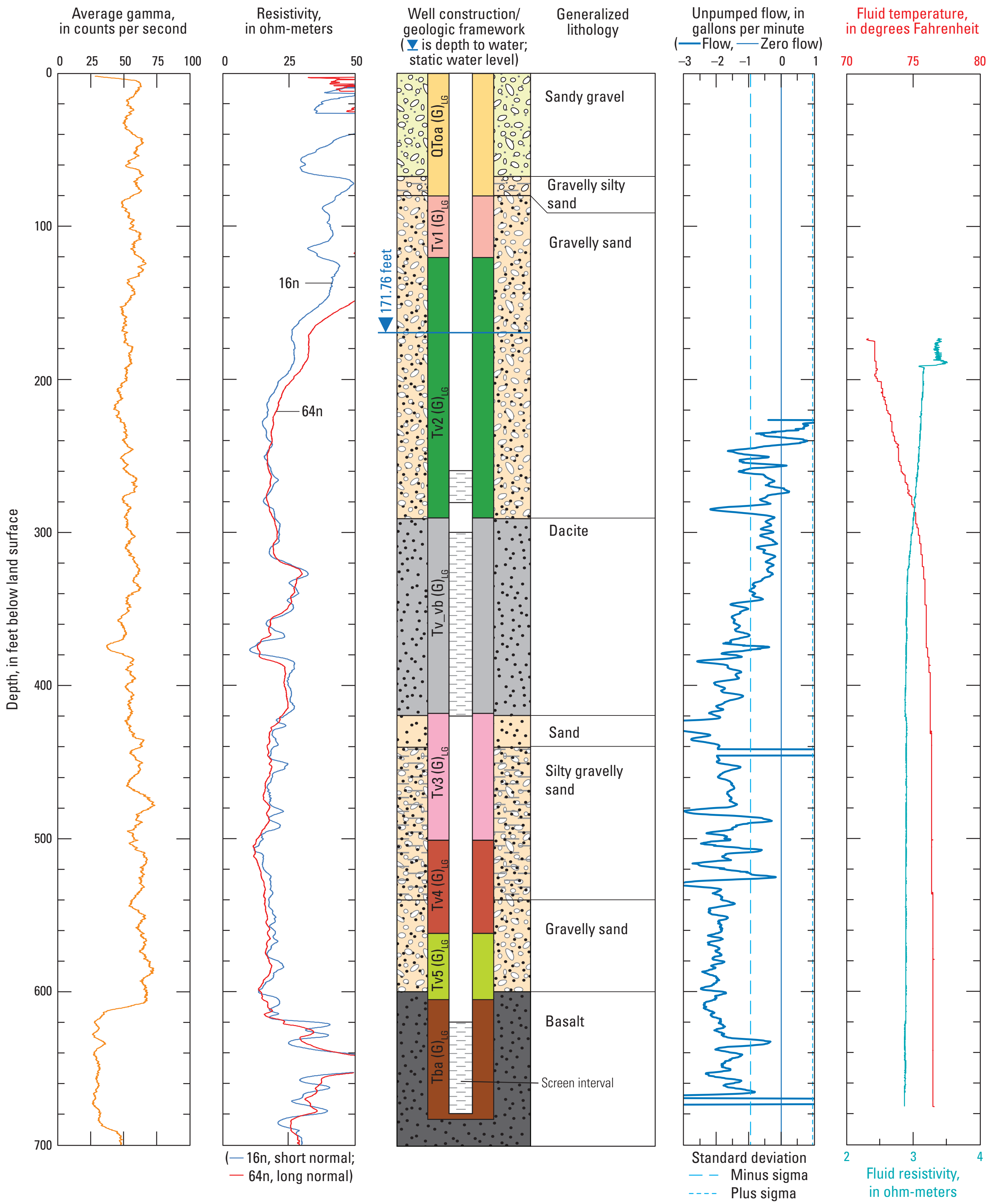


Figure 4. Natural gamma, 16/64 normal resistivity, generalized lithology, lithostratigraphic-geophysical units, well construction, unpumped wellbore flow, fluid resistivity, and fluid temperature collected from well GOLD1-T #1 (15N/01E-28R4S) under unpumped conditions, July 2015 (geologic units are described in detail in fig. 3), Fort Irwin National Training Center, California. [Note: negative values represent downward flow in the well, and positive values represent upward flow.]

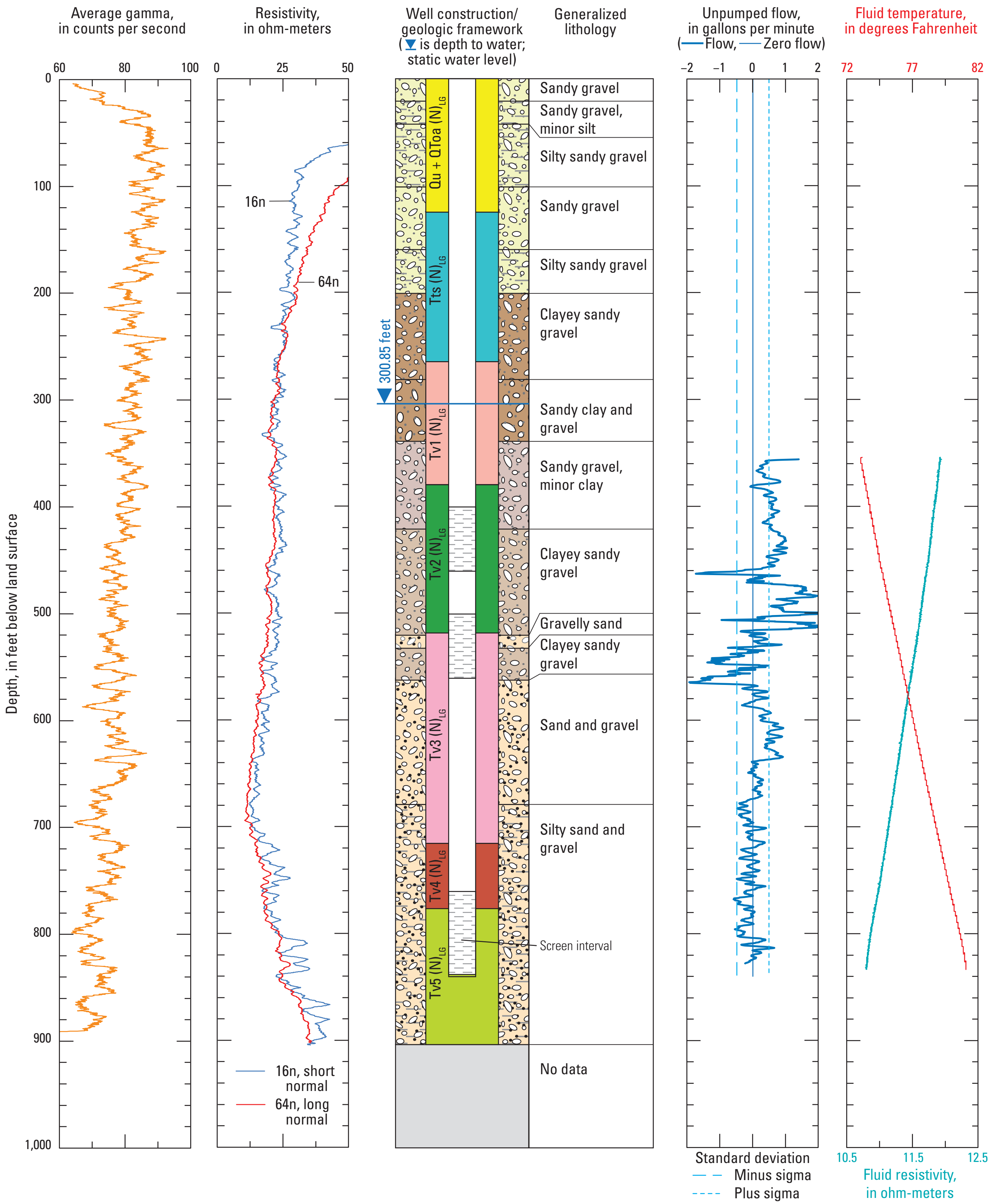


Figure 5. Natural gamma, 16/64 normal resistivity, generalized lithology, lithostratigraphic-geophysical units, well construction, unpumped wellbore flow, fluid resistivity, and fluid temperature collected from well NELT6 (15N/02E-05N1S) under unpumped conditions, July 2015 (geologic units are described in detail in fig. 3), Fort Irwin National Training Center, California. [Note: negative values represent downward flow in the well, and positive values represent upward flow.]

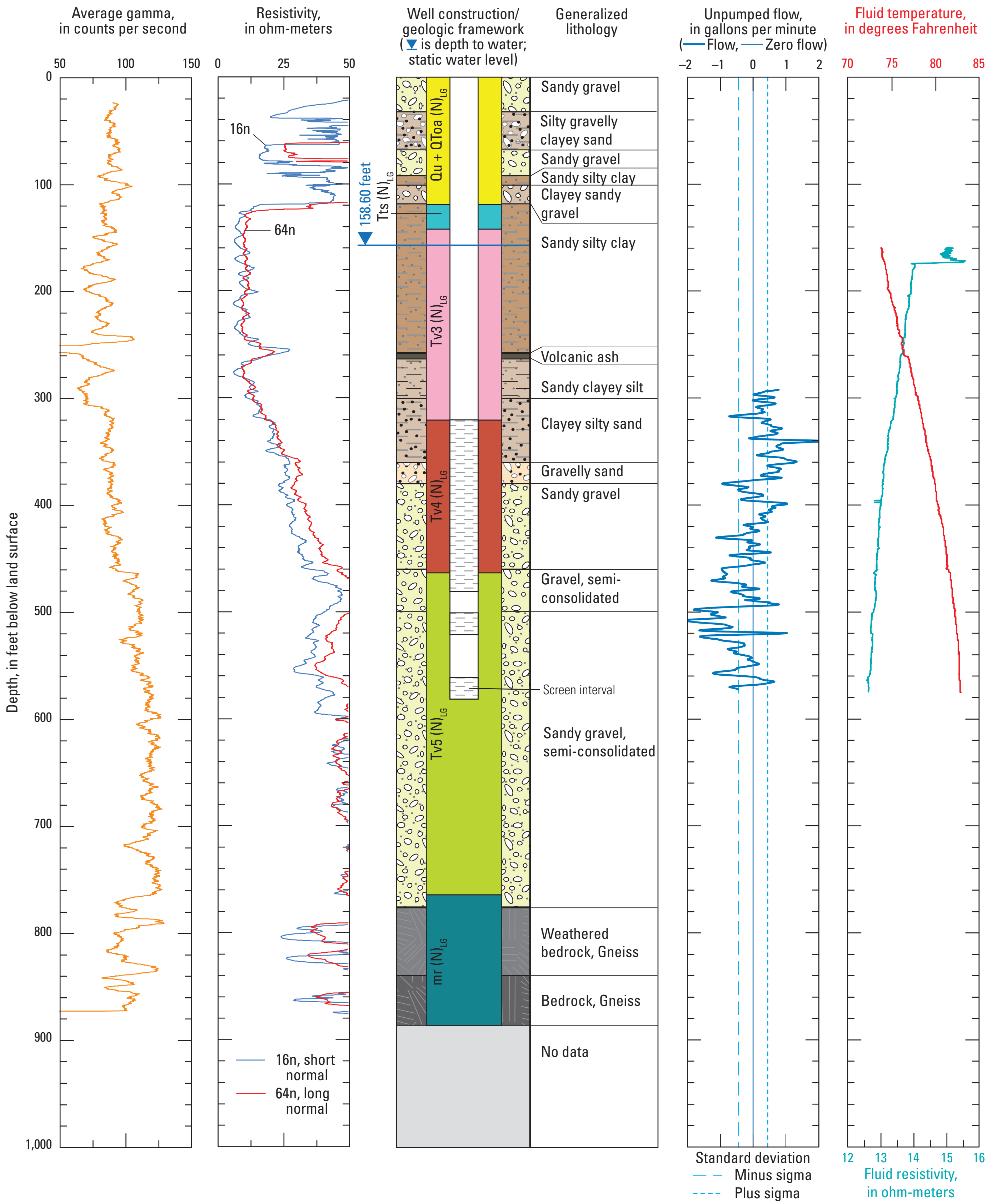


Figure 6. Natural gamma, 16/64 normal resistivity, generalized lithology, lithostratigraphic-geophysical units, well construction, unpumped wellbore flow, fluid resistivity, and fluid temperature collected from well NELT4 (15N/03E-08L1S) under unpumped conditions, January 2015 (geologic units are described in detail in fig. 3), Fort Irwin National Training Center, California. [Note: negative values represent downward flow in the well, and positive values represent upward flow.]

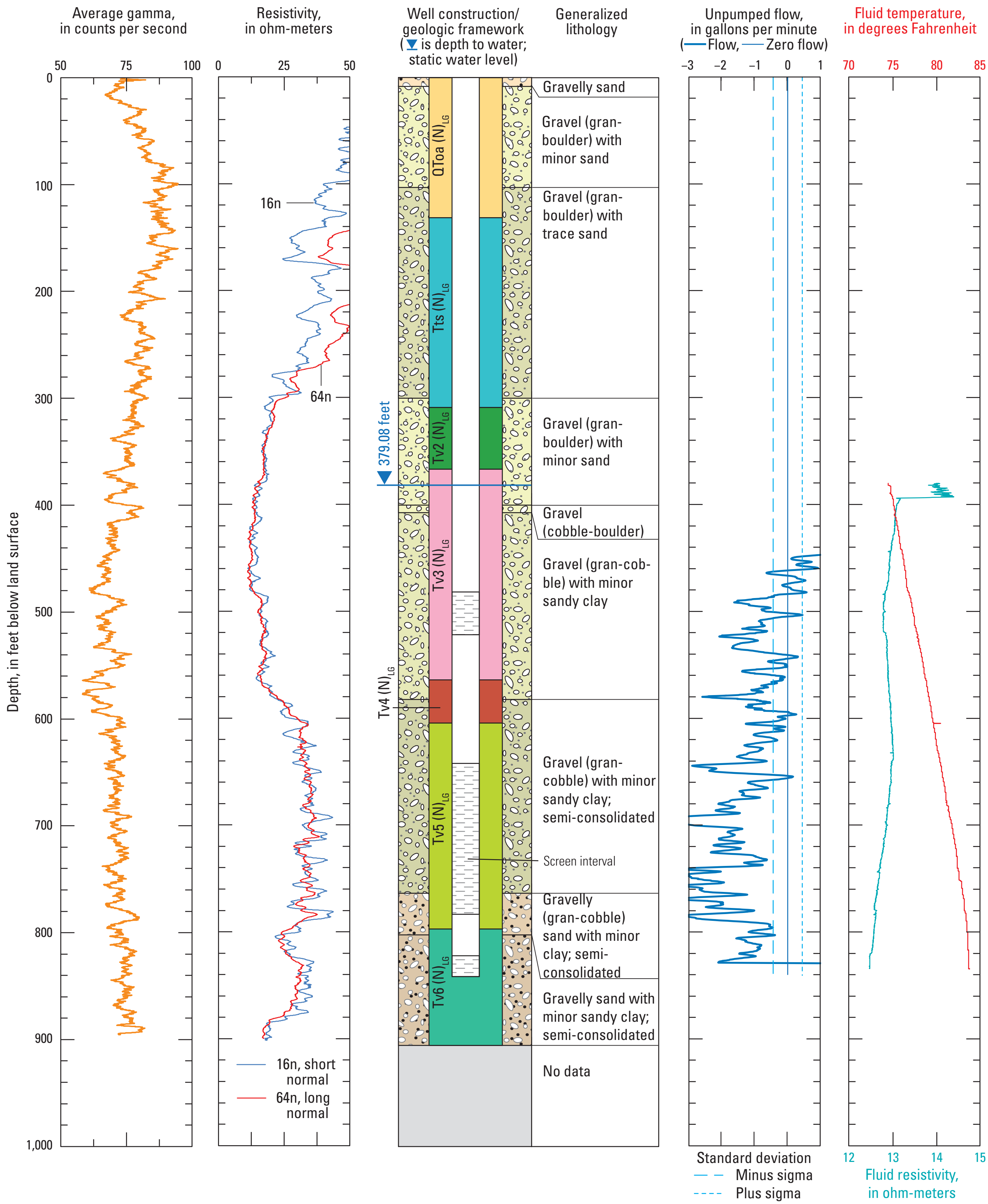


Figure 7. Natural gamma, 16/64 normal resistivity, generalized lithology, lithostratigraphic-geophysical units, well construction, unpumped wellbore flow, fluid resistivity, and fluid temperature collected from well NELT5 (16N/01E-35P1S) under unpumped conditions, January 2015 (geologic units are described in detail in fig. 3), Fort Irwin National Training Center, California. [Note: negative values represent downward flow in the well, and positive values represent upward flow.]

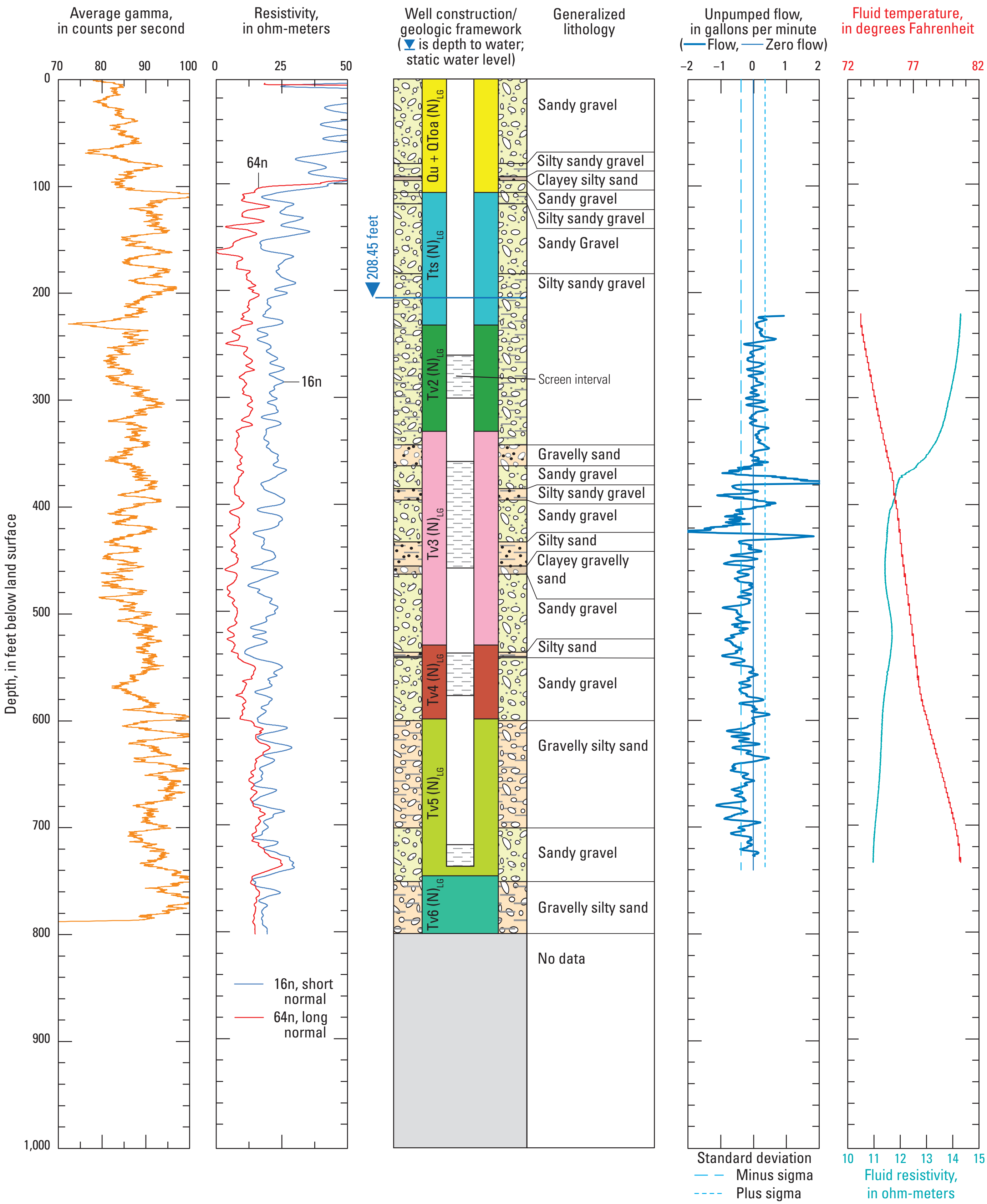


Figure 8. Natural gamma, 16/64 normal resistivity, generalized lithology, lithostratigraphic-geophysical units, well construction, unpumped wellbore flow, fluid resistivity, and fluid temperature collected from well NELT3 (16N/02E-31H1S) under unpumped conditions, July 2015 (geologic units are described in detail in fig. 3), Fort Irwin National Training Center, California. [Note: negative values represent downward flow in the well, and positive values represent upward flow.]

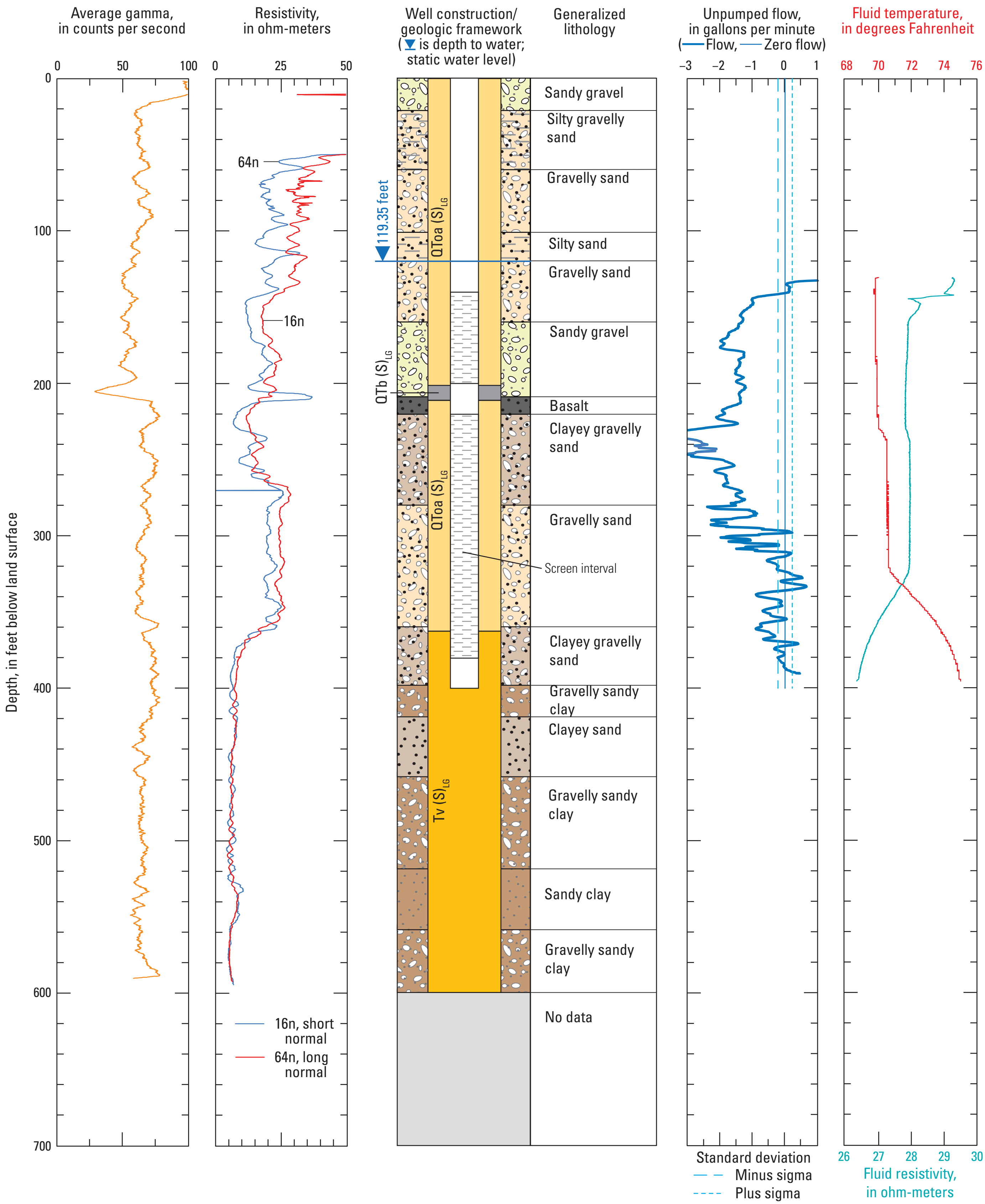


Figure 9. Natural gamma, 16/64 normal resistivity, generalized lithology, lithostratigraphic-geophysical units, well construction, unpumped wellbore flow, fluid resistivity, and fluid temperature collected from well SBTW (31S/46E-05B1M) under unpumped conditions, July 2015 (geologic units are described in detail in fig. 3), Fort Irwin National Training Center, California. [Note: negative values represent downward flow in the well, and positive values represent upward flow.]

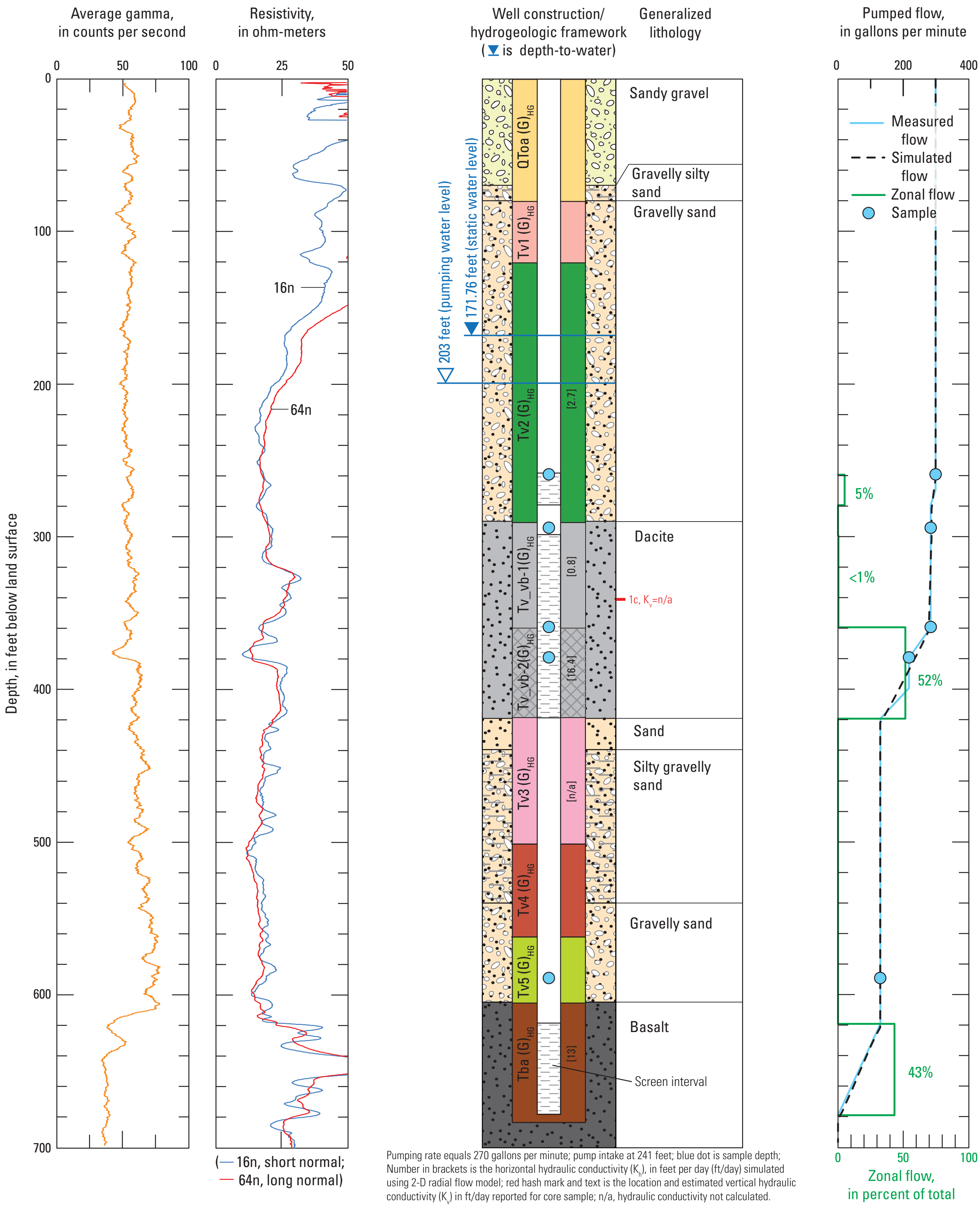


Figure 10. Natural gamma, 16/64 normal resistivity, generalized lithology, hydrogeologic units, well construction, and pumped wellbore flow properties collected from test well GOLD1-T (15N/01E-28R4S) under pumped conditions, March 2012 (hydrogeologic units are described in detail in fig. 3), Fort Irwin National Training Center, California.

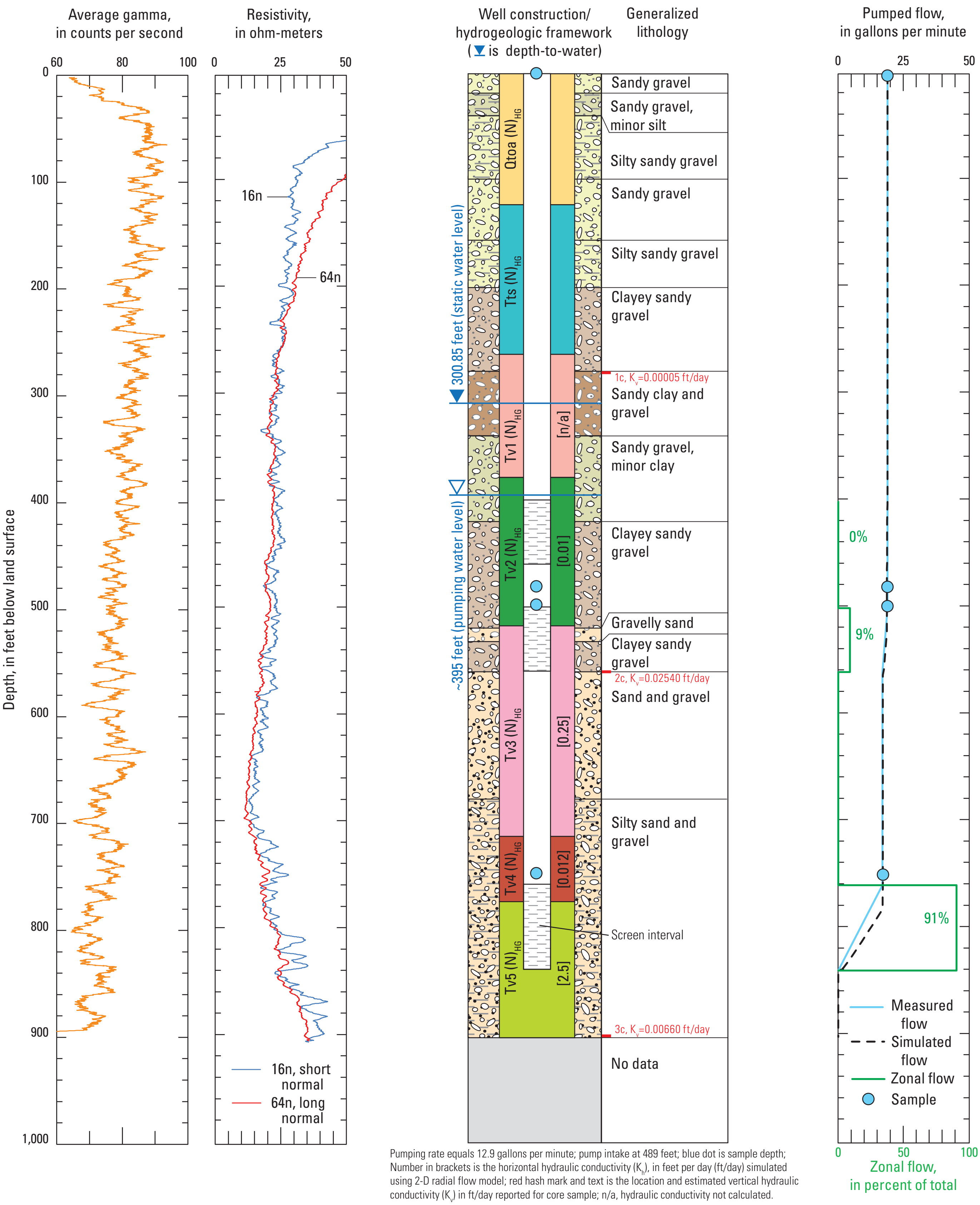


Figure 11. Natural gamma, 16/64 normal resistivity, generalized lithology, hydrogeologic units, well construction, and pumped wellbore flow properties collected from test well NELT6 (15N/02E-05N1S) under pumped conditions, March 2012 (hydrogeologic units are described in detail in fig. 3), Fort Irwin National Training Center, California.

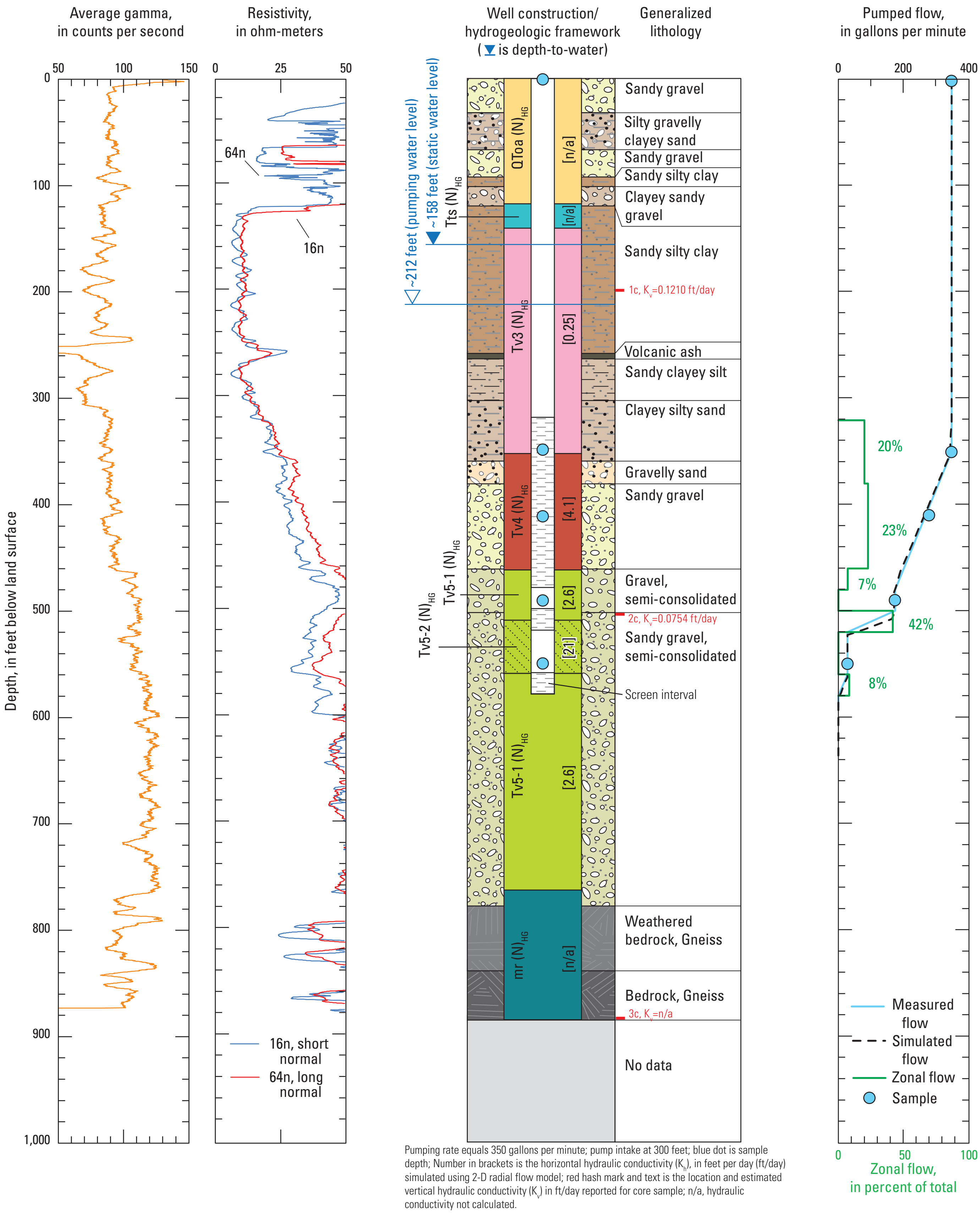


Figure 12. Natural gamma, 16/64 normal resistivity, generalized lithology, hydrogeologic units, well construction, and pumped wellbore flow properties collected from test well NELT4 (15N/03E-08L1S) under pumped conditions, February 2012 (hydrogeologic units are described in detail in fig. 3), Fort Irwin National Training Center, California.

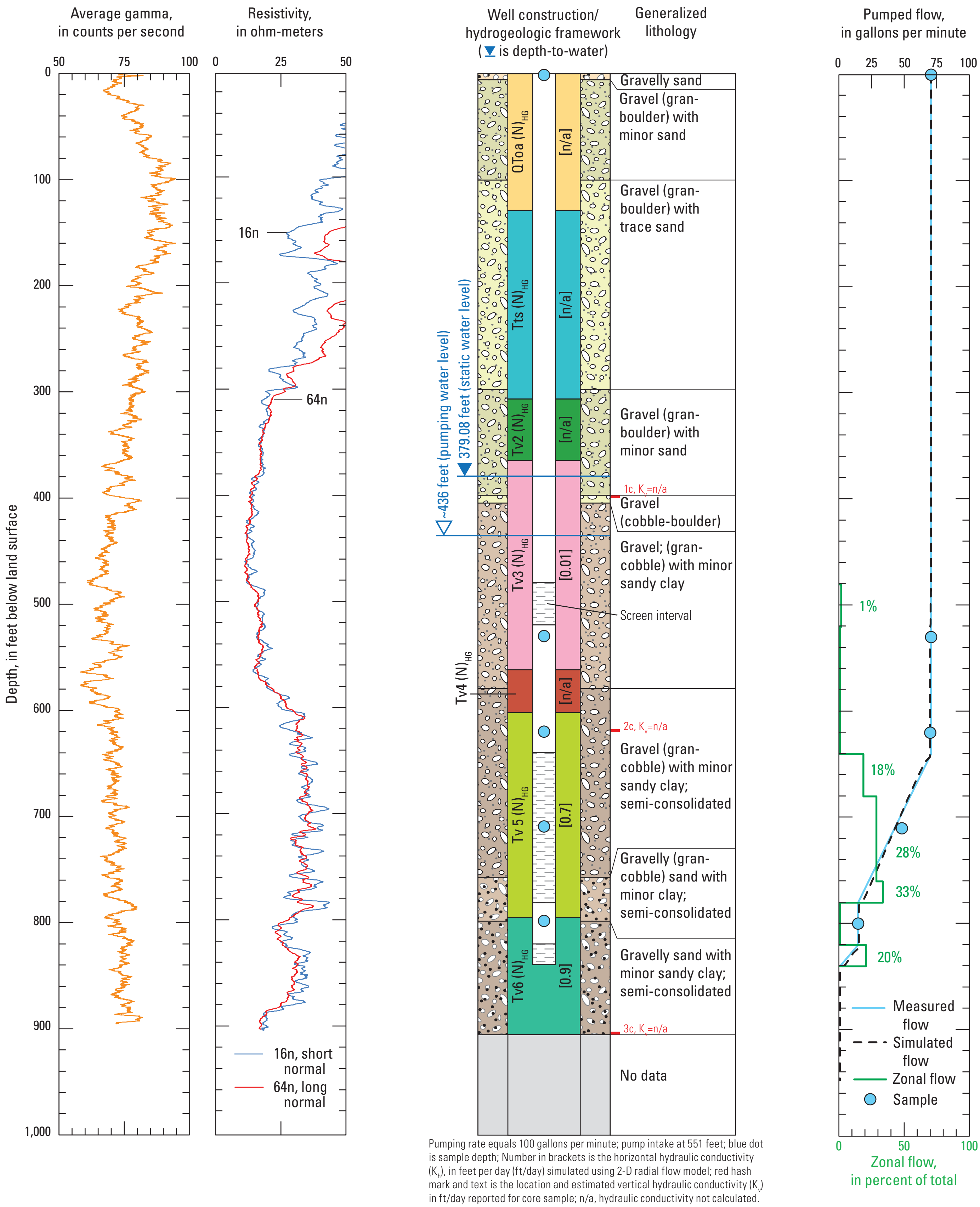


Figure 13. Natural gamma, 16/64 normal resistivity, generalized lithology, hydrogeologic units, well construction, and pumped wellbore flow properties collected from test well NELT5 (16N/01E-35P1S) under pumped conditions, March 2012 (hydrogeologic units are described in detail in fig. 3), Fort Irwin National Training Center, California.

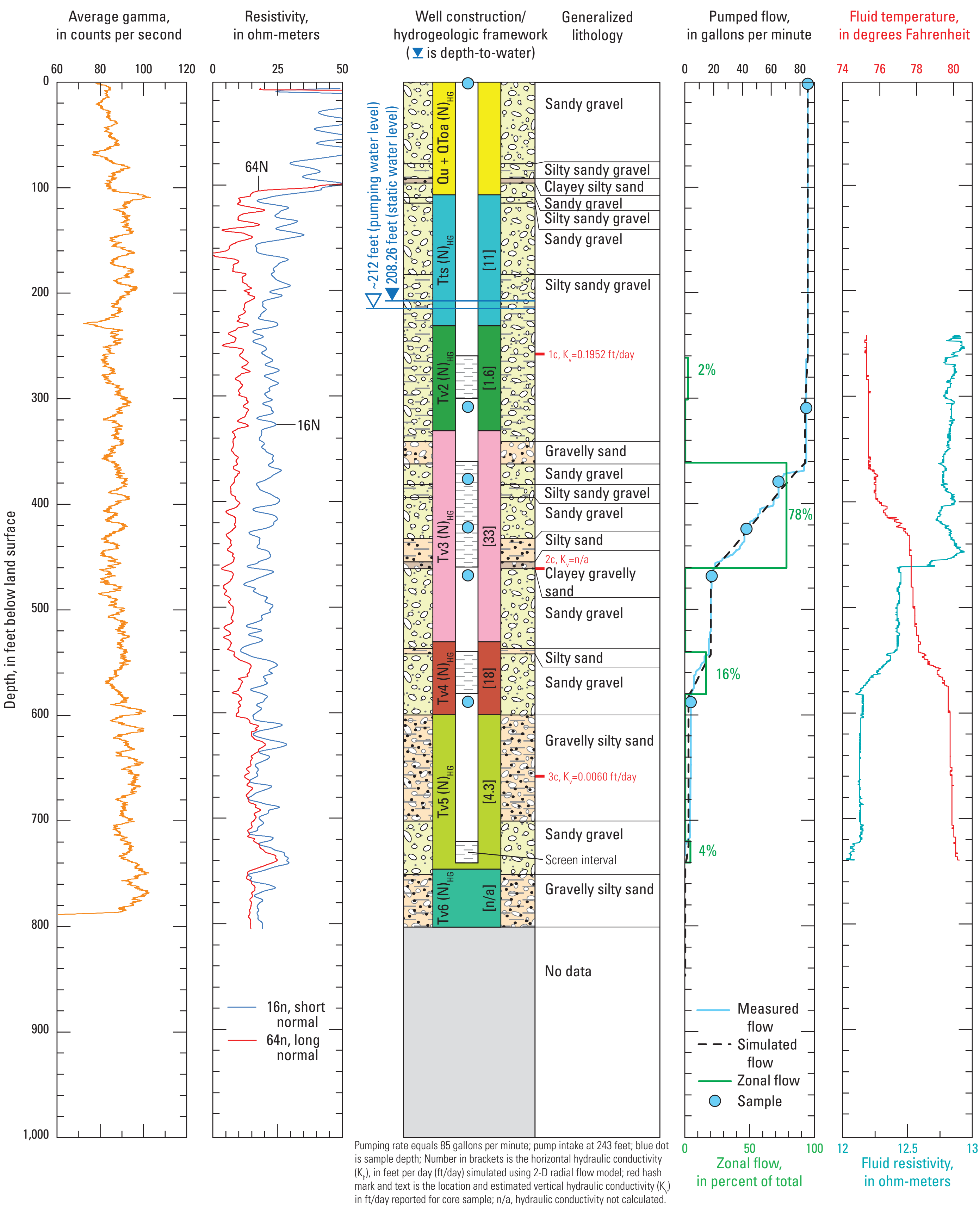


Figure 14. Natural gamma, 16/64 normal resistivity, generalized lithology, hydrogeologic units, well construction, pumped wellbore flow, fluid resistivity, and fluid temperature collected from well NELT3 (16N/02E-31H1S) under pumped conditions, February 2015 (hydrogeologic units are described in detail in fig. 3), Fort Irwin National Training Center, California.

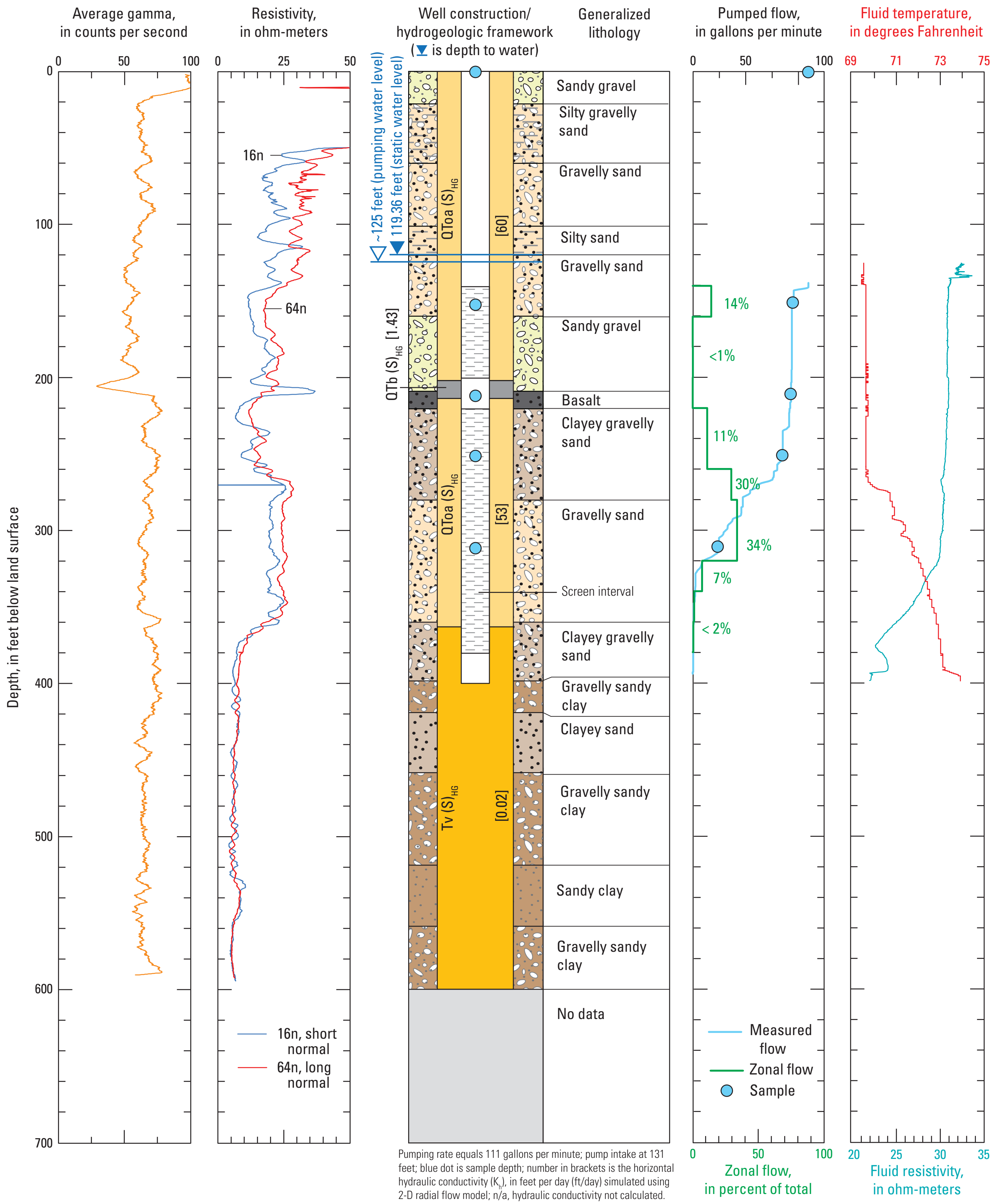


Figure 15. Natural gamma, 16/64 normal resistivity, generalized lithology, hydrogeologic units, well construction, pumped wellbore flow, fluid resistivity, and fluid temperature collected from well SBTW (31S/46E-05B1M) under pumped conditions, February 2015 (hydrogeologic units are described in detail in fig. 3), Fort Irwin National Training Center, California.

GOLD1-T

Well 15N/01E-28R4S (GOLD1-T #1), drilled to a depth of 700 ft with screened intervals at 260–280, 300–420, and 620–680 ft, is completed in interbedded Miocene volcanic-rich strata ($Tv2(G)_{LG}$-$Tv5(G)_{LG}$), an avalanche breccia of dacite lava ($Tv\_vb(G)_{LG}$), and basalt flows (Tba_{LG}; fig. 4). This stratigraphy correlates to the detailed stratigraphy determined previously for borehole GOLD1 (148 ft to the southwest; Kjos and others, 2014). In January 2015, unpumped flow and fluid-property (temperature and resistivity) log data collected at GOLD1-T #1 indicated the shallowest screened interval (260–280 ft) did not contribute flow to the wellbore under ambient conditions. The logs also indicate an average of 1.75 gpm of downward flow moved from the middle-screened interval (300–420 ft) to the deepest interval (620–680 ft). The break in slope observed in fluid temperature and fluid resistivity logs confirm water contribution to the wellbore below 300 ft.

Pumped flow logs were collected in March 2012 during the pumping test at well GOLD1-T #1; the average pumping rate was 270 gpm (fig. 10). The average specific capacity measured during the test for well GOLD1-T #1 was 9.5 gpm/ft of drawdown (table 4). As previously described in the “Pumped Flow Logs” in the “Methods of Study” section, the data collected were used to calculate contribution to wellbore flow between injection points and to create wellbore-flow logs. Approximately 5 percent (13.5 gpm) of the total well yield was contributed by the shallowest screened interval (fig. 10). Flow contribution to the well was relatively uniform across the middle- and deep-screened intervals, such that each zone contributed about 52 percent (140 gpm) and 43 percent (116 gpm), respectively. Less than 1 percent (less than 1 gpm) of the total flow was contributed by the screened interval between 300 and 360 ft, however. Although this zone was logged as a single dacite unit from about 290 to 420 ft (Kjos and others, 2014), the flow logs demonstrate that this LGU ($Tv\text{-}vb(G)_{LG}$) does not produce water uniformly, indicating possible presence of fractures in the bottom part of the unit (at depths greater than 360 ft). For numerical modeling purposes (discussed later), the LGU was divided into two hydrogeologic subunits ($Tv\_vb\text{-}1(G)_{HG}$ and $Tv\_vb\text{-}2(G)_{HG}$).

NELT6

Well 15N/02E-05N1S (NELT6 #1), drilled to a depth of 903 ft with screened intervals at 400–460, 500–560, and 760–840 ft bls, is completed in Miocene volcanic-rich strata ($Tv2(N)_{LG}$-$Tv5(N)_{LG}$; fig. 5), subunits of the volcanic-rich sedimentary rocks described in the “Lithostratigraphic-Geophysical Units” section of this report. Unpumped flow data collected in July 2015 indicate very little wellbore flow in NELT6 #1 under ambient conditions. Fluid-property logs show little change in slope over the screened sections and indicate stagnant conditions in the wellbore under ambient conditions (fig. 5). The unpumped flow log indicates some redistribution of water between the shallow and middle screened intervals; however, the steady increase and no change in slope in fluid temperature by depth indicate a geothermal gradient and are indicative of no vertical flow in the wellbore. Additionally, the unpumped flow log also indicates water was contributed in a blank section of casing from 480 to 500 ft above the perforated interval. Given the lack of response observed in fluid-property logs, it is believed that there is very little wellbore flow under ambient conditions. The variability in flow of plus or minus (±) 2 gpm observed from 460 to 560 ft is believed to be noise due to the tool moving around in the wellbore (for example, bouncing between the casing side walls because of a possibly bent casing or screen). Because NELT6 #1 had such low yield (12.9 gpm), small movements of the tool between the casing wall of the blank section (low flow) and the center of the well (high flow) could create a false sense of flow.

Pumped flow logs were collected in March 2012 during the pumping test at well NELT6 #1; the average pumping rate was 12.9 gpm. The average specific capacity of well NELT6 #1, measured during collection of pumped flow log data, was 0.2 gpm/ft of drawdown (table 4). Under pumping conditions, no measurable flow was contributed to the well from the shallow screened interval (400–460 ft). The middle-screened interval (500–560 ft) contributed about 9 percent (roughly 1.3 gpm) of the total. Under pumping conditions, about 91 percent (11.6 gpm) of total wellbore flow was contributed by the deepest screened interval (760–840 ft; fig. 11). The low well yield from the upper screened intervals is consistent with physical properties of LGU Tv2(N)-Tv3(N) because the formations are thought to be rather impermeable.

NELT4

Well 15N/03E-08L1S (NELT4 #1), drilled to a depth of 885 ft with screened intervals at 320–480, 500–520, and 560–580 ft bls, is completed in Miocene volcanic-rich strata ($Tv3(N)_{LG}$-$Tv5(N)_{LG}$; fig. 6); according to geophysical data collected from the borehole, the deeper deposits were not screened. In January 2015, unpumped flow through NELT4 #1 was downward from the bottom half of the upper screen (below 420 ft) to deepest screened interval (560–580 ft) at rates as high as about 1.5 (±0.44 sigma) gpm. According to the unpumped flow and fluid-property logs, there could be some slight contribution of upward flow to the well above 380 ft, and the fluid resistivity log shows a slight break in slope between 360 and 380 ft. In contrast, the fluid temperature log displays a steady geothermal gradient until 500 ft, where it levels slightly (fig. 6). Given the lack of break in slope in fluid temperature, little water is likely contributed to the wellbore above 380 ft bls relative to the lower part of the well. Fluid property and unpumped flow logs each indicate the majority of water influx is from the middle-screened interval, from 500 to 520 ft bls.

Pumped flow logs were collected in February 2012 during the pumping test at well NELT4 #1; the average pumping rate was 350 gpm. The average specific capacity of well NELT4 #1, measured during collection of pumped flow log data, was 4.6 gpm/ft of drawdown (table 4). The shallow screened interval (320–480 ft bls) contributed about 50 percent of the flow (175 gpm; fig. 12). The middle screen produced 42 percent (147 gpm), and the lower screen produced 8 percent (28 gpm). Although these screens are perforated in the same LGU, the flow logs demonstrate that this LGU ($Tv5(N)_{LG}$) did not produce water uniformly. For numerical modeling purposes (discussed later), the unit was divided into two hydrogeologic subunits ($Tv5\text{-}1(N)_{HG}$ and $Tv5\text{-}2(N)_{HG}$).

NELT5

Well 16N/01E-35P1S (NELT5 #1), drilled to a depth of 905 ft with screened intervals at 480–520, 640–780, 820–840 ft, is completed in Miocene volcanic-rich strata ($Tv3(N)_{LG}$, $Tv5(N)_{LG}$, and $Tv6(N)_{LG}$; fig. 7). In January 2015, unpumped flow through NELT5 #1 was downward from the shallow screen (480–520 ft) to the deeper screened intervals (640–780 and 820–840 ft) at rates averaging about 1–2 gpm. Breaks in slope on the fluid resistivity log adjacent to the shallow and middle screened intervals, at 480, 520, and 640 ft, support the flow log and indicate water movement in the well under ambient conditions.

Pumped flow logs were collected in February 2012 during the pumping test at well NELT5 #1; the average pumping rate was 100 gpm. The average specific capacity of well NELT5 #1, measured during collection of pumped flow log data, was 0.7 gpm/ft of drawdown (table 4). Pumped flow data from NELT5 #1 indicate that very little water was contributed to the wellbore from the shallow screened interval (480–520 ft) under pumping conditions, whereas 99 percent of total discharge was contributed to the wellbore from the middle and deep screens (fig. 13). About 79 percent (roughly 79 gpm) was contributed from the middle well screen, with the remaining 20 percent (20 gpm) contributed from the deepest well screen.

NELT3

Well 16N/02E-31H1S (NELT3 #1), drilled to a depth of 800 ft with screened intervals at 260–300, 360–460, 540–580 and 720–740 ft, is completed in Miocene volcanic-rich strata ($Tv2(N)_{LG}$–$Tv5(N)_{LG}$; fig. 8). Unpumped flow and fluid-property logs, collected in July 2015, indicate the shallowest screened interval (260–300 ft) did not contribute flow to the wellbore under ambient conditions (fig. 8). The unpumped flow log at NELT3 #1 indicates downward flow from the second screened interval (360–460 ft) to the third screened interval (540–580 ft) at rates as high as about 1 gpm. The breaks in slope on fluid resistivity and fluid temperature logs at 360 ft and again between 540 and 580 ft both support the unpumped flow log and indicate the downward movement of water in the well under ambient conditions.

Pumped flow logs were collected in February 2015 during the pumping test at well NELT3 #1; the average pumping rate was 85 gpm. The average specific capacity of well NELT3 #1, measured during collection of pumped flow log data, was 21.1 gpm/ft of drawdown (table 4). Under pumping conditions, about 94 percent (80 gpm) of total wellbore flow was contributed by the middle two screened intervals (360–460 and 540–580 ft); the shallowest and deepest screened intervals (260–300 and 720–740 ft, respectively) contributed about 2 percent (1.7 gpm) and 4 percent (3.4 gpm), respectively (fig. 14).

SBTW

Well 31S/46E-05B1M (SBTW #1), drilled to a depth of 600 ft with screened intervals at 140–200 and 220–380 ft bls, is completed in Quaternary to Pliocene sand and gravel (conglomerate and sandstone, $QToa(S)_{LG}$) and Miocene volcanic-rich strata ($Tv(S)_{LG}$, undifferentiated; fig. 9). A Quaternary to Pliocene basalt ($QTb(S)_{LG}$) was also present from 203 to 213 ft bls. On the basis of the geophysical data, the basalt as well as fine-grained deposits below 400 ft were not screened. In June 2015, unpumped flow through well SBTW #1 was downward from the shallow- to the deep-screened interval at rates as high as about 3 gpm. Fluid temperature and fluid resistivity logs display a subtle break in slope near the top of the deep screen, around 220 ft, supporting the unpumped flow log showing downward vertical flow of water. The flow logs indicate no notable unpumped flow at depths greater than about 320 ft. Fluid-property logs show a distinct break in slope around 320 ft. The increased temperature and lower resistivity indicate little flow at the bottom of the well, below 320 ft.

Pumped flow logs were collected in February 2015 during the pumping test at well SBTW #1; the average pumping rate was 111 gpm. The average specific capacity of well SBTW #1, measured during collection of pumped flow log data, was 20.0 gpm/ft of drawdown (table 4). Under pumping conditions, about 15 percent (17 gpm) of total wellbore flow was contributed by the shallow screen (140–200 ft), and most of this flow came from the top of the screen, as supported by the fluid resistivity log; the deep screen interval (220–380 ft) contributed the remaining 84 percent (94 gpm; fig. 15). Additionally, flow data indicate about 64 percent (71 gpm) of total wellbore flow was contributed to the wellbore between the 260 and 320 ft interval (of the deeper screened interval) under pumping conditions.

Generalizing the findings across all six sets of wellbore-flow results, flow data from the test wells under unpumped conditions show downward movement of water, from the uppermost screens to lower more productive zones in the aquifer, at rates ranging from about 1 to 3 gpm. The downward flow indicates a redistribution of shallow aquifer water to lower parts of the system under ambient groundwater conditions. Flow data collected from the six test wells under pumping conditions show increasing flow from shallower to deeper screens in the wells and indicate higher yields from deeper aquifers. In most cases, the test wells yielded little to no water from the shallower parts of the screened interval during pumping. These data indicate generally higher hydraulic conductivities at deeper depths and lower hydraulic conductivities at shallower depths.

Groundwater Levels, Gradients, and Water-Quality Data

Between 2011 and 2015, water levels were measured periodically from all wells and prior to collection of water-quality samples. Water-quality samples were collected at most wells and analyzed for selected constituents.

Water-Level Data

Water-level data from 2015, collected using methods described in the “Groundwater Data Collection” section, are presented in table 5. These data supplement those of Kjos and others (2014); links to all historical water-level data available from the NWISWeb interface are provided in table 5. Hydrographs of groundwater elevation from each of the single- and multiple-well monitoring sites, grouped by area, are presented in the upper graph on figure 16. The groundwater elevation axes of the graphs are variable in scale to show the water levels from multiple wells at each monitoring site.

Water levels have remained stable since 2011 in most of monitoring and test wells measured, except at monitoring sites BLA5 (14N/03E-26K1, 3, and 4S) and LL04 (12N/03E-01M1, 4, and 5S; figs. 2, 16; table 5). Hydrographs for these sites display a consistent trend of declining groundwater elevation since 2011. Water levels at the BLA5 and BLA5B sites declined more than 6.7 ft since 2011 in each monitoring well measured. The sharp water-level decline measured during 2011 in well LL04 #1 (12N/03E-01M1S) likely reflected recent pumping in the well and, thus, was not representative of static conditions. These wells are in basins proximal to the cantonment area, where withdrawals from production wells supply the majority of Fort Irwin facilities.

Vertical Hydraulic Gradients in Multiple-Well Monitoring Sites

Vertical hydraulic gradients were calculated to determine the direction of vertical groundwater flow in the aquifer system at each of the multiple-well monitoring sites (table 6). Vertical hydraulic gradients between two vertically contiguous wells were calculated by dividing the difference in hydraulic head (water level in feet) between the shallower and deeper well by the vertical distance between the midpoints of the two screened intervals (in feet). Gradients were also calculated from data collected by Kjos and others (2014) to look at trends through time (fig. 16); links to water-level data used to calculate these gradients are in table 5. For this discussion, the wells are grouped by basin or by adjacent basins where there are only a few wells. Values for vertical hydraulic gradient (foot per foot, ft/ft) are reported as unitless numbers; a positive value represents downward flow, and a negative value represents upward groundwater flow. In the absence of pumping, downward flow can indicate surficial recharge, and upward flow can indicate discharge at or near the land surface. The calculated vertical hydraulic gradients, grouped by area, are presented in the lower graph of each pair shown on figure 16. Fluctuations in early time water-level data and the associated gradients from most wells are likely the result of disturbances related to well installation, including residual effects of drilling or well development, and may not be representative of actual aquifer conditions.

Vertical head gradients were generally low across the NTC but ranged from –0.0003 between wells 14N/01E-07R1S (GOLD2 #1) and 14N/01E-07R2S (GOLD2 #2) to 0.27 between wells 14N/01E-07R2S (GOLD2 #2) and 14N/01E-07R3S (GOLD2 #3) during summer 2015 (table 6). Multiple-well monitoring sites in the Central Corridor area (CCT1) and Bicycle (BLA5) Basins; (fig. 16*A*), Cronise (CRTH1) Basin (fig. 16*B*), Goldstone (GOLD2 #2 – #3) and Superior (SBMW) Basins (fig. 16*C*), and Nelson Basin (NELT1, NELT2, NELT7; fig. 16*D*) had downward vertical gradients, as shown by positive values (table 6), indicating surficial recharge at or near these locations. As is common in desert environments with limited potential recharge, however, vertical gradients were generally low and generally decreased in deeper zones. All other monitoring sites displayed upward vertical gradients during 2015.

Vertical gradients calculated for multiple-well monitoring sites 14N/03E-26K1, 3 (BLA5), 14N/03E-26K4S (BLA5B), and 15N3E-25L1–3S (CCT1) indicate slight downward gradients between vertically contiguous wells (table 6). A larger gradient (0.0142) was calculated between the two shallow wells at site BLA5 (fig. 16*A*). Kjos and others (2014) described fine-grained playa deposits penetrated by the shallowest well 14N/03E-26K3S (BLA5 #3) that overlie coarser, fractured bedrock surrounding well 14N/03E-26K4S (BLA5B #1).

Table 5. Summary of water-level data from single- and multiple-well monitoring sites and test wells, Fort Irwin National Training Center, California, 2015.

[Elevations were interpolated from a topographic map. Water-level time datum is Pacific Daylight Time. Water levels are from the most recent complete set of static water levels for each site. All water-level data for each well may by accessed by the NWISWeb links on the right side of the table. **Abbreviations**: ft bls, feet below land surface; ft, feet; hh:mm, hour:minute; mm/dd/yyyy, month/day/year; NAVD88, North American Vertical Datum of 1988; NWIS, National Water Information System]

Common name	State well number	Perforated interval (ft bls)	Water-level time (hh:mm)	Water level (ft bls)	Link to water levels in NWIS
			LL04: June 29, 2015, at 2,410 ft above NAVD88		
LL04 #1	12N/03E-01M1S	950–970	10:11	296.09	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=350929116372301
			LL04B: June 29, 2015, at 2,410 ft above NAVD88		
LL04B #1	12N/03E-01M4S	470–490	10:27	296.41	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=350929116372201
LL04B #2	12N/03E-01M5S	330–350	10:31	296.42	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=350929116372202
			CRTH2: June 29, 2015, at 1,432 ft above NAVD88		
CRTH2 #1	13N/05E-08B1S	920–940	13:11	56.41	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351416116281501
[1]CRTH2 #2	13N/05E-08B2S	270–290	13:19	58.49	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351416116281502
			CRTH1: June 29, 2015, at 1,577 ft above NAVD88		
CRTH1 #1	13N/05E-28Q1S	1,240–1,260	12:09	193.02	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351100116271001
CRTH1 #2	13N/05E-28Q2S	700–720	12:11	181.27	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351100116271002
CRTH1 #3	13N/05E-28Q3S	235–255, 175–195	12:17	160.29	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351100116271003
			GOLD2: July 1, 2015, at 3,107 ft above NAVD88		
GOLD2 #1	14N/01E-07R1S	420–440	10:35	246.61	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351904116543101
GOLD2 #2	14N/01E-07R2S	330–350	10:39	246.64	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351904116543102
[2]GOLD2 #3	14N/01E-07R3S	220–240	10:44	[Z]216.63	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351904116543103
			BLA5: July 2, 2015, at 2,345 ft above NAVD88		
BLA5 #1	14N/03E-26K1S	320–340	10:03	191.90	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351638116374301
BLA5 #3	14N/03E-26K3S	190–210	10:06	190.91	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351638116374303
			BLA5B: July 2, 2015, at 2,345 ft above NAVD88		
BLA5B #1	14N/03E-26K4S	250–270	10:08	191.76	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351638116374304
			GOLD1: July 1, 2015, at 3,058 ft above NAVD88		
GOLD1 #1	15N/01E-28R1S	650–670	11:24	171.28	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352144116522601
GOLD1 #2	15N/01E-28R2S	560–580	11:26	171.19	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352144116522602
GOLD1 #3	15N/01E-28R3S	350–370	11:30	171.23	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352144116522603
			GOLD1-T: July 1, 2015, at 3,064 ft above NAVD88		
GOLD1-T #1	15N/01E-28R4S	620–680, 300–420, 260–280	11:12	171.86	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352145116522401

Table 5. Summary of water-level data from single- and multiple-well monitoring sites and test wells, Fort Irwin National Training Center, California, 2015.—Continued

[Elevations were interpolated from a topographic map. Water-level time datum is Pacific Daylight Time. Water levels are from the most recent complete set of static water levels for each site. All water-level data for each well may by accessed by the NWISWeb links on the right side of the table. **Abbreviations**: ft bls, feet below land surface; ft, feet; hh:mm, hour:minute; mm/dd/yyyy, month/day/year; NAVD88, North American Vertical Datum of 1988; NWIS, National Water Information System]

Common name	State well number	Perforated interval (ft bls)	Water-level time (hh:mm)	Water level (ft bls)	Link to water levels in NWIS
NELT6: June 30, 2015, at 3,139 ft above NAVD88					
NELT6 #1	15N/02E-05N1S	760–840, 500–560, 400–460	15:34	300.85	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352436116474001
NELT2: July 1, 2015, at 3,054 ft above NAVD88					
NELT2 #1	15N/03E-06L1S	760–800	17:17	216.54	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352450116421101
NELT2 #2	15N/03E-06L2S	510–530	17:23	216.42	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352450116421102
NELT2 #3	15N/03E-06L3S	280–300	17:27	216.17	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352450116421103
NELT4: June 29, 2015, at 2,990 ft above NAVD88					
NELT4 #1	15N/03E-08L1S	560–580, 500–520, 320–480	17:26	158.45	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352354116411201
CCT1: July 1, 2015, at 2,688 ft above NAVD88					
CCT1 #1	15N/03E-25L1S	875–895	18:11	527.16	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352149116370701
CCT1 #2	15N/03E-25L2S	730–750	18:17	527.11	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352149116370702
CCT1 #3	15N/03E-25L3S	645–665	18:25	527.04	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352149116370703
RDPS: June 29, 2015, at 2,102 ft above NAVD88					
RDPS #1	15N/06E-33L1S	520–700, 420–440	15:22	420.68	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352058116205901
NELT5: July 1, 2015, at 3,243 ft above NAVD88					
NELT5 #1	16N/01E-35P1S	820–840, 640–780, 480–520	16:21	379.08	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352530116503601
NELT7: June 30, 2015, at 3,172 ft above NAVD88					
NELT7 #1	16N/02E-16P1S	780–800	12:39	293.79	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352806116462101
NELT7 #2	16N/02E-16P2S	620–640	12:45	293.71	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352806116462102
NELT7 #3	16N/02E-16P3S	380–400	12:49	279.8	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352806116462103
NELT3: July 1, 2015, at 3,097 ft above NAVD88					
NELT3 #1	16N/02E-31H1S	720–740, 540–580, 360–460, 260–300	10:05	208.45	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352556116475501

Table 5. Summary of water-level data from single- and multiple-well monitoring sites and test wells, Fort Irwin National Training Center, California, 2015.—Continued

[Elevations were interpolated from a topographic map. Water-level time datum is Pacific Daylight Time. Water levels are from the most recent complete set of static water levels for each site. All water-level data for each well may by accessed by the NWISWeb links on the right side of the table. **Abbreviations**: ft bls, feet below land surface; ft, feet; hh:mm, hour:minute; mm/dd/yyyy, month/day/year; NAVD88, North American Vertical Datum of 1988; NWIS, National Water Information System]

Common name	State well number	Perforated interval (ft bls)	Water-level time (hh:mm)	Water level (ft bls)	Link to water levels in NWIS
NELT1: June 29, 2015, at 3,074 ft above NAVD88					
NELT1 #1	16N/02E-34Q1S	740–760	19:06	207.34	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352535116451001
NELT1 #2	16N/02E-34Q2S	280–300	19:12	202.89	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=352535116451002
SBTW: July 1, 2015, at 3,041 ft above NAVD88					
SBTW #1	31S/46E-05B1M	220–400, 140–200	12:47	119.39	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351619117041301
SBMW: July 1, 2015, at 3,044 ft above NAVD88					
SBMW #1	31S/46E-05B2M	270–290	13:05	120.03	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351620117041101
SBMW #2	31S/46E-05B3M	130–150	13:08	119.88	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351620117041102
SBMC: July 1, 2015, at 3,041 ft above NAVD88					
SBMC #1	31S/46E-05D1M	180–200	13:23	119.32	http://nwis.waterdata.usgs.gov/nwis/gwlevels?search_site_no=351619117045701

[Z]Status codes for water-level measurements: Z, other conditions existed that would affect the measured water level.

[1]Status code Z: high salinity formational water affected the grout and it infiltrated the sand-pack; water level may not be representative.

[2]Status code Z: well in a perched zone and was not able to be fully developed; water level may not be representative.

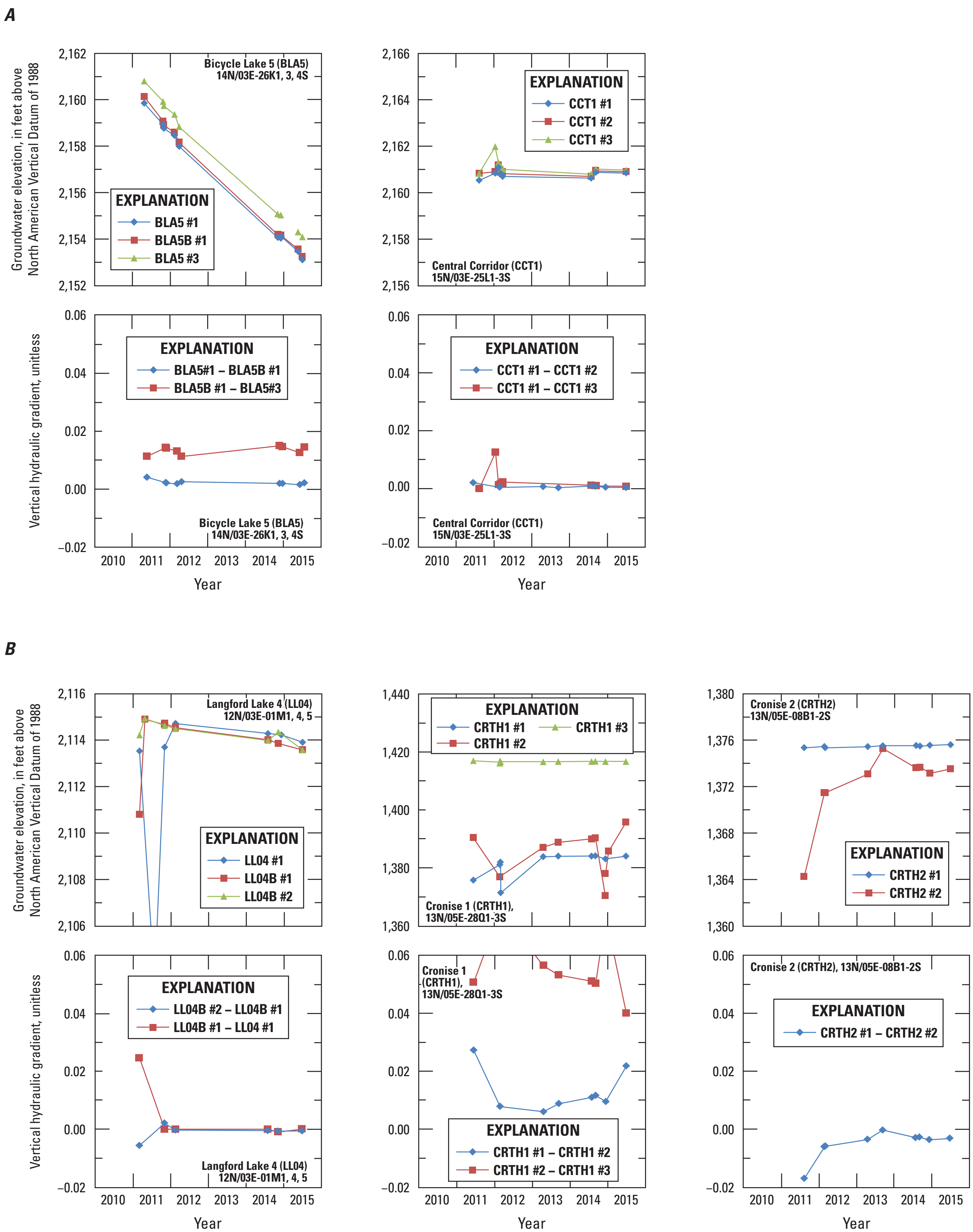
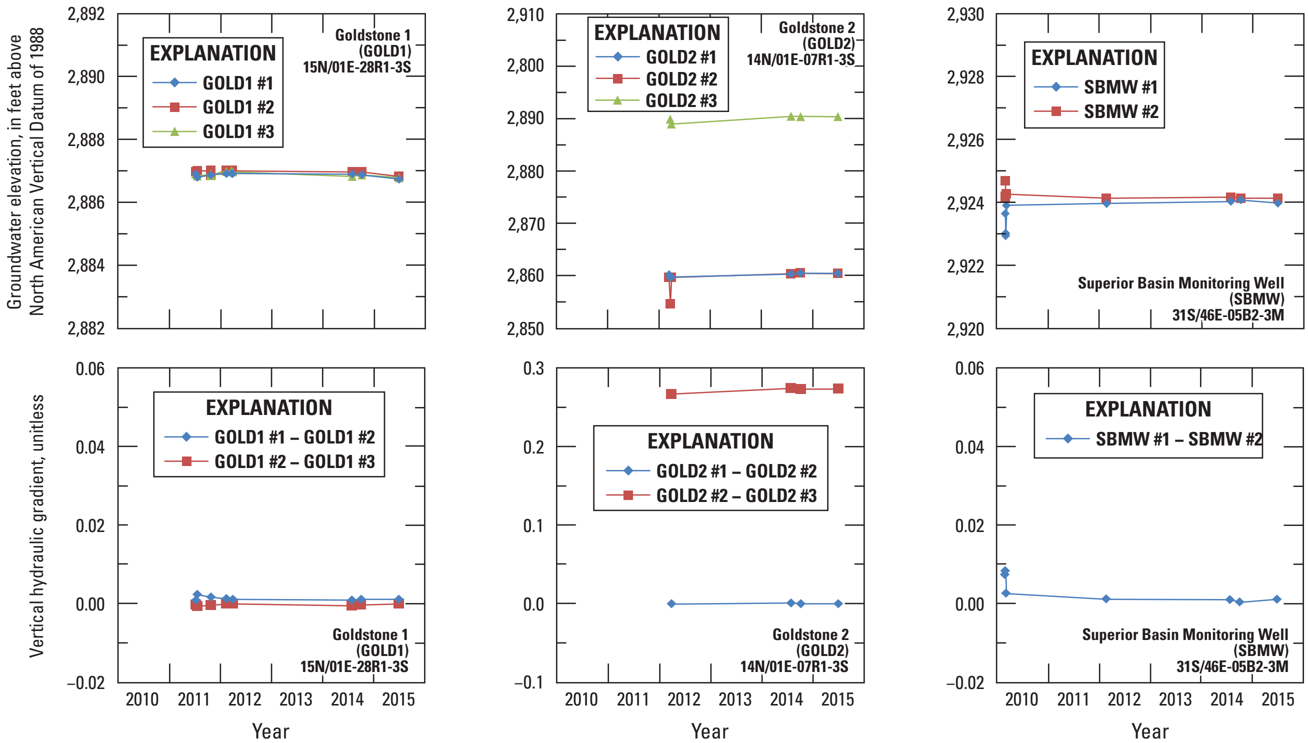


Figure 16. Groundwater elevation and vertical hydraulic gradients at single- and multiple-well monitoring sites in groundwater basins, Fort Irwin National Training Center, California: *A,* Bicycle and Central Corridor area; and *B,* Langford Lake. [Note: For vertical hydraulic gradient axes, negative numbers signify upward flow and positive numbers signify downward flow.]

C



D

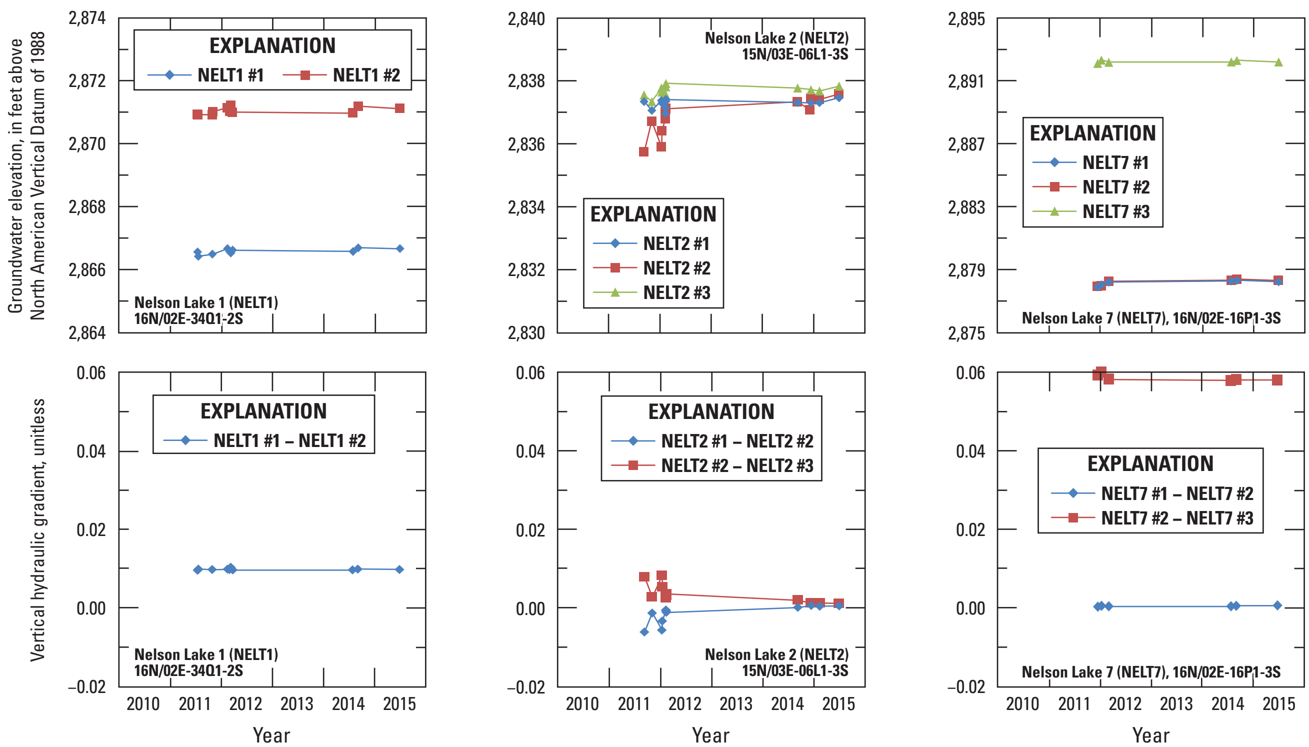


Figure 16. Groundwater elevation and vertical hydraulic gradients at single- and multiple-well monitoring sites in groundwater basins, Fort Irwin National Training Center, California—Continued: *C,* Goldstone and Superior; and *D,* Nelson Lake. [Note: For vertical hydraulic gradient axes negative numbers signify upward flow and positive numbers signify downward flow.]

Table 6. Summary of water-level data and calculated vertical hydraulic gradients from multiple-well monitoring sites, Fort Irwin National Training Center, California, 2015.

[Elevations were interpolated from a topographic map. Water levels are from the most recent complete set of static water levels for each site. **Abbreviations**: ft bls, feet below land surface; ft, feet; mm/dd/yyyy, month/day/year; NAVD88, North American Vertical Datum of 1988; nd, not determined]

State well number	U.S. Geological Survey site identifier	Common name	Water level (ft bls)	Screen interval (ft bls)		Screen mid-point (ft bls)	Vertical distance between mid-points (ft)	Vertical head difference (ft)	Vertical head gradient	Direction of flow
				Top	Bottom					
LL04 : June 29, 2015, at 2,410 ft above NAVD88										
12N/03E-01M5S	350929116372202	LL04B #2	296.42	330	350	340	140	–0.01	–0.0001	nd[1]
12N/03E-01M4S	350929116372201	LL04B #1	296.41	470	490	480	480	–0.32	–0.0007	Up
12N/03E-01M1S	350929116372301	LL04 #1	296.09	950	970	960				
CRTH2 : June 29, 2015, at 1,432 ft above NAVD88										
13N/05E-08B2S	351416116281502	CRTH2 #2	58.49	270	290	280	650	–2.08	–0.0032	Up
13N/05E-08B1S	351416116281501	CRTH2 #1	56.41	920	940	930				
CRTH1: June 29, 2015, at 1,577 ft above NAVD88										
13N/05E-28Q3S	351100116271003	CRTH1 #3	160.29	235	255	245	465	20.98	0.045	Down
13N/05E-28Q2S	351100116271002	CRTH1 #2	181.27	700	720	710	540	11.75	0.022	Down
13N/05E-28Q1S	351100116271001	CRTH1 #1	193.02	1,240	1,260	1,250				
GOLD2: July 1, 2015, at 3,107 ft above NAVD88										
14N/01E-07R3S	351904116543103	GOLD2 #3	216.63	220	240	230	110	30.01	0.273	Down
14N/01E-07R2S	351904116543102	GOLD2 #2	246.64	330	350	340	90	–0.03	–0.0003	Up
14N/01E-07R1S	351904116543101	GOLD2 #1	246.61	420	440	430				
BLA5: July 2, 2015, at 2,345 ft above NAVD88										
14N/03E-26K3S	351638116374303	BLA5 #3	190.91	190	210	200	60	0.85	0.014	Down
14N/03E-26K4S	351638116374304	BLA5B #1	191.76	250	270	260	70	0.14	0.0020	Down
14N/03E-26K1S	351638116374301	BLA5 #1	191.9	320	340	330				
GOLD1: July 1, 2015, at 3,058 ft above NAVD88										
15N/01E-28R3S	352144116522603	GOLD1 #3	171.23	350	370	360	210	–0.04	–0.0002	Up
15N/01E-28R2S	352144116522602	GOLD1 #2	171.19	560	580	570	90	0.09	0.001	Down
15N/01E-28R1S	352144116522601	GOLD1 #1	171.28	650	670	660				
NELT2: July 1, 2015, at 3,054 ft above NAVD88										
15N/03E-06L3S	352450116421103	NELT2 #3	216.17	280	300	290	230	0.25	0.001	Down
15N/03E-06L2S	352450116421102	NELT2 #2	216.42	510	530	520	260	0.12	0.0005	Down
15N/03E-06L1S	352450116421101	NELT2 #1	216.54	760	800	780				
CCT1: July 1, 2015, at 2,688 ft above NAVD88										
15N/03E-25L3S	352149116370703	CCT1 #3	527.04	645	665	655	85	0.07	0.0008	Down
15N/03E-25L2S	352149116370702	CCT1 #2	527.11	730	750	740	145	0.05	0.0003	Down
15N/03E-25L1S	352149116370701	CCT1 #1	527.16	875	895	885				
NELT7: June 30, 2015, at 3,172 ft above NAVD88										
16N/02E-16P3S	352806116462103	NELT7 #3	279.8	380	400	390	240	13.91	0.058	Down
16N/02E-16P2S	352806116462102	NELT7 #2	293.71	620	640	630	160	0.08	0.0005	Down
16N/02E-16P1S	352806116462101	NELT7 #1	293.79	780	800	790				
NELT1: June 29, 2015, at 3,074 ft above NAVD88										
16N/02E-34Q2S	352535116451002	NELT1 #2	202.89	280	300	290	460	4.45	0.0097	Down
16N/02E-34Q1S	352535116451001	NELT1 #1	207.34	740	760	750				

Table 6. Summary of water-level data and calculated vertical hydraulic gradients from multiple-well monitoring sites, Fort Irwin National Training Center, California, 2015.—Continued

[Elevations were interpolated from a topographic map. Water levels are from the most recent complete set of static water levels for each site. **Abbreviations**: ft bls, feet below land surface; ft, feet; mm/dd/yyyy, month/day/year; NAVD88, North American Vertical Datum of 1988; nd, not determined]

State well number	U.S. Geological Survey site identifier	Common name	Water level (ft bls)	Screen interval (ft bls)		Screen mid-point (ft bls)	Vertical distance between mid-points (ft)	Vertical head difference (ft)	Vertical head gradient	Direction of flow
				Top	Bottom					
SBMW: July 1, 2015, at 3,044 ft above NAVD88										
31S/46E-05B3M	351620117041102	SBMW #2	119.88	130	150	140	140	0.15	0.0011	Down
31S/46E-05B2M	351620117041101	SBMW #1	120.03	270	290	280				

[1]Flow directions were not determined for vertical head differences if water levels were less than the measurement accuracy of 0.02 foot.

Vertical gradients calculated for multiple-well monitoring sites 12N/03E-01M1S (LL04) and 12N/03E-01M4, 5S (LL04B) indicate slight upward gradients between vertically contiguous wells (table 6). This site had the lowest gradients calculated for all monitoring sites, indicating little water movement between wells (fig. 16*B*).

Vertical gradients calculated for multiple-well monitoring site 13N/5E-28Q1–3S (CRTH1) indicate a downward gradient between all vertically contiguous wells (fig. 16*B*; table 6). In June 2015, the vertical difference in water level between the shallowest zone 13N/05E-28Q3S (CRTH1 #3, 175–195 and 235–255 ft) and the two deeper wells 13N/05E-28Q2S (CRTH1 #2) and 13N/05E-28Q1S (CRTH1 #1) was 20.98 ft and 32.73 ft, respectively (fig. 16*B*, upper graph). The large difference in water level between 13N/05E-28Q2S (CRTH1 #2) and 13N/05E-28Q3S (CRTH1 #3) indicates material of low permeability between the vertically contiguous wells. Kjos and others (2014) described the presence of a basalt layer from 222 to 273 ft bls in borehole CRTH1, which could act as a barrier to vertical flow. Water levels for 13N/05E-28Q3S (CRTH1 #3, 175–195 and 235–255 ft) likely reflect perched conditions with an unsaturated zone between wells 13N/05E-281–2S (CRTH1 #1 and CRTH1 #2).

In June 2015, the vertical difference in water level between 13N/05E-08B2S (CRTH2 #2, 270–290 ft) and 13N/05-08B2S (CRTH2 #1, 920–940 ft) was 2.08 ft (fig. 16*B*; table 6). Kjos and others (2014) described the lithology around the deeper well (13N/05-08B2S, CRTH2 #1) as basalt. The basalt layer is overlain by a more than 600-ft thick section of clay, and the shallow well (13N/3E-08B2 #2, CRTH2 #2) is perforated in the uppermost part of this thick clay unit. The vertical gradient between the two contiguous wells is upward (June 2015, –0.0032) and indicates confinement between the lower basalt unit and the shallow well in the uppermost part of the clay unit.

Multiple-well monitoring sites 15N/01E-28R1–3S (GOLD1) and 14N/01E-07R1–3S (GOLD2) display opposing gradients between vertically contiguous wells (fig. 16*C*; table 6). Vertical gradients calculated for GOLD1 indicate divergent flow from the middle interval (15N/01E-28R2S, or GOLD1 #2, 560–580 ft), upward to the shallowest interval (15N/01E-28R3S, or GOLD1 #3, 350–370 ft), and downward to the deepest interval (15N/01E-28R1S, or GOLD1 #1, 650–670 ft; fig. 16*C*). Lithology adjacent to monitoring well 15N/01E-28R2S (GOLD1 #2) is described by Kjos and others (2014) as gravelly sand (Tv) bounded by volcanic units above and below: dacite (Tv_vb) above and vesicular basalt (QTba) below. Wells 15N/01E-28R3S (GOLD1 #3) and 15N/01E-28R1S (GOLD1 #1) are screened adjacent to these respective units. Vertical gradients between adjacent wells in GOLD1 indicate minor downward flow from the gravelly sand to the lower basalt and upward flow to the dacite above, indicating some level of confinement in the gravelly sand between.

Multiple-well monitoring site 14N/01E-07R1–3S (GOLD2) also displayed opposing gradients between vertically contiguous wells (fig. 16*C*; table 6); however, in this case, calculated vertical gradients converged to the middle screened interval (14N/01E-07R2S, or GOLD2 #2, 330–350 ft), displaying an upward gradient from the deepest interval (14N/01E-07R1S, or GOLD2 #1, 420–440 ft) and downward from the shallowest (14N/01E-07R3S, or GOLD2 #3, 220–240 ft; fig. 16*C*). Kjos and others (2014) described the shallowest interval (14N/01E-07R3S, or GOLD2 #3) as a zone of potentially perched water; therefore, water levels and calculated vertical gradient related to 14N/01E-07R3S (GOLD2 #3) might not be representative of the overall aquifer conditions. Variations in hydraulic head between 14N/01E-07R1S (GOLD2 #1) and 14N/01E-07R2S (GOLD2 #2) were historically very low (table 6, –0.03 ft difference in July 2015), indicating these wells may be perforated in the same or hydraulically connected fracture system in the weathered bedrock (described by Kjos and others, 2014).

Vertical gradients calculated for multiple-well monitoring sites 31S/46E-05B2–3M (SBMW, fig. 16*C*) and 16N/02E-34Q1–2S (NELT1, fig. 16*D*) indicate downward gradients between vertically contiguous wells (table 6). Kjos and others (2014) described Quaternary sand and gravel around the shallowest well 31S/46E-05B3M (SBMW #2) overlying a thin basalt flow and Miocene sandy gravelly volcanic strata around well 31S/46E-05B2M (SBMW #1). A larger gradient (0.0097) was calculated between the two wells at NELT1. Kjos and others (2014) described fine-grained deposits surrounding wells 16N/02E-34Q1–2S (NELT1 #1 and #2).

Vertical gradients calculated for multiple-well monitoring site 15N/03E-06L1–3S (NELT2) indicate a downward gradient between vertically contiguous wells during July 2015 (fig. 16*D*; table 6). The vertical gradient between 15N/03E-06L1S (NELT2 #1) and 15N/03E-06L2S (NELT2 #2) changed from negative (upward flow) to positive (downward flow) between February 2012 and September 2014 (fig. 16*D*). The change took place after a period of variable water levels measured during late 2011 and early 2012. Lithologic details presented by Kjos and others (2014) indicate the well is screened adjacent to ‘silty sand; tephra (volcanic ash)’ and had a low pumping rate (less than 1 gpm). Because of the pumping rate and high turbidity observed during pumping, additional development was completed at 15N/03E-06L2S (NELT2 #2), in late 2012. Changes in water-level data after additional well development indicate a shift in gradient. Data collected prior to and after redevelopment indicated the additional well development might have improved well performance and the hydraulic connection between the well and the formation, consequently changing the apparent vertical gradient measured between these wells. Since 2012, the vertical gradient between this nested pair at the NELT2 site has maintained a downward vertical gradient of 0.0005 (fig. 16*D*; table 6).

Vertical gradients calculated for multiple-well monitoring site NELT7 indicate a downward gradient between the shallow and middle wells (fig. 16*D*; table 6). The vertical difference in water level between the shallowest zone 16N/02E-16P3S (NELT7 #3, 380–400 ft) and the two deeper wells 16N/02E-16P2S (NELT7 #2, 620–640 ft) and 16N/02E-16P1S (NELT7 #1, 780–800 ft) was 13.91 and 13.99 ft, respectively. The large difference in water level between 16N/02E-16P2S (NELT7 #2) and 16N/02E-16P3S (NELT7 #3) indicates material with low permeability between the vertically contiguous wells. Kjos and others (2014) described the presence of a sandy clay from 460 to 560 ft bls in borehole NELT7, which could restrict vertical flow.

Water-Quality Data

Composite (also known as bulk discharge, BD) water-quality samples were collected from the surface discharge of pumps in selected single- and multiple-well monitoring sites and test wells (table 7). Additional samples were collected at different depths (depth-dependent) in test wells under pumping conditions. A summary of the most recent (2014–15) water-quality data for each single- and multiple-well monitoring site and test well (including depth-dependent samples) is presented in table 7. The benchmark levels for summarized constituents are also presented, in column heads of table 7 (where available), and are based on drinking-water threshold criteria established by the U.S. Environmental Protection Agency and the California Department of Public Health, as presented by Mathany and others (2012). The higher, secondary maximum contaminant level (SMCL) was used for specific conductance, chloride, sulfate, and total dissolved solids. Results that exceeded benchmark levels are listed in boldface in table 7. There were no water-quality data for failed and abandoned wells 12N/03E-01M2S (LL04 #2), 12N/03E-01M3S (LL04 #3), and 14N/03E-26K2S (BLA5 #2). Water-quality data presented in table 7 are intended to augment that of Kjos and others (2014). The general water quality, source, and age of groundwater are discussed by basin in the sections that follow.

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

Common name	State well number	Well depth (ft bls)	Date and time (mm/dd/yyyy hh:mm)	Time datum	Sampling depth (ft bls) (00003)	Field parameters				
						Dissolved oxygen (mg/L) (00300) [na]	pH, unfiltered, field (standard units) (00400) [<6.5 or >8.5 SMCL-US]	Specific conductance, unfiltered (µS/cm at 25 °C) (00095) [1,600 SMCL-CA]	Alkalinity, filtered, inflection point method, field (mg/L as $CaCO_3$) (39086) [na]	Bicarbonate, filtered, inflection point, field (mg/L) (00453) [na]
LL04 #1	12N/03E-01M1S	970	12/04/14 18:20	PST	BD	0.8	**8.8**	**2,270**	26	29
LL04B #1	12N/03E-01M4S	490	11/07/14 12:30	PST	BD	0.2	**8.9**	**2,570**	20	22
LL04B #2	12N/03E-01M5S	350	11/07/14 09:50	PST	BD	2.6	**8.6**	1,570	103	119
CRTH2 #1	13N/05E-08B1S	940	12/10/14 11:50	PST	BD	0.1	8.1	1,230	113	136
CRTH2 #2	13N/05E-08B2S	290	09/06/14 16:40	PDT	BD	E 8.7	8.1	**E 15,000**	48	56
CRTH1 #1	13N/05E-28Q1S	1,260	09/07/14 16:10	PDT	BD	0.2	**8.6**	**2,990**	38	43
CRTH1 #2	13N/05E-28Q2S	720	02/22/15 15:00	PST	BD	—	**9.0**	**5,860**	20	19
CRTH1 #3	13N/05E-28Q3S	255	09/06/14 10:30	PDT	BD	6.9	8.2	**2,140**	105	124
GOLD2 #1	14N/01E-07R1S	440	10/08/14 15:00	PDT	BD	1.4	7.9	874	62	75
GOLD2 #2	14N/01E-07R2S	350	10/08/14 12:30	PDT	BD	0.1	7.5	E 1,310	295	358
GOLD2 #3	14N/01E-07R3S	240	10/08/14 16:30	PDT	BD	8.6	7.7	1,220	94	113
BLA5 #1	14N/03E-26K1S	360	11/05/14 12:30	PST	BD	4.4	**8.7**	818	159	183
BLA5B #1	14N/03E-26K4S	270	11/05/14 15:00	PST	BD	4.2	8.3	780	146	174
GOLD1 #1	15N/01E-28R1S	670	10/07/14 15:40	PDT	BD	6.3	7.7	**3,450**	81	98
GOLD1 #2	15N/01E-28R2S	580	10/10/14 11:30	PDT	BD	1.4	7.8	**3,220**	185	223
GOLD1 #3	15N/01E-28R3S	370	10/07/14 11:00	PDT	BD	6.2	7.5	**3,560**	79	96
GOLD1-T #1	15N/01E-28R4S	680	01/15/15 14:40	PST	BD	6.0	7.5	**3,590**	81	98
NELT6 #1	15N/02E-05N1S	840	02/19/15 14:00	PST	BD	2.2	7.8	824	181	219
NELT2 #1	15N/03E-06L1S	800	09/11/14 15:00	PDT	BD	5.5	7.9	803	154	186
NELT2 #3	15N/03E-06L3S	300	09/09/14 10:00	PDT	BD	3.4	8.1	799	193	231
NELT4 #1	15N/03E-08L1S	580	01/13/15 14:20	PST	BD	6.3	8.1	769	142	171
CCT1 #1	15N/03E-25L1S	895	09/10/14 20:20	PDT	BD	0.8	7.9	855	232	280
CCT1 #2	15N/03E-25L2S	750	09/12/14 15:20	PDT	BD	2.0	7.8	896	247	298
CCT1 #3	15N/03E-25L3S	665	09/10/14 11:40	PDT	BD	2.8	7.9	918	251	302
NELT5 #1	16N/01E-35P1S	840	01/14/15 14:40	PST	BD	3.7	7.7	749	168	203
NELT7 #1	16N/02E-16P1S	800	09/08/14 15:20	PDT	BD	0.9	**8.8**	699	137	154

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.—Continued

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

						Field parameters				
Common name	State well number	Well depth (ft bls)	Date and time (mm/dd/yyyy hh:mm)	Time datum	Sampling depth (ft bls) (00003)	Dissolved oxygen (mg/L) (00300) [na]	pH, unfiltered, field (standard units) (00400) [<6.5 or >8.5 SMCL-US]	Specific conductance, unfiltered (µS/cm at 25 °C) (00095) [1,600 SMCL-CA]	Alkalinity, filtered, inflection point method, field (mg/L as $CaCO_3$) (39086) [na]	Bicarbonate, filtered, inflection point, field (mg/L) (00453) [na]
NELT7 #2	16N/02E-16P2S	640	09/05/14 14:30	PDT	BD	0.1	**9.2**	488	136	132
NELT7 #3	16N/02E-16P3S	400	09/05/14 10:50	PDT	BD	3.6	**8.6**	521	166	192
NELT3 #1	16N/02E-31H1S	740	02/14/15 10:50	PST	BD	4.3	7.8	825	131	158
NELT3 #1	16N/02E-31H1S	740	02/14/15 11:50	PST	308	4.7	7.8	832	133	161
NELT3 #1	16N/02E-31H1S	740	02/14/15 14:30	PST	468	4.1	7.8	837	135	164
NELT3 #1	16N/02E-31H1S	740	02/14/15 17:00	PST	588	4.0	7.8	839	134	162
NELT3 #1	16N/02E-31H1S	740	02/14/15 19:10	PST	423	4.4	7.7	805	133	161
NELT3 #1	16N/02E-31H1S	740	02/14/15 21:00	PST	378	4.3	7.7	829	134	162
NELT1 #1	16N/02E-34Q1S	760	09/04/14 16:00	PDT	BD	3.0	7.9	948	176	212
NELT1 #2	16N/02E-34Q2S	300	09/04/14 10:50	PDT	BD	5.6	8.1	—	162	194
SBTW #1	31S/46E-05B1M	400	02/24/15 11:10	PST	BD	5.7	7.7	372	92	112
SBTW #1	31S/46E-05B1M	400	02/24/15 12:00	PST	151	5.6	7.7	373	92	111
SBTW #1	31S/46E-05B1M	400	02/24/15 13:40	PST	251	5.9	7.7	374	90	109
SBTW #1	31S/46E-05B1M	400	02/24/15 15:10	PST	211	5.4	7.7	372	90	110
SBTW #1	31S/46E-05B1M	400	02/24/15 16:10	PST	311	5.4	7.7	373	92	112
SBMW #1	31S/46E-05B2M	290	10/09/14 10:50	PDT	BD	1.9	8.0	389	117	140
SBMW #2	31S/46E-05B3M	150	10/09/14 12:20	PDT	BD	3.5	8.0	404	115	138
SBMC #1	31S/46E-05D1M	200	10/09/14 14:30	PDT	BD	3.9	8.1	422	117	140

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.—Continued

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

		Total dissolved solids and major ions									
Common name	State well number	Dissolved solids, residue on evaporation at 180 °C, filtered (mg/L) (70300) [1,000 SMCL-CA]	Calcium, filtered (mg/L) (00915) [na]	Magnesium, filtered (mg/L) (00925) [na]	Potassium, filtered (mg/L) (00935) [na]	Sodium, filtered (mg/L) (00930) [na]	Bromide, filtered (mg/L) (71870) [na]	Chloride, filtered (mg/L) (00940) [500 SMCL-CA]	Fluoride, filtered (mg/L) (00950) [2 MCL-CA]	Silica, filtered (mg/L) (00955) [na]	Sulfate, filtered (mg/L) (00945) [500 SMCL-CA]
LL04 #1	12N/03E-01M1S	**1,340**	30.6	0.507	2.56	423	1.76	443	**3.66**	14.5	402
LL04B #1	12N/03E-01M4S	**1,570**	55.1	1.12	3.84	490	1.41	407	0.87	10.3	**537**
LL04B #2	12N/03E-01M5S	964	14.8	1.59	2.88	314	0.781	219	**2.04**	13.7	273
CRTH2 #1	13N/05E-08B1S	829	26.5	9.6	7.38	218	0.311	128	1.88	48.5	281
CRTH2 #2	13N/05E-08B2S	**13,400**	463	43.5	43.7	4,050	<3.00	**1,030**	**2.07**	24.3	**7,070**
CRTH1 #1	13N/05E-28Q1S	**1,910**	41.9	0.378	5.62	639	1.05	398	**11.9**	32.3	**754**
CRTH1 #2	13N/05E-28Q2S	**5,000**	420	1.41	4.69	1,070	0.689	246	0.45	20.2	**2,880**
CRTH1 #3	13N/05E-28Q3S	**1,290**	13.6	4.42	6.3	454	1.01	357	**3.89**	40.1	356
GOLD2 #1	14N/01E-07R1S	591	63	6.4	5.99	113	0.343	76	0.98	25.7	252
GOLD2 #2	14N/01E-07R2S	947	51.4	6.09	7.28	254	0.413	96	0.89	31.7	192
GOLD2 #3	14N/01E-07R3S	882	89.4	9.32	15.8	163	0.516	142	0.67	70.4	309
BLA5 #1	14N/03E-26K1S	561	6.64	1.66	6.23	165	0.304	68	**3.16**	62.6	117
BLA5B #1	14N/03E-26K4S	536	18.5	4.44	10.2	139	0.298	65	**3.32**	71.2	115
GOLD1 #1	15N/01E-28R1S	**2,170**	196	84.5	36.9	392	1.62	**860**	0.38	71.9	422
GOLD1 #2	15N/01E-28R2S	**2,070**	145	58.7	30.4	452	1.37	**685**	0.63	65.5	428
GOLD1 #3	15N/01E-28R3S	**2,210**	204	79.0	36.8	412	1.67	**830**	0.40	74.8	404
GOLD1-T #1	15N/01E-28R4S	**2,330**	198	73.7	35.5	402	1.64	**890**	0.42	74.7	445
NELT6 #1	15N/02E-05N1S	546	30.9	7.79	18.8	128	0.371	109	0.48	74.4	57
NELT2 #1	15N/03E-06L1S	528	19.0	3.61	15.5	145	0.361	78	**3.53**	68.4	97
NELT2 #3	15N/03E-06L3S	571	14.4	2.73	9.22	168	0.296	50	**3.13**	79.6	113
NELT4 #1	15N/03E-08L1S	521	17.8	3.88	15.6	126	0.351	79	**3.22**	66.0	96
CCT1 #1	15N/03E-25L1S	582	15.0	3.95	14.3	174	0.264	57	**4.49**	73.5	99
CCT1 #2	15N/03E-25L2S	613	15.6	5.02	16.1	172	0.264	57	**4.4**	80.2	99
CCT1 #3	15N/03E-25L3S	628	14.8	3.92	14.0	178	0.285	56	**6.83**	76.7	101
NELT5 #1	16N/01E-35P1S	532	26.8	4.05	18.4	113	0.33	59	0.84	84.7	103
NELT7 #1	16N/02E-16P1S	431	3.21	0.228	2.39	146	0.298	53	**13.9**	35.4	77

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.—Continued

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

Common name	State well number	Total dissolved solids and major ions									
		Dissolved solids, residue on evaporation at 180 °C, filtered (mg/L) (70300) [1,000 SMCL-CA]	Calcium, filtered (mg/L) (00915) [na]	Magnesium, filtered (mg/L) (00925) [na]	Potassium, filtered (mg/L) (00935) [na]	Sodium, filtered (mg/L) (00930) [na]	Bromide, filtered (mg/L) (71870) [na]	Chloride, filtered (mg/L) (00940) [500 SMCL-CA]	Fluoride, filtered (mg/L) (00950) [2 MCL-CA]	Silica, filtered (mg/L) (00955) [na]	Sulfate, filtered (mg/L) (00945) [500 SMCL-CA]
NELT7 #2	16N/02E-16P2S	313	2.55	0.194	2.04	106	0.163	24	**10.8**	34.0	36
NELT7 #3	16N/02E-16P3S	387	5.07	0.531	5.5	108	0.137	19	**8.0**	73.5	39
NELT3 #1	16N/02E-31H1S	582	32.1	5.08	12.2	126	0.442	73	0.82	74.9	80
NELT3 #1	16N/02E-31H1S	586	31.7	5.33	12.3	129	0.449	74	0.79	74.0	80
NELT3 #1	16N/02E-31H1S	597	32.1	5.22	12.2	131	0.454	75	0.84	73.6	81
NELT3 #1	16N/02E-31H1S	598	33.2	5.04	11.8	129	0.458	75	0.83	74.5	81
NELT3 #1	16N/02E-31H1S	567	30.6	5.51	11.8	119	0.432	70	0.77	75.8	77
NELT3 #1	16N/02E-31H1S	583	31.8	5.28	11.7	124	0.454	73	0.74	74.5	79
NELT1 #1	16N/02E-34Q1S	665	16.1	2.57	9.4	179	0.208	32	**4.32**	72.9	213
NELT1 #2	16N/02E-34Q2S	422	4.31	0.708	7.8	138	0.195	32	**4.48**	68.4	64
SBTW #1	31S/46E-05B1M	285	20.0	4.26	8.92	44	0.114	23	0.54	74.2	39
SBTW #1	31S/46E-05B1M	286	20.2	4.23	8.58	44	0.117	23	0.55	72.0	39
SBTW #1	31S/46E-05B1M	285	19.9	4.24	9.00	45	0.116	23	0.54	71.5	39
SBTW #1	31S/46E-05B1M	284	19.6	4.08	9.12	48	0.116	23	0.53	70.2	39
SBTW #1	31S/46E-05B1M	293	19.6	4.06	8.51	45	0.115	23	0.54	69.6	39
SBMW #1	31S/46E-05B2M	287	22.4	3.33	8.72	57	0.113	19	0.52	60.3	37
SBMW #2	31S/46E-05B3M	321	19.6	4.89	8.56	60	0.116	21	0.57	72.2	45
SBMC #1	31S/46E-05D1M	320	19.6	5.15	8.34	64	0.12	19	0.40	71.7	51

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.—Continued

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

Common name	State well number	Trace elements									
		Aluminum, filtered (µg/L) (01106) [1,000 MCL-CA]	Barium, filtered (µg/L) (01005) [1,000 MCL-CA]	Chromium, filtered (µg/L) (01030) [10 MCL-CA]	Iron, filtered (µg/L) (01046) [300 SMCL-CA]	Lithium, filtered (µg/L) (01130) [na]	Manganese, filtered (µg/L) (01056) [50 SMCL-CA]	Strontium, filtered (µg/L) (01080) [4,000 HAL-US]	Arsenic, filtered (µg/L) (01000) [10 MCL-US]	Boron, filtered (µg/L) (01020) [1,000 NL-CA]	Iodide, filtered (mg/L) (71865) [na]
LL04 #1	12N/03E-01M1S	12.1	19.2	<0.30	<8.0	37.5	39.3	833	2.4	202	0.153
LL04B #1	12N/03E-01M4S	12.3	17.6	<0.60	<8.0	48.9	10.8	1,950	5.5	**1,030**	0.295
LL04B #2	12N/03E-01M5S	20.3	8.2	7.5	<4.0	37.4	<0.20	490	**13.6**	**2,680**	0.019
CRTH2 #1	13N/05E-08B1S	7.9	11.7	0.66	<24.0	83.5	7.67	1,120	**33.9**	**1,580**	0.152
CRTH2 #2	13N/05E-08B2S	<22.0	13.8	<3.0	<32.0	2,280	**238**	**8,750**	**60.7**	**7,790**	0.845
CRTH1 #1	13N/05E-28Q1S	13.4	17.6	<1.5	<8.0	593	4.94	1,440	**178**	**4,840**	0.279
CRTH1 #2	13N/05E-28Q2S	9.8	14.4	<0.90	37.7	1,320	5.46	2,670	4.8	**5,680**	0.333
CRTH1 #3	13N/05E-28Q3S	16.0	8.3	**17**	<8.0	58.6	<0.40	829	**13.5**	**2,000**	0.013
GOLD2 #1	14N/01E-07R1S	4.4	12.6	<0.30	24.8	10.3	**86.6**	750	1.2	618	0.085
GOLD2 #2	14N/01E-07R2S	17.1	83.5	<0.30	174	16.6	**526**	702	1.7	517	0.307
GOLD2 #3	14N/01E-07R3S	5.3	10.9	0.48	<4.0	15.7	0.91	1,130	**15.4**	992	0.031
BLA5 #1	14N/03E-26K1S	6.5	3.4	8.4	<4.0	15.2	<0.20	108	**26.3**	**1,030**	0.007
BLA5B #1	14N/03E-26K4S	5.6	25.4	9.7	<4.0	26.1	<0.20	327	**12.8**	1,000	0.006
GOLD1 #1	15N/01E-28R1S	<6.0	23.5	1.8	<8.0	74.4	<0.40	1,960	5.1	**1,090**	0.005
GOLD1 #2	15N/01E-28R2S	<6.0	31.6	<0.60	<8.0	71.0	**70.3**	1,420	6.8	1,000	0.077
GOLD1 #3	15N/01E-28R3S	<9.0	27.7	1.7	<8.0	74.5	<0.40	1,870	6.0	**1,160**	<0.005
GOLD1-T #1	15N/01E-28R4S	7.4	23.7	1.4	96.3	73.6	0.95	1,870	5.4	**1,120**	0.007
NELT6 #1	15N/02E-05N1S	10.3	61.1	2.4	121	41.5	10.5	358	**15.0**	846	0.028
NELT2 #1	15N/03E-06L1S	6.1	35.1	7.9	<4.0	44.2	<0.20	370	**36.9**	**1,240**	0.009
NELT2 #3	15N/03E-06L3S	31.6	19.0	6.0	12.1	62.8	1.34	264	**20.2**	**1,310**	0.027
NELT4 #1	15N/03E-08L1S	8.3	34.9	7.5	52.1	47.0	1.35	344	**35.3**	**1,130**	0.007
CCT1 #1	15N/03E-25L1S	14.1	40.2	1.7	<4.0	47.0	**50.1**	241	**31.9**	**1,310**	0.044
CCT1 #2	15N/03E-25L2S	9.1	33.4	1.9	11.8	52.5	41.2	246	**30.6**	**1,370**	0.066
CCT1 #3	15N/03E-25L3S	7.8	28.1	2.6	<4.0	48.8	13.0	238	**64.0**	**1,330**	0.045
NELT5 #1	16N/01E-35P1S	9.4	34.4	3.6	152	41.1	12.2	391	**36.4**	**1,130**	0.045
NELT7 #1	16N/02E-16P1S	114	2.6	<0.30	6.5	190	2.48	32	**135**	1,060	0.063
NELT7 #2	16N/02E-16P2S	180	2.8	0.67	23.5	99.2	2.52	27	**146**	**1,240**	0.049

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.—Continued

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

Common name	State well number	Trace elements									
		Aluminum, filtered (µg/L) (01106) [1,000 MCL-CA]	Barium, filtered (µg/L) (01005) [1,000 MCL-CA]	Chromium, filtered (µg/L) (01030) [10 MCL-CA]	Iron, filtered (µg/L) (01046) [300 SMCL-CA]	Lithium, filtered (µg/L) (01130) [na]	Manganese, filtered (µg/L) (01056) [50 SMCL-CA]	Strontium, filtered (µg/L) (01080) [4,000 HAL-US]	Arsenic, filtered (µg/L) (01000) [10 MCL-US]	Boron, filtered (µg/L) (01020) [1,000 NL-CA]	Iodide, filtered (mg/L) (71865) [na]
NELT7 #3	16N/02E-16P3S	315	5.7	6.3	133	57.6	2.19	106	**41.0**	674	0.016
NELT3 #1	16N/02E-31H1S	6.5	46.0	6.1	42	59.3	1.48	434	**32.2**	969	0.004
NELT3 #1	16N/02E-31H1S	6.9	46.1	5.9	5.1	53.5	0.34	455	**31.5**	959	0.004
NELT3 #1	16N/02E-31H1S	8.2	47.2	5.9	4.2	53.7	0.41	461	**33.5**	988	0.006
NELT3 #1	16N/02E-31H1S	8.2	44.4	6.0	4.7	57.6	0.40	449	**33.0**	**1,070**	0.007
NELT3 #1	16N/02E-31H1S	6.8	49.3	6.0	<4.0	49.2	<0.20	402	**31.0**	925	0.004
NELT3 #1	16N/02E-31H1S	7.3	48.6	5.7	<4.0	57.0	0.32	413	**29.9**	944	0.004
NELT1 #1	16N/02E-34Q1S	5.2	19.3	4.6	<4.0	33.0	0.35	186	**46.9**	**1,660**	0.007
NELT1 #2	16N/02E-34Q2S	11.8	11.2	8.4	<4.0	33.4	0.23	51	**43.8**	**1,070**	0.005
SBTW #1	31S/46E-05B1M	12.0	59.7	2.0	6.0	17.8	0.45	205	**13.3**	354	0.002
SBTW #1	31S/46E-05B1M	21.0	59.1	2.0	5.9	17.0	0.47	211	**12.8**	354	0.002
SBTW #1	31S/46E-05B1M	11.7	58.3	2.0	<4.0	17.7	0.29	203	**12.9**	350	0.002
SBTW #1	31S/46E-05B1M	11.8	58.4	2.1	<4.0	18.3	0.22	203	**13.2**	354	0.002
SBTW #1	31S/46E-05B1M	9.7	57.6	2.1	<4.0	16.8	0.22	201	**12.8**	352	0.002
SBMW #1	31S/46E-05B2M	4.1	36.7	1.5	<4.0	17.9	1.85	236	**14.2**	377	0.013
SBMW #2	31S/46E-05B3M	6.1	27.5	1.2	<4.0	17.8	5.45	204	**15.5**	406	0.009
SBMC #1	31S/46E-05D1M	9.0	17.1	1.6	<4.0	16.2	2.76	202	**20.8**	357	0.008

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.—Continued

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

Common name	State well number	Stable isotopes			Radioisotopes		
		delta Deuterium, unfiltered (per mil) (82082) [na]	delta Oxygen-18, unfiltered (per mil) (82085) [na]	delta Carbon-13, unfiltered (per mil) (82081) [na]	Carbon-14, filtered (percent modern) (49933) [na]	Tritium, unfiltered (pCi/L) (07000) [20,000 MCL-CA]	Uranium, filtered (µg/L) (22703) [30 MCL-US]
LL04 #1	12N/03E-01M1S	–89.0	–10.44	—	—	—	0.111
LL04B #1	12N/03E-01M4S	–91.6	–10.42	—	—	—	0.161
LL04B #2	12N/03E-01M5S	–96.2	–11.43	—	—	—	3.74
CRTH2 #1	13N/05E-08B1S	–90.0	–11.22	—	—	—	18.5
CRTH2 #2	13N/05E-08B2S	–95.5	–11.88	–6.28	7.87	R 0.0	8.75
CRTH1 #1	13N/05E-28Q1S	–89.9	–10.50	—	—	—	0.157
CRTH1 #2	13N/05E-28Q2S	–87.6	–10.06	—	—	—	<0.042
CRTH1 #3	13N/05E-28Q3S	–95.4	–11.35	—	—	—	4.85
GOLD2 #1	14N/01E-07R1S	–99.1	–12.62	—	—	R 0.1	0.075
GOLD2 #2	14N/01E-07R2S	–99.2	–12.43	—	—	R 0.1	1.38
GOLD2 #3	14N/01E-07R3S	–99.6	–12.44	–6.28	23.49	R –0.3	2.64
BLA5 #1	14N/03E-26K1S	–94.6	–12.02	—	—	—	8.39
BLA5B #1	14N/03E-26K4S	–95.8	–11.94	—	—	—	11.9
GOLD1 #1	15N/01E-28R1S	–95.8	–11.84	—	—	—	1.98
GOLD1 #2	15N/01E-28R2S	–95.5	–11.79	—	—	—	12.7
GOLD1 #3	15N/01E-28R3S	–96.2	–11.86	—	—	R 0.1	1.47
GOLD1-T #1	15N/01E-28R4S	–96.8	–11.81	—	—	R 0.0	1.43
NELT6 #1	15N/02E-05N1S	–103.0	–13.23	—	—	—	3.01
NELT2 #1	15N/03E-06L1S	–100.0	–12.80	—	—	R 0.1	6.08
NELT2 #3	15N/03E-06L3S	–101.0	–13.13	—	—	R –0.1	10.2
NELT4 #1	15N/03E-08L1S	–101.0	–12.72	–7.56	18.72	R –0.1	4.62
CCT1 #1	15N/03E-25L1S	–98.5	–12.38	—	—	R –0.1	8.5
CCT1 #2	15N/03E-25L2S	–96.0	–12.22	—	—	R –0.1	10.8
CCT1 #3	15N/03E-25L3S	–97.0	–12.28	–6.61	18.38	R 0.0	7.56
NELT5 #1	16N/01E-35P1S	–102.0	–12.74	—	—	—	3.05
NELT7 #1	16N/02E-16P1S	–102.0	–13.18	—	—	—	2.07
NELT7 #2	16N/02E-16P2S	–102.0	–13.39	—	—	—	2.8

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

Common name	State well number	Stable isotopes			Radioisotopes		
		delta Deuterium, unfiltered (per mil) (82082) [na]	delta Oxygen-18, unfiltered (per mil) (82085) [na]	delta Carbon-13, unfiltered (per mil) (82081) [na]	Carbon-14, filtered (percent modern) (49933) [na]	Tritium, unfiltered (pCi/L) (07000) [20,000 MCL-CA]	Uranium, filtered (µg/L) (22703) [30 MCL-US]
NELT7 #3	16N/02E-16P3S	–105.0	–13.68	—	—	—	4.76
NELT3 #1	16N/02E-31H1S	–100.0	–12.76	—	—	—	1.67
NELT3 #1	16N/02E-31H1S	–102.0	–12.90	—	—	—	1.64
NELT3 #1	16N/02E-31H1S	–101.0	–12.78	—	—	—	1.61
NELT3 #1	16N/02E-31H1S	–102.0	–12.86	—	—	—	1.65
NELT3 #1	16N/02E-31H1S	–101.0	–12.83	—	—	—	1.5
NELT3 #1	16N/02E-31H1S	–102.0	–12.88	—	—	—	1.58
NELT1 #1	16N/02E-34Q1S	–104.0	–13.06	—	—	—	1.5
NELT1 #2	16N/02E-34Q2S	–103.0	–13.09	—	—	—	0.831
SBTW #1	31S/46E-05B1M	–98.7	–12.62	—	—	R 0.0	0.33
SBTW #1	31S/46E-05B1M	–98.4	–12.58	—	—	R 0.0	0.35
SBTW #1	31S/46E-05B1M	–98.1	–12.58	—	—	R 0.1	0.337
SBTW #1	31S/46E-05B1M	–99.0	–12.59	—	—	R 0.1	0.356
SBTW #1	31S/46E-05B1M	–98.0	–12.57	—	—	R 0.0	0.35
SBMW #1	31S/46E-05B2M	–98.9	–12.64	—	—	—	1.16
SBMW #2	31S/46E-05B3M	–97.0	–12.44	—	—	—	0.717
SBMC #1	31S/46E-05D1M	–98.6	–12.72	—	—	—	0.515

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.—Continued

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

Common name	State well number	Nutrients			U.S. Geological Survey National Water Information System water-quality link
		Ammonia, filtered (mg/L as N) (00608) [30 HAL-US]	Nitrate plus nitrite, filtered (mg/L as N) (00631) [10 MCL-US]	Nitrite, filtered (mg/L as N) (00613) [1 MCL-US]	
LL04 #1	12N/03E-01M1S	0.04	0.053	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=350929116372301
LL04B #1	12N/03E-01M4S	0.06	**13.6**	0.089	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=350929116372201
LL04B #2	12N/03E-01M5S	<0.01	8.91	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=350929116372202
CRTH2 #1	13N/05E-08B1S	—	—	—	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351416116281501
CRTH2 #2	13N/05E-08B2S	0.27	<0.040	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351416116281502
CRTH1 #1	13N/05E-28Q1S	0.10	<0.040	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351100116271001
CRTH1 #2	13N/05E-28Q2S	0.17	<0.040	0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351100116271002
CRTH1 #3	13N/05E-28Q3S	<0.01	4.96	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351100116271003
GOLD2 #1	14N/01E-07R1S	0.03	<0.040	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351904116543101
GOLD2 #2	14N/01E-07R2S	0.06	<0.040	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351904116543102
GOLD2 #3	14N/01E-07R3S	0.01	2.43	0.006	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351904116543103
BLA5 #1	14N/03E-26K1S	<0.01	4.68	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351638116374301
BLA5B #1	14N/03E-26K4S	<0.01	4.77	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352144116522601
GOLD1 #1	15N/01E-28R1S	0.01	5.06	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352144116522601
GOLD1 #2	15N/01E-28R2S	0.01	2.19	0.011	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352144116522602
GOLD1 #3	15N/01E-28R3S	<0.01	4.94	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352144116522603
GOLD1-T #1	15N/01E-28R4S	<0.01	5.29	0.002	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352145116522401
NELT6 #1	15N/02E-05N1S	<0.01	1.94	0.003	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352436116474001
NELT2 #1	15N/03E-06L1S	<0.01	2.75	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352450116421101
NELT2 #3	15N/03E-06L3S	0.01	4.24	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352450116421103
NELT4 #1	15N/03E-08L1S	0.02	2.91	0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352354116411201
CCT1 #1	15N/03E-25L1S	0.05	0.455	0.003	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352149116370701
CCT1 #2	15N/03E-25L2S	0.04	0.981	0.007	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352149116370702
CCT1 #3	15N/03E-25L3S	0.01	1.28	0.005	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352149116370703
NELT5 #1	16N/01E-35P1S	<0.01	3.05	0.015	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352530116503601
NELT7 #1	16N/02E-16P1S	0.07	1.68	0.072	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352806116462101
NELT7 #2	16N/02E-16P2S	0.06	1.79	0.344	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352806116462102

Table 7. Summary of water-quality data from monitoring and test wells at the Fort Irwin National Training Center, San Bernardino County, California, 2014–15.—Continued

[Wells are listed in order by state well number. The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. The information below the parameter code in brackets is the drinking water benchmark level and type. Values in the table that exceed the benchmark level are in bold. Maximum contaminant level (MCL) benchmarks are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA MCL; MCL-CA, California Department of Public Health (CDPH) MCL; SMCL-US, USEPA secondary MCL; SMCL-CA, CDPH secondary MCL; NL-CA, CDPH notification level; na, not available. The upper secondary MCL was used for specific-conductance, chloride, sulfate and total dissolved solids. Abbreviations: b, value extrapolated at low end; CaCO3, calcium carbonate; °C, degrees Celsius; d, sample was diluted before analysis; E, estimated or having a higher degree of uncertainty; ft bls, feet below land surface datum; BD, bulk discharge collected at land surface; mg/L, milligrams per liter; uS/cm, micro Siemens per centimeter; mm/dd/yyyy hh:mm, month/day/year hours:minutes; n, result was below the laboratory reporting level but above the long-term method detection limit; per mil,per thousand; PDT, Pacific Daylight Time; PST, Pacific Standard Time; R, reported; —, not analyzed; <, less than; >, greater than]

Common name	State well number	Nutrients			U.S. Geological Survey National Water Information System water-quality link
		Ammonia, filtered (mg/L as N) (00608) [30 HAL-US]	Nitrate plus nitrite, filtered (mg/L as N) (00631) [10 MCL-US]	Nitrite, filtered (mg/L as N) (00613) [1 MCL-US]	
NELT7 #3	16N/02E-16P3S	<0.01	2.91	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352806116462103
NELT3 #1	16N/02E-31H1S	<0.01	**19.7**	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352556116475501
NELT3 #1	16N/02E-31H1S	<0.01	**21.2**	0.002	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352556116475501
NELT3 #1	16N/02E-31H1S	<0.01	**21.0**	0.002	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352556116475501
NELT3 #1	16N/02E-31H1S	<0.01	**20.8**	0.006	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352556116475501
NELT3 #1	16N/02E-31H1S	<0.01	**20.1**	0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352556116475501
NELT3 #1	16N/02E-31H1S	<0.01	**21.1**	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352556116475501
NELT1 #1	16N/02E-34Q1S	<0.01	4.41	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352535116451001
NELT1 #2	16N/02E-34Q2S	<0.01	4.64	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=352535116451002
SBTW #1	31S/46E-05B1M	<0.01	2.61	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351619117041301
SBTW #1	31S/46E-05B1M	<0.01	2.59	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351619117041301
SBTW #1	31S/46E-05B1M	<0.01	2.61	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351619117041301
SBTW #1	31S/46E-05B1M	<0.01	2.55	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351619117041301
SBTW #1	31S/46E-05B1M	<0.01	2.6	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351619117041301
SBMW #1	31S/46E-05B2M	<0.01	2.87	0.004	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351620117041101
SBMW #2	31S/46E-05B3M	0.02	2.36	0.002	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351620117041102
SBMC #1	31S/46E-05D1M	0.01	2.81	<0.001	http://nwis.waterdata.usgs.gov/nwis/qwdata?search_site_no=351619117045701

General Water-Quality Characteristics of Multiple-Well Monitoring Sites and Test Well Samples

The water-quality characteristics of groundwater sampled during the study period for selected wells in the Central Corridor area, and Bicycle, Nelson, Cronise, Langford, Goldstone, and Superior Basins were determined using a trilinear diagram (fig. 17). A trilinear diagram shows the relative contribution of major cations and anions on a charge-equivalent basis to the ionic content of the water (Piper, 1944). Percentage scales along the sides of the diagram indicate the relative concentration, in milliequivalents per liter (meq/L), of each major ion. Cations are shown in the left triangle, anions are shown in the right triangle, and the central diamond integrates the data. For simplicity, only the common names of wells are shown on figure 17. State well numbers are listed in table 7. Trilinear diagrams are useful for determining if there is simple mixing between chemically different water (Hem, 1989). For wells with multiple samples, only the sample with the lowest dissolved-solids concentration is discussed in this report; no trends in major-ion composition were observed in water from wells for which more than one analysis was done.

Groundwater from wells in Nelson and Superior Basins and wells BLA5, CCT1, and GOLD2 #2 was characterized as sodium-bicarbonate water (fig. 17); whereas groundwater from the remaining wells in Goldstone Basin was characterized as sodium-chloride water. Groundwater from wells in Cronise and Langford Basins (CRTH1 and CRTH2, and LL04, respectively) was characterized as sodium-sulfate water. The samples from the wells in Cronise Basin and LL04 were enriched in sulfate relative to the samples from wells in Goldstone Basin.

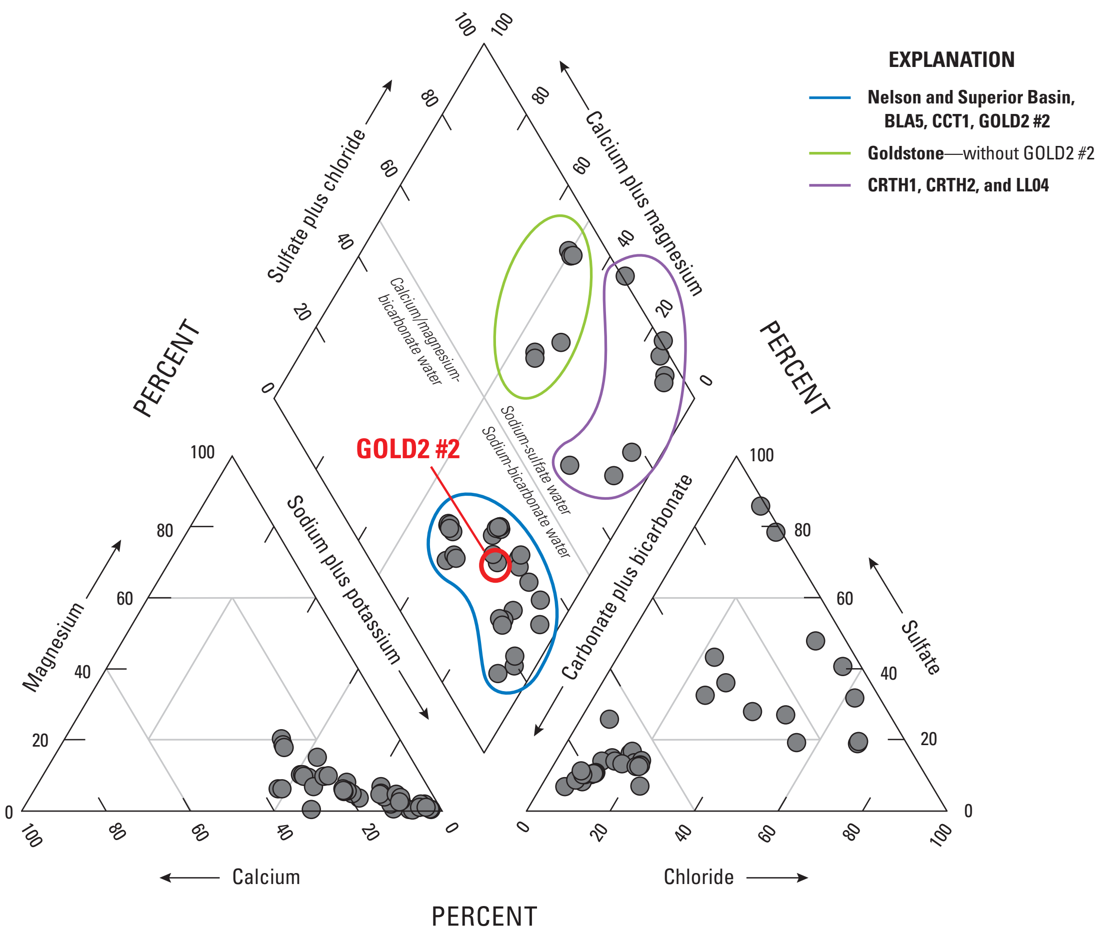


Figure 17. Multiple-well monitoring sites and test holes, Fort Irwin National Training Center, California.

Total dissolved solids (TDS), chloride (Cl), and nitrate plus nitrite as nitrogen ($NO_3 + NO_2$ as N) concentrations were used to further describe water-quality variability in the samples. Because nitrite concentrations were generally below the detection limit in most of the samples, nitrate plus nitrite as nitrogen (table 7) was used as an approximation of nitrate concentrations in these groundwater samples. Total dissolved-solids concentrations ranged from 285 milligrams per liter (mg/L) in water from well 31S/46E-05B1M (SBTW #1, BD) in Superior Basin to 13,400 mg/L in water from well 13N/05E-08B2S (CRTH2 #2) in Cronise Basin (table 7). Chloride concentrations ranged from 19 mg/L in water from wells 31S/46E-05D1M (SBMC #1) and 31S/46E-05B2M (SBMW #1) in Superior Basin and 16N/02E-16P3S (NELT7 #3) in Nelson Basin to 1,030 mg/L in water from well 13N/05E-08B2S (CRTH2 #2) in Cronise Basin. Nitrate plus nitrite ranged from less than 0.040 mg/L in water from five wells (table 7) to about 20 mg/L in water from well 16N/02E-31H1S (NELT3 #1, BD) in Nelson Basin. A secondary maximum contaminant level of 500 mg/L for total dissolved solids has been established by the U.S. Environmental Protection Agency (2002), and a level of 250 mg/L for chloride has been established by the California Department of Public Health (2008a, b). A primary maximum contaminant level of 10 mg/L for nitrate as nitrogen has been established by the U.S. Environmental Protection Agency (2013). The highest total dissolved solids and chloride concentrations were in samples from wells in Cronise Basin and wells 15N/01E-28R1–4S (GOLD1) in Goldstone Basin; the highest nitrate plus nitrite concentrations were in water from wells 16N/02E-31H1S (NELT3 #1) in Nelson Basin and 12N/03E-01M4S (LL04B #1) in Langford Basin.

Source and Age of Groundwater

Groundwater samples collected from 35 wells were analyzed for the stable isotopes oxygen-18 and deuterium to help determine the source of water to wells and to evaluate the movement of water through the study area (table 7). Samples were also collected from selected wells for the radioactive isotopes of tritium and carbon-14 to determine the apparent age, or time since recharge, of groundwater. These samples were collected to augment those of Kjos and others (2014) and provide a complete data set for source and age of groundwater. Data presented in Kjos and others (2014) are not included in table 7, but can be accessed by the hyperlinks in the table.

Stable Isotopes of Water

The stable isotope ratios of oxygen-18 ($\delta^{18}O$) and deuterium (D or $\delta^{2}H$) were plotted to evaluate the hydrologic history of these samples. The ratios of oxygen isotopes [^{18}O:^{16}O] and hydrogen isotopes [D:^{1}H] are expressed in delta notation (δ) as parts per thousand (per mil) differences relative to the standard known as Vienna Standard Mean Ocean Water (VSMOW; Gonfiantini, 1978). The relation between $\delta^{18}O$ and δD in natural precipitation is linear throughout the world (Craig, 1961) and is referred to as the global meteoric water line (fig. 18). Differences in isotopic composition can be used to help determine general atmospheric conditions at the time of precipitation and the effects of evaporation before water entered the groundwater system. For simplicity, only the common names of wells are shown on figure 18. State well numbers are listed in table 7.

The isotopic composition of groundwater from wells sampled as part of this study plotted below the global meteoric water line, indicating possible evaporation at land surface prior to recharge, partial evaporation of falling raindrops in an arid atmosphere, or a “local” meteoric water line. The isotopic composition of these samples was similar to the isotopic composition in groundwater samples from wells in Irwin, Langford, and Bicycle Basins from previous studies (Densmore and Londquist, 1997; Voronin and others, 2013; Densmore and others, 2018). The isotopic compositions in groundwater from individual multiple-well monitoring sites plotted tightly, indicating the same source or a trend line showing similar evaporative histories at the sites through time. The isotopic data for groundwater from wells in Nelson Basin were tightly grouped and isotopically light; whereas the groundwater samples from multiple-well monitoring sites CRTH1 (13N/05E-28Q1–3S), CRTH2 (13N/03E-08B1–2S), and LL04 (12N/03E-01M1, 4, 5S) were isotopically heavier and plotted along an evaporative trend line approximated by a best-fit line through the isotopic data for these wells. In CRTH1, CRTH2, and LL04, high chloride concentrations were associated with heavier isotopic signatures along the evaporative trend line, indicating high chloride concentrations could be related to evaporation.

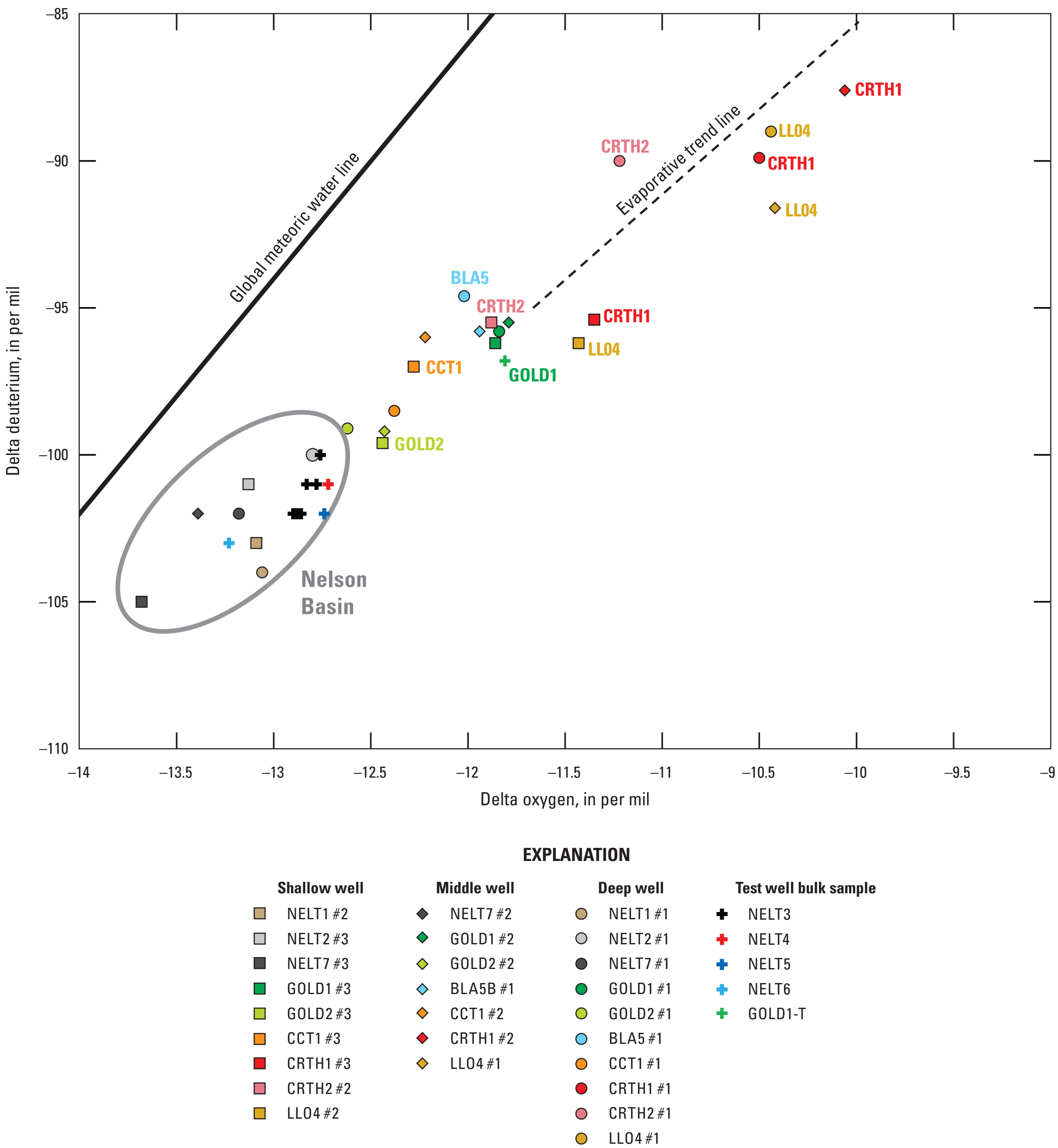


Figure 18. Relation between stable isotopes from groundwater samples in Nelson, Goldstone, and Bicycle Basins, and the Central Corridor area, Fort Irwin National Training Center, California.

Tritium and Carbon-14

Tritium is a natural, radioactive isotope of hydrogen that has a half-life of 12.4 years (Clark and Fritz, 1997). The concentration of tritium is measured in picocuries per liter (pCi/L); each pCi/L represents 2.2 disintegrations per minute. The conversion of picocuries per liter to tritium units (TU), using a tritium half-life of 12.32 years (Lucas and Unterweger, 2000), is 1 TU equals 3.22 pCi/L. Approximately 1,760 pounds of tritium was released to the atmosphere as a result of the atmospheric testing of nuclear weapons between 1952 and 1962 (Michel, 1976). As a result, tritium concentrations in precipitation and groundwater recharge increased beyond the natural concentration during that time. Tritium concentrations are not affected by chemical reactions other than radioactive decay because tritium is part of the water molecule; therefore, tritium is an excellent tracer of the movement and relative age of water on timescales ranging from recent to about 60 years before present (post atomic bomb). The absence of tritium indicates water that was infiltrated prior to 1952; high tritium concentrations indicate water that infiltrated near the time of the atmospheric-testing peak in the early 1960s; and low tritium concentrations indicate either very recent recharge or a mixture of water with different ages. In this report, groundwater that had detectable tritium (greater than 0.6 pCi/L or 0.2 TU) was interpreted to be water that contained at least some water that was recharged after 1952, or recent recharge (post atomic bomb; Clark and Fritz, 1997).

Carbon-14 is a radioactive isotope of carbon having a half-life of about 5,730 years (Mook, 1980). Carbon-14 data are expressed as percent modern carbon (pmc) by comparing ^{14}C activities to the specific activity of National Bureau of Standards oxalic acid: 13.56 disintegrations per minute per gram of carbon in the year 1950 equals 100 pmc (Kalin, 2000). Carbon-14 was produced, as was tritium, by the atmospheric testing of nuclear weapons (Mook, 1980). Carbon-14 activities are used to determine the age of a groundwater sample on timescales ranging from recent to more than 20,000 years before present. Unlike tritium, carbon-14 is not part of the water molecule, and carbon-14 activities can be affected by reactions other than radioactive decay. In addition, ^{14}C activities are affected by mixing younger water that has high ^{14}C activity with older water that has low ^{14}C activity. In this report, only uncorrected ^{14}C activities that do not account for reactions with aquifer material or mixing are presented and, therefore, are considered uncorrected ages. In general, uncorrected ^{14}C ages are older than the actual age of the associated water (Izbicki and others, 1995). In this report, groundwater that had ^{14}C activities less than 90 pmc was interpreted as having been recharged before 1952; groundwater having ^{14}C activities greater than 90 pmc was interpreted as having been recharged after 1952 (Izbicki and Michel, 2003).

No measurable tritium was detected in groundwater from 13 wells sampled in 2015 (table 7). The lack of tritium in these samples indicates that water was recharged prior to 1952. Measured ^{14}C activities in groundwater from four wells sampled in 2015 ranged from about 7.87 pmc to 23.49 pmc (table 7). The uncorrected ^{14}C data indicated the groundwater in these four wells had apparent ages of 11,970–20,980 years. The ^{14}C data for these four wells represent a small subset of a larger dataset for all the wells in table 7; these data are presented in Kjos and others (2014) and accessed by the hyperlinks in table 7. The measured ^{14}C activities of groundwater collected during 2010–12 from the other wells listed in table 7 ranged from 1.3 to 53 pmc (Kjos and others, 2014). The low ^{14}C activities indicate that groundwater from these wells was old; these results are similar to ^{14}C activities in groundwater samples from wells in Irwin, Langford, and Bicycle Basins (Densmore and Londquist, 1997; Voronin and others, 2013; Densmore and others, 2018).

Other Constituents of Concern

Other constituents of concern in groundwater at Fort Irwin are arsenic (As) and fluoride (F^-). Arsenic concentrations ranged from 1.2 micrograms per liter (µg/L) in water from well 14N/01E-07R1S (GOLD2 #1, BD) in Goldstone Basin to 178 µg/L from well 13N/05E-28Q1S (CRTH1 #1) in Cronise Basin (table 7). The primary maximum contaminant level of arsenic in drinking water of 50 µg/L, established in 1977 by the U.S. Environmental Protection Agency (2002), was lowered to 10 µg/L in 2006 (U.S. Environmental Protection Agency, http://www.epa.gov/safewater/contaminants/index.html#7, accessed Dec. 18, 2015). Arsenic concentrations were above the maximum contaminant level (MCL) in groundwater from most wells, except those in Goldstone Basin and the two deepest wells in Langford Basin (12N/03E-01M1S, 4S, LL04). The highest arsenic concentrations were measured in water samples from deep wells in Cronise Basin (13N/05E-28Q1S, CRTH1 #1) and Nelson Basin (6N/02E-16P1S NELT7 #1 and 6N/02E-16P2S, NELT7 #2) with values of 178, 135, and 146 µg/L, respectively. Groundwater from well 13N/05E-08B2S (CRTH2 #2), with an uncorrected ^{14}C age of 20,420 years, also had high concentrations of arsenic, boron, chloride, manganese, and strontium.

The primary MCL of 4 mg/L fluoride was established in 1986 as a drinking water guideline for public water systems (U.S. Environmental Protection Agency, 2002), but the lower California MCL of 2 mg/L, established in 1998, was the benchmark used for comparisons in this study. Fluoride concentrations ranged from 0.38 mg/L in water from well 15N/01E-28R1S (GOLD1 #1) in Goldstone Basin to 13.9 mg/L from well 16N/02E-16P1S (NELT7 #1) in Nelson Basin. Fluoride concentrations were above the California MCL in groundwater from most wells, except those in Goldstone and Superior Basins; well 12N/03E-01M1S (LL04B #1) in Langford Basin; well 13N/05E-28Q2S (CRTH1 #2) and deep well 13N/05E-08B2S (CRTH2 #1) in Cronise Basin; and from wells 16N/02E-31H1S (NELT3 #1), 16N/01E-35P1S (NELT5 #1), and 15N/02E-05N1S (NELT6 #1) in Nelson Basin.

Depth-Dependent Samples and Monitoring Wells

Wellbore-flow and selected depth-dependent water-quality data were collected under typical pumping conditions from individual test wells. Results are shown in figures 19–24. Flow logs collected from wells under pumped conditions were coupled with depth-dependent water-quality data, collected from discrete depths in the wells and as bulk discharge (BD) at land surface, to evaluate aquifer water-quality using techniques described by Izbicki and others (1999) and Izbicki (2004). Depth-dependent water-quality data were collected from selected test wells 15N/01E-28R4S (GOLD1-T #1), 15N/02E-05N1S (NELT6 #1), 15N/03E-08L1S (NELT4 #1), and 16N/01E-35P1S (NELT5 #1) under pumping conditions by a small-diameter (less than 1 in.) gas-displacement pump following procedures described by Izbicki (2004). In situations where space in the well casing allowed, samples were collected under pumping conditions from 2-in. diameter PVC casing emplaced in the test well at the sample depth —16N/02E-31H1S (NELT3 #1) and 31S/46E-05B1M (SBTW #1). In these wells, groundwater was pumped from the casing at the surface by small-diameter positive-displacement pumps. Sample depths were determined in the field on the basis of the wellbore-flow data, including fluid resistivity and fluid temperature, when available. The samples collected using this method are a composite of water from the contributing perforated interval above or below the sample point, depending on flow direction in the well. The water quality and isotopic composition of water entering the well between two sample depths were estimated using measured changes in flow (V) and concentrations (C) according to the following equation (Izbicki and others, 1999; Izbicki, 2004), where subscripts refer to sample depth:

$$(C_3 * V_3) = (C_1 * V_1) + (C_2 * V_2) \qquad (2)$$

This can be rearranged as follows:

$$C_2 = ((C_3 * V_3) - (C_1 * V_1)) / V_2 \qquad (3)$$

where

- depth 1 is the measurement point at the bottom of the sample interval,
- depth 2 is the interval between sample points, and
- depth 3 is the measurement point at the top of the sample interval.

The flow in the interval between sample points (V_2) is calculated from measured flow data as $V_2 = V_3 - V_1$. This calculation assumes conservative mixing and conservation of mass. There are some limitations in resolution with this estimation, however. Small errors in constituent concentration or flow measurements in zones with low flow can cause erroneous estimations. Because of laboratory reporting limits of analytical constituents and the limited resolution of wellbore flow techniques used, estimated concentrations for select constituents were not calculated for flow differences between sample depth zones that were less than 5 percent of total flow.

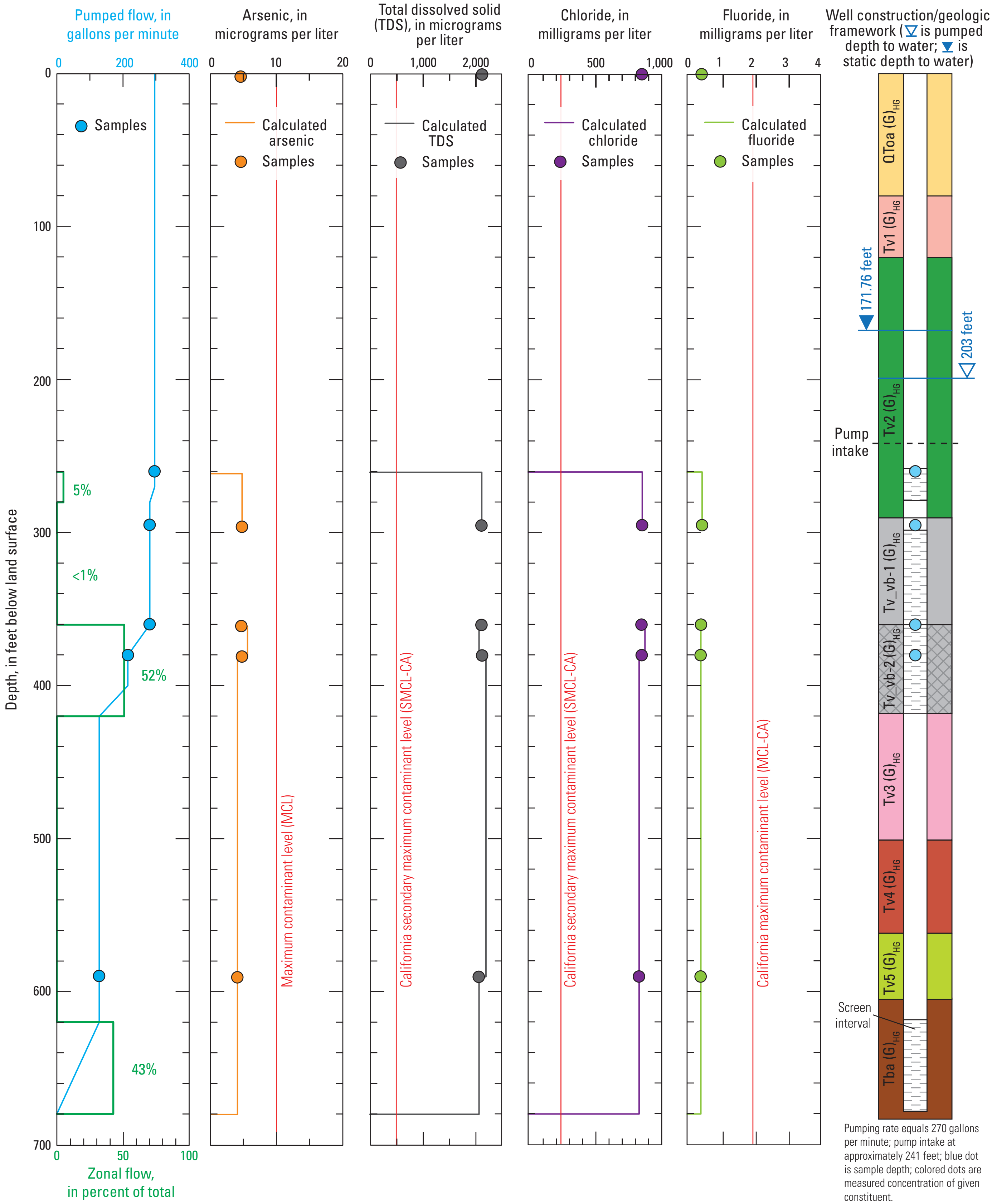


Figure 19. Well construction, wellbore-flow log, and selected depth-dependent water-quality data from test well GOLD1-T #1 (15N/01E-28R4S), March 2012, Fort Irwin National Training Center, California. (Sample results plotted at depth of zero feet below land surface represent bulk discharge.)

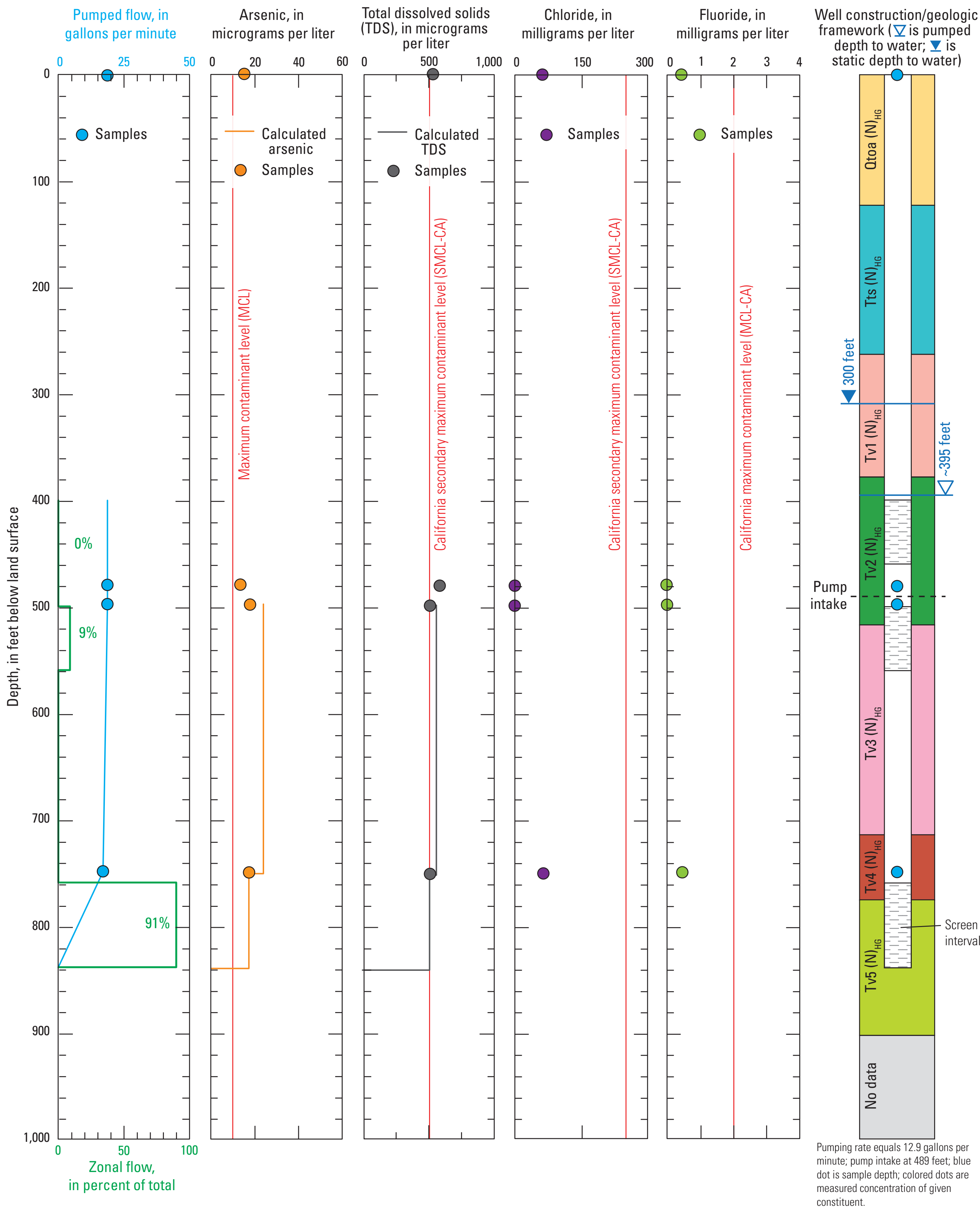


Figure 20. Well construction, wellbore-flow log, and selected depth-dependent water-quality data from test well NELT6 #1 (15N/02E-05N1S), March 2012, Fort Irwin National Training Center, California. (Sample results plotted at depth of zero feet below land surface represent bulk discharge.)

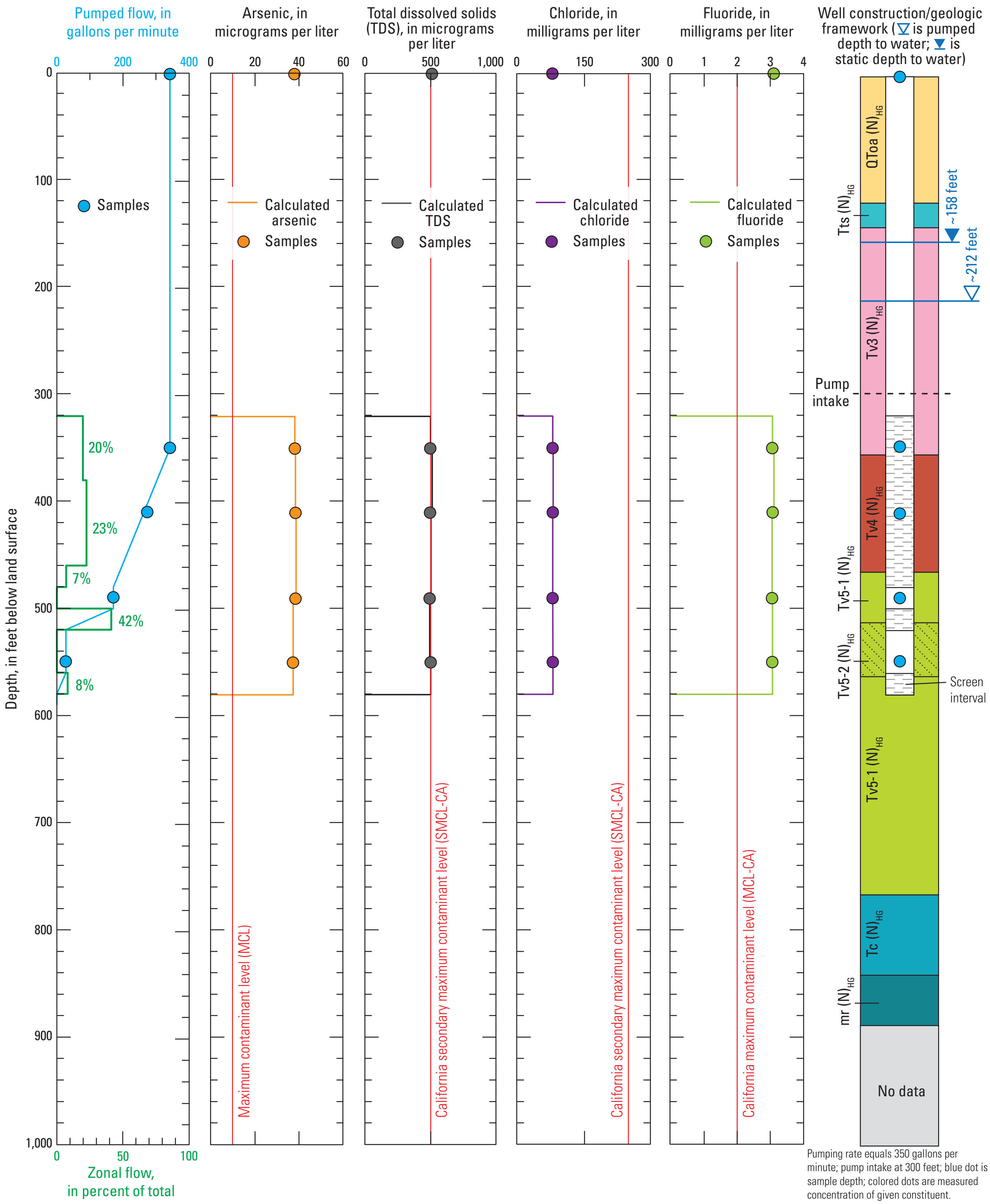


Figure 21. Well construction, wellbore-flow log, and selected depth-dependent water-quality data from test well NELT4 #1 (15N/03E-08L1S), February 2012, Fort Irwin National Training Center, California. (Sample results plotted at depth of zero feet below land surface represent bulk discharge.)

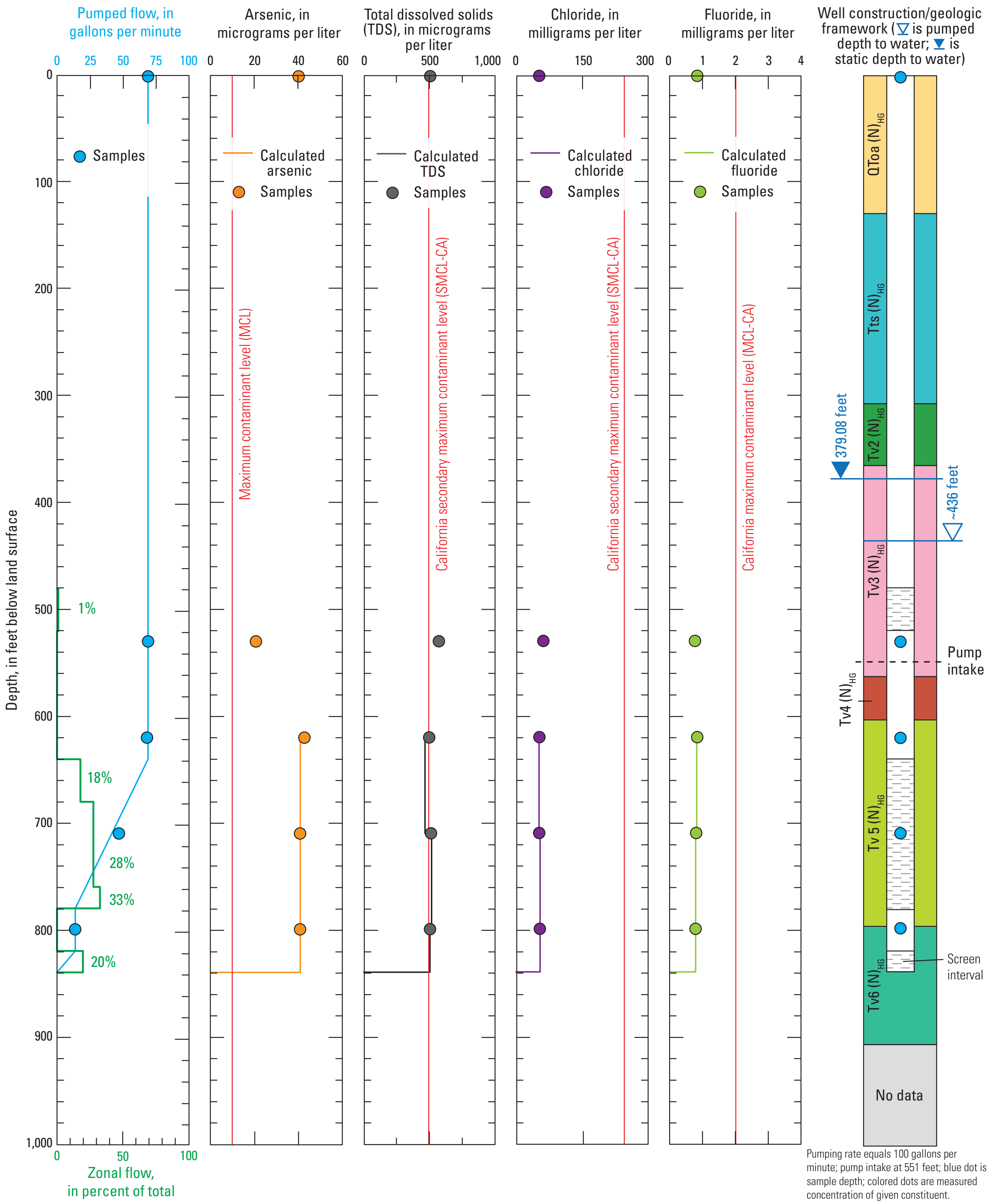


Figure 22. Well construction, wellbore-flow log, and selected depth-dependent water-quality data from test well NELT5 #1 (16N/01E-35P1S), March 2012, Fort Irwin National Training Center, California. (Sample results plotted at depth of zero feet below land surface represent bulk discharge.)

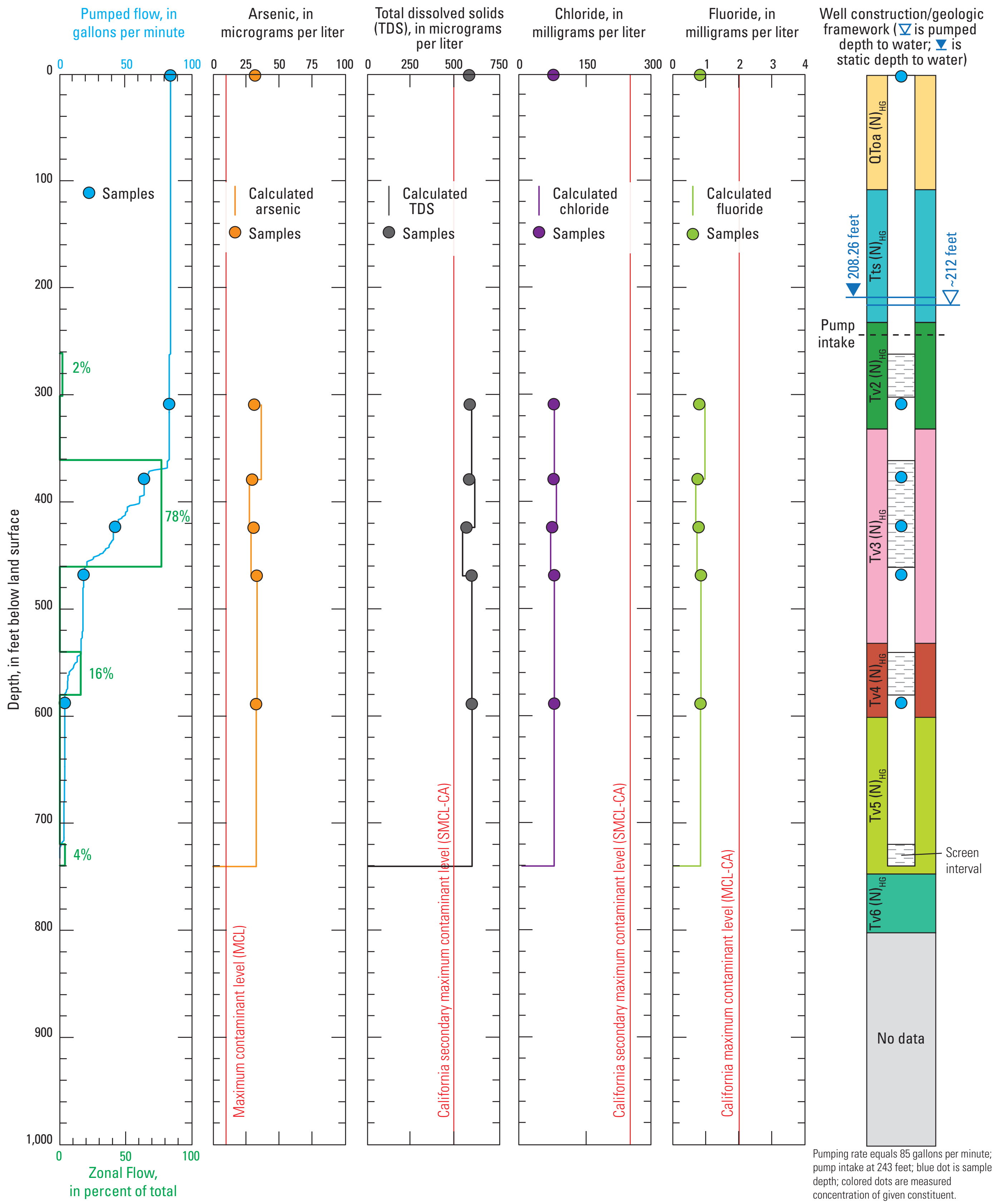


Figure 23. Well construction, wellbore-flow log, and selected depth-dependent water-quality data from test well NELT3 #1 (16N/02E-31H1S), February 2015, Fort Irwin National Training Center, California. (Sample results plotted at depth of zero feet below land surface represent bulk discharge.)

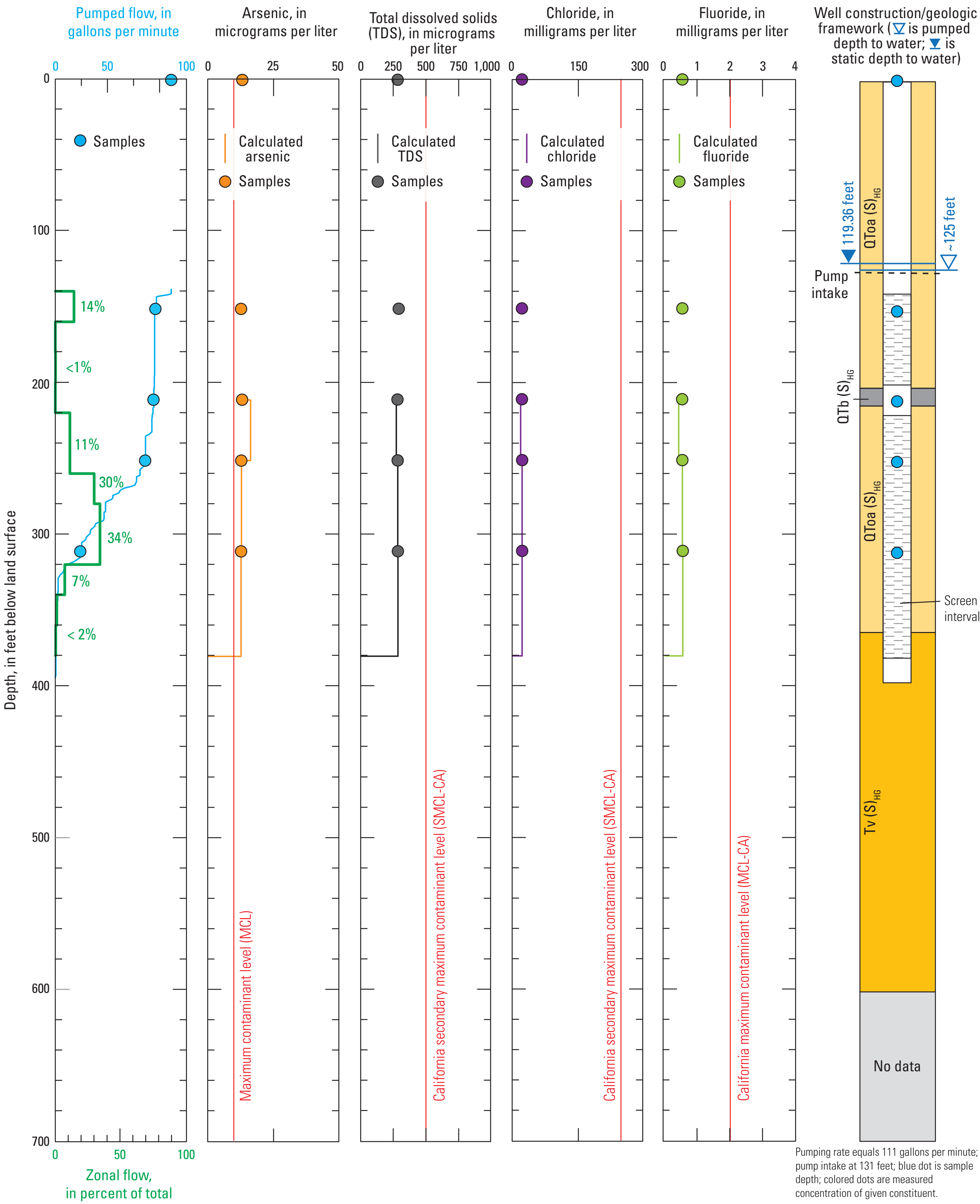


Figure 24. Well construction, wellbore-flow log, and selected depth-dependent water-quality data from test well SBTW #1 (31S/46E-05B1M), February 2015, Fort Irwin National Training Center, California. (Sample results plotted at depth of zero feet below land surface represent bulk discharge.)

Overall, the data show that there was little variability in water quality by depth in the wells sampled as part of this study (figs. 19–24), with minor exceptions of calculated arsenic in wells 15N/02E-05N1S (NELT6 #1) and 16N/01E-35P1S (NELT5 #1), all constituents in 16N/02E-31H1S (NELT3 #1), and calculated arsenic in 31S/46E-05B1M (SBTW #1). Although small errors in constituent concentration or low-flow measurements can cause erroneous estimations, these calculated concentrations were similar to those measured in groundwater from most of the nearby multiple-well monitoring sites, described later. The water-quality data indicate calculated arsenic concentrations were higher in water from well 15N/02E-05N1S (NELT6 #1) between about 500–750 ft bls than below 750 ft (fig. 20), whereas the measured concentrations increased with depth in 16N/01E-35P1S (NELT5 #1; fig. 22). Similarly, calculated total dissolved solids and chloride concentrations generally increased with depth in 16N/02E-31H1S (NELT3 #1), with a slight decrease between about 420–465 ft bls (fig. 23). The data also indicate decreases in calculated arsenic and fluoride concentrations in water below the upper screened interval in well 16N/02E-31H1S (NELT3 #1; fig. 23) and an overall decrease in arsenic concentrations with depth below the upper screen in 31S/46E-05B1M (SBTW #1; fig. 24). Because flow in the upper zones between samples, used in the calculation, was low, the calculated concentrations for 16N/02E-31H1S (NELT3 #1) and 31S/46E-05B1M (SBTW #1) may be biased by the very low flow measured in the upper perforation of these wells.

Water-quality data collected from multiple-well monitoring sites, grouped by basin, were also assessed to provide depth-dependent information to help evaluate the variability in water quality by depth (figs. 25–29). Overall, there was considerable variability in water quality, particularly arsenic concentration, by depth in these monitoring wells, depending on the deposits that were perforated. As described in the "Other Constituents of Concern" section, arsenic concentrations exceeded the MCL in water from most monitoring wells that were sampled (table 7). Arsenic concentrations were highest in water from wells perforated in fine-grained deposits, including wells 13N/05E-28Q1S (CRTH1 #1) in Cronise Basin and 16N/02E-16P1S, 2S (NELT7 #1 and NELT7 #2) in Nelson Basin. Arsenic concentrations were below the MCL in water from wells 13N/05E-08B2S (CRTH1 #2) in Cronise Basin, and 14N/01E-07R1, 2S (GOLD2 #1 and #2), and 15N/01E-28R1–3S (GOLD1 #1–3) in Goldstone Basin. Total dissolved solids, chloride, and fluoride concentrations also varied considerably in Cronise Basin. These concentrations showed less variability by depth in Goldstone, Nelson, Superior Basins, and the Central Corridor area.

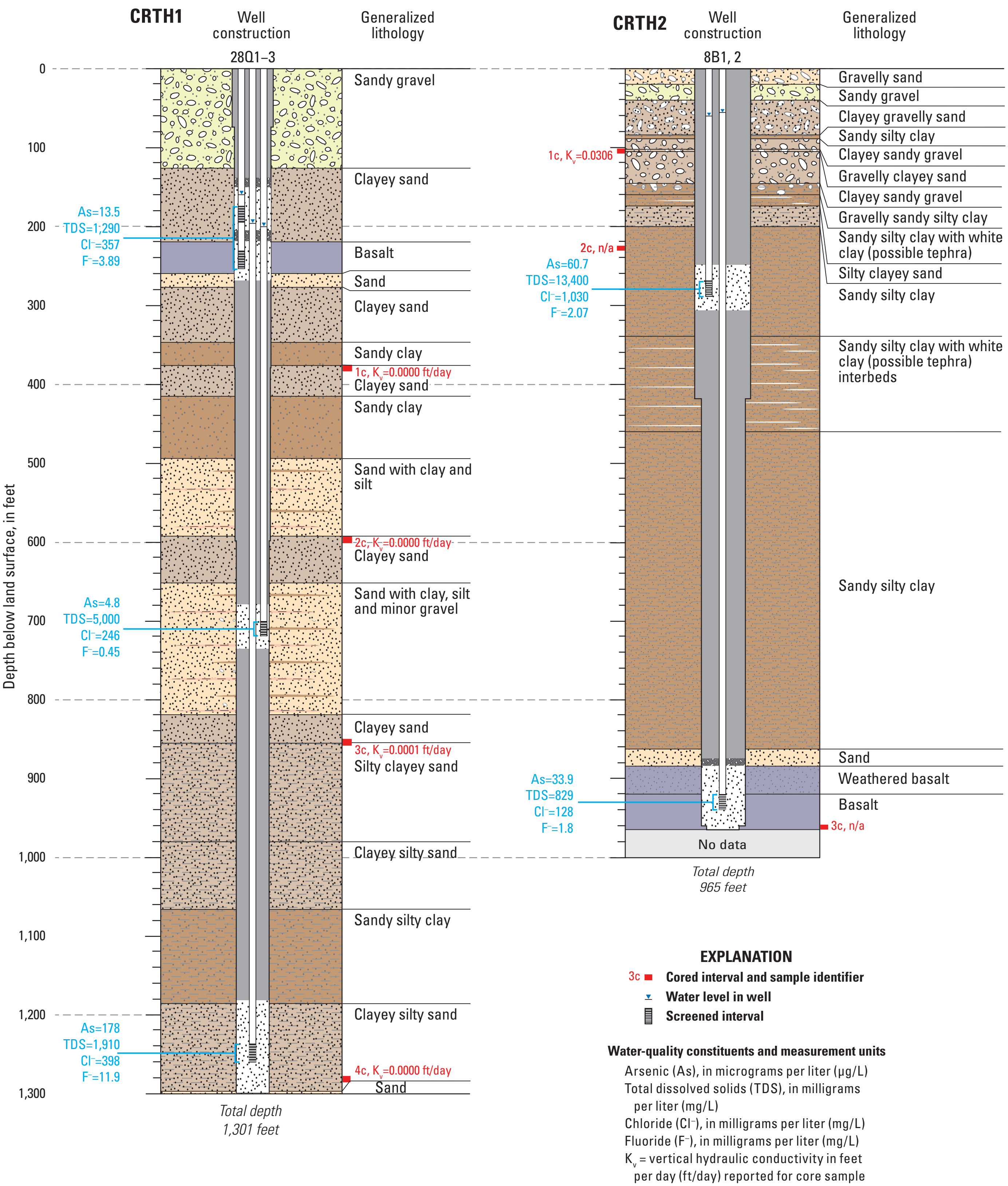


Figure 25. Selected water-quality data, well construction, and generalized lithology for multiple-well monitoring sites, CRTH1 (13N/05E-28Q01S, -28Q02S, -28Q03S) and CRTH2 (13N/05E-08B01S, -08B02S), Fort Irwin National Training Center, California.

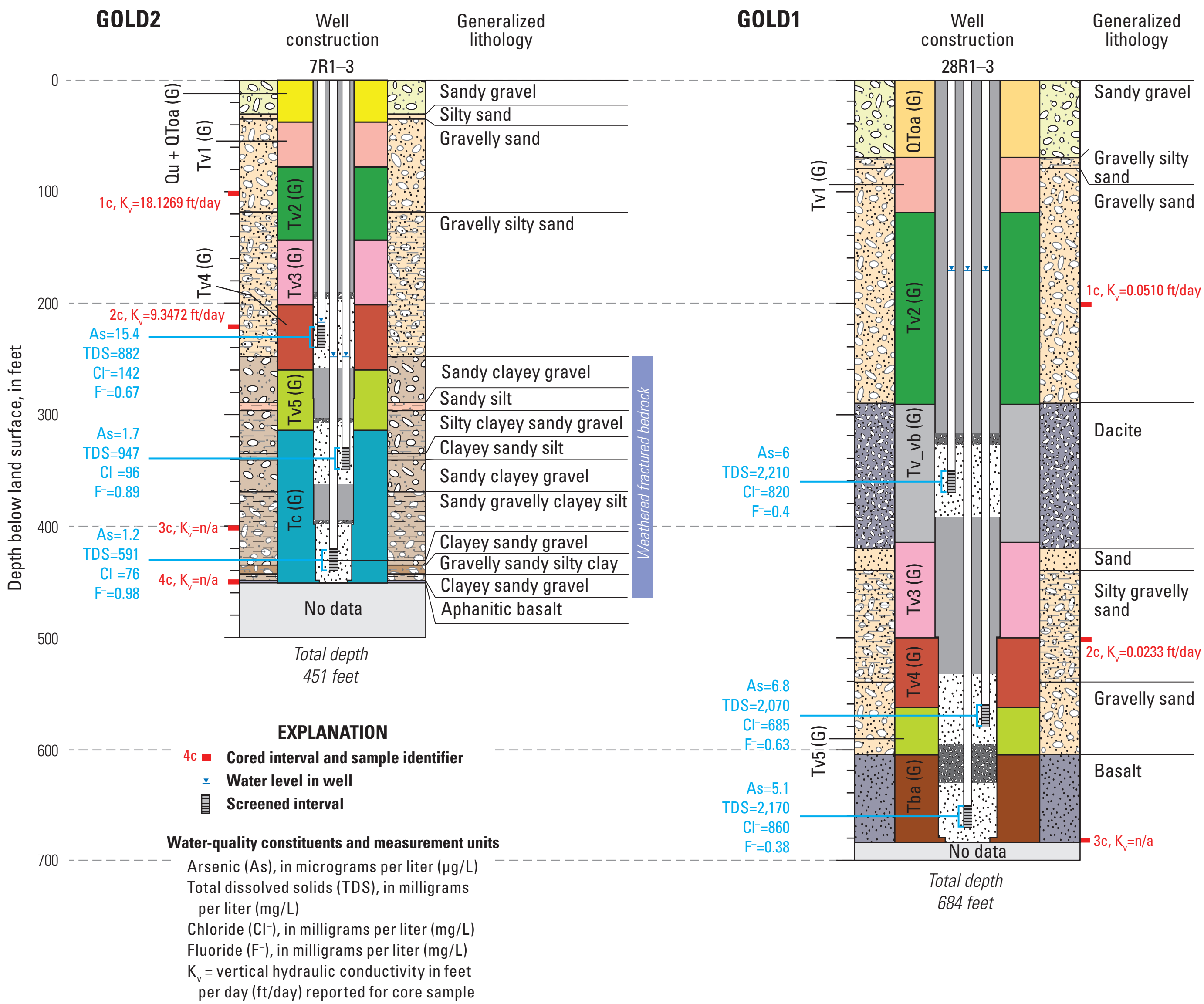


Figure 26. Selected water-quality data, well construction, and generalized lithology for multiple-well monitoring sites, GOLD2 (14N/01E-07R01S, -07R02S, -07R03S) and GOLD1 (15N/01E-28R01S, -28R02S, -28R03S), Fort Irwin National Training Center, California.

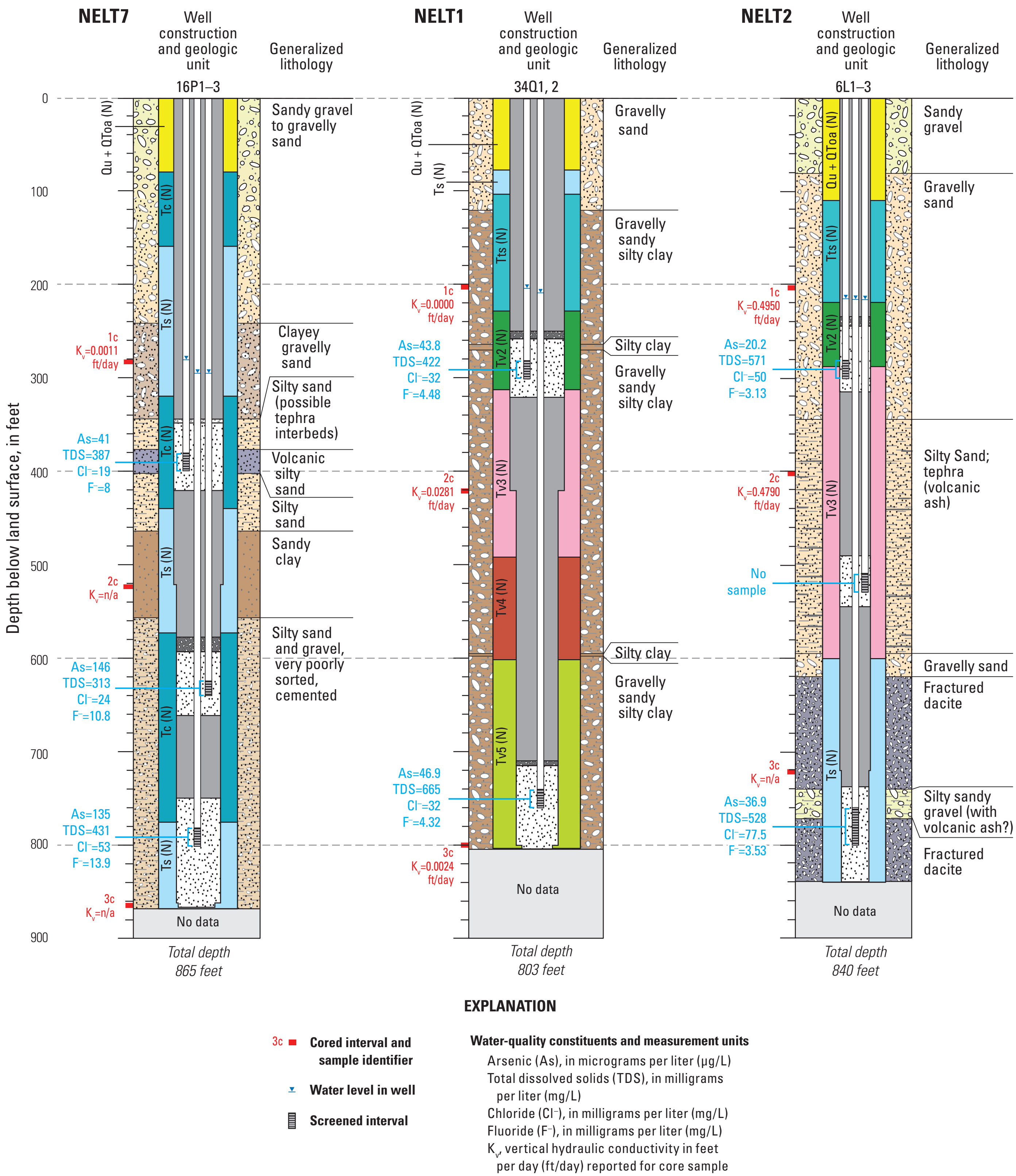


Figure 27. Selected water-quality data, well construction, and generalized lithology for multiple-well monitoring sites, NELT7 (16N/02E-16P01S, -16P02S, -16P03S), NELT1 (16N/02E-34Q01S, -34Q02S), and NELT2 (15N/03E-06L01S, -06L02S, -06L03S), Fort Irwin National Training Center, California.

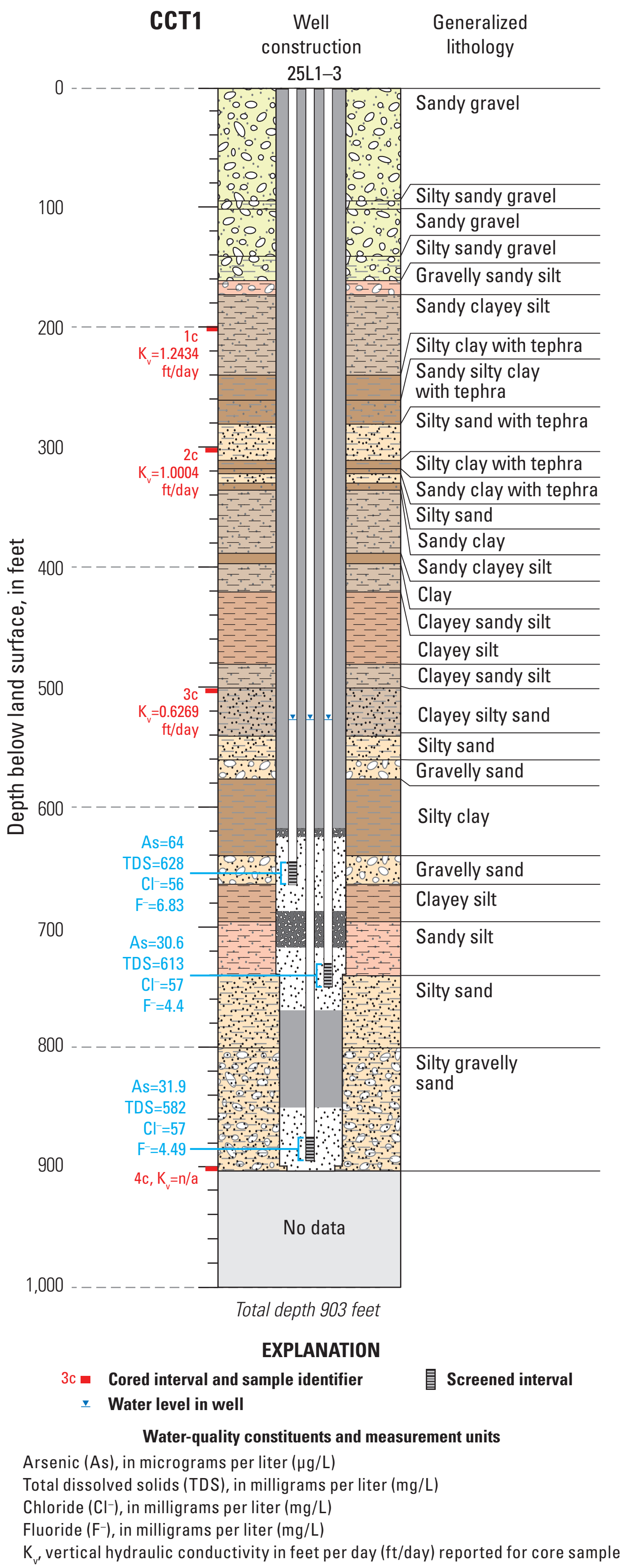


Figure 28. Selected water-quality data, well construction, and generalized lithology for multiple-well monitoring sites, CCT1 (15N/03E-25L01S, -25L02S, -25L03S), Fort Irwin National Training Center, California.

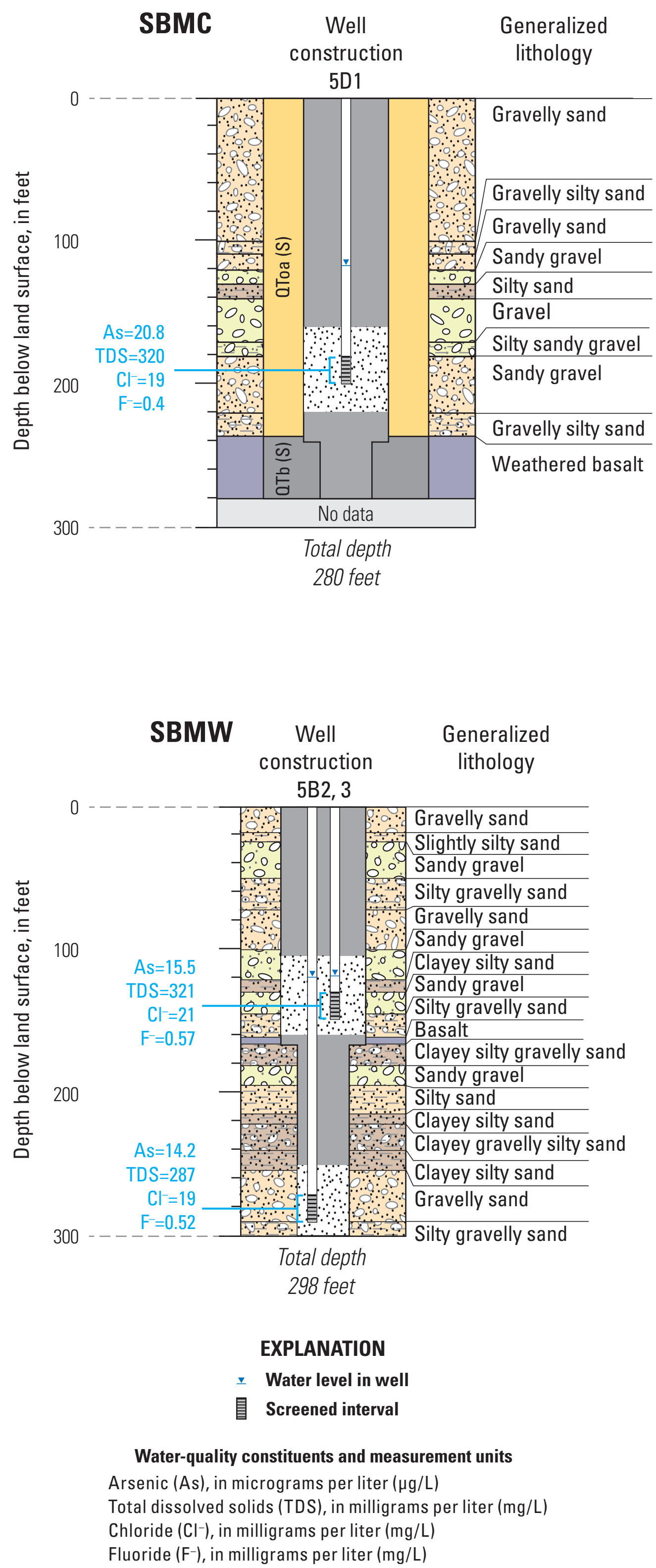


Figure 29. Selected water-quality data, well construction, and generalized lithology for single-well monitoring sites SBMC (31S/46E-05D01M) and multiple-well monitoring site, SBMW (31S/46E-05B02M, -05B03M), Fort Irwin National Training Center, California.

Numerical Modeling

AnalyzeHOLE (Halford, 2009) was used to simulate transient groundwater flow and estimate hydraulic properties of hydrogeologic units intersected by each of the test wells on the basis of data collected during aquifer testing (tables 1, 4). Each model consists of 80 vertical columns (lateral distance from the pumping well) and between 90 and 130 5-foot-thick horizontal rows (depth), representing a cylinder of aquifer material having a radius of 5,000 ft and a thickness ranging between 450 and 650 ft (table 8). Each test well was simulated as a high hydraulic conductivity (K) zone in the first column of the model. The well casing and well screens were simulated in the second column of the model. The well casing was simulated with a K of 0 ft/d. The well screens were assumed to be 100 percent efficient and set to the same K value as the well. The gravel pack and sanitary seal were simulated in the third column of the model. The gravel pack was simulated with a K of 300 ft/d; the annular grout seal was simulated with a K of 0 ft/d. Model discretization of 16N/02E-31H1S (NELT3 #1) is presented in figure 30. Layers in the models (referred to as hydrogeologic units or HGUs) were based on the lithostratigraphic-geophysical units (LGU) and wellbore-flow logs from each borehole (figs. 10–15). In general, the GFM and LGU stratigraphy provided good approximations for the boundaries of the HGUs; however, unit depths and boundaries are not absolute, and some LGU boundaries did not correspond to modeled HGU boundaries. Variations of the modeled HGU boundaries are discussed later.

A hydrologic unit was assigned to each 5-ft-thick model row. Unit depths were adjusted slightly to conform to the model grid and were assumed to be radially symmetric, flat-lying, and laterally extensive through the model domain (fig. 30). Hydraulic properties from literature-derived values (Freeze and Cherry, 1979) were initially assigned according to lithologic and geophysical logs; these properties were adjusted automatically during model calibration. The radial extent of the model was larger than the influence of simulated pumping from the well, and no-flow boundaries were used to represent the outside and the bottom of the cylinder. For each model, regional groundwater flow and regional pumping effects were not simulated. Pumping stress from the simulated well was assumed to dominate groundwater flow near the well, and the water extracted from aquifer storage was the only source of water to the well. The pressure responses in the aquifer to pumping stress (drawdown) were approximated using the Theis equation (1935). Simulations assume confined conditions; thus, specific storage was used rather than specific yield (table 8).

Table 8. Details of radial groundwater-flow model construction, Fort Irwin National Training Center, California.

[Cooper-Jacob refers to methods described by Cooper and Jacob (1946). **Abbreviations**: gpm, gallons per minute; gpm/ft, gallons per minute per foot; ft^2/d, square feet per day]

Test borehole	Columns	Rows	Total radius (feet)	Total thickness (feet)	Well radius (feet)	Borehole annulus (feet)	Specific storage (per foot)	Porosity	Vertical anisotropy
GOLD1-T	80	100	5,000	500	0.33	0.61	1×10^{-6}	0.2	0.1
NELT6	80	121	5,000	605	0.33	0.63	1×10^{-6}	0.2	0.1
NELT4	80	90	5,000	450	0.33	0.54	1×10^{-6}	0.2	0.1
NELT5	80	110	5,000	550	0.33	0.61	1×10^{-6}	0.2	0.1
NELT3	80	130	5,000	650	0.33	0.54	1×10^{-6}	0.2	0.1
SBTW	80	99	5,000	495	0.33	0.61	1×10^{-6}	0.2	0.1

Test borehole	Measured drawdown (feet)	Simulated drawdown (feet)	Simulated pump rate (gpm)	Specific capacity (gpm/ft)	Simulated total transmissivity (ft^2/d)	Aquifer-test total transmissivity (Cooper-Jacob) (ft^2/d)	Aquifer-test total transmissivity (Cooper-Jacob recovery) (ft^2/d)
GOLD1-T	31.6	31.7	300	9.5	4,017	28,000	25,000
NELT6	99.9	99.3	16	0.2	435	100	50
NELT4	76.4	76.3	350	4.6	1,905	2,200	3,900
NELT5	106.1	106.5	70	0.7	877	130	140
NELT3	4.03	4.02	85	21.1	9,254	12,000	3,300
SBTW	5.55	5.60	111	20.0	5,871	3,000	4,500

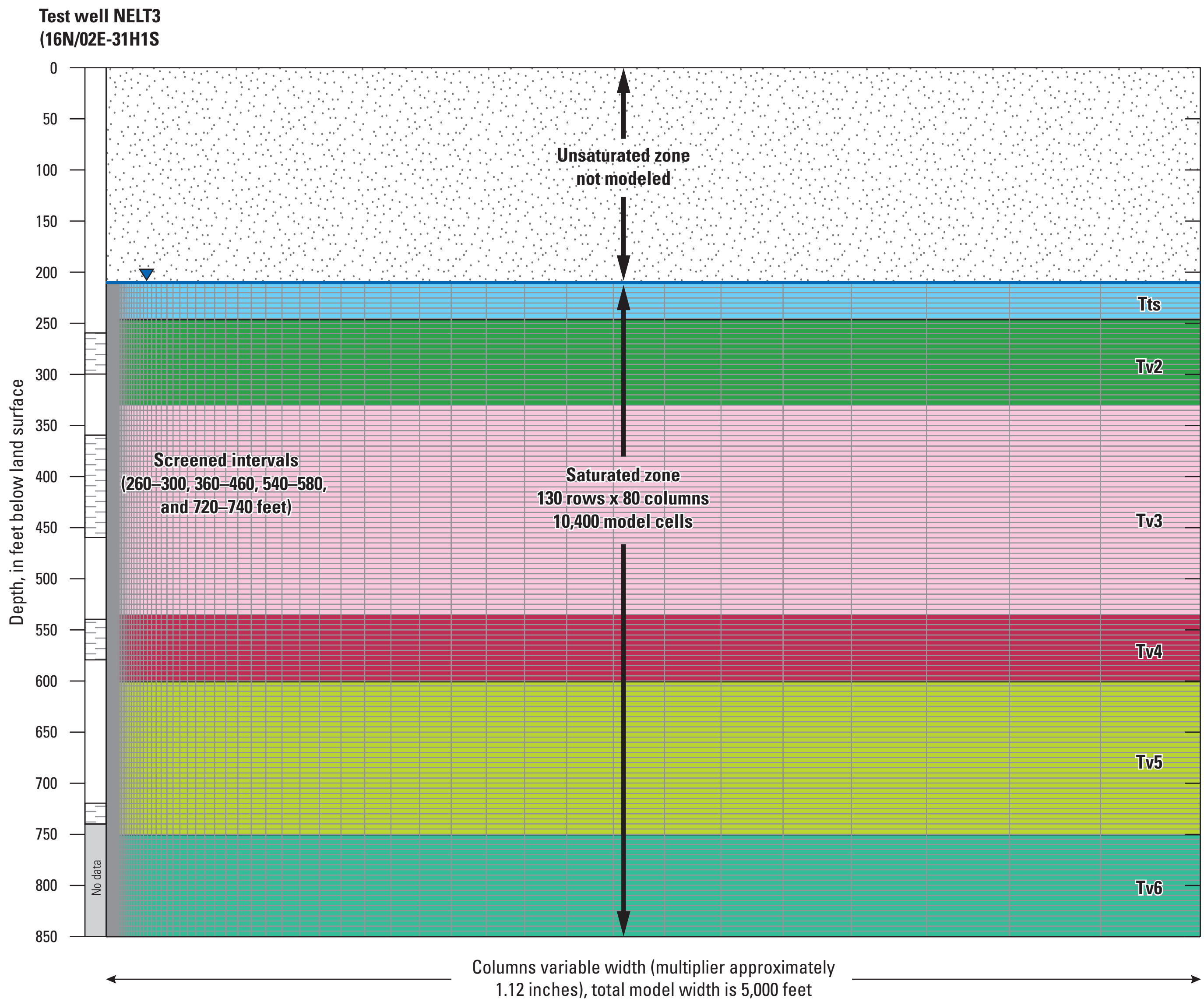


Figure 30. Model grid and hydrogeologic layering (based on the lithostratigraphic-geophysical units, LGUs, and wellbore-flow logs from borehole shown in fig. 14) used to simulate flow at test well NELT3 #1 (16N/02E-31H01S), Fort Irwin National Training Center, California.

Numerical Model Calibration

Each model was calibrated by automatically adjusting the hydraulic conductivity (K_h) of each HGU to match measured drawdown and wellbore-flow data collected from each test well under pumping conditions as well as possible. The hydraulic conductivities of each HGU in each model were adjusted so that the simulated wellbore flow approximated the measured wellbore flow and the Theis-calculated drawdown approximated the measured drawdown (figs. 10–15; table 8). Simulated K values in Nelson, Goldstone, and Superior Basins derived during calibration ranged from less than 0.01 to 60 ft/day (tables 9–11). For the purposes of this report, the intent of the flow logging was to characterize bulk hydraulic properties of major HGUs. Relatively small fluctuations in flow contribution within a given unit were not necessarily explicitly simulated, as long as the overall HGU properties were suitable to achieve a satisfactory calibration with respect to aquifer transmissivity, HGU hydraulic conductivity, wellbore-flow contribution, and drawdown in response to pumping.

Table 9. Simulated hydraulic conductivity of hydrogeologic units in test wells, Nelson Basin, Fort Irwin National Training Center, California.

[NA, borehole intersects hydrogeologic unit, but is not screened within unit; Tv, Miocene volcanic-rich sedimentary strata; —, hydrogeologic unit not present]

Hydrogeologic unit	Simulated hydraulic conductivity (feet/day)			
	NELT6	NELT4	NELT5	NELT3
Tv1	NA	NA	—	—
Tv2	0.01	NA	NA	1.7
Tv3	0.25	0.25	0.01	33
Tv4	0.012	4	NA	17.6
Tv5	2.5	—	0.66	4.4
Tv5-1	—	2.5	—	—
Tv5-2	—	18.3	—	—
Tv6	—	—	0.85	NA

Table 10. Simulated hydraulic conductivity of hydrogeologic units in test well GOLD1-T #1 (15N/01E-28R4S), Goldstone Basin, Fort Irwin National Training Center, California.

Hydrogeologic unit	Simulated hydraulic conductivity (feet/day)
Miocene volcanic-rich sedimentary strata, Tv2(G)	2.7
Miocene avalanche breccia of dacite lava, Tv_vb-1(G)	0.8
Miocene avalanche breccia of dacite lava, Tv_vb-2(G)	16.4
Miocene volcanic-rich sedimentary strata, Tv3-5(G), undifferentiated	8.1
Miocene basalt flows, Tba(G)	13

Table 11. Simulated hydraulic conductivity of hydrogeologic units in test well SBTW #1 (31S/46E-05B1M), Superior Basin, Fort Irwin National Training Center, California.

Hydrogeologic unit	Simulated hydraulic conductivity (feet/day)
Quaternary to Pliocene sand and gravel (conglomerate and sandstone), QToa(S)	60
Quaternary to Pliocene basalt, QTb(S)	1.43
Quaternary to Pliocene sand and gravel (conglomerate and sandstone), QToa(S)	53
Miocene volcanic-rich sedimentary strata, Tv(S)	0.02

For boreholes drilled in Nelson Basin (fig. 2), the depths to the top and bottom of LGUs, described in the "Lithostratigraphic-Geophysical Units" section, were unchanged for the corresponding HGUs, except for Tv5$(N)_{LG}$ in well 15N/03E-08L1S (NELT4 #1; figs. 3, 12). In this well (NELT4 #1), the bottom 20 ft of the shallow screen (460–480 ft) and the entire intervals of the middle and deep screens (500–520 and 560–580 ft, respectively) are entirely within Tv5$(N)_{LG}$. Based on the wellbore-flow data from discrete depths for this well, however, described earlier in the "Wellbore-Flow Data" section, the distribution of flow is variable in this unit. The middle well screen (500–520 ft) produces water at a rate of about 7.4 gpm/ft of screen (147 gpm per 20 ft), whereas the shallow and deep screens that are in unit Tv5$(N)_{LG}$ produce water at a rates of about 1.2 and 1.4 gpm/ft, respectively (24.5 and 28 gpm per 20 ft, respectively). On the basis of these results, the LGU Tv5$(N)_{LG}$ (fig. 3) was subdivided into two HGU, Tv5-1$(N)_{HG}$ and Tv5-2$(N)_{HG}$, having hydraulic conductivities of 2.6 and 21 ft/day, respectively (fig. 12). Additionally, the contact between LGUs Tv3$(N)_{LG}$ and Tv4$(N)_{LG}$ was lowered from 320 to 350 ft bls for the creation of corresponding HGUs Tv3$(N)_{HG}$ and Tv4$(N)_{HG}$. The wellbore-flow log for well 15N/03E-08L1S (NELT4 #1; fig. 12) was collected using the tracer-pulse method, which collects data from discrete depths in the well; therefore, a continuous wellbore flow profile using an EM flowmeter of the well was not generated, and the precise depth between the tracer-pulse data points where the flow changees is unknown. Consequently, the modeled solution used to simulate 15N/03E-08L1S (NELT4 #1) was non-unique, based on the available data, and the subdivision of Tv5$(N)_{LG}$ was based on observed changes in geologic logs, in addition to observed changes in wellbore flow (fig. 12).

For borehole GOLD1-T (15N/01E-28R4S; fig. 2), the depths to top and bottom of LGUs were unchanged for the corresponding HGUs, except for LGU Tv_vb$(G)_{LG}$ in well 15N/01E-28R4S (GOLD1-T #1; figs. 3, 10). In this well (GOLD1-T #1), the middle screen (300–420 ft) is entirely in LGU Tv_vb$(G)_{LG}$, described as dacite. According to the wellbore-flow test, the distribution of flow is variable in this unit. The upper 60 ft of the middle screen (300–360 ft) produces water at a rate of about 0.01 gpm/ft (1 gpm per 60 ft), whereas the lower 60 ft of the middle screen (360–420 ft) produces water at a rate of about 2.58 gpm/ft (155 gpm per 60 ft). On the basis of these results, the LGU Tv_vb$(G)_{LG}$ was subdivided into two HGUs, Tv_vb-1$(G)_{HG}$ and Tv_vb-2$(G)_{HG}$, having hydraulic conductivities of 0.8 and 16.4 ft/day, respectively (fig. 10).

For borehole 31S/46E-05B1M (SBTW; fig. 2), the depths to top and bottom of geologic units were unchanged for the corresponding HGUs in well 31S/46E-05B1M (SBTW #1; figs. 3, 15). In this well (SBTW #1), upper and lower instances of LGU QToa$(S)_{LG}$ are separated by QTb$(S)_{LG}$, described as basalt. These three LGUs were retained as HGUs. According to the wellbore-flow test, the distribution of flow was variable between the upper and lower QToa$(S)_{HG}$.

Numerical Model Results

Model results provided estimates of aquifer properties near test wells, as constrained by pressure responses (measured drawdown) to pumping stresses. These results also provide some information regarding lateral continuity of HGUs and spatial variability in their hydraulic properties. Four test wells were drilled in Nelson Basin, allowing for comparison of estimated hydraulic properties in various HGUs. In contrast, only one test well was drilled in each of Goldstone and Superior Basins, so such comparisons were not possible for these basins. Hydraulic properties of HGUs, intersected by the borehole but not by a screened interval of a test well, were constrained using slug-test data collected from nearby monitoring wells (where available). In Nelson Basin, efforts were made to maintain consistent hydraulic conductivities in a given HGU between test wells. However, in order to calibrate the simulated wellbore flow and drawdown to the observed wellbore flow and drawdown, hydraulic conductivities in the models were updated and varied considerably between boreholes in some HGUs. For example, all test wells in Nelson Basin—wells 15N/02E-05N1S (NELT6 #1), 15N/03E-08L1S (NELT4 #1), 16N/01E-35P1S (NELT5 #1), and 16N/02E-31H1S (NELT3 #1)—have screened sections open to hydrogeologic unit $Tv3(N)_{HG}$ (figs. 11–14; table 9). Only wells 15N/02E-05N1S (NELT6 #1) and 15N/03E-08L1S (NELT4 #1) were found to have similar calibrated hydraulic properties for this unit (K = 0.25 ft/d), however; the calibrated K values for $Tv3(N)_{HG}$ in wells 16N/01E-35P1S (NELT5 #1) and 16N/02E-31H1S (NELT3 #1) were 0.01 and 33 ft/d, respectively. Heterogeneities, attributed to likely facies changes (lateral and vertical) or secondary permeability features (such as fractures or cementation), are likely present in each geologic or hydrogeologic unit. Attempts were made to minimize the subdivision of HGUs; however, subunits were incorporated where notable heterogeneities were apparent in a given wellbore-flow log.

The transmissivity values estimated from aquifer tests compared well with transmissivity values estimated using the two-dimensional radial flow model, except the results from well 15N/01E-28R4S (GOLD1T #1; fig. 31). The transmissivity value estimated from the aquifer-test data collected at well 15N/01E-28R4S (GOLD1T #1) during pumping was 28,000 ft^2/d using the Cooper-Jacob method; in contrast, the radial flow model estimated the transmissivity at 4,017 ft^2/d. Aquifer-test data from this well (GOLD1T #1) was subsequently re-analyzed using the Hantush (1960) early time solution, yielding a transmissivity of 4,627 ft^2/d (fig. 31). The Hantush early time solution assumes a leaky aquifer and allows for a partially penetrating well. The observed response in this well could be due to increasing permeability in deposits at increasing distance from the well.

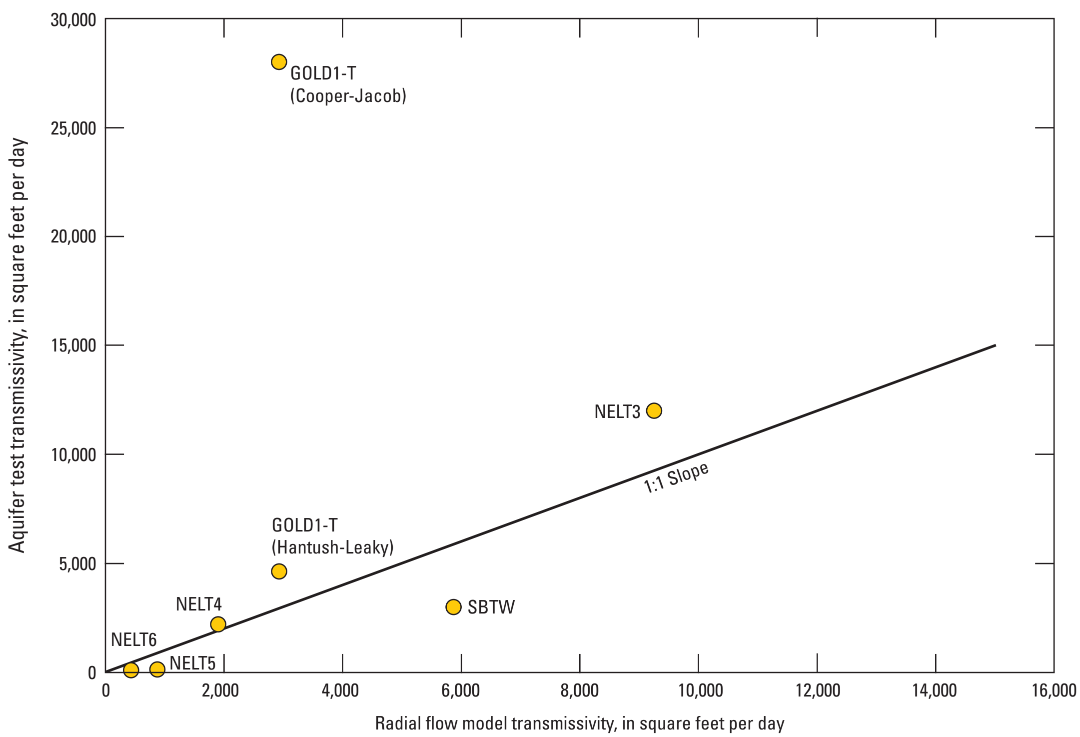


Figure 31. Comparison of calculated transmissivities from radial flow models and aquifer tests, Fort Irwin National Training Center, California.

Numerical Model Limitations

The two-dimensional radial groundwater-flow models developed to simulate wellbore-flow data from long-screened test wells are a simplified representation of the groundwater flow system near the well. The flat-lying, areally extensive aquifer materials simulated in the model domain were intended only to represent a generalized subsurface geology, including the areal extent and hydraulic connections between the materials. Similarly, the simulated water table does not accurately represent regional groundwater flow or interactions between pumping wells. Additionally, the radial flow models are relatively insensitive to zones that are not open to a well screen or intervals where wellbore-flow measurements were not taken, which is the case for much of the length of the well screen when using the tracer-pulse method. In the models, hydrogeologic units are extrapolated out over the entire model domain, even in zones where data are lacking; consequently, spatial variability in aquifer properties may occur. The simplified models do provide a reasonable tool, however, for estimating aquifer properties and evaluating the effects of aquifer heterogeneity on the movement of water in aquifers of the NTC.

Summary and Conclusions

The U.S. Army, Fort Irwin National Training Center (NTC) has relied on groundwater pumped from three developed groundwater basins (Irwin, Langford, and Bicycle Basins) to supply the water for base operations. Extraction of groundwater at the NTC began as early as 1941 in Irwin Basin. Since the 1990s, reduced pumping in the Irwin Basin and artificial recharge by infiltration of wastewater from Irwin, Bicycle, and Langford Basins has caused water levels to stabilize or recover throughout much of the Irwin Basin (Voronin and others, 2013). Water levels have declined in Bicycle and Langford Basins, however, as a result of pumping. Because of an expansion of training and increasing water demands at the NTC, the U.S. Geological Survey, in cooperation with the U.S. Army, studied the water resources, including water quality and potential groundwater supply, of undeveloped groundwater basins at the NTC.

During 2009–12, the U.S. Geological Survey installed 41 wells at the NTC. There were 34 (2-inch diameter) monitoring wells constructed at 14 single- or multiple-well monitoring sites, and 7 long-screen test wells (8-inch diameter) were installed. Hydrologic properties were tested in 32 of the wells during 2012–15 to characterize the aquifer system in 8 basins at the NTC. Cores, cuttings, and geophysical logs, previously collected from the boreholes prior to well installation, were used to aid in analysis of the hydrologic testing. Results and data from these tests, presented in this report, include slug tests and single-well aquifer tests, coupled wellbore-flow measurements and depth-dependent water-quality samples, water-level and water-quality data, and two-dimensional numerical modeling.

Cores collected during drilling from 12 boreholes at depths ranging from 55 to 1,298 feet (ft) below land surface (bls) were tested for vertical saturated hydraulic conductivity, physical properties (including bulk density, volumetric water content, residual saturation, total and effective porosity), and particle size analysis. Vertical saturated hydraulic conductivities (K_v) of the cores from laboratory analyses ranged from less than 0.00001 to 18.13 feet per day (ft/day), and total porosities ranged from 0.15 to 0.56.

Slug tests were carried out at 22 monitoring wells throughout 6 basins (Cronise, Central Corridor area, Goldstone, Langford, Bicycle, and Nelson Basins) to estimate horizontal hydraulic conductivities. The slug tests used a pneumatic method and utilized compressed nitrogen gas as a tool for physical displacement of water in each monitoring well. Horizontal hydraulic conductivities from slug tests ranged from less than 0.1 to 40 ft/day across the six basins tested. Values of hydraulic conductivity were consistent with common soil and rock properties (Halford and Kuniansky, 2002) for the observed lithology adjacent to each screened interval, as recorded during borehole drilling and geophysical logging (Kjos and others, 2014).

Single-well aquifer tests were done at six test wells to estimate hydraulic conductivity and transmissivity in the Goldstone, Nelson, and Superior Basins. For each aquifer test, the well was pumped at a constant rate, drawdown was monitored using a pressure transducer, and discharge was recorded using a sonic flow meter. For all aquifer tests, pumping durations were between roughly 22 and 26 hours, with the exception of well 15N/02E-05N1S (NELT6 #1) which had a pumping duration of 9 hours. The test duration for well NELT6 #1 was limited due to a combination of site conditions (low specific capacity) and timing of military operations. Analysis of drawdown data (and recovery data, where applicable) from each pumped well was performed using a straight-line analytical method developed by Cooper and Jacob (1946). Results of aquifer tests indicate hydraulic conductivities ranged from 0.37 to 66 ft/day with subsequent transmissivity values ranging from 130 to 28,000 square feet per day.

Wellbore-flow data were collected from the six test wells under unpumped and pumped conditions. In general, flow data from the test wells under unpumped conditions show downward movement of water, from the uppermost screens, to lower more productive zones in the aquifer, at rates ranging from about 1 to 3 gallons per minute (gpm). The downward flow indicates a redistribution of shallow aquifer water to lower parts of the system under ambient groundwater conditions. Flow data collected from the six test wells under pumping conditions show increasing flow from shallower to deeper screens in the wells and indicate higher yields from deeper aquifers. In most cases, the test wells yield little to no water from the shallower parts of the screened interval during pumping. These data indicate generally higher hydraulic conductivities at deeper depths and lower hydraulic conductivities at shallower depths.

Water levels were measured periodically between 2011 and 2015 in all available wells and prior to collection of water-quality samples. Water levels have remained stable since 2011 in the majority of monitoring and test wells measured, except at monitoring sites BLA5 (14N/03E-26K1, -26K3, and -26K4) and LL04 (12N/03E-01M1, -01M4, and -01M5). Vertical hydraulic gradients were calculated to determine the direction of vertical groundwater flow in the aquifer system at each of the multiple-well monitoring sites. Vertical head gradients were generally low across the NTC but ranged from –0.0003 between wells 14N/01E-07R1S (GOLD2 #1) and 14N/01E-07R2S (GOLD2 #2) to 0.27 between wells GOLD2 #2, #3, during summer 2015. Multiple-well monitoring sites in Bicycle (BLA5), Central Corridor area (CCT1), Cronise (CRTH1), Goldstone (GOLD2 #2, #3), Nelson (NELT1, NELT2, NELT7), and Superior (SBMW) Basins had downward vertical gradients. All other wells had upward vertical gradients during 2015.

Composite water-quality, or bulk discharge, samples were collected from the surface discharge of pumps in selected single- and multiple-well monitoring sites and test wells. Additional samples were collected at different depths (depth-dependent) in test wells under pumping conditions to determine changes in concentration of select water-quality constituents by depth. Groundwater in sampled wells in Nelson and Superior Basins, and wells 14N/03E-26K1, 3, 4S (BLA5), 15N/03E-25L1–3S (CCT1), and 14N/01E-07R2S (GOLD2 #2) was characterized as sodium-bicarbonate water; whereas from remaining wells in Goldstone Basin, it was characterized as sodium-chloride water, and from wells in Cronise and Langford Basins (CRTH1 and CRTH2, and LL04, respectively) as sodium-sulfate water. Total dissolved solids concentrations ranged from 285 milligrams per liter (mg/L) in groundwater from Superior Basin to 13,400 mg/L in that from Cronise Basin. Chloride concentrations ranged from 19 mg/L in groundwater from Superior and Nelson Basins to 1,030 mg/L in that from Cronise Basin. Nitrate plus nitrite as nitrogen ranged from less than 0.040 mg/L in groundwater from Cronise and Goldstone Basins to about 20 mg/L in that from Nelson Basin. The highest total dissolved solids and chloride concentrations were in groundwater from well CRTH2 #2 in Cronise Basin; the highest nitrate plus nitrite as nitrogen concentrations were in water from well NELT3 #1 in Nelson Basin.

Groundwater samples collected from 35 wells were analyzed for the stable isotopes oxygen-18 and deuterium to help determine the source of water to wells and to evaluate the movement of water through the study area. The isotopic composition of groundwater in these wells plotted below the global meteoric water line, indicating possible evaporation at land surface prior to recharge, partial evaporation of falling raindrops in an arid atmosphere, or a “local” meteoric water line, and isotopic similarity to previously studied groundwater in Irwin, Langford, and Bicycle Basins. The groundwater samples from wells in Nelson Basin were isotopically light, whereas the groundwater samples from wells 13N/05E-28Q1–3S (CRTH1), 13N/03E-08B1–2S (CRTH2), and 12N/03E-01M1, 4, 5S (LL04) were isotopically heavier and plotted along an evaporative trend line.

No measurable tritium was detected in groundwater from 13 wells sampled in 2015. The lack of tritium in these samples indicates that water was recharged prior to 1952. Measured Carbon-14 (^{14}C) activities in groundwater from four wells sampled in 2015 ranged from about 7.87 to 23.49 percent modern carbon. The uncorrected ^{14}C data indicated the groundwater in these four wells had apparent ages of 11,970 to 20,980 years.

Arsenic concentrations were above the maximum contaminant level (MCL) in groundwater in all wells, except those in Goldstone Basin and the two deepest wells in Langford Basin (LL04). The highest arsenic concentrations were in Cronise and Nelson Basins. Fluoride concentrations were above the California MCL in groundwater in most wells, except those in Goldstone and Superior Basins, the middle-depth well in Langford Basin, a middle and deep well at separate locations in Cronise Basin, and in two wells in Nelson Basin.

Wellbore-flow and aquifer-property data, coupled with geologic data, provided a basis for basin-scale hydrogeologic framework and site-specific groundwater modeling efforts. Data collected under pumped conditions were used to estimate the vertical distribution of flow contributions to a well from the surrounding aquifer system. Wellbore flow was simulated for each well by using an integrated flow analysis tool, AnalyzeHOLE, to evaluate aquifer properties and heterogeneity. Horizontal layers in the model (hydrogeologic units, or HGUs) were initially defined by lithostratigraphic-geophysical units (LGUs) based on lithologic and geophysical logs from each well. The saturated hydraulic conductivity (K_h) of each HGU was adjusted so that the simulated wellbore flow and drawdown approximated the measured wellbore flow and calculated drawdown. The K values derived from the calibrated simulations ranged from less than 0.01 to 60 feet per day. In general, LGUs provided good approximations for the boundaries of each HGU. Some LGU boundaries did not correspond to modeled HGUs, however, which may be due to large-scale secondary permeability features such as fracturing or faulting, smaller scale mineralization or cementation, effects of well construction, or potentially gradational changes between units that were modeled as sharp changes in aquifer properties at unit boundaries. Efforts were made to maintain consistent values of K in a given HGU across wells; however, calibrated K values varied considerably in some HGUs between boreholes, representing the potential variability in hydraulic properties within a given LGU. Overall, wellbore flow simulation results correlated well with the interpretations of geologic and geophysical data used to generate the basin-scale hydrogeologic framework.

References Cited

Butler, J.J., Jr., and Garnett, E.J., 2000, Simple procedures for analysis of slug tests in formations of high hydraulic conductivity using spreadsheet and scientific graphics software: Lawrence, Kansas Geological Survey Open-File Report 2000–40, 21 p.

California Department of Water Resources, 2003, Bulletin 118—Statewide groundwater basin map version 3 (October 2003): California Department of Water Resources database, accessed November 03, 2011, at http://www.water.ca.gov/groundwater/bulletin118/gwbasin_maps_descriptions.cfm; Fort Irwin region: http://www.water.ca.gov/groundwater/bulletin118/south_lahontan.cfm. [Printout of this work available in USGS files of senior author.]

California Department of Public Health, 2008a, California drinking water-related laws, Drinking water-related regulations (Title 22). Program transferred to the State Water Resources Control Board in July 2014, accessed August 17, 2015, at http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Lawbook.shtml.

California Department of Public Health, 2008b, Drinking water notification levels: Notification levels. Program transferred to the State Water Resources Control Board in July 2014, accessed August 17, 2015, at http://www.waterboards.ca.gov/drinking_water/certlic.

Clark, D.A., Izbicki, J.A., Metzger, L.F., Everett, R.R., Smith, G.A., O'Leary, D.R., Teague, N.F., Burgess, M.K., 2012, Groundwater data for selected wells within the Eastern San Joaquin Groundwater Subbasin, California, 2003–08: U.S. Geological Survey Data Series 696, 154 p., https://doi.org/10.3133/ds696.

Clark, I.D., and Fritz, P., 1997, Environmental isotopes in hydrogeology: CRC Press/Lewis Publishers, Boca Raton, Fla, 328 p.

Cooper, H.H., and Jacob, C.E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: American Geophysical Union Transactions, v. 27, p. 526–534, https://doi.org/10.1029/TR027i004p00526.

Craig, H., 1961, Isotopic variations in meteoric waters: Science, v. 133, p. 1702–1703.

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 p., http://pubs.usgs.gov/tm/1a1/.

Dane, J.H., and Topp, G.C., eds., 2002, Methods of soil analysis, Part 4—Physical methods: Madison, Wisc., Soil Science Society of America Book Series, v. 5, 1,692 p.

Densmore, J.N., 2003, Simulation of ground-water flow in the Irwin Basin aquifer system, Fort Irwin Training Center, California: U.S. Geological Survey Water-Resources Investigations Report 2002–4264, 69 p., https://doi.org/10.3133/wri024264.

Densmore, J.N., and Londquist, C.J., 1997, Ground-water hydrology and water quality of Irwin Basin at Fort Irwin National Training Center, California: U.S. Geological Survey Water-Resources Investigations Report 97–4092, 159 p., https://doi.org/10.3133/wri974092.

Densmore, J.N., Woolfenden, L.R., Rewis, D.L., Martin, P.M., Sneed, M., Ellett, K.M., Solt, M., and Miller, D.M., 2018, Geohydrology, geochemistry, and numerical simulation of groundwater flow and land subsidence in the Bicycle Basin, Fort Irwin National Training Center, California: U.S. Geological Survey Scientific Investigations Report 2018–5067, 176 p., https://doi.org/10.3133/sir20185067.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, New Jersey, Prentice-Hall Inc., 624 p., http://hydrogeologistswithoutborders.org/wordpress/wp-content/uploads/Freeze_and_Cherry_1979-smaller.pdf.

Gonfiantini, R., 1978, Standards for stable isotope measurements in natural compounds: Nature, v. 271, p. 534–536, https://doi.org/10.1038/271534a0.

Greene, E.A., and Shapiro, A.M., 1995, Methods of conducting air-pressurized slug tests and computation of type curves for estimating transmissivity and storativity: U.S. Geological Survey Open-File Report 95–424, 43 p., https://doi.org/10.3133/ofr95424.

Halford, K.J., 2009, AnalyzeHOLE—An integrated wellbore flow analysis tool: U.S. Geological Survey Techniques and Methods 4–F2, 46 p., https://doi.org/10.3133/tm4F2.

Halford, K.J., and Kuniansky, E.L., 2002, Documentation of spreadsheets for the analysis of aquifer-test and slug-test data: U.S. Geological Survey Open-File Report 2002–197, 54 p., https://doi.org/10.3133/ofr02197.

Halford, K.J., Weight, W.D., and Schreiber, R.P., 2006, Interpretation of transmissivity estimates from single-well pumping aquifer tests: Groundwater, v. 44, no. 3, p. 467–471, https://doi.org/10.1111/j.1745-6584.2005.00151.x.

Hantush, M.S., 1960, Modification of the theory of leaky aquifers: Journal of Geophysical Research, v. 65, no. 11, p. 3713–3725, https://doi.org/10.1029/JZ065i011p03713.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, Modflow-2000, The U.S. Geological Survey modular ground-water model—User guide to modularization concepts and the ground-water flow process: U.S. Geological Survey Open-File Report 2000–92, 121 p., https://doi.org/10.3133/ofr200092.

Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water Supply Paper 2254, 263 p., https://doi.org/10.3133/wsp2254.

Izbicki, J.A., 2004, A small-diameter sample pump for collection of depth-dependent samples from production wells under pumping conditions: U.S. Geological Survey Fact Sheet 2004–3096, 2 p., https://doi.org/10.3133/fs20043096.

Izbicki, J.A., and Michel, R.L., 2003, Movement and age of ground water in the western part of the Mojave Desert, Southern California, USA: U.S. Geological Survey Water-Resources Investigations Report 2003–4314, 35 p., https://doi.org/10.3133/wri034314.

Izbicki, J.A., Martin, P.M., and Michel, R.L., 1995, Source, movement, and age of groundwater in the upper part of the Mojave River Basin, California, U.S.A., *in* Adar, E.M., and Leibundgut, C., eds., Application of tracers in arid zone hydrology: Wallingford, United Kingdom, International Association of Hydrological Sciences Publication no. 232, p. 43–56.

Izbicki, J.A., Christensen, A.H., Hanson, R.T., Martin, P., Crawford, S.M., and Smith, G.A., 1999, U.S. Geological Survey combined well-bore flow and depth-dependent water sampler: U.S. Geological Survey Fact Sheet 196–99, 2 p., https://doi.org/10.3133/fs19699.

Izbicki, J.A., Teague, N.F., Hatzinger, P.B., Bohlke, J.K., and Sturchio, N.C., 2015, Groundwater movement, recharge, and perchlorate occurrence in a faulted alluvial aquifer in California (USA): Hydrogeology Journal, v. 23, no. 3, p. 467–491, https://doi.org/10.1007/s10040-014-1217-y.

Jennings, C.W., Burnett, J.L., and Troxel, B.W., comps., 1962, Geologic map of California—Trona sheet: California Geological Survey, Geologic atlas of California, map no. 023, scale 1:250,000, https://ngmdb.usgs.gov/Prodesc/proddesc_332.htm.

Kalin, R.M., 2000, Radiocarbon dating of groundwater systems *in* Cook, P.G., and Herczeg, A.L., eds., Environmental tracers in subsurface hydrology: Boston, Massachusetts, Springer, p. 111–144, https://doi.org/10.1007/978-1-4615-4557-6_4.

Kjos, A.R., Densmore, J.N., Nawikas, J.M., and Brown, A.A., 2014, Construction, water-level, and water-quality data for multiple-well monitoring sites and test wells, Fort Irwin National Training Center, San Bernardino County, California, 2009–12: U.S. Geological Survey Data Series 788, 139 p., https://doi.org/10.3133/ds788.

Lohman, S.W., 1972, Ground-water hydraulics: U.S. Geological Survey Professional Paper 708, 70 p., https://doi.org/10.3133/pp708.

Lucas, L.L., and Unterweger, M.P., 2000, Comprehensive review and critical evaluation of the half-life of tritium: Journal of Research of the National Institute of Standards and Technology, v. 105, no. 4, p. 541–549, https://doi.org/10.6028/jres.105.043.

Mathany, T.M., Wright, M.T., Beuttel, B.S., and Belitz, K., 2012, Groundwater-quality data in the Borrego Valley, Central Desert, and low-use basins of the Mojave and Sonoran Deserts study unit, 2008–2010—Results from the California GAMA Program: U.S. Geological Survey Data Series 659, 100 p., https://doi.org/10.3133/ds659.

Mendez, G.O., and Christensen, A.H., 1997, Regional water table (1996) and water-level changes in the Mojave River, and Morongo, and Fort Irwin ground-water basins, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations Report 97–4160, 34 p., https://doi.org/10.3133/wri974160.

Michel, R.L., 1976, Tritium inventories of the world oceans and their implications: Nature, v. 263, p. 103–106.

Miller, D.M., Menges, C.M., and Lidke, D.J., 2014, Generalized surficial geologic map of the Fort Irwin area, San Bernardino County, California, chap. B *in* Buesch, D.C., ed., Geology and geophysics applied to groundwater hydrology at Fort Irwin, California: U.S. Geological Survey Open-File Report 2013–1024, 11 p., scale 1:100,000, https://doi.org/10.3133/ofr20131024B.

Mook, W.G., 1980, The dissolution-exchange model for dating of groundwater with 14C., *in* Fritz, P., and Fontes, J.C., eds., Handbook of Environmental Isotopes Geochemistry: Amsterdam, Elsevier, v. 1, p. 50–74.

Newhouse, M.W., Izbicki, J.A., and Smith, G.A., 2005, Comparison of velocity-log data collected using impeller and electromagnetic flowmeters: Groundwater, v. 43, no. 3, p. 434–438, https://doi.org/10.1111/j.1745-6584.2005.0030.x.

Paillet, F.L., 2000, Flow logging in difficult boreholes—Making the best of a bad deal, *in* International Symposium on Borehole Geophysics for Minerals, Geotechnical, and Groundwater Applications, 7th, Denver, Colo., 2000, Proceedings: Houston, The Minerals and Geotechnical Logging Society, a Chapter at Large of the Society of Professional Well Log Analysts, p. 125–135.

Piper, A.M., 1944, A graphic procedure in the geochemical interpretation of water analyses: American Geophysical Union, v. 25, no. 6, p. 914–928, https://doi.org/10.1029/TR025i006p00914.

Révész, K., and Coplen, T.B., 2008a, Determination of the δ(^{2}H/^{1}H) of water—RSIL lab code 1574: U.S. Geological Survey Techniques and Methods 10–C1, 27 p., https://doi.org/10.3133/tm10C1.

Révész, K., and Coplen, T.B., 2008b, Determination of the δ(^{18}O/^{16}O) of water—RSIL lab code 489: U.S. Geological Survey Techniques and Methods 10–C2, 28 p., https://doi.org/10.3133/tm10C2.

Sabin, A.E., 1994, Geology of the Eagle Crags volcanic field, northern Mojave Desert, China Lake Naval Air Weapons Station, California: Golden, Colorado, Colorado School of Mines, Ph.D. Thesis, 209 p., https://dspace.library.colostate.edu/handle/11124/170512.

Schermer, E.R., Luyendyk, B.P., and Cisowski, S., 1996, Late Cenozoic structure and tectonics of the northern Mojave Desert: Tectonics, v. 15, no. 5, p. 905–932, https://doi.org/10.1029/96TC00131.

Thatcher, L.L., Janzer, V.J., and Edwards, K.W., 1977, Methods for determination of radioactive substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations 05–A5, 95 p., https://doi.org/10.3133/twri05A5.

Theis, C.V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: American Geophysical Union, v. 16, no. 2, p. 519–524, https://doi.org/10.1029/TR016i002p00519.

U.S. Environmental Protection Agency, 2002, Drinking water contaminants—Standards and regulations: U.S. Environmental Protection Agency, accessed September 3, 2002, at http://www.epa.gov/safewater/standards.html.

U.S. Environmental Protection Agency, 2013, Drinking water contaminants—Standards and regulations: U.S. Environmental Protection Agency, accessed May 3, 2013, at http://www.epa.gov/safewater/contaminants/index.html.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1–A9, http://pubs.water.usgs.gov/twri9A.

Voronin, L.M., Densmore, J.N., Martin, P., Brush, C.F., Carlson, C.S., and Miller, D.M., 2013, Geohydrology, geochemistry, and groundwater simulation (1992–2011) and analysis of potential water-supply management options, 2010–60, of the Langford Basin, California: U.S. Geological Survey Scientific Investigations Report 2013–5101, 86 p., https://doi.org/10.3133/sir20135101.

Western Region Climate Center, 2009, Goldstone ECHO 2, California (043498) Period of record monthly climate summary—Period of record December 01, 1973, to July 31, 2006: Western Region Climate Center database, accessed September 27, 2012, at http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca3498.

Young, S.C, and Pearson, H.S., 1995, The electromagnetic borehole flowmeter—Description and application: Groundwater Monitoring and Remediation, v. 15, no. 4, p. 138–147, https://doi.org/10.1111/j.1745-6592.1995.tb00561.x.

Appendix 1. Physical Properties of Cores

Table 1–1. Particle-size distribution for sampled intervals of cores from monitoring and test wells, Fort Irwin National Training Center, California, 2011–15.

[ft, foot; ID, identification; m, meter; mm, millimeter; SSC, total percent of sand, silt, and clay (minus the gravels); %, percent; <, less than; >, greater than]

Sample ID	Depth (ft)	Depth (m)	Particle-size distribution				<2 mm percentages			Cumulative percent passing (particle diameter in microns)										
			Gravel %	Sand %	Silt %	Clay %	Sand	Silt	Clay	19000	9500	4750	2000	1000	500	250	125	53	2	0
NELT1-1C-2	200.0	61.0	52	34	9	5	70	19	11	88	76	66	48	36	27	21	17	15	5	0
NELT1-3C-2	800.0	243.8	44	39	9	7	70	17	13	93	84	75	56	46	36	27	20	16	7	0
NELT2-1C-3	200.0	61.0	11	82	5	2	92	5	3	100	100	98	89	67	42	11	11	7	2	0
NELT2-2C-2	400.0	121.9	6	40	44	10	43	47	10	100	100	99	94	91	86	79	69	54	10	0
NELT3-1C-3	260.0	79.2	21	70	6	2	89	8	3	100	99	95	79	63	45	26	15	9	2	0
NELT3-2C-2	460.0	140.2	92	6	1	1	83	9	8	33	16	11	8	6	4	3	2	1	1	0
NELT3-3C-2	660.0	201.2	17	61	17	5	73	21	6	100	99	95	83	73	63	53	37	22	5	0
NELT4-1C-2	200.0	61.0	6	61	27	6	65	29	6	100	97	96	94	93	91	86	64	33	6	0
GOLD1-1C-2	200.0	61.0	33	50	12	4	75	18	6	100	98	89	67	57	46	34	23	17	4	0
GOLD1-2C-2	500.0	152.4	34	57	7	2	86	11	4	97	93	82	66	53	38	25	15	9	2	0
CCT1-2C-2	300.0	91.4	2	72	21	5	74	21	5	100	100	100	98	95	86	69	39	26	5	0
BLA5-13C-3	55.0	16.8	0	14	59	26	14	59	26	100	100	100	100	99	99	98	95	86	26	0
CRTH1-1C-3	380.0	115.8	0	7	61	32	7	61	32	100	100	100	100	100	99	98	97	93	32	0
CRTH1-2C-3	600.0	182.9	0	13	57	30	13	57	30	100	100	100	100	100	99	98	96	87	30	0
NELT1-2C-2	420.0	128.0	42	44	7	7	76	12	12	99	89	77	58	46	33	23	17	14	7	0
NELT6-2C-2	560.0	170.7	63	30	3	4	80	9	10	81	65	53	37	28	20	15	10	7	4	0
CCT1-1C-3	200.0	61.0	3	86	6	4	89	6	4	100	100	99	97	76	54	41	19	10	4	0
CCT1-3C-3	500.0	152.4	7	67	20	6	72	22	6	100	99	98	93	87	75	41	29	26	6	0
CRTH1-3C-2	860.0	262.1	1	41	49	8	42	50	8	100	100	99	99	98	96	86	70	57	8	0
CRTH1-4C-3	1,298.0	395.6	1	65	25	10	65	25	10	100	100	100	99	99	98	87	60	34	10	0
CRTH2-1C-3	100.0	30.5	32	56	6	6	82	10	9	100	96	86	68	58	48	30	16	12	6	0
NELT4-2C-2	500.0	152.4	65	30	4	1	86	10	4	77	62	49	35	25	18	14	9	5	1	0
NELT6-1C-2	280.0	85.3	35	46	8	10	72	13	15	98	91	82	65	49	38	29	22	18	10	0
NELT6-3C-2	900.0	274.3	55	36	7	2	81	15	4	69	62	54	45	38	30	22	14	9	2	0
NELT7-1C-2	280.0	85.3	3	75	15	7	77	15	8	100	100	99	97	77	65	56	37	22	7	0
NELT7-2C-2	520.0	158.5	1	61	17	22	61	17	22	100	100	100	99	96	89	72	50	39	22	0
GOLD2-1C-2	100.0	30.5	50	43	4	3	87	8	5	95	84	70	50	33	33	23	13	7	3	0
GOLD2-2C-2	219.0	66.8	23	59	11	7	77	14	9	97	91	87	77	66	49	34	24	18	7	0

Table 1–1. Particle-size distribution for sampled intervals of cores from monitoring and test wells, Fort Irwin National Training Center, California, 2011–15.—Continued

[ft, foot; ID, identification; m, meter; mm, millimeter; SSC, total percent of sand, silt, and clay (minus the gravels); %, percent; <, less than; >, greater than]

Sample ID	Percent retained											
	>19 mm	9500 microns	4750 microns	2000 microns	1000 microns	500 microns	250 microns	125 microns	53 microns	2 microns	<2 microns	TOTAL
NELT1-1C-2	12	13	9	18	12	10	6	4	2	9	5	100
NELT1-3C-2	7	9	9	19	10	10	9	7	4	9	7	100
NELT2-1C-3	0	0	1	9	23	25	31	0	4	5	2	100
NELT2-2C-2	0	0	0	5	3	5	7	10	15	44	10	100
NELT3-1C-3	0	1	4	17	16	18	18	12	6	6	2	100
NELT3-2C-2	67	17	6	3	2	1	1	1	1	1	1	100
NELT3-3C-2	0	1	3	12	11	9	10	16	14	17	5	100
NELT4-1C-2	0	3	1	2	1	2	4	23	31	27	6	100
GOLD1-1C-2	0	2	9	23	10	10	12	12	6	12	4	100
GOLD1-2C-2	3	4	10	16	12	15	14	10	6	7	2	100
CCT1-2C-2	0	0	0	2	2	10	16	31	13	21	5	100
BLA5-13C-3	0	0	0	0	0	0	1	3	9	59	26	100
CRTH1-1C-3	0	0	0	0	0	1	1	1	4	61	32	100
CRTH1-2C-3	0	0	0	0	0	1	1	2	9	57	30	100
NELT1-2C-2	1	10	12	20	12	13	10	6	3	7	7	100
NELT6-2C-2	19	17	11	16	9	7	6	5	3	3	4	100
CCT1-1C-3	0	0	1	3	21	22	13	22	9	6	4	100
CCT1-3C-3	0	1	2	5	6	12	33	12	3	20	6	100
CRTH1-3C-2	0	0	1	0	1	3	9	16	13	49	8	100
CRTH1-4C-3	0	0	0	1	0	1	11	27	25	25	10	100
CRTH2-1C-3	0	4	10	18	10	11	18	13	4	6	6	100
NELT4-2C-2	23	15	13	15	10	6	5	5	4	4	1	100
NELT6-1C-2	2	6	9	17	15	12	9	7	4	8	10	100
NELT6-3C-2	31	7	8	10	7	7	8	8	6	7	2	100
NELT7-1C-2	0	0	1	3	20	12	9	19	15	15	7	100
NELT7-2C-2	0	0	0	1	3	6	17	23	11	17	22	100
GOLD2-1C-2	5	11	14	20	17	-0	11	9	7	4	3	100
GOLD2-2C-2	3	6	4	10	11	16	15	10	6	11	7	100

Table 1–1. Particle-size distribution for sampled intervals of cores from monitoring and test wells, Fort Irwin National Training Center, California, 2011–15.—Continued

[ft, foot; ID, identification; m, meter; mm, millimeter; SSC, total percent of sand, silt, and clay (minus the gravels); %, percent; <, less than; >, greater than]

Sample ID	Sand fraction percentages (mm)					Gravel fraction percentages			
	1.0–2.0	0.50–1.0	0.25–0.50	0.125–0.25	0.053–0.125	>19 mm	9.5–19.0	4.75–9.5	2.0–4.75
NELT1-1C-2	36	28	18	11	7	12	13	9	18
NELT1-3C-2	25	25	22	18	10	7	9	9	19
NELT2-1C-3	28	30	38	0	5	0	0	1	9
NELT2-2C-2	8	12	16	25	38	0	0	0	5
NELT3-1C-3	22	26	26	17	9	0	1	4	17
NELT3-2C-2	30	23	20	16	11	67	17	6	3
NELT3-3C-2	17	15	17	27	23	0	1	3	12
NELT4-1C-2	2	3	7	37	51	0	3	1	2
GOLD1-1C-2	20	21	24	23	13	0	2	9	23
GOLD1-2C-2	22	27	24	17	10	3	4	10	16
CCT1-2C-2	3	14	23	43	18	0	0	0	2
BLA5-13C-3	3	3	6	24	65	0	0	0	0
CRTH1-1C-3	0	9	12	17	62	0	0	0	0
CRTH1-2C-3	4	5	5	18	68	0	0	0	0
NELT1-2C-2	27	29	22	13	8	1	10	12	20
NELT6-2C-2	31	25	19	15	10	19	17	11	16
CCT1-1C-3	24	25	15	25	10	0	0	1	3
CCT1-3C-3	8	18	50	18	5	0	1	2	5
CRTH1-3C-2	1	6	23	38	31	0	0	1	0
CRTH1-4C-3	0	2	16	42	39	0	0	0	1
CRTH2-1C-3	17	19	33	24	7	0	4	10	18
NELT4-2C-2	34	21	16	15	14	23	15	13	15
NELT6-1C-2	33	25	19	14	9	2	6	9	17
NELT6-3C-2	19	21	22	22	16	31	7	8	10
NELT7-1C-2	27	16	12	25	20	0	0	1	3
NELT7-2C-2	6	11	29	37	18	0	0	0	1
GOLD2-1C-2	39	-1	25	22	16	5	11	14	20
GOLD2-2C-2	19	28	26	16	10	3	6	4	10

Table 1–2. Physical properties data for sampled intervals of cores from monitoring and test wells, Fort Irwin National Training Center, California, 2011–15.

[g/cm³, gram per cubic meter; ft, foot; ID, identification; m, meter; m³/m³, unitless; NA, not applicable; RH, relative humidity; —, not available]

Sample ID	Depth (ft)	Depth (m)	Bulk density (g/cm³)	Porosity (m³/m³)	Volumetric water content (m³/m³)	Saturation (-)	Residual water content (m³/m³)	Effective porosity (m³/m³)	Effective saturation (-)	Comments
GOLD1-1C-2	200.0	61.0	1.61	0.40	0.35	0.88	0.07	0.33	0.86	—
GOLD1-2C-2	500.0	152.4	1.89	0.33	0.32	0.97	0.11	0.22	0.95	—
NELT2-1C-3	200.0	61.0	1.59	0.39	0.37	0.95	0.02	0.36	0.95	—
NELT2-2C-2	400.0	121.9	1.04	0.56	0.47	0.85	0.04	0.52	0.84	—
NELT3-1C-3	260.0	79.2	1.71	0.33	0.32	0.97	0.03	0.31	0.97	—
NELT3-2C-2	460.0	140.2	1.53	0.40	0.39	0.97	0.02	0.38	0.96	—
NELT3-3C-2	660.0	201.2	1.74	0.31	0.30	0.98	0.02	0.29	0.98	—
CRTH1-1C-3	380.0	115.8	1.41	0.49	0.45	0.92	—	—	—	RH oven broken.
CRTH1-2C-3	600.0	182.9	1.71	0.39	0.34	0.87	—	—	—	RH oven broken.
CRTH1-3C-2	860.0	262.1	1.95	0.32	0.27	0.85	—	—	—	RH oven broken.
CRTH1-4C-3	1,298.0	395.6	1.89	0.27	0.25	0.92	—	—	—	RH oven broken.
NELT1-1C-2	200.0	61.0	1.93	0.29	0.26	0.89	—	—	—	RH oven broken.
NELT1-2C-2	420.0	128.0	1.79	0.32	0.28	0.88	—	—	—	RH oven broken.
NELT1-3C-2	800.0	243.8	1.89	0.29	0.20	0.69	—	—	—	RH oven broken.
CRTH2-1C-3	100.0	30.5	1.70	0.36	0.36	0.98	—	—	—	RH oven broken.
BLA5-13C-3	55.0	16.8	1.37	0.50	0.41	0.83	—	—	—	RH oven broken.
CCT1-1C-3	200.0	61.0	1.62	0.39	0.35	0.91	—	—	—	RH oven broken.
CCT1-2C-2	300.0	91.4	1.70	0.36	0.30	0.85	—	—	—	RH oven broken.
CCT1-3C-2	500.0	152.4	1.62	0.38	0.29	0.77	—	—	—	RH oven broken.
NELT4-1C-2	200.0	61.0	1.52	0.41	0.40	0.97	—	—	—	RH oven broken.
NELT6-2C-2	560.0	170.7	1.97	0.28	0.20	0.70	—	—	—	RH oven broken.
NELT6-3C-2	900.0	274.3	1.94	0.28	0.24	0.84	—	—	—	RH oven broken.
NELT4-2C-2	500.0	152.4	2.15	0.30	0.25	0.83	NA	NA	NA	—
NELT6-1C-2	280.0	85.3	1.95	0.32	0.29	0.92	NA	NA	NA	—
NELT7-1C-2	280.0	85.3	1.80	0.37	0.33	0.90	NA	NA	NA	—
NELT7-2C-2	520.0	158.5	1.87	0.37	0.33	0.90	0.07	0.30	0.87	—
GOLD2-1C-2	100.0	30.5	1.88	0.31	0.21	0.66	0.05	0.26	0.58	—
GOLD2-2C-2	220.0	67.1	1.41	0.41	0.30	0.74	0.11	0.30	0.64	—
GOLD2-3C-2	400.0	121.9	2.39	0.15	0.08	0.55	0.05	0.10	0.33	Not able to remove core sample from sleeve.

Appendix 2. Slug-Test Hydrographs

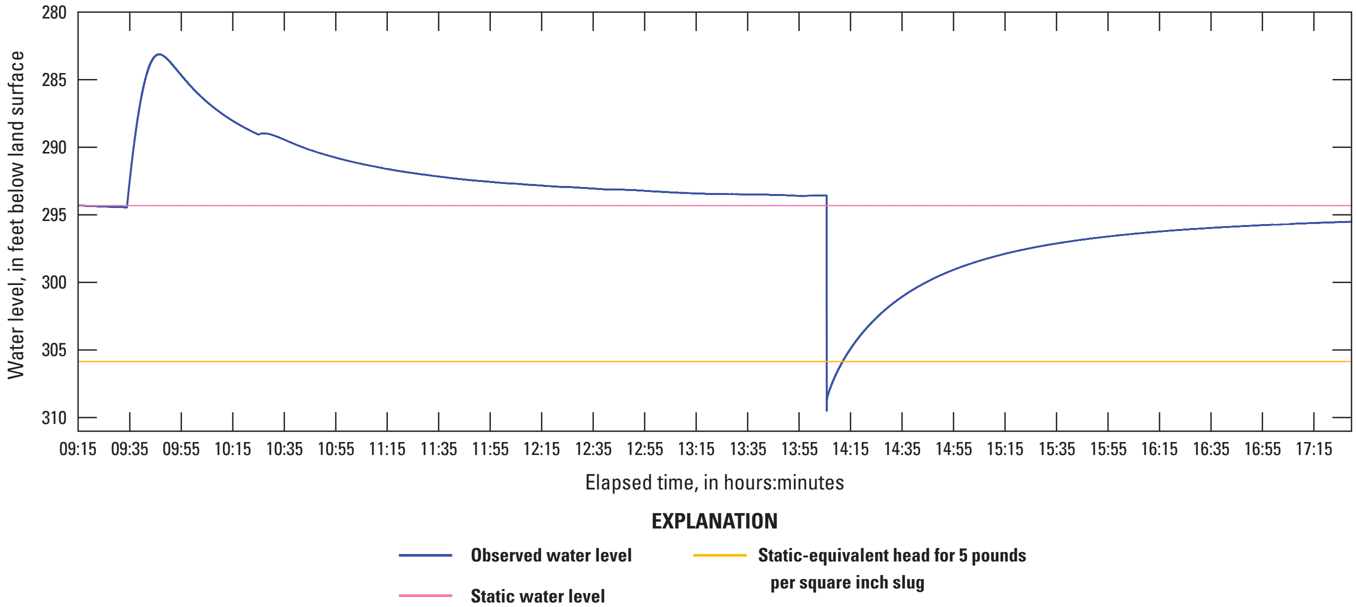


Figure 2–1. Slug-test water-level hydrograph for test well LL04 #1 (12N/03E-01M1S) for 20-foot interval of well casing (950–970 feet below land surface), Fort Irwin National Training Center, California, October 2011.

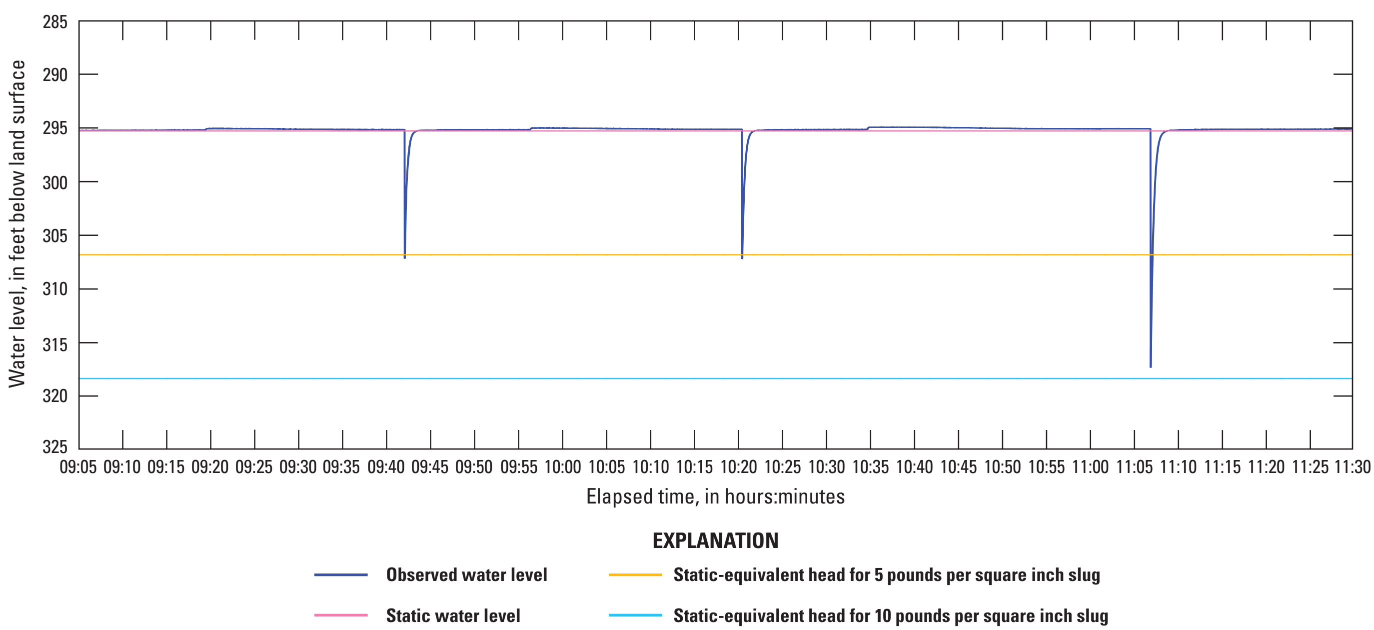
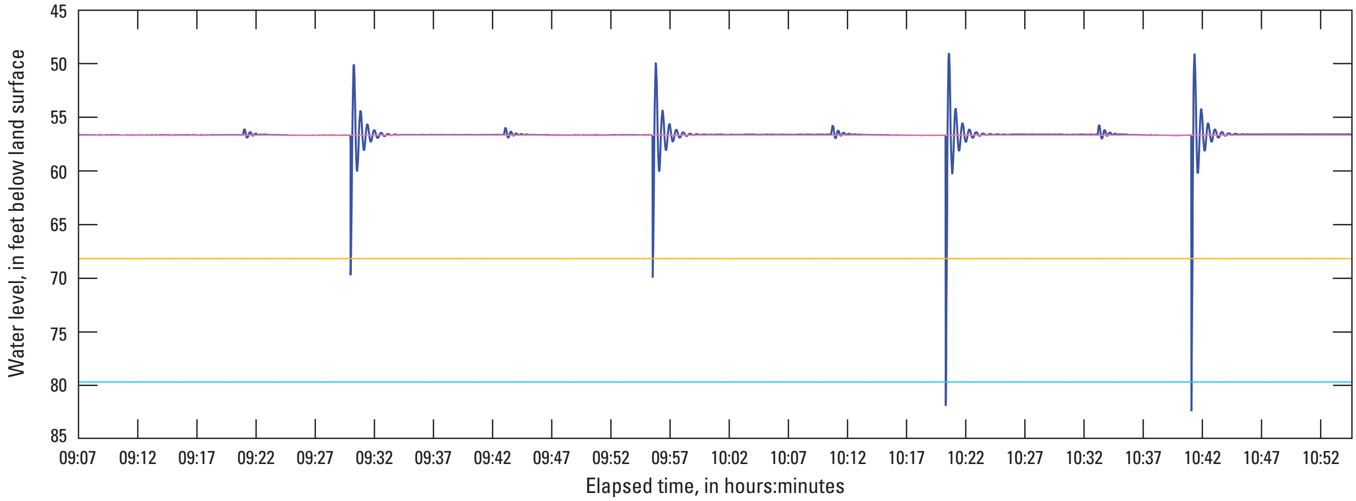


Figure 2–2. Slug-test water-level hydrograph for test well LL04B #1 (12N/03E-01M4S) for 20-foot interval of well casing (470–490 feet below land surface), Fort Irwin National Training Center, California, November 2011.



EXPLANATION

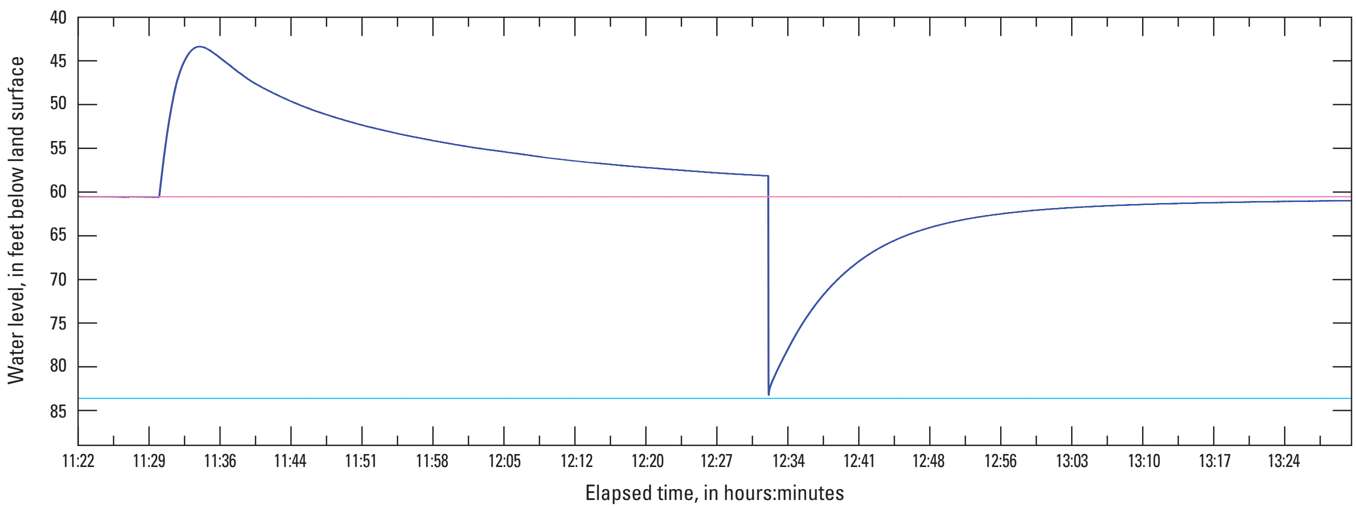
Observed water level

Static water level

Static-equivalent head for 5 pounds per square inch slug

Static-equivalent head for 10 pounds per square inch slug

Figure 2–3. Slug-test water-level hydrograph for test well CRTH2 #1 (13N/05E-08B1S) for 20-foot interval of well casing (920–940 feet below land surface), Fort Irwin National Training Center, California, March 2012.



EXPLANATION

Observed water level

Static water level

Static-equivalent head for 10 pounds per square inch slug

Figure 2–4. Slug-test water-level hydrograph for test well CRTH2 #2 (13N/05E-08B2S) for 20-foot interval of well casing (270–290 feet below land surface), Fort Irwin National Training Center, California, March 2012.

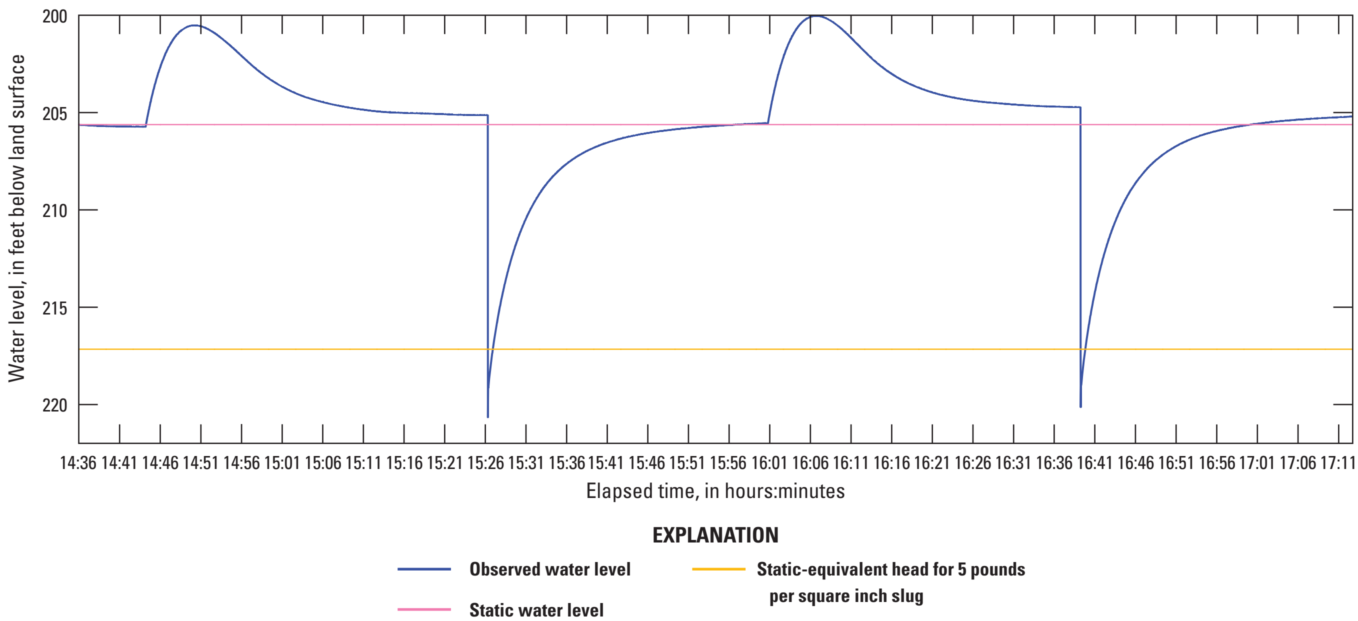


Figure 2–5. Slug-test water-level hydrograph for test well CRTH1 #1 (13N/05E-28Q1S) for 20-foot interval of well casing (1,240–1,260 feet below land surface), Fort Irwin National Training Center, California, March 2012.

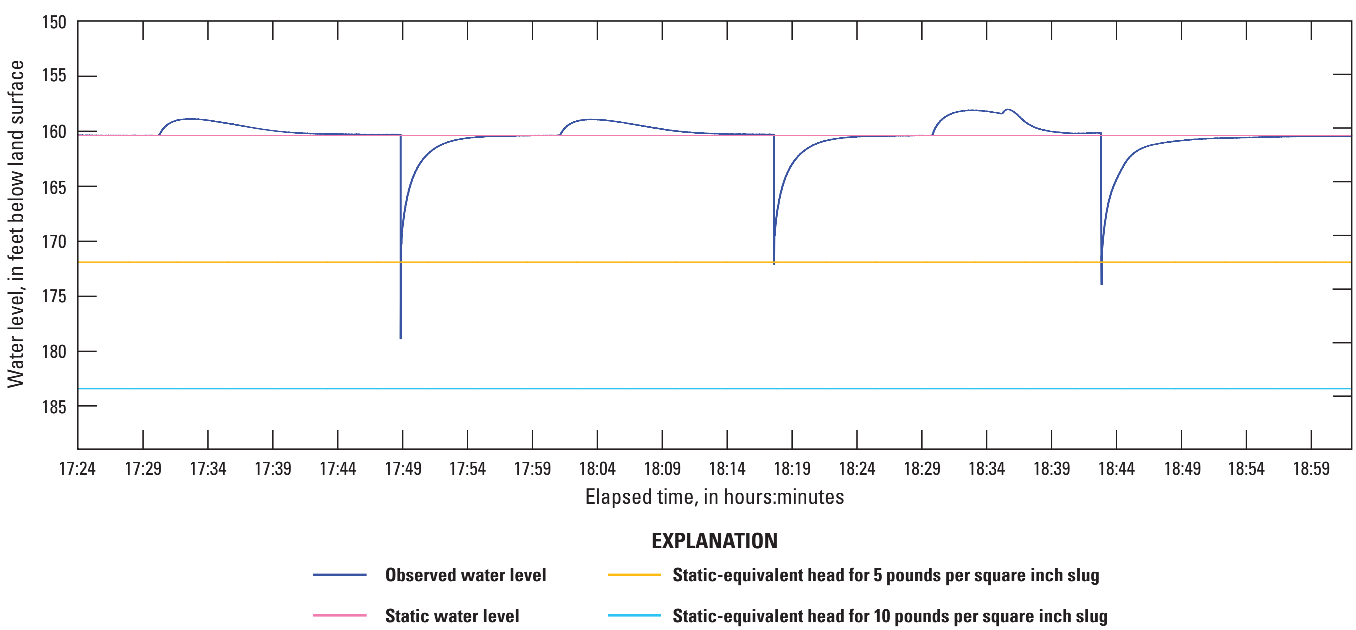


Figure 2–6. Slug-test water-level hydrograph for test well CRTH1 #3 (13N/05E-28Q3S) for 40-foot interval of well casing (175–195 and 235–255 feet below land surface), Fort Irwin National Training Center, California, March 2012.

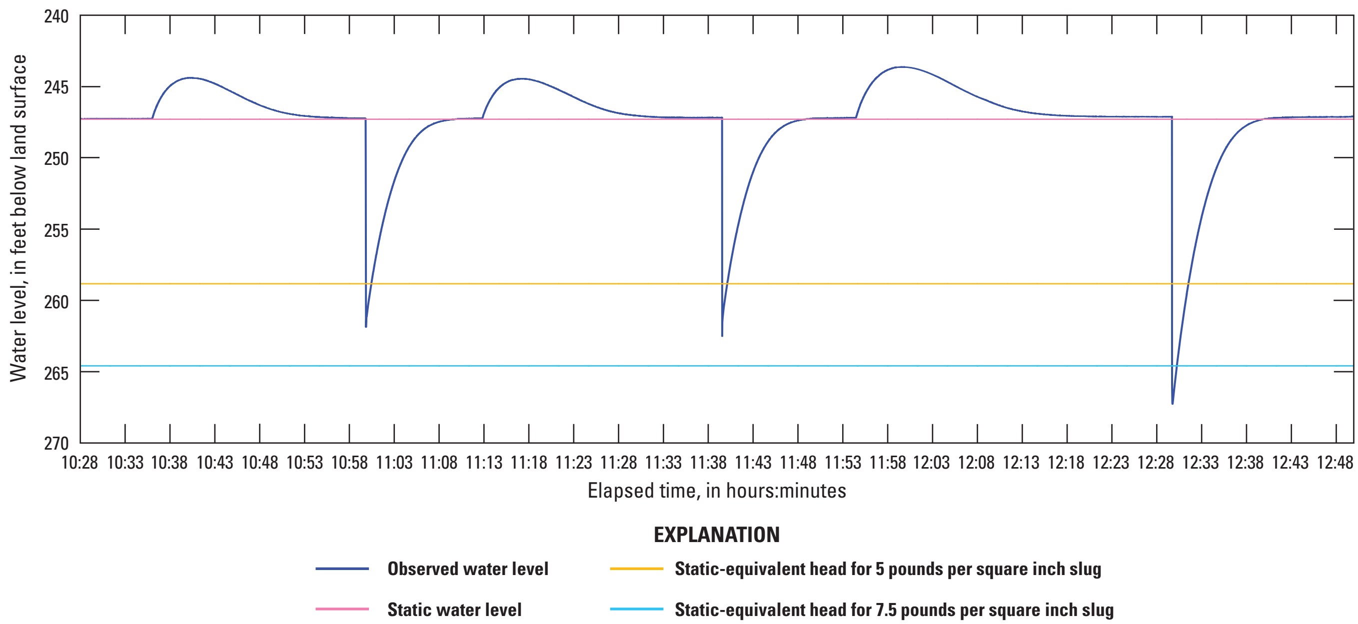


Figure 2–7. Slug-test water-level hydrograph for test well GOLD2 #1 (14N/01E-07R1S) for 20-foot interval of well casing (420–440 feet below land surface), Fort Irwin National Training Center, California, March 2012.

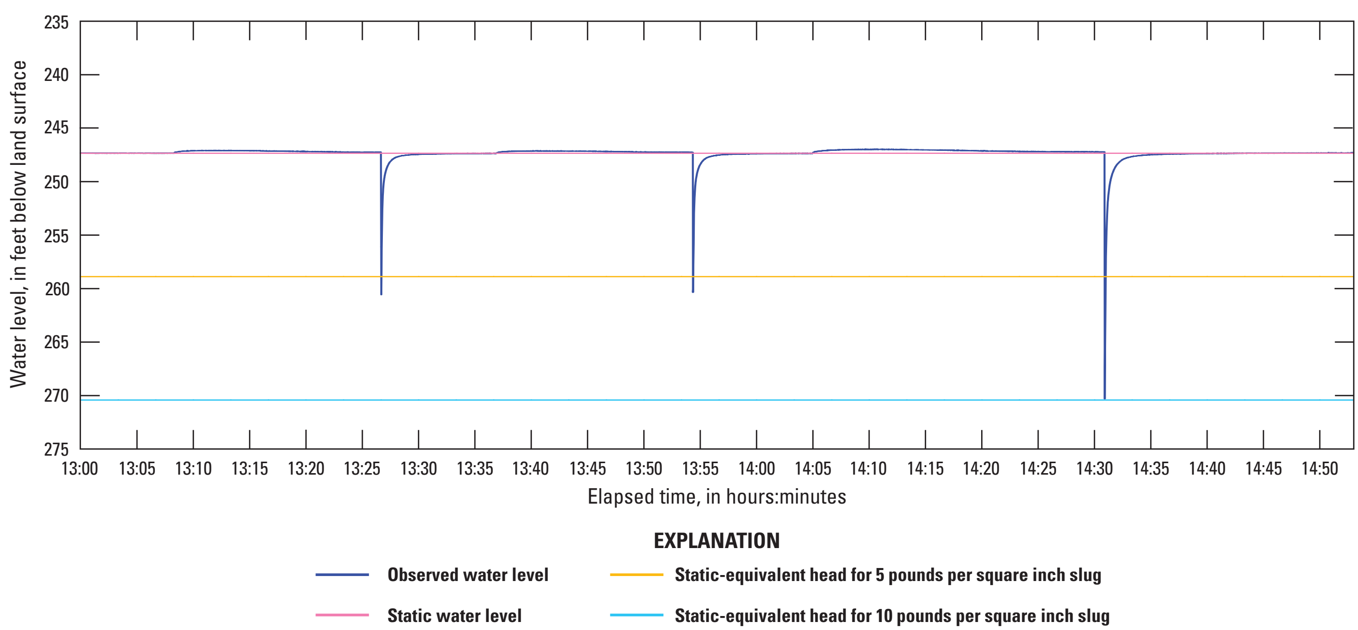


Figure 2–8. Slug-test water-level hydrograph for test well GOLD2 #2 (14N/01E-07R2S) for 20-foot interval of well casing (330–350 feet below land surface), Fort Irwin National Training Center, California, March 2012.

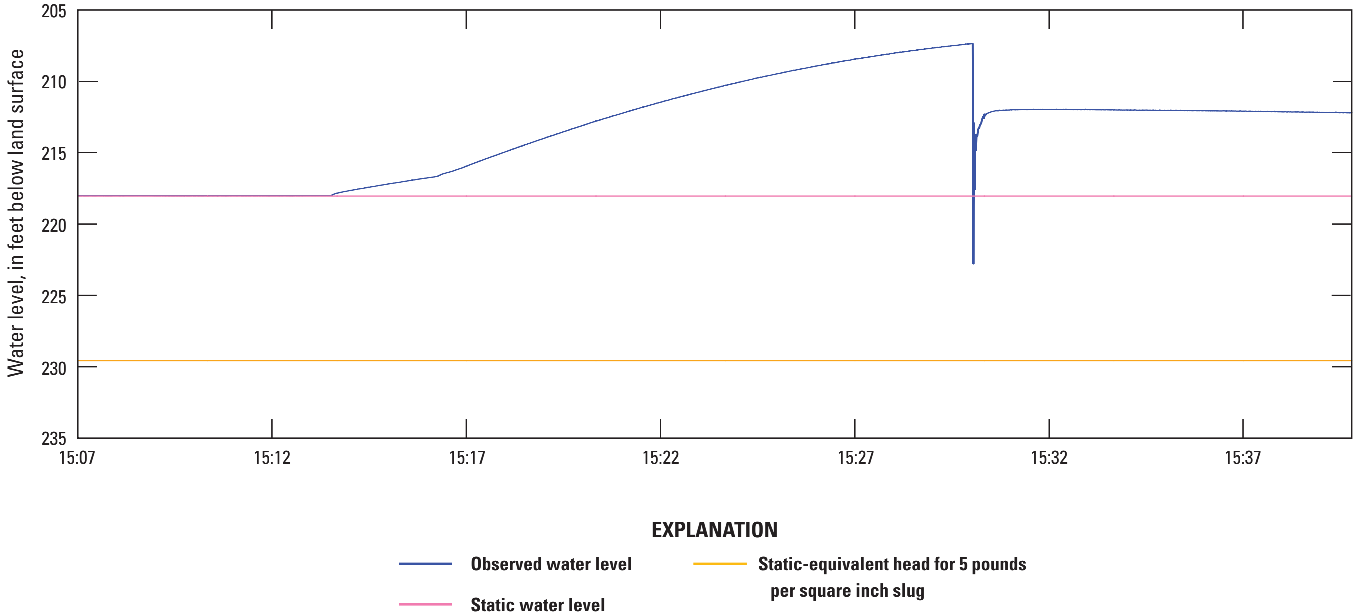


Figure 2–9. Slug-test water-level hydrograph for test well GOLD2 #3 (14N/01E-07R3S) for 20-foot interval of well casing (220–240 feet below land surface), Fort Irwin National Training Center, California, March 2012.

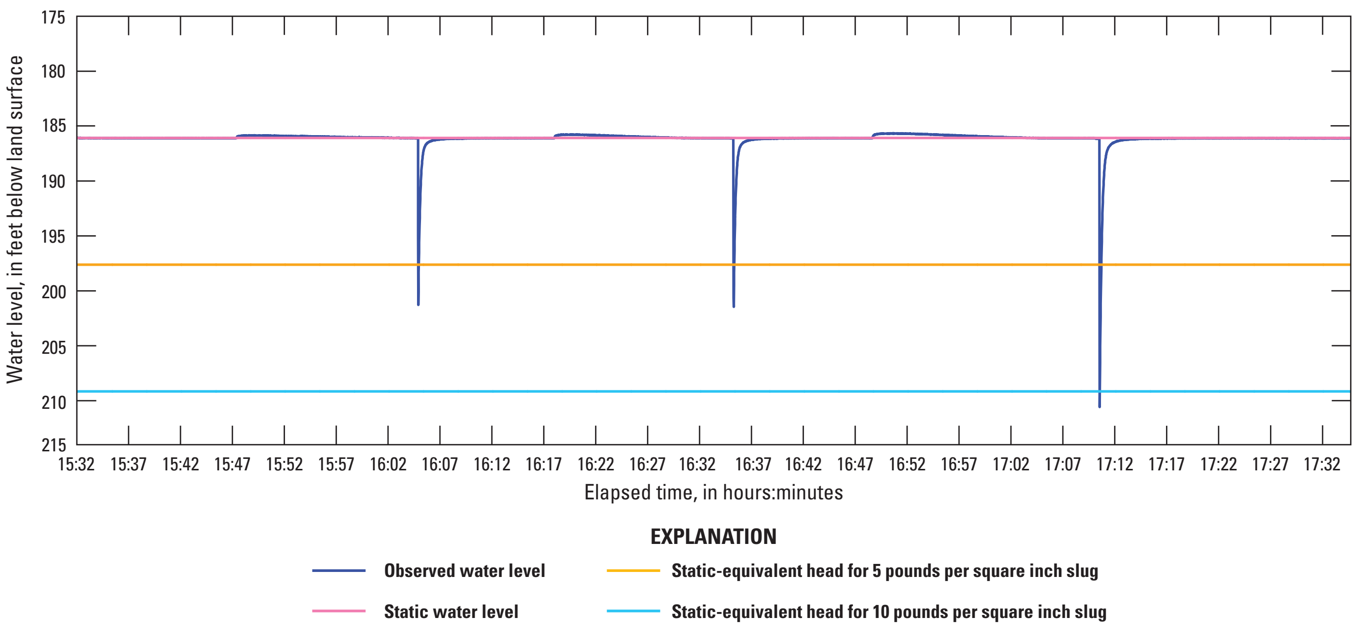


Figure 2–10. Slug-test water-level hydrograph for test well BLA5 #1 (14N/03E-26K1S) for 20-foot interval of well casing (320–340 feet below land surface), Fort Irwin National Training Center, California, October 2011.

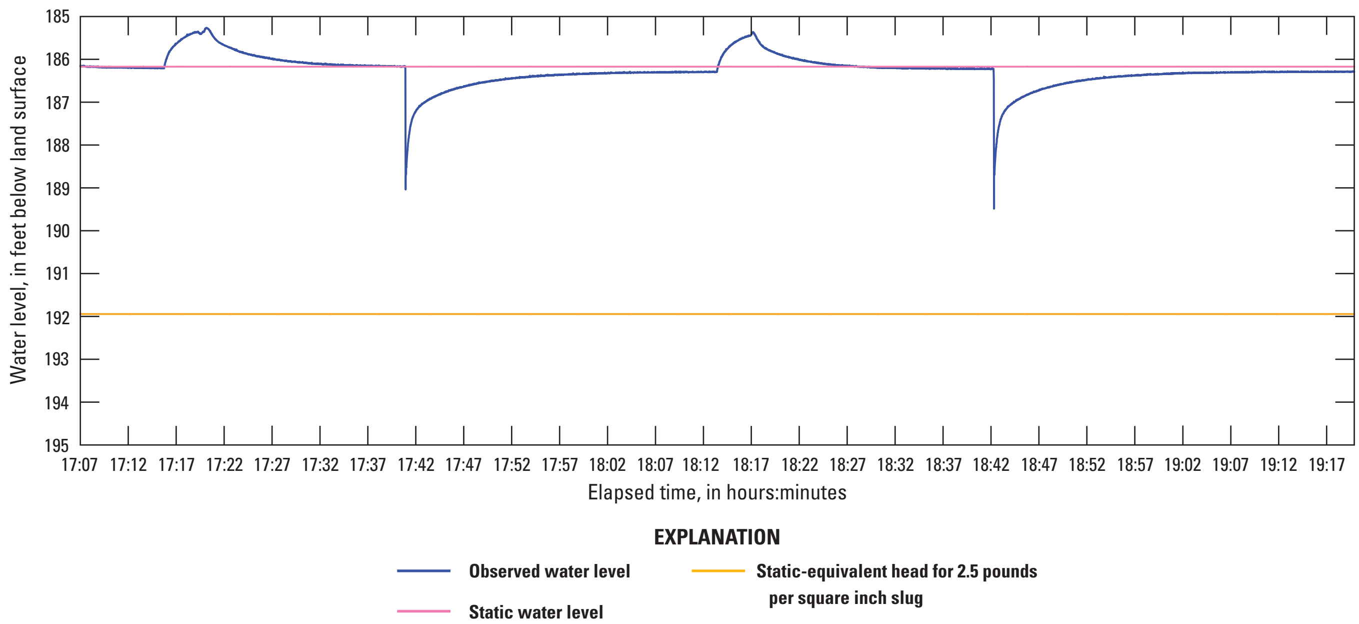


Figure 2–11. Slug-test water-level hydrograph for test well BLA5 #3 (14N/03E-26K3S) for 20-foot interval of well casing (190–210 feet below land surface), Fort Irwin National Training Center, California, October 2011.

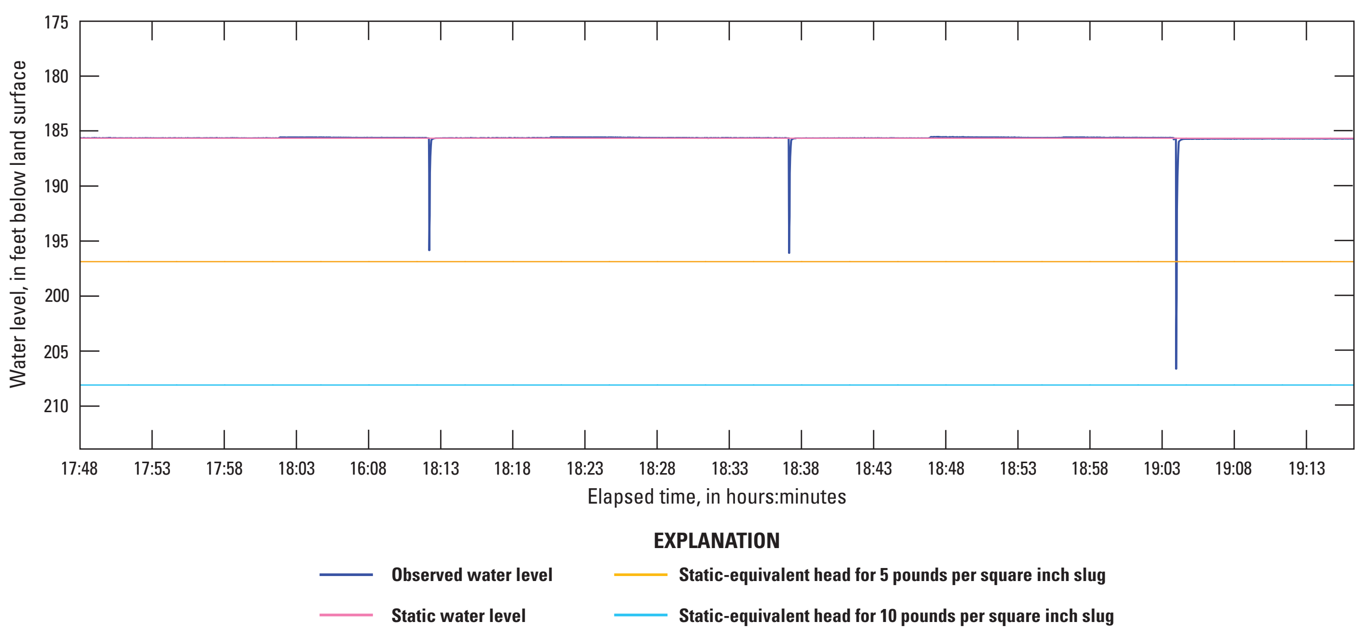


Figure 2–12. Slug-test water-level hydrograph for test well BLA5-B #1 (14N/03E-26K4S) for 20-foot interval of well casing (250–270 feet below land surface), Fort Irwin National Training Center, California, October 2011.

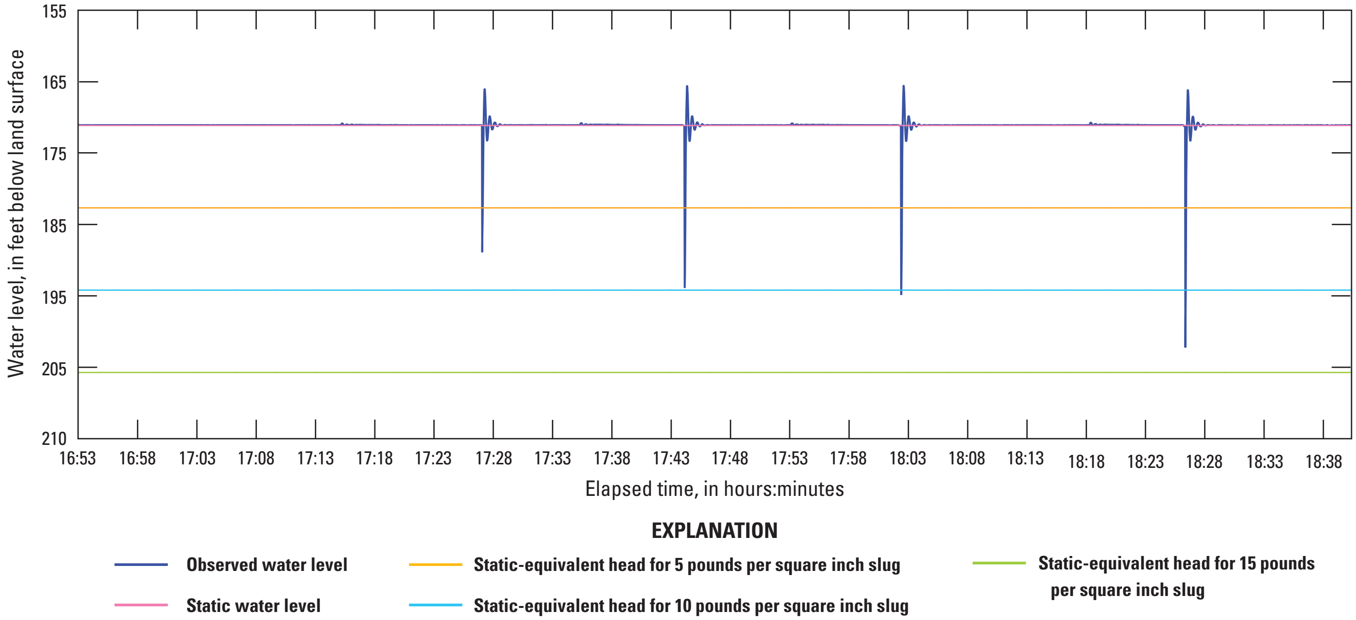


Figure 2–13. Slug-test water-level hydrograph for test well GOLD1 #1 (15N/01E-28R1S) for 20-foot interval of well casing (650–670 feet below land surface), Fort Irwin National Training Center, California, October 2011.

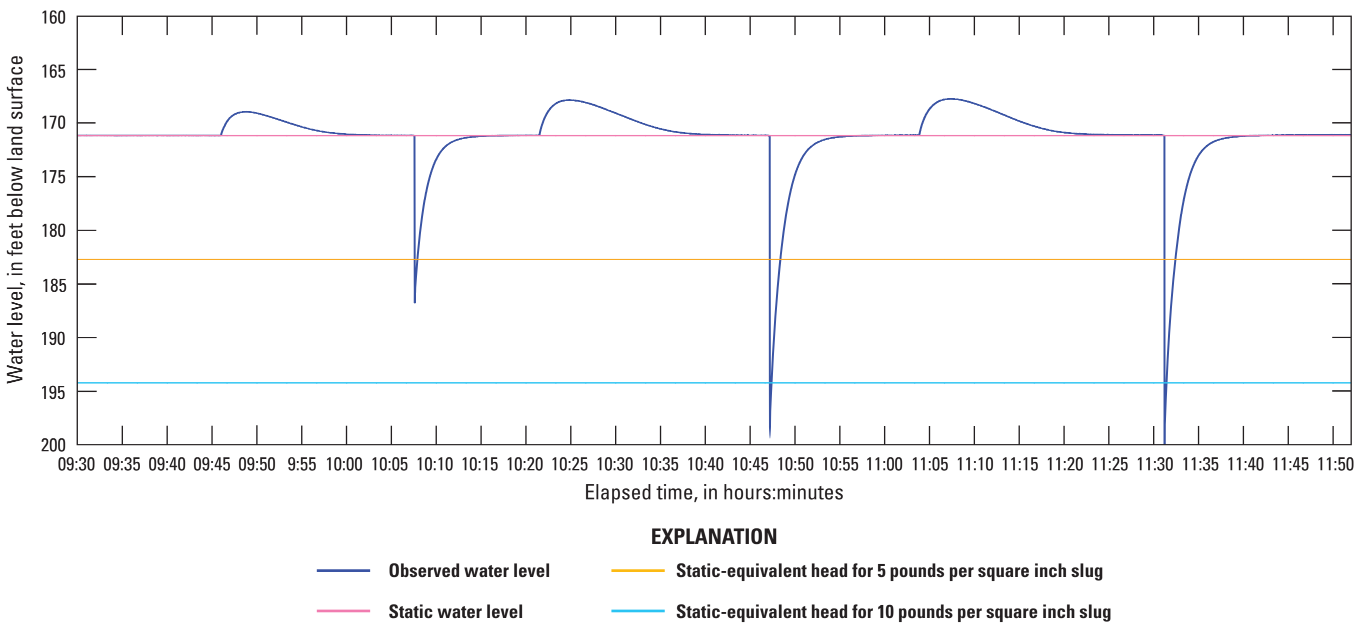


Figure 2–14. Slug-test water-level hydrograph for test well GOLD1 #2 (15N/01E-28R2S) for 20-foot interval of well casing (560–580 feet below land surface), Fort Irwin National Training Center, California, October 2011.

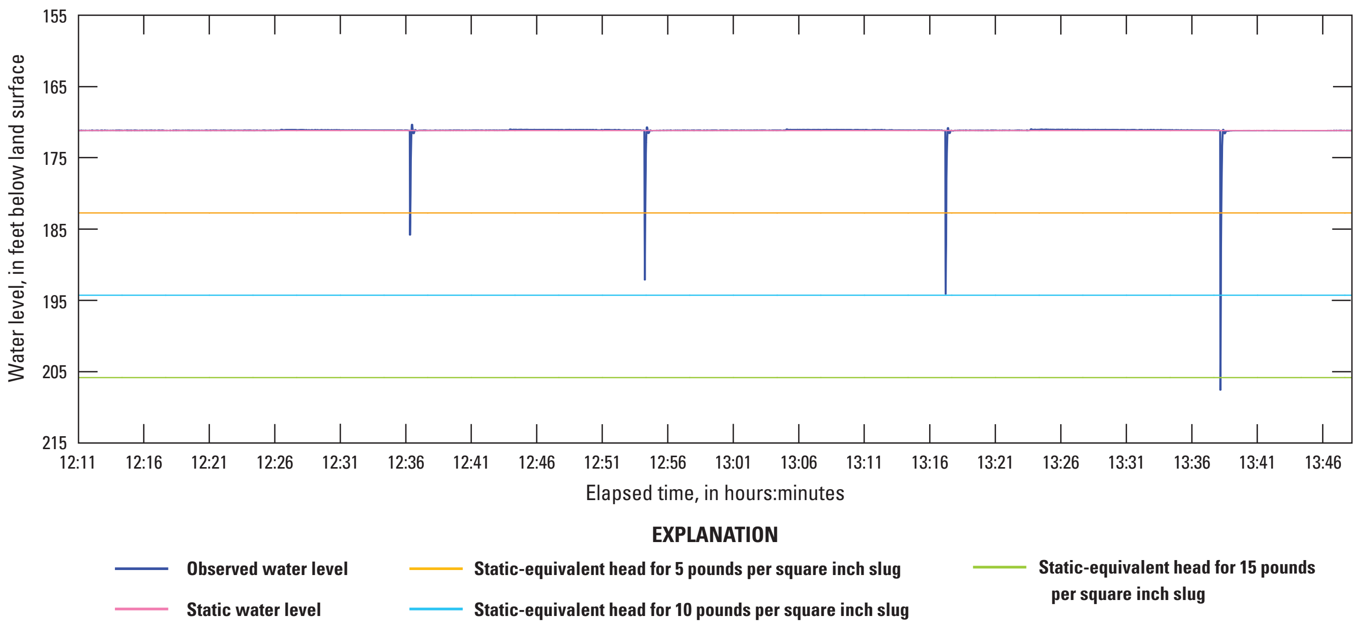


Figure 2–15. Slug-test water-level hydrograph for test well GOLD1 #3 (15N/01E-28R3S) for 20-foot interval of well casing (350–370 feet below land surface), Fort Irwin National Training Center, California, October 2011.

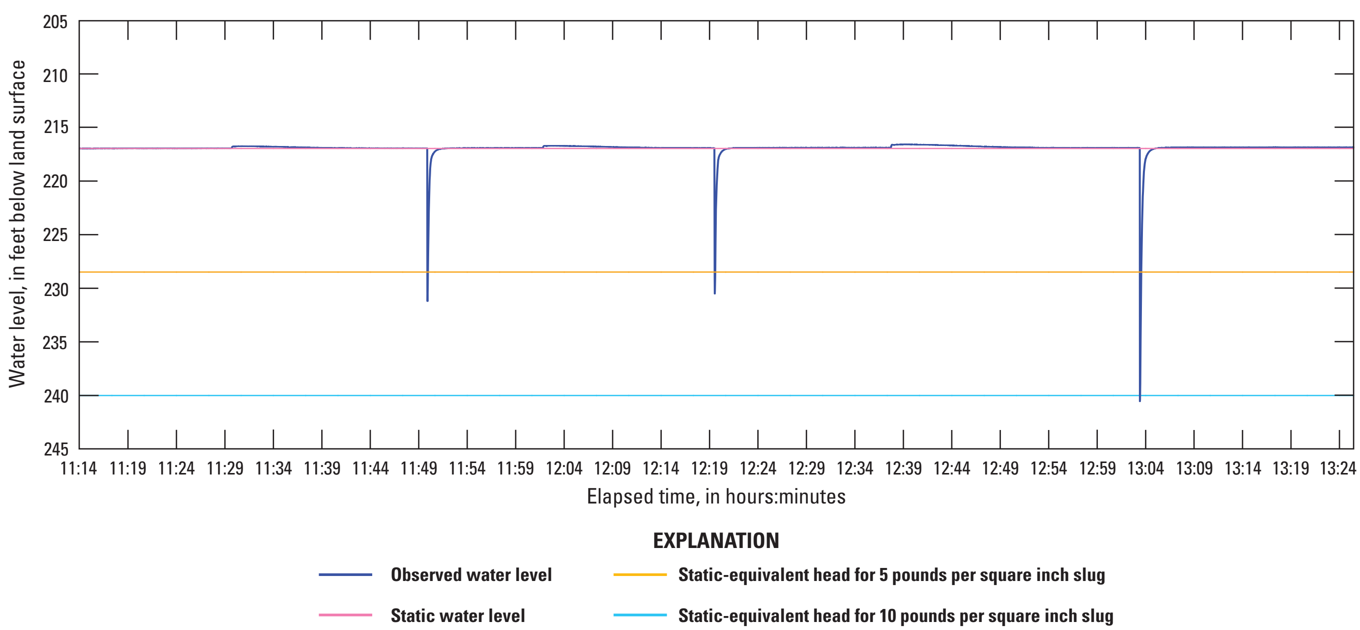


Figure 2–16. Slug-test water-level hydrograph for test well NELT2 #1 (15N/03E-06L1S) for 40-foot interval of well casing (760–800 feet below land surface), Fort Irwin National Training Center, California, November 2011.

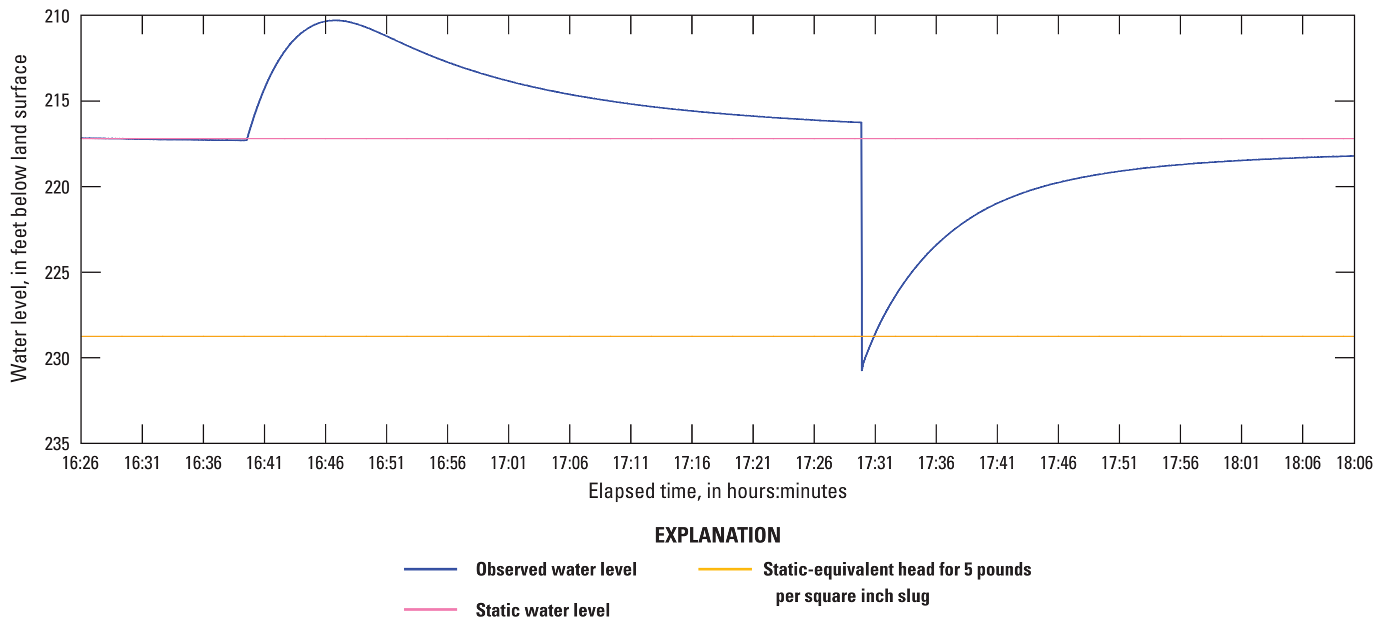


Figure 2–17. Slug-test water-level hydrograph for test well NELT2 #2 (15N/03E-06L2S) for 20-foot interval of well casing (510–530 feet below land surface), Fort Irwin National Training Center, California, November 2011.

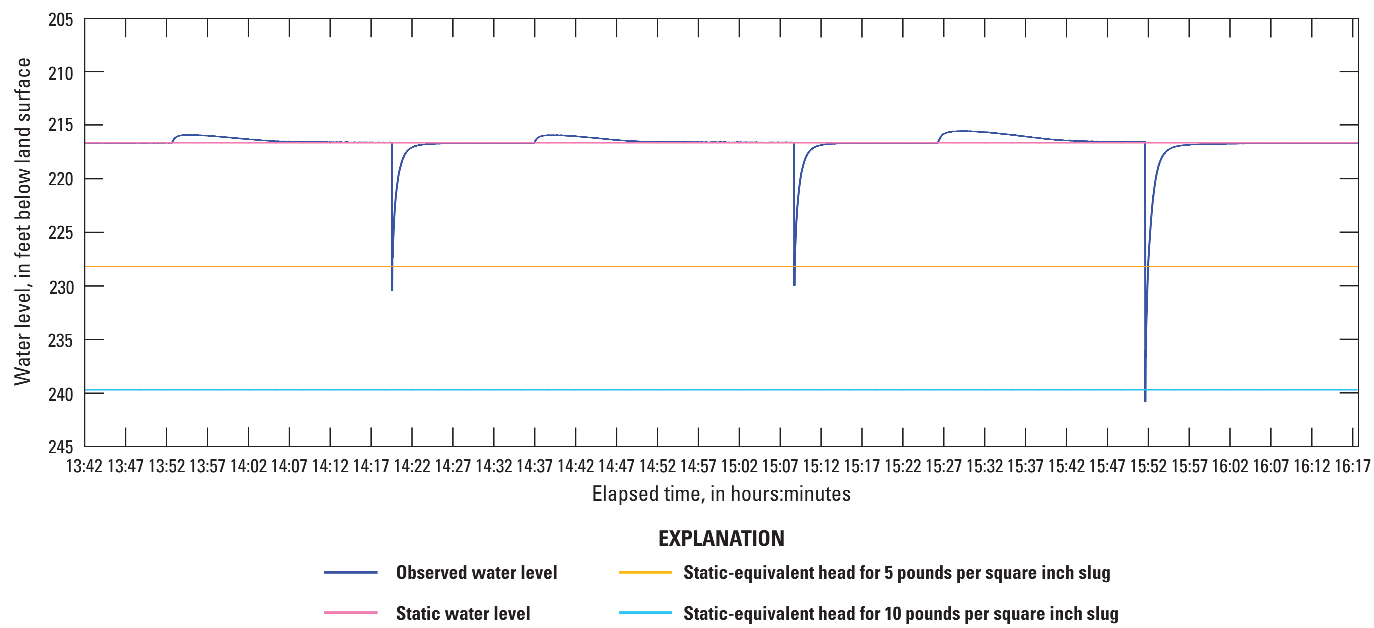


Figure 2–18. Slug-test water-level hydrograph for test well NELT2 #3 (15N/03E-06L3S) for 20-foot interval of well casing (280–300 feet below land surface), Fort Irwin National Training Center, California, November 2011.

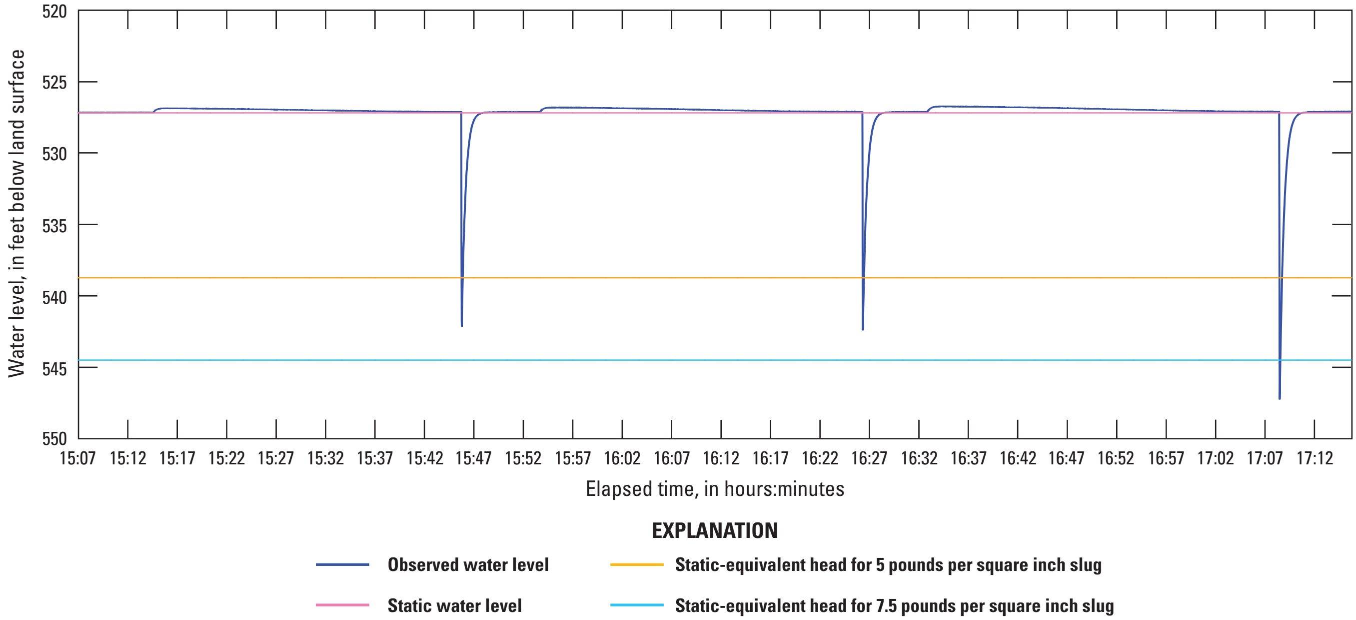


Figure 2–19. Slug-test water-level hydrograph for test well CCT1 #1 (15N/03E-25L1S) for 20-foot interval of well casing (875–895 feet below land surface), Fort Irwin National Training Center, California, March 2012.

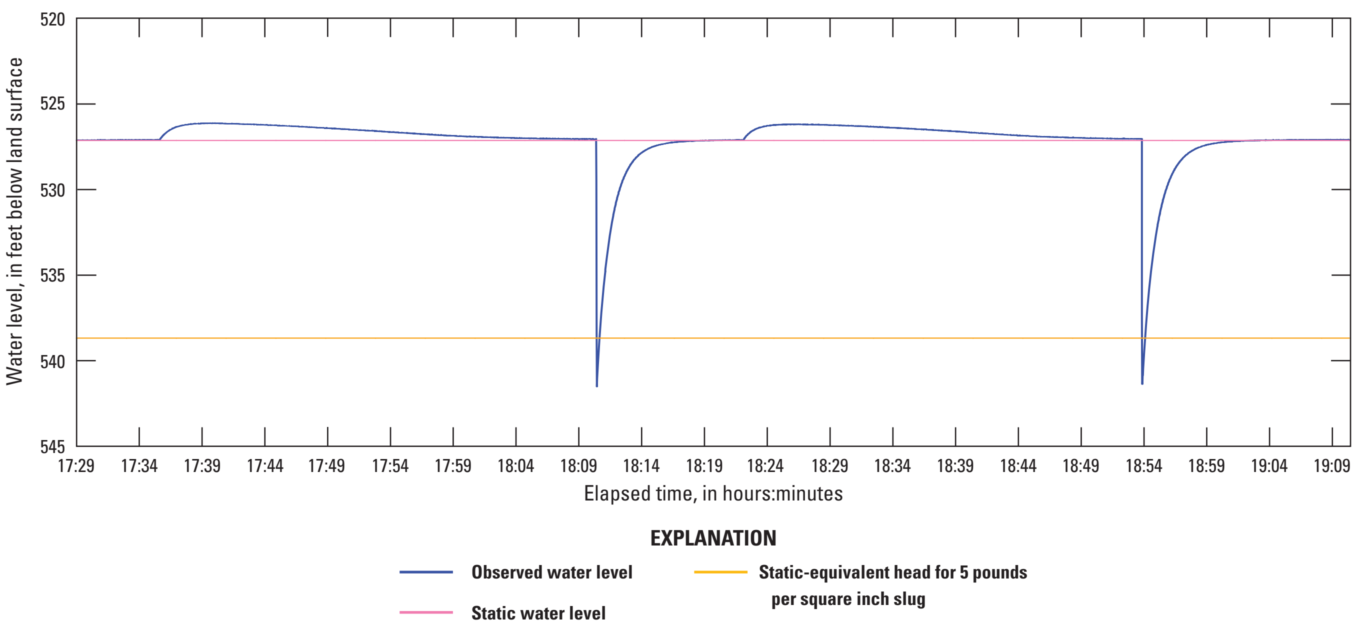


Figure 2–20. Slug-test water-level hydrograph for test well CCT1 #2 (15N/03E-25L2S) for 20-foot interval of well casing (730–750 feet below land surface), Fort Irwin National Training Center, California, March 2012.

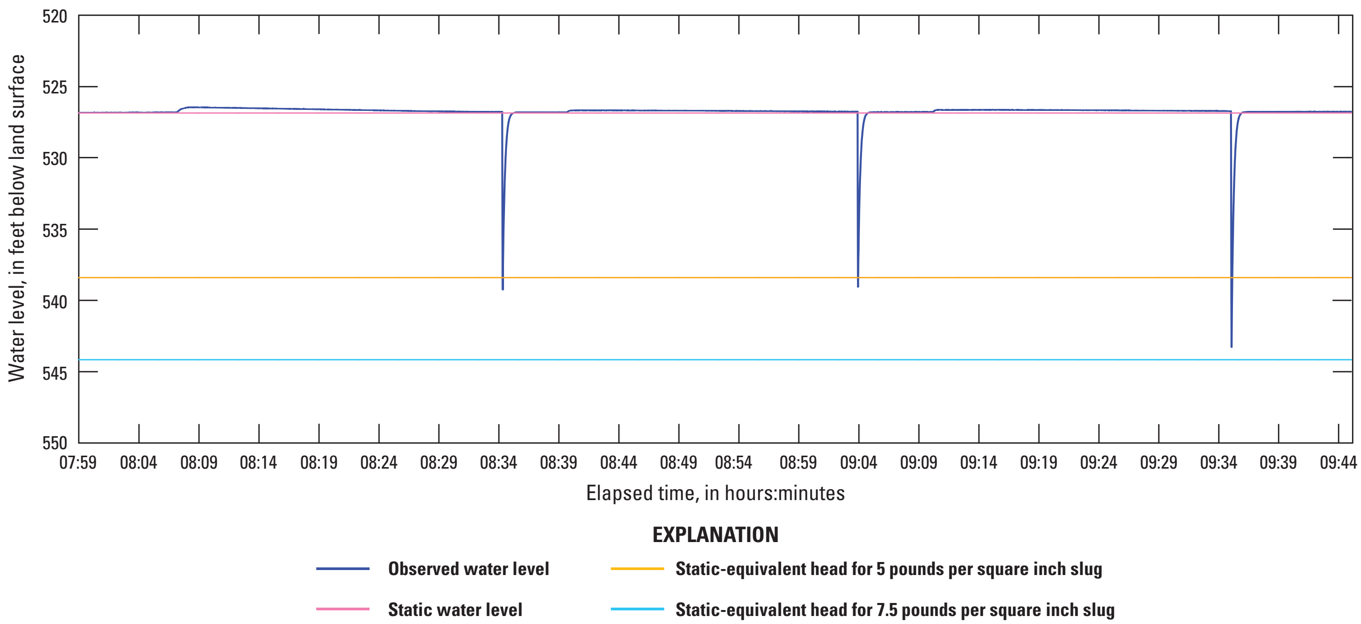


Figure 2–21. Slug-test water-level hydrograph for test well CCT1 #3 (15N/03E-25L3S) for 20-foot interval of well casing (645–665 feet below land surface), Fort Irwin National Training Center, California, March 2012.

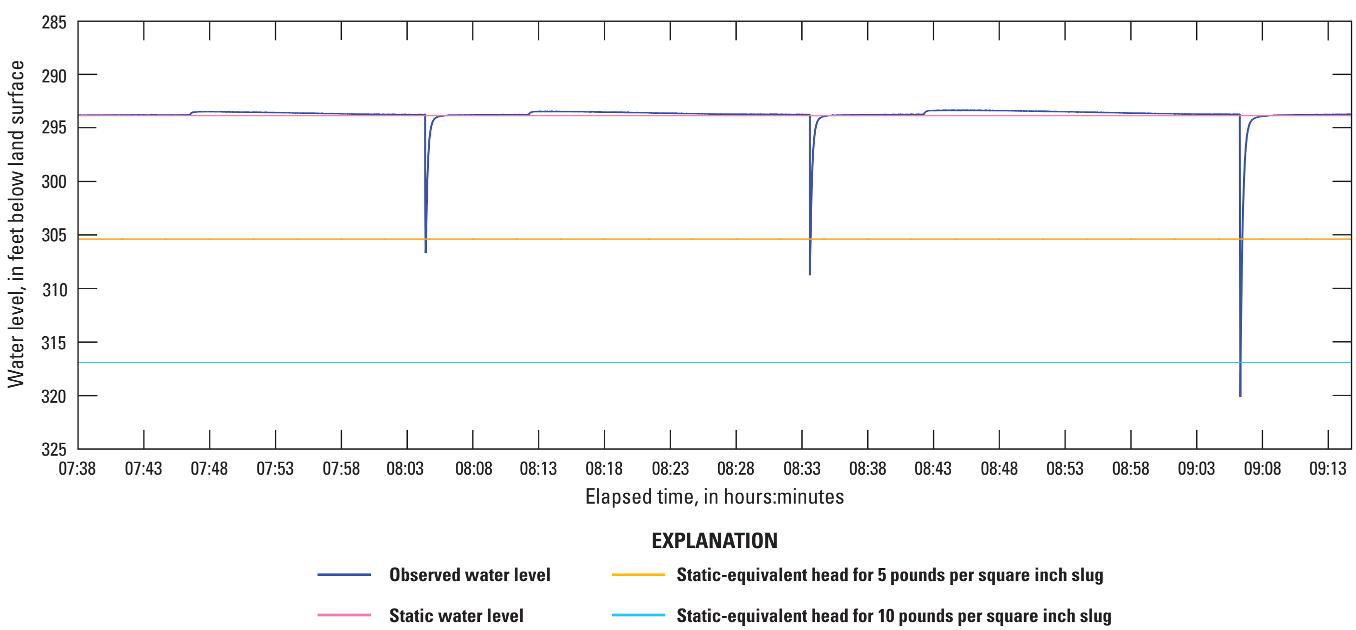


Figure 2–22. Slug-test water-level hydrograph for test well NELT7 #1 (16N/02E-16P1S) for 20-foot interval of well casing (780–800 feet below land surface), Fort Irwin National Training Center, California, March 2012.

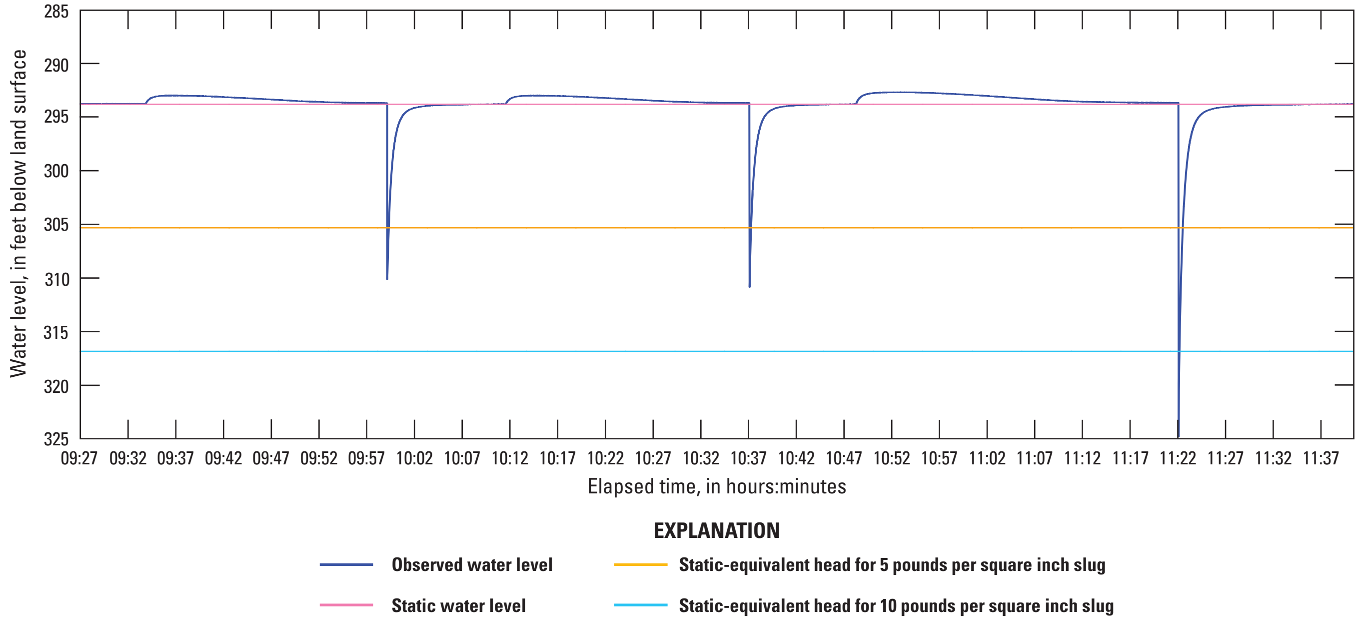


Figure 2–23. Slug-test water-level hydrograph for test well NELT7 #2 (16N/02E-16P2S) for 20-foot interval of well casing (620–640 feet below land surface), Fort Irwin National Training Center, California, March 2012.

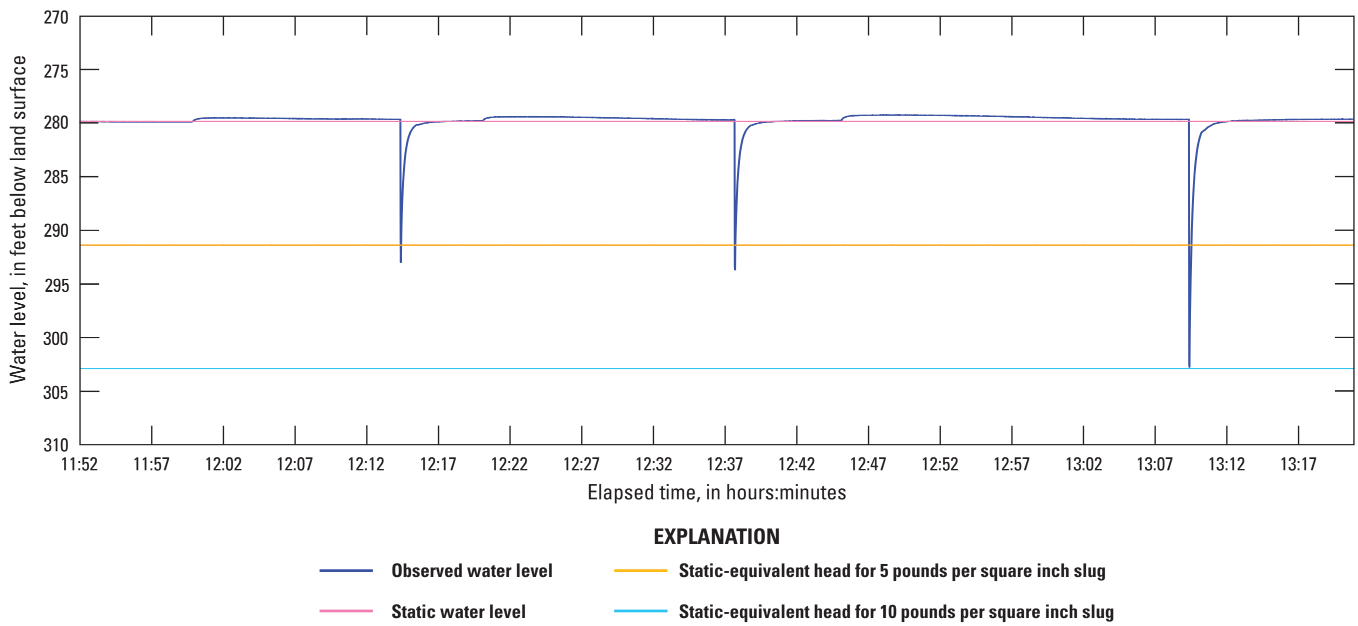


Figure 2–24. Slug-test water-level hydrograph for test well NELT7 #3 (16N/02E-16P3S) for 20-foot interval of well casing (380–400 feet below land surface), Fort Irwin National Training Center, California, March 2012.

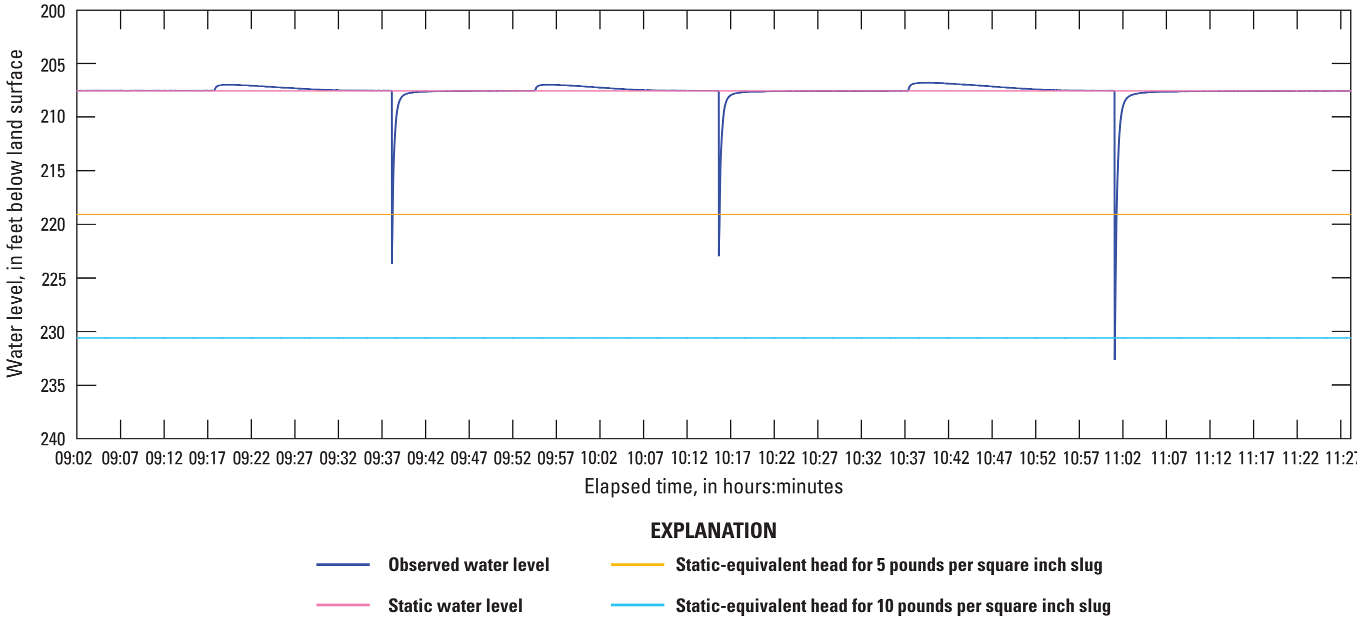


Figure 2–25. Slug-test water-level hydrograph for test well NELT1 #1 (16N/02E-34Q1S) for 20-foot interval of well casing (740–760 feet below land surface), Fort Irwin National Training Center, California, October 2011.

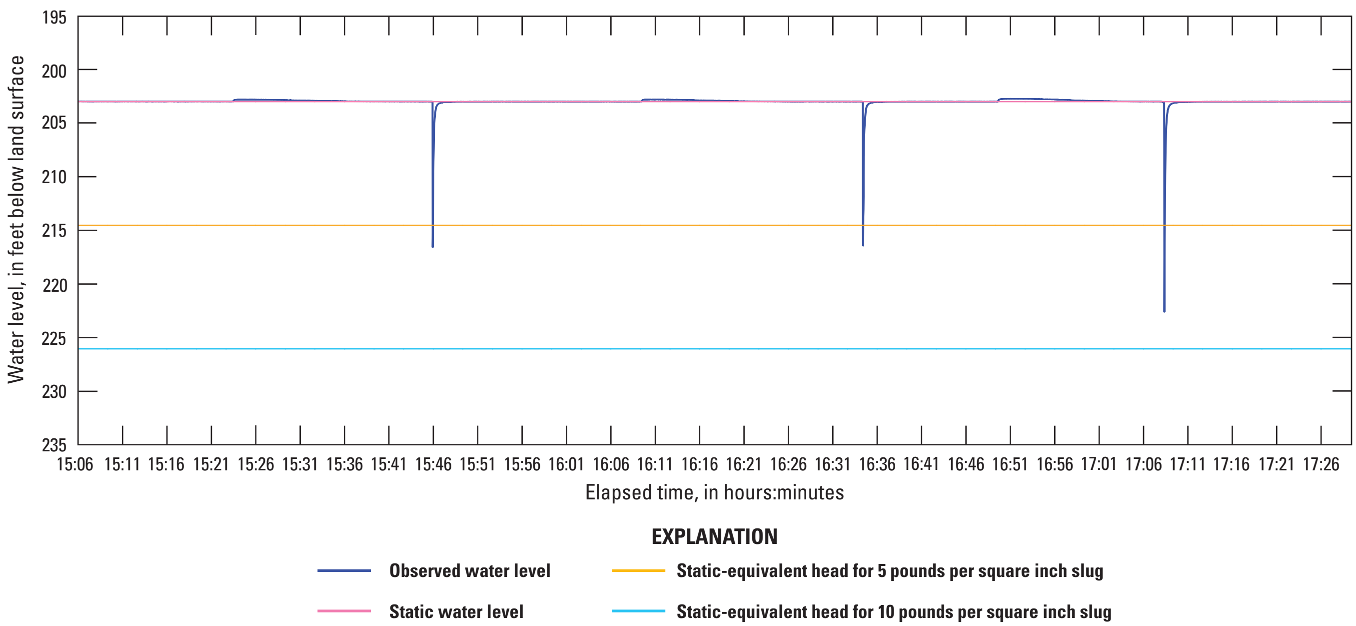


Figure 2–26. Slug-test water-level hydrograph for test well NELT1 #2 (16N/02E-34Q2S) for 20-foot interval of well casing (280–300 feet below land surface), Fort Irwin National Training Center, California, November 2011.

Appendix 3. Slug-Test Modeling (Curve Matching)

Slug-test analytical modeling computations were done using a spreadsheet-based aquifer-test analysis program developed by the U.S. Geological Survey (USGS; Halford and Kuniansky, 2002). Data were analyzed using the "KGS_High-K" methods developed by Butler and Garnett (2000) for formations of high hydraulic conductivity, based on the water-level response to the respective slug test. The USGS aquifer-test analysis program allows the user to compare slug test results to type curves. The type curve (that is, pre-plotted solutions of horizontal hydraulic conductivity) can be fit to match the observed response by adjusting the dimensionless dampening coefficient (MF) or the horizontal hydraulic conductivity (K). The fit between the type curve and the measured response curve is most accurately characterized by the residual standard error (RMS). For detailed descriptions of these parameters, the reader is referred to Halford and Kuniansky (2002).

In figures 3–1 through 3–22, the test well identity, test date, input parameters, and computed parameters are listed above a hydrograph showing the best-fit result (simulated) in juxtaposition with the type curve (measured).

Langford Lake 4 #1 (LLO4#1)

State well number: 12N/3E-01M1S **USGS site identifier:** 350929116372301

Date: 10/31/2011 **Time:** 14:06

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	296.3 feet
Top of screen	=	950.0 feet
Base of screen	=	970.0 feet
Top of aquifer	=	950.0 feet
Base of aquifer	=	970.0 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Clay soils (surface)

Input is consistent

COMPUTED

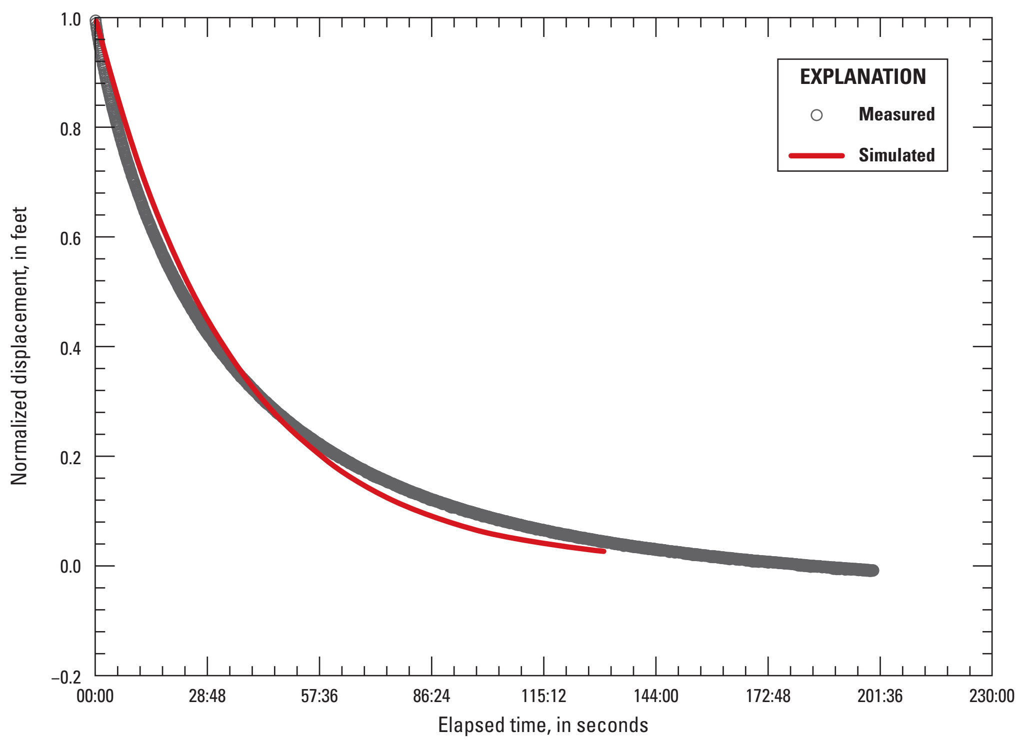
Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	12.86 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	610 feet
$L_{\text{THEORETICAL}}$	=	660 feet

MF = 4.35

K = 0.036 feet/day

Residual standard error = 0 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—950–970 feet
Analysis presets: All tests included

Figure 3–1. Slug-test analysis for test well LL04 #1 (12N/03E-01M1S) for 20-foot interval of well casing (950–970 feet below land surface), Fort Irwin National Training Center, California, January 2015. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Langford Lake 4-B (LL04-B #1)

State well number: 12N/03E-01M4S **USGS site identifier:** 350929116372201

Date: 11/03/2011 **Time:** 09:42

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	295.28 feet
Top of screen	=	470.0 feet
Base of screen	=	490.0 feet
Top of aquifer	=	470 feet
Base of aquifer	=	490 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

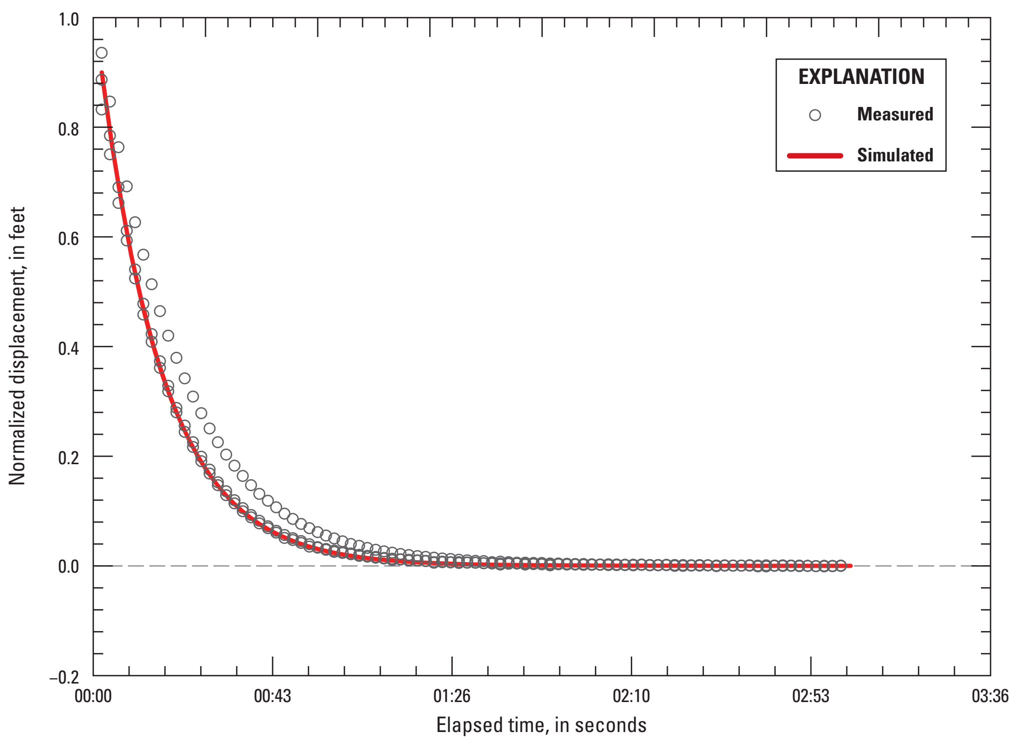
Input is consistent

COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	15.12 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	180 feet
$L_{\text{THEORETICAL}}$	=	180 feet

MF	**=**	**2.38**
K	**=**	**4.9 feet/day**
Residual standard error	**=**	**0.37 feet**

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—470–490 feet
Analysis presets: All tests included

Figure 3–2. Slug-test analysis for test well LL04B #1 (12N/03E-01M4S) for 20-foot interval of well casing (470–490 feet below land surface), Fort Irwin National Training Center, California, November 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Cronise 1 #1 (CRTH1 #1)

State well number: 13N/05E-28Q1S **USGS site identifier:** 351100116271001

Date: 03/04/2012 **Time:** 15:26

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	205.62 feet
Top of screen	=	1,240.0 feet
Base of screen	=	1,260.0 feet
Top of aquifer	=	1,240 feet
Base of aquifer	=	1,260 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Clay soils (surface)

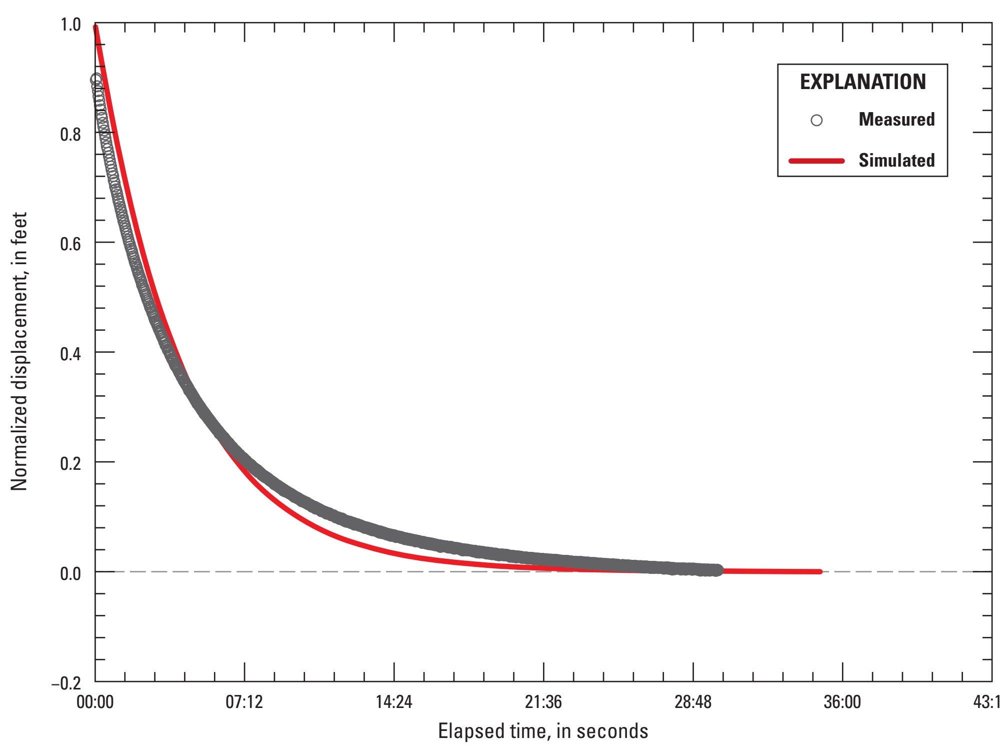
Input is consistent

COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	15.07 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	990 feet
$L_{\text{THEORETICAL}}$	=	1,000 feet
MF	**=**	**5.54**
K	**=**	**0.31 feet/day**

Residual standard error = 0.47 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—1,240–1,260 feet
Analysis presets—First test only, transducer slipped during the second test

Figure 3–3. Slug-test analysis for test well CRTH1 #1 (13N/05E-28Q1S) for 20-foot interval of well casing (1,240–1,260 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Cronise 2 #1 (CRTH2 #1)

State well number: 13N/05E-08B1S **USGS site identifier:** 351416116281501

Date: 03/04/2012 **Time:** 09:30

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	56.68 feet
Top of screen	=	920.0 feet
Base of screen	=	940.0 feet
Top of aquifer	=	920 feet
Base of aquifer	=	940 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Permeable basalt

Input is consistent

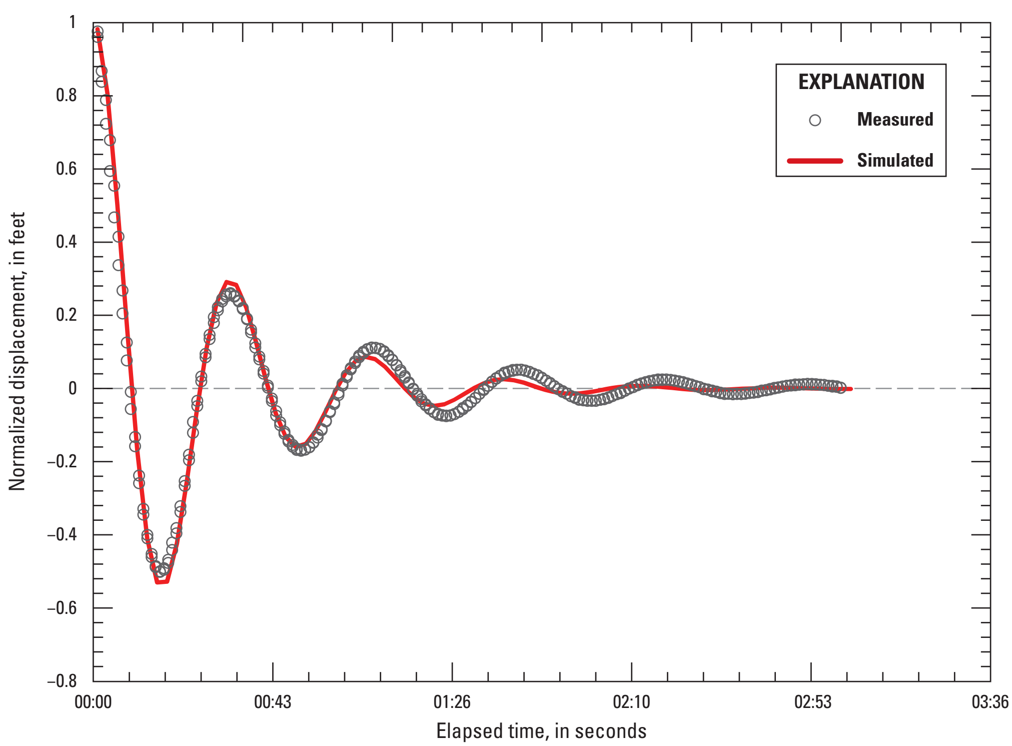
COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	19.41 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{ESTIMATED}$	=	850 feet
$L_{THEORETICAL}$	=	870 feet

MF	**=**	**5.14**
K	**=**	**40 feet/day**

Residual standard error = 0.54 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)

Pneumatic slug test—920–940 feet

Analysis presets—Tests #3 and #4 (10 psi) not included. Analysis of tests #1 and #2 (5 psi) display a lower RMS error and a better visual fit

Figure 3–4. Slug-test analysis for test well CRTH2 #1 (13N/05E-08B2S) for 20-foot interval of well casing (920–940 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Cronise 1 #3 (CRTH1 #3)

State well number: 13N/05E-28Q3S **USGS site identifier:** 351100116271003

Date: 03/04/2012 **Time:** 17:49

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	160.4 feet
Top of screen	=	175.0 feet
Base of screen	=	215.0 feet
Top of aquifer	=	175 feet
Base of aquifer	=	215 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

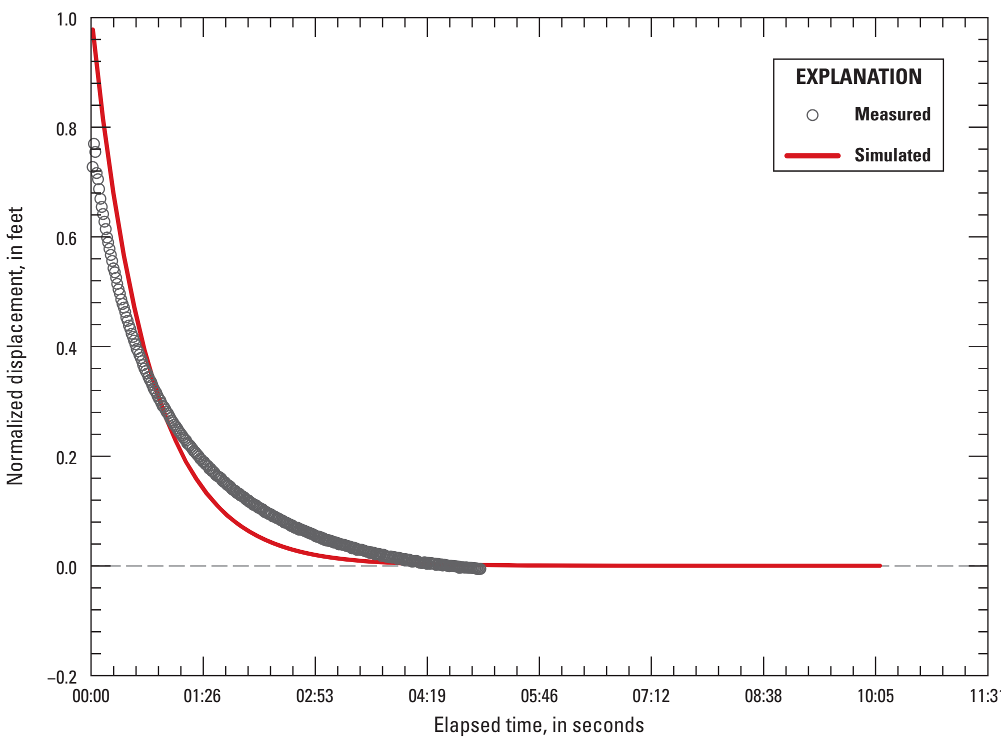
Aquifer material: Permeable basalt

Input is consistent

COMPUTED

Aquifer thickness	=	40 feet
$Y_{0\text{-DISPLACEMENT}}$	=	14.15 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	34 feet
$L_{\text{THEORETICAL}}$	=	35 feet
MF	**=**	**1.03**
K	**=**	**1 feet/day**
Residual standard error	**=**	**0.62 feet**

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—175–195 feet and 235–255 feet
Analysis presets—Tests #1 and #3 not included; the observed head displacement (water level) is within the screened interval

Figure 3–5. Slug-test analysis for test well CRTH1 #3 (13N/05E-28Q3S) for 40-foot interval of well casing (175–195 and 235–255 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Goldstone 2 #1 (GOLD2 #1)

State well number: 14N/01E-07R1S **USGS site identifier:** 351904116543101

Date: 03/27/2012 **Time:** 11:00

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	247.29 feet
Top of screen	=	420.0 feet
Base of screen	=	440.0 feet
Top of aquifer	=	420 feet
Base of aquifer	=	440 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Clay soils (surface)

Input is consistent

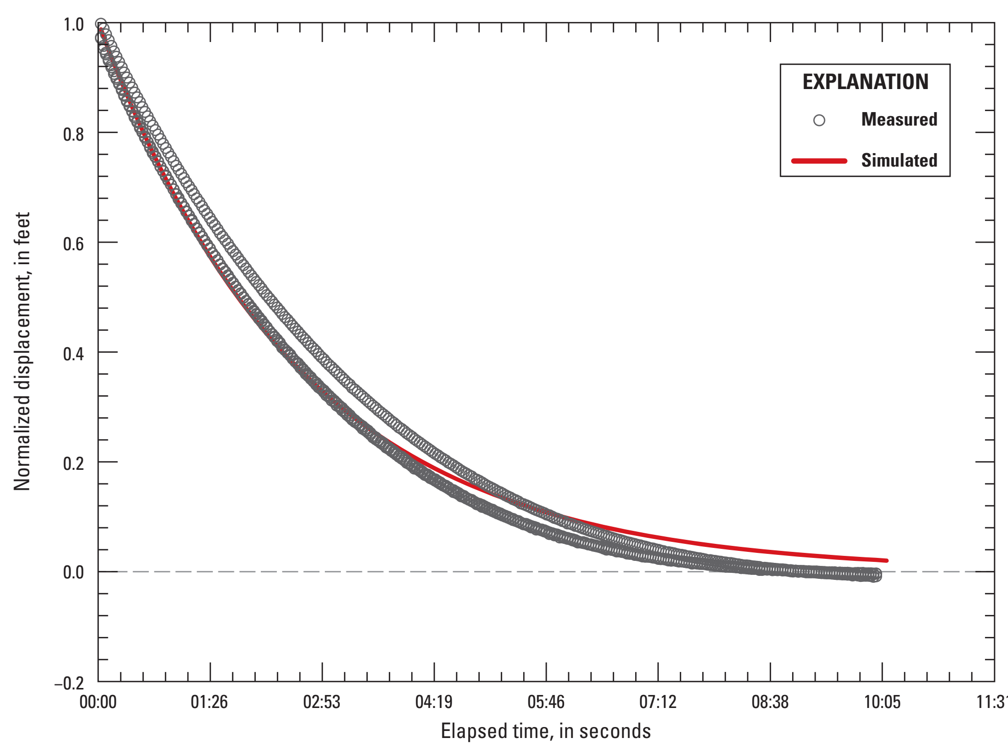
COMPUTED

Aquifer thickness	=	20 feet
$Y_{\text{0-DISPLACEMENT}}$	=	16.19 feet
$Y_{\text{0-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	190 feet
$L_{\text{THEORETICAL}}$	=	180 feet

MF	**=**	**2.43**
K	**=**	**0.5 feet/day**

Residual standard error = 0.51 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—420–440 feet
Analysis presets—All tests included

Figure 3–6. Slug-test analysis for test well GOLD2 #1 (14N/01E-07R1S) for 20-foot interval of well casing (420–440 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Goldstone 2 #2 (GOLD2 #2)

State well number: 14N/01E-07R2S **USGS site identifier:** 351904116543102

Date: 03/27/2012 **Time:** 13:26

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	247.35 feet
Top of screen	=	330.0 feet
Base of screen	=	350.0 feet
Top of aquifer	=	330 feet
Base of aquifer	=	350 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Permeable basalt

Input is consistent

COMPUTED

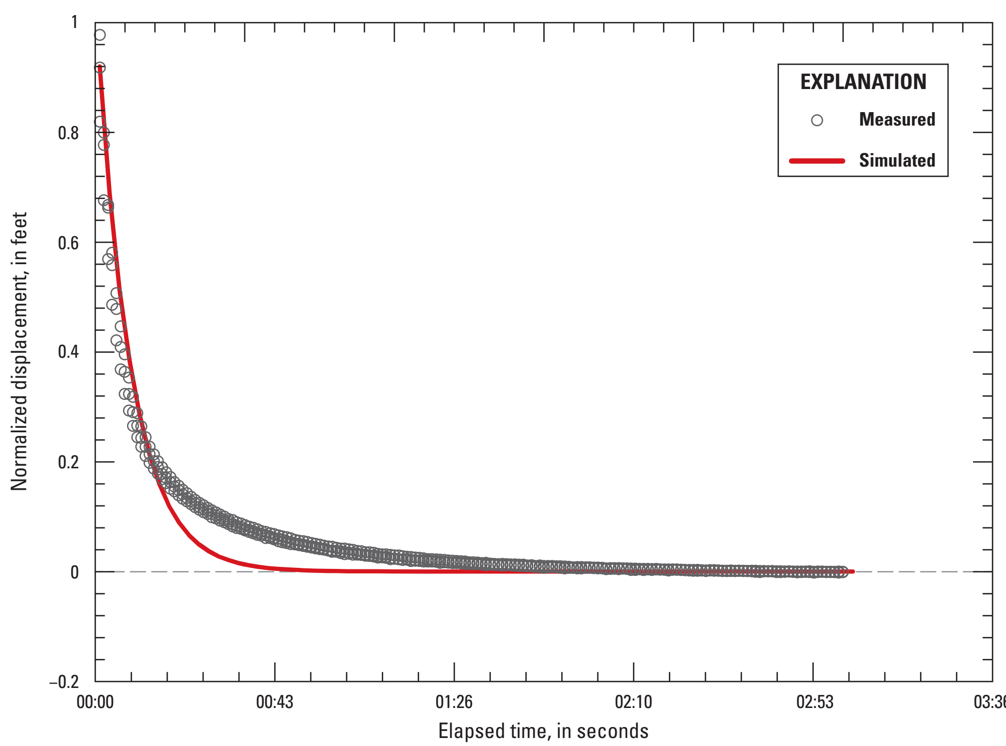
Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	16.23 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	87 feet
$L_{\text{THEORETICAL}}$	=	93 feet

MF = 1.65

K = 9.2 feet/day

Residual standard error = 0.6 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—330–350 feet
Analysis presets—All tests included

Figure 3–7. Slug-test analysis for test well GOLD2 #2 (14N/01E-07R2S) for 20-foot interval of well casing (330–350 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Bicycle Lake 5 #1 (BLA5 #1)

State well number: 14N/03E-26K1S **USGS site identifier:** 351638116374301

Date: 10/25/2011 **Time:** 16:04

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	186.06 feet
Top of screen	=	320.0 feet
Base of screen	=	340.0 feet
Top of aquifer	=	320 feet
Base of aquifer	=	340 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

Input is consistent

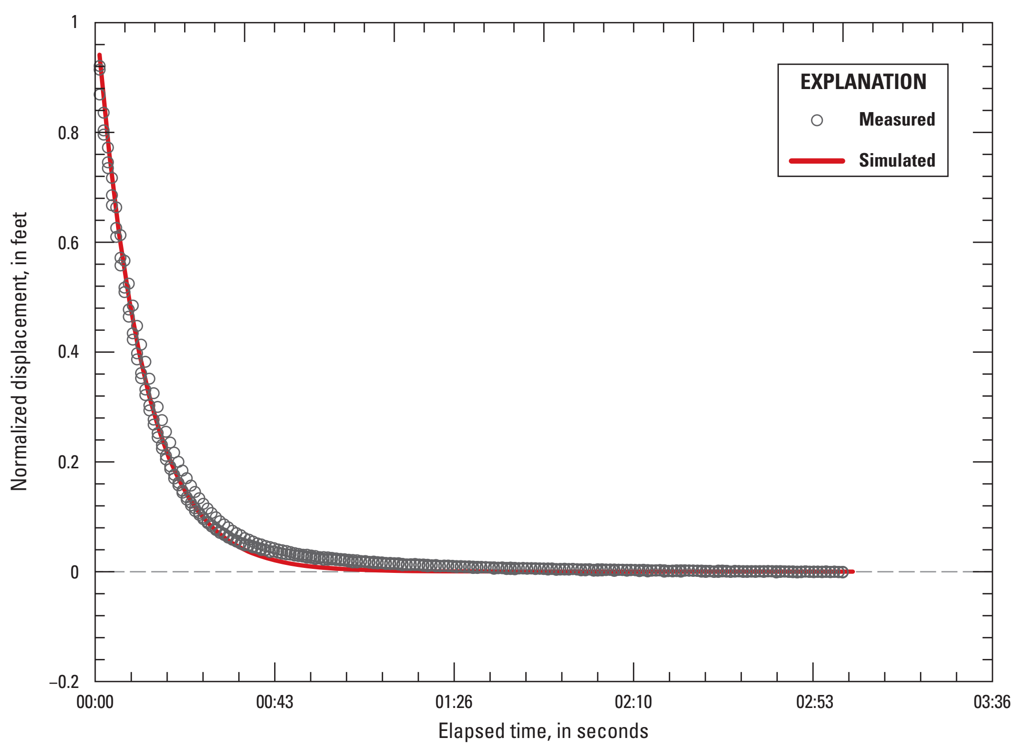
COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	18.25 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	120 feet
$L_{\text{THEORETICAL}}$	=	140 feet

MF	**=**	**1.97**
K	**=**	**6.8 feet/day**

Residual standard error = 0.26 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—320–340 feet
Analysis presets—All tests included

Figure 3–8. Slug-test analysis for test well BLA5 #1 (14N/03E-26K1S) for 20-foot interval of well casing (320–340 feet below land surface), Fort Irwin National Training Center, California, October 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Bicycle Lake 5-B #1 (BLA5-B #1)

State well number: 14N/03E-26K4S **USGS site identifier:** 351638116374304

Date: 10/25/2011 **Time:** 17:48

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	185.93 feet
Top of screen	=	250.0 feet
Base of screen	=	270.0 feet
Top of aquifer	=	250 feet
Base of aquifer	=	270 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Medium-grained sand

Input is consistent

COMPUTED

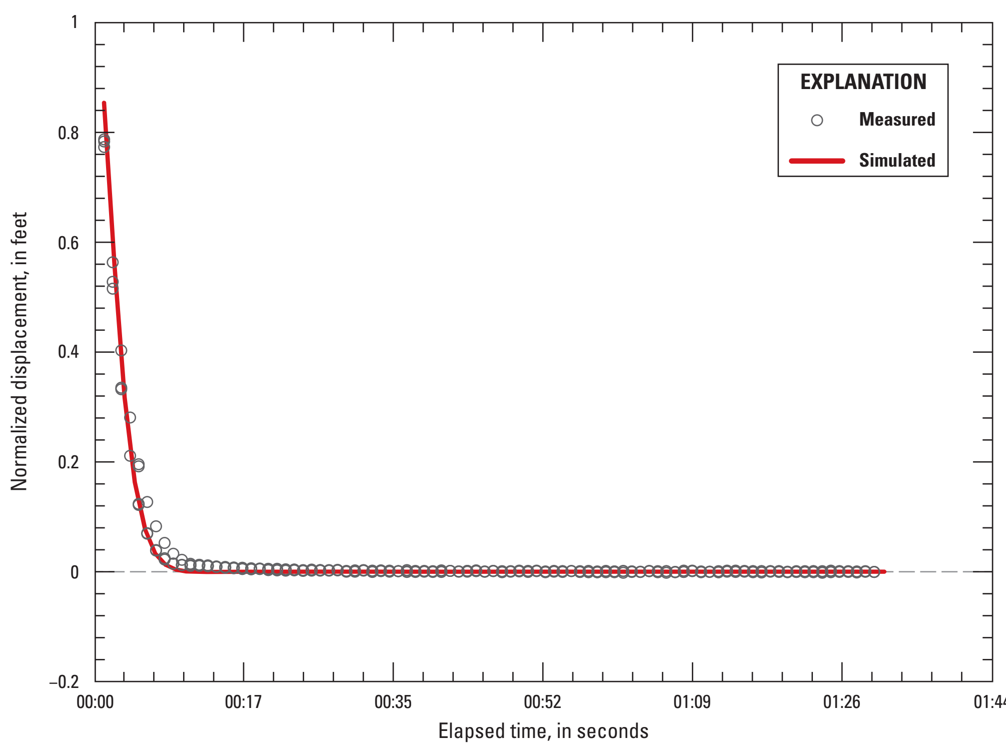
Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	14.27 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	74 feet
$L_{\text{THEORETICAL}}$	=	74 feet

MF = 1.51

K = 28 feet/day

Residual standard error = 0.22 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—250–270 feet
Analysis presets—All tests included

Figure 3–9. Slug-test analysis for test well BLA5-B #1 (14N/03E-26K4S) for 20-foot interval of well casing (250–270 feet below land surface), Fort Irwin National Training Center, California, October 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Goldstone 1 #1 (GOLD1 #1)

State well number: 15N/01E-28R1S **USGS site identifier:** 352144116522601

Date: 10/24/2011 **Time:** 17:27

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	171.15 feet
Top of screen	=	650.0 feet
Base of screen	=	670.0 feet
Top of aquifer	=	650 feet
Base of aquifer	=	670 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Permeable basalt

Input is consistent

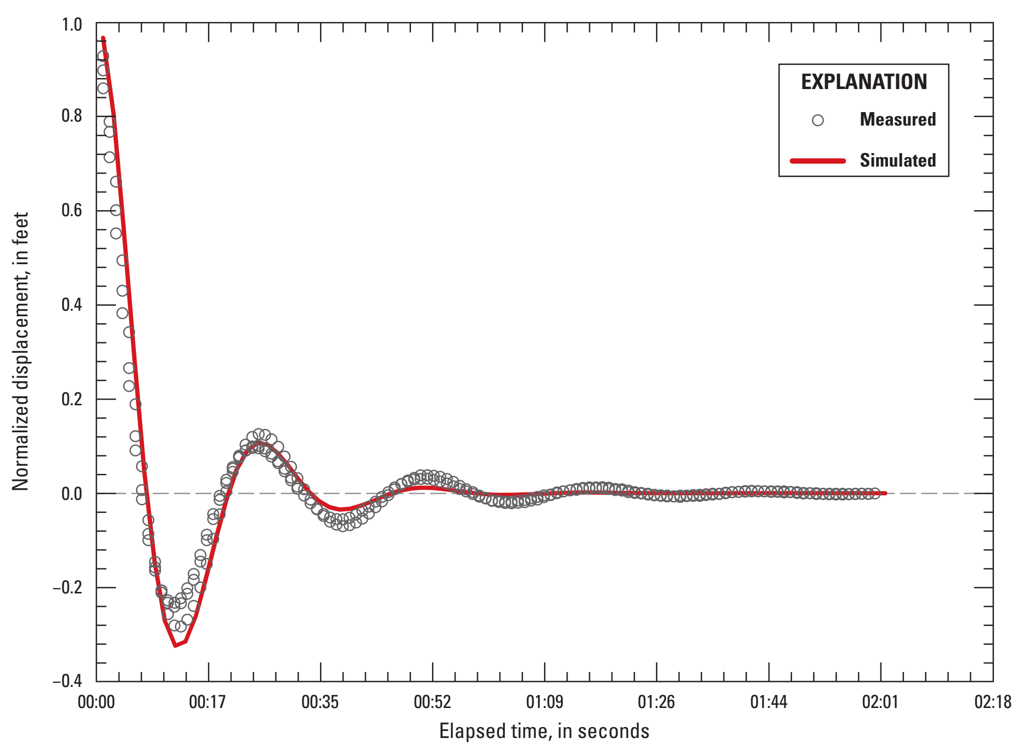
COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	23.85 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	460 feet
$L_{\text{THEORETICAL}}$	=	490 feet

MF	**=**	**3.79**
K	**=**	**31 feet/day**

Residual standard error = 0.91 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)

Pneumatic slug test—650–670 feet

Analysis presets—Test #4 (15 psi) not included in analysis. Head displacement was not equal to the 15 psi applied. 5 psi and 10 psi tests display a better visual curve match.

Figure 3–10. Slug-test analysis for test well GOLD1 #1 (15N/01E-28R1S) for 20-foot interval of well casing (650–670 feet below land surface), Fort Irwin National Training Center, California, October 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Goldstone 1 #2 (GOLD1 #2)

State well number: 15N/01E-28R2S **USGS site identifier:** 352144116522602

Date: 10/25/2011 **Time:** 10:05

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	171.16 feet
Top of screen	=	560.0 feet
Base of screen	=	580.0 feet
Top of aquifer	=	560 feet
Base of aquifer	=	580 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Clay soils (surface)

Input is consistent

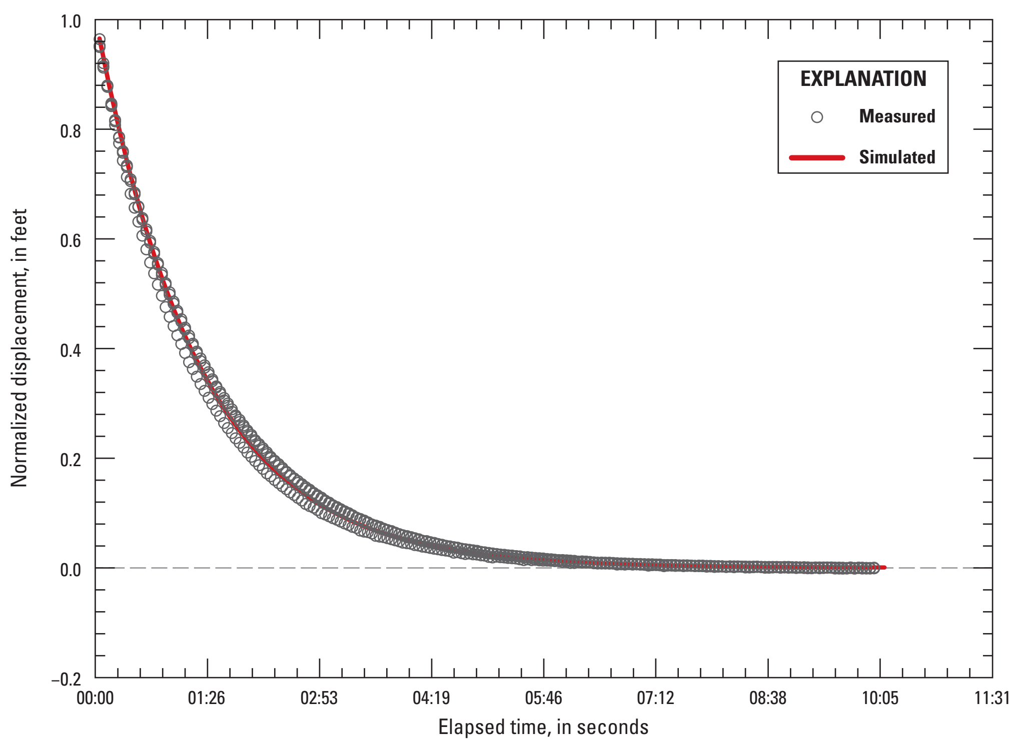
COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	22.59 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	410 feet
$L_{\text{THEORETICAL}}$	=	400 feet

MF	**=**	**3.57**
K	**=**	**0.97 feet/day**

Residual standard error = 0.24 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—560–580 feet
Analysis presets—All tests included

Figure 3–11. Slug-test analysis for test well GOLD1 #2 (15N/01E-28R2S) for 20-foot interval of well casing (560–580 feet below land surface), Fort Irwin National Training Center, California, October 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Goldstone 1 #3 (GOLD1 #3)

State well number: 15N/01E-28R3S **USGS site identifier:** 352144116522603

Date: 10/25/2011 **Time:** 12:36

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	171 feet
Top of screen	=	350.0 feet
Base of screen	=	370.0 feet
Top of aquifer	=	350 feet
Base of aquifer	=	370 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Medium-grained sand

Input is consistent

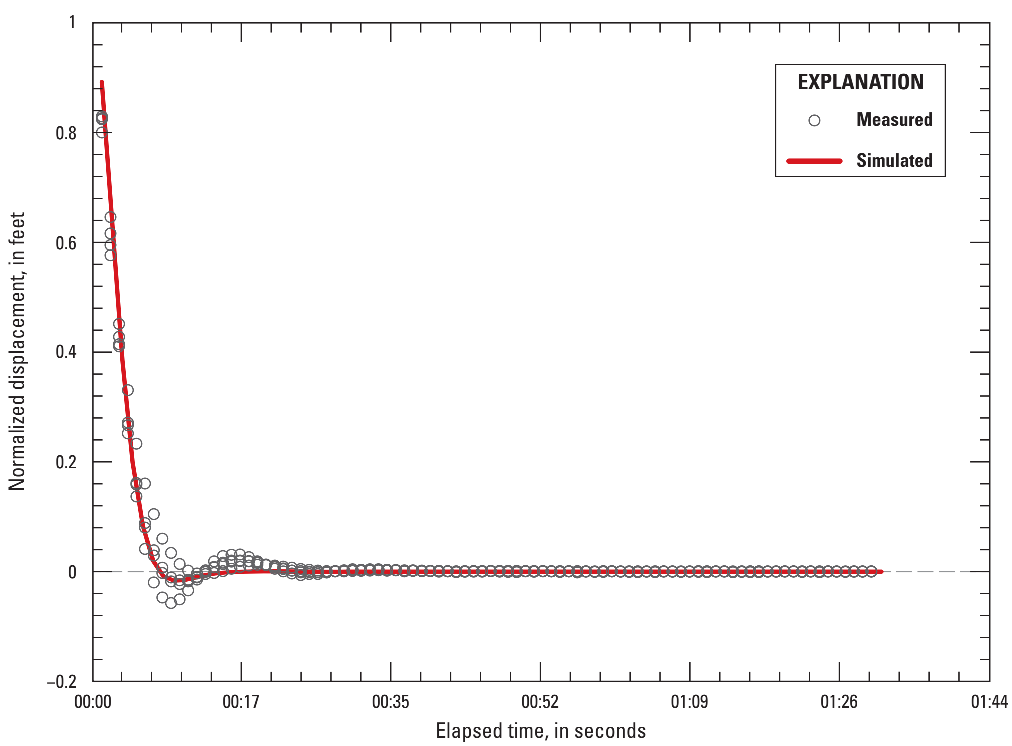
COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	23.71 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	110 feet
$L_{\text{THEORETICAL}}$	=	190 feet

MF	**=**	**1.87**
K	**=**	**26 feet/day**

Residual standard error = 0.4 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—350–370 feet
Analysis presets—All tests included

Figure 3–12. Slug-test analysis for test well GOLD1 #3 (15N/01E-28R3S) for 20-foot interval of well casing (350–370 feet below land surface), Fort Irwin National Training Center, California, October 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Nelson Lake 2 #1 (NELT2 #1)

State well number: 15N/03E-06L1S **USGS site identifier:** 352450116421101

Date: 11/02/2011 **Time:** 11:50

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	216.94 feet
Top of screen	=	760.0 feet
Base of screen	=	800.0 feet
Top of aquifer	=	760 feet
Base of aquifer	=	800 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

Input is consistent

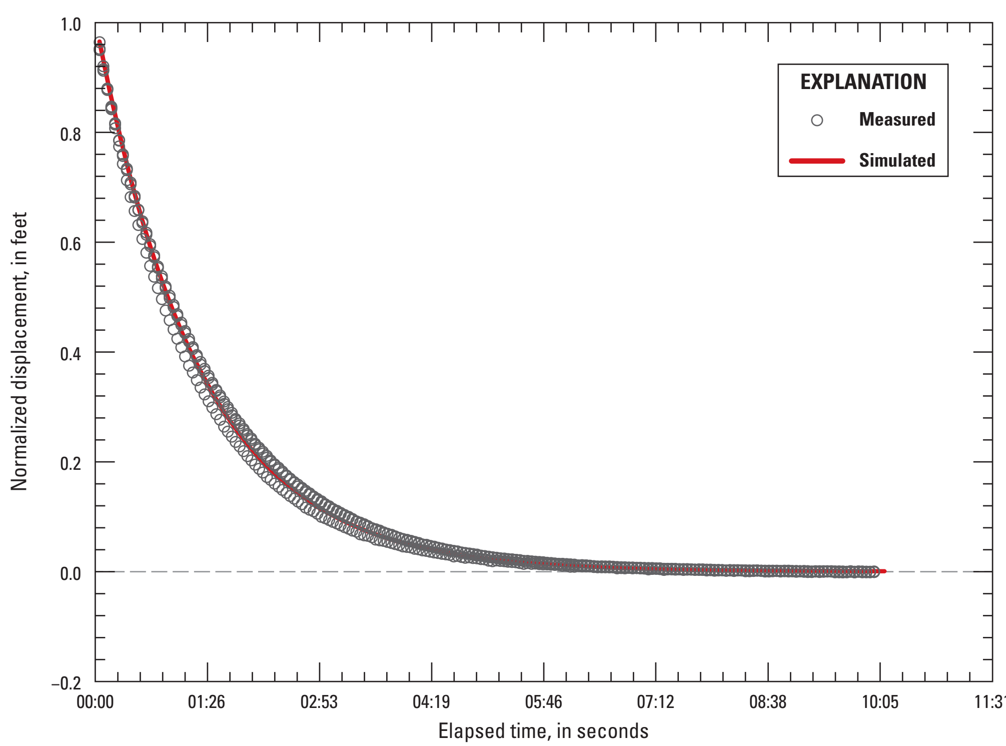
COMPUTED

Aquifer thickness	=	40 feet
$Y_{0\text{-DISPLACEMENT}}$	=	17.17 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	560 feet
$L_{\text{THEORETICAL}}$	=	560 feet

MF	**=**	**4.17**
K	**=**	**4.5 feet/day**

Residual standard error = 0.42 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—760–800 feet
Analysis presets—All tests included

Figure 3–13. Slug-test analysis for test well NELT2 #1 (15N/03E-06L1S) for 40-foot interval of well casing (760–800 feet below land surface), Fort Irwin National Training Center, California, November 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Nelson Lake 2 #3 (NELT2 #3)

State well number: 15N/03E-06L3S **USGS site identifier:** 352450116421103

Date: 11/02/2011 **Time:** 14:19

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	216.63 feet
Top of screen	=	280.0 feet
Base of screen	=	300.0 feet
Top of aquifer	=	280 feet
Base of aquifer	=	300 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Medium-grained sand

Input is consistent

COMPUTED

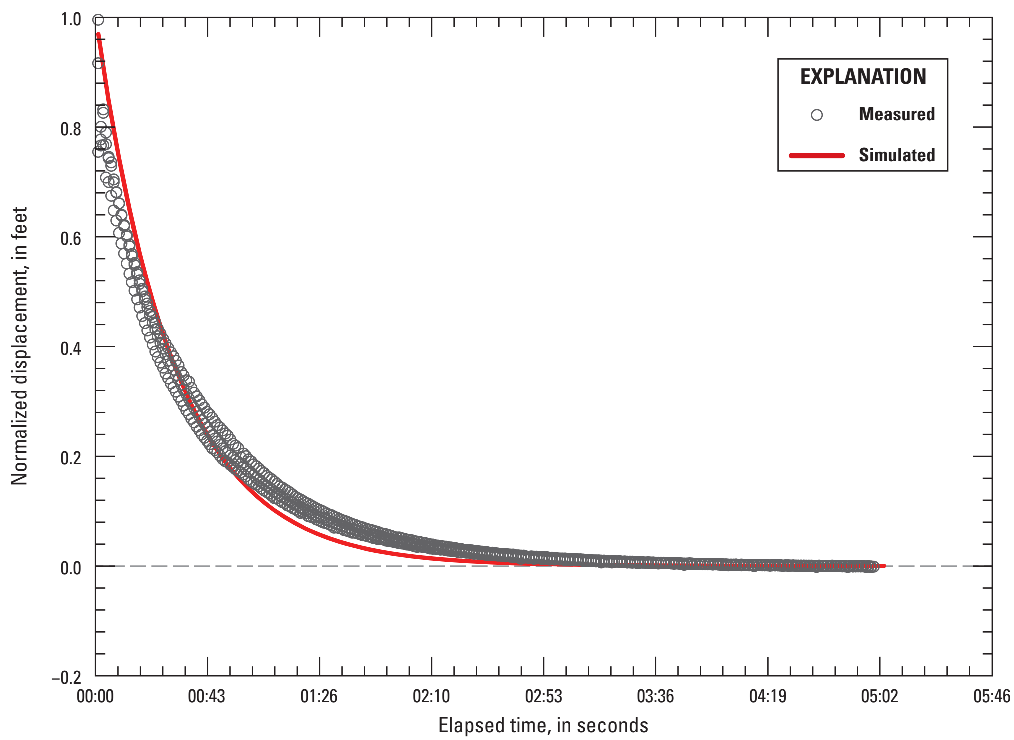
Aquifer thickness	=	20 feet
$Y_{\text{0-DISPLACEMENT}}$	=	16.95 feet
$Y_{\text{0-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	77 feet
$L_{\text{THEORETICAL}}$	=	73 feet

MF = 1.54

K = 2.6 feet/day

Residual standard error = 0.57 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—280–300 feet
Analysis presets—All tests included

Figure 3–14. Slug-test analysis for test well NELT2 #3 (15N/03E-06L3S) for 20-foot interval of well casing (280–300 feet below land surface), Fort Irwin National Training Center, California, November 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Central Corridor 1 #1 (CCT1 #1)

State well number: 15N/03E-25L1S **USGS site identifier:** 352149116370701

Date: 03/05/2012 **Time:** 15:45

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	527.19 feet
Top of screen	=	875.0 feet
Base of screen	=	895.0 feet
Top of aquifer	=	875 feet
Base of aquifer	=	895 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

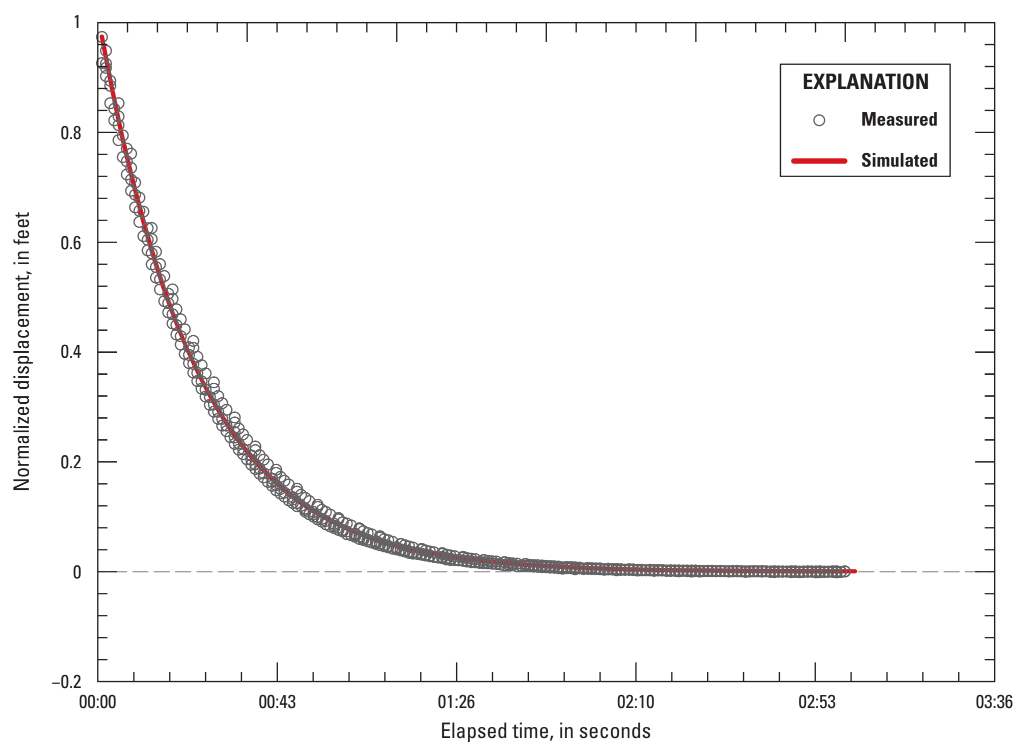
Aquifer material: Fine-grained sand

Input is consistent

COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	16.76 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{ESTIMATED}$	=	330 feet
$L_{THEORETICAL}$	=	360 feet
MF	**=**	**3.21**
K	**=**	**3.3 feet/day**
Residual standard error	**=**	**0.18 feet**

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—875–895 feet
Analysis presets—All tests included

Figure 3–15. Slug-test analysis for test well CCT1 #1 (15N/03E-25L1S) for 20-foot interval of well casing (875–895 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Central Corridor 1 #2 (CCT1 #2)

State well number: 15N/03E-25L2S **USGS site identifier:** 352149116370702

Date: 03/05/2012 **Time:** 18:10

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	527.14 feet
Top of screen	=	730.0 feet
Base of screen	=	750.0 feet
Top of aquifer	=	730 feet
Base of aquifer	=	750 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Clay soils (surface)

K = 1.1 is greater than extreme; K = 1.1 is greater than likely maximum of 1 for clay soils (surface)

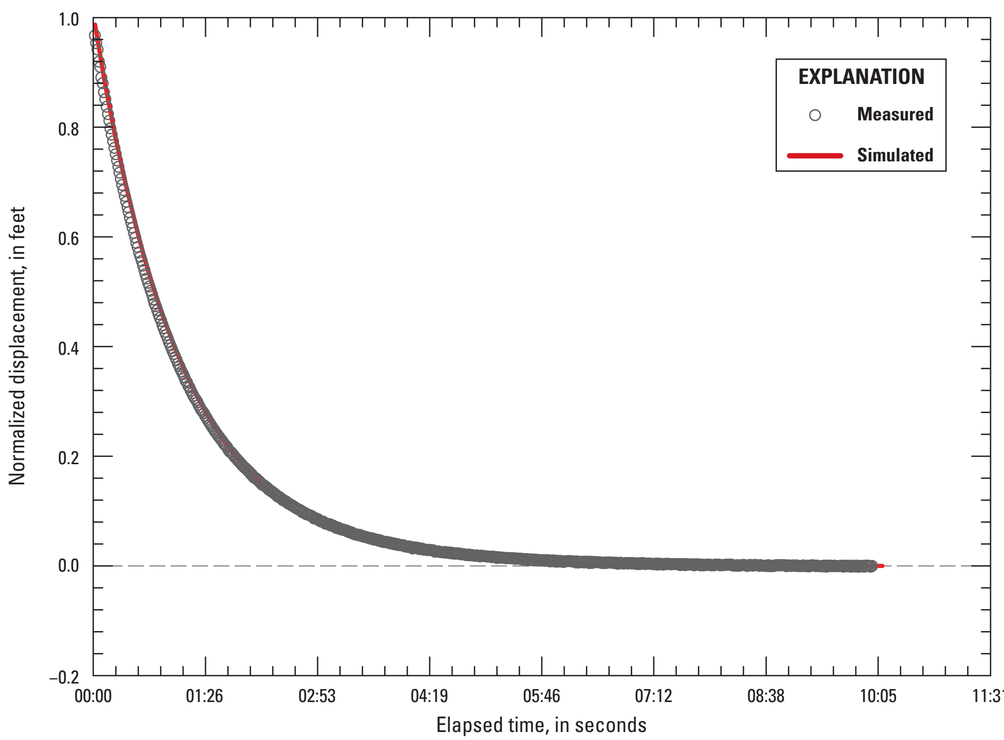
COMPUTED

Aquifer thickness	=	20 feet
$Y_{\text{0-DISPLACEMENT}}$	=	14.30 feet
$Y_{\text{0-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	220 feet
$L_{\text{THEORETICAL}}$	=	210 feet

MF	**=**	**2.61**
K	**=**	**1.1 feet/day**

Residual standard error = 0.13 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—730–750 feet
Analysis presets—All tests included

Figure 3–16. Slug-test analysis for test well CCT1 #2 (15N/03E-25L2S) for 20-foot interval of well casing (730–750 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Central Corridor 1 #3 (CCT1 #3)

State well number: 15N/03E-25L3S **USGS site identifier:** 352149116370703

Date: 03/06/2012 **Time:** 08:34

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	526.88 feet
Top of screen	=	645.0 feet
Base of screen	=	665.0 feet
Top of aquifer	=	645 feet
Base of aquifer	=	665 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

Input is consistent

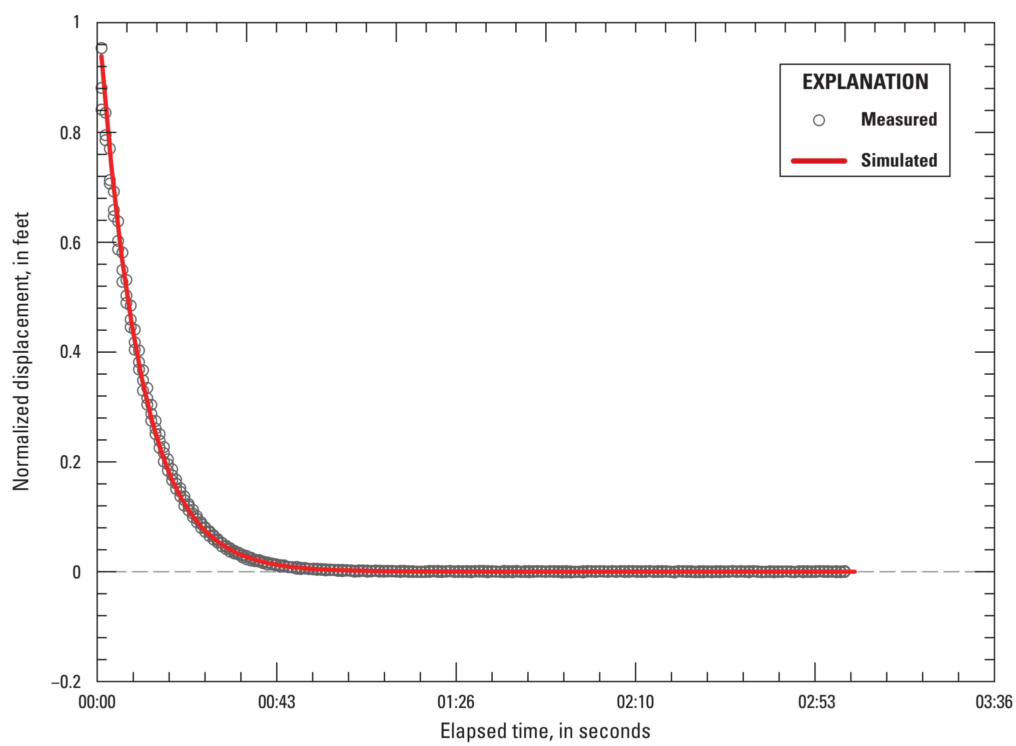
COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	13.74 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	130 feet
$L_{\text{THEORETICAL}}$	=	160 feet

MF	**=**	**2.01**
K	**=**	**7.6 feet/day**

Residual standard error = 0.13 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—645–665 feet
Analysis presets—All tests included

Figure 3–17. Slug-test analysis for test well CCT1 #3 (15N/03E-25L3S) for 20-foot interval of well casing (645–665 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Nelson Lake 7 #1 (NELT7 #1)

State well number: 16N/02E-16P1S **USGS site identifier:** 352806116462101

Date: 03/05/2012 **Time:** 08:05

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	293.83 feet
Top of screen	=	780.0 feet
Base of screen	=	800.0 feet
Top of aquifer	=	780 feet
Base of aquifer	=	800 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

Input is consistent

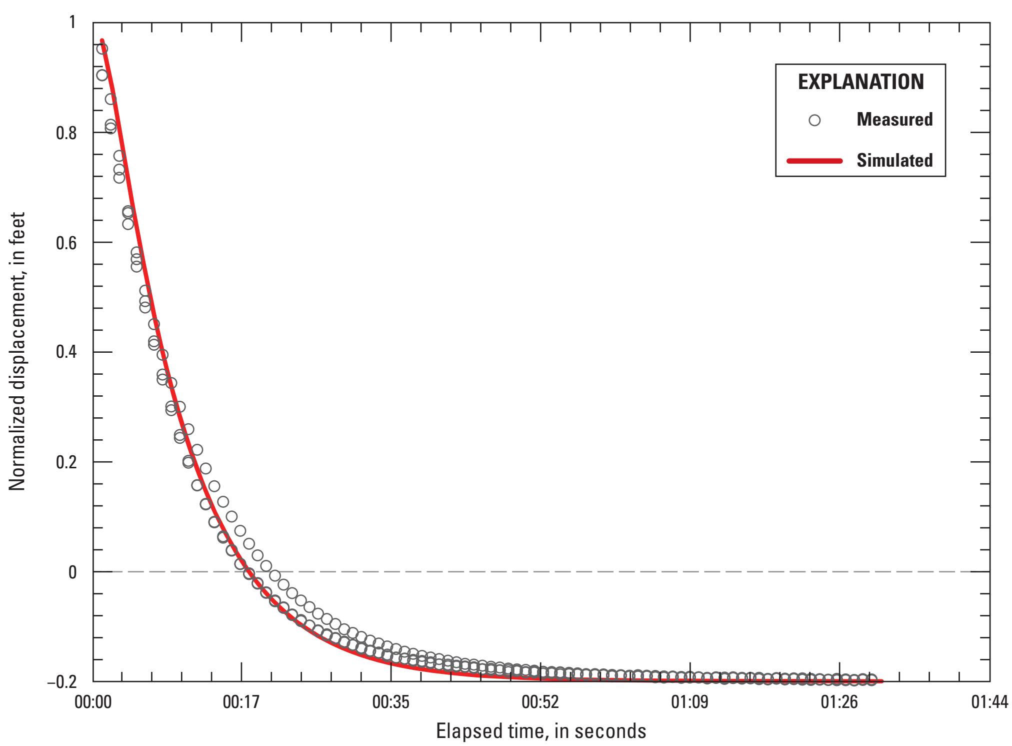
COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	17.99 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	460 feet
$L_{\text{THEORETICAL}}$	=	500 feet

MF	**=**	**3.79**
K	**=**	**7.3 feet/day**

Residual standard error **=** **0.36 feet**

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—780–800 feet
Analysis presets—All tests included

Figure 3–18. Slug-test analysis for test well NELT7 #1 (16N/02E-16P1S) for 20-foot interval of well casing (780–800 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Nelson Lake 7 #2 (NELT7 #2)

State well number: 16N/02E-16P2S **USGS site identifier:** 352806116462102

Date: 03/05/2012 **Time:** 09:59

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	293.77 feet
Top of screen	=	620.0 feet
Base of screen	=	640.0 feet
Top of aquifer	=	620 feet
Base of aquifer	=	640 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Medium-grained sand

Input is consistent

COMPUTED

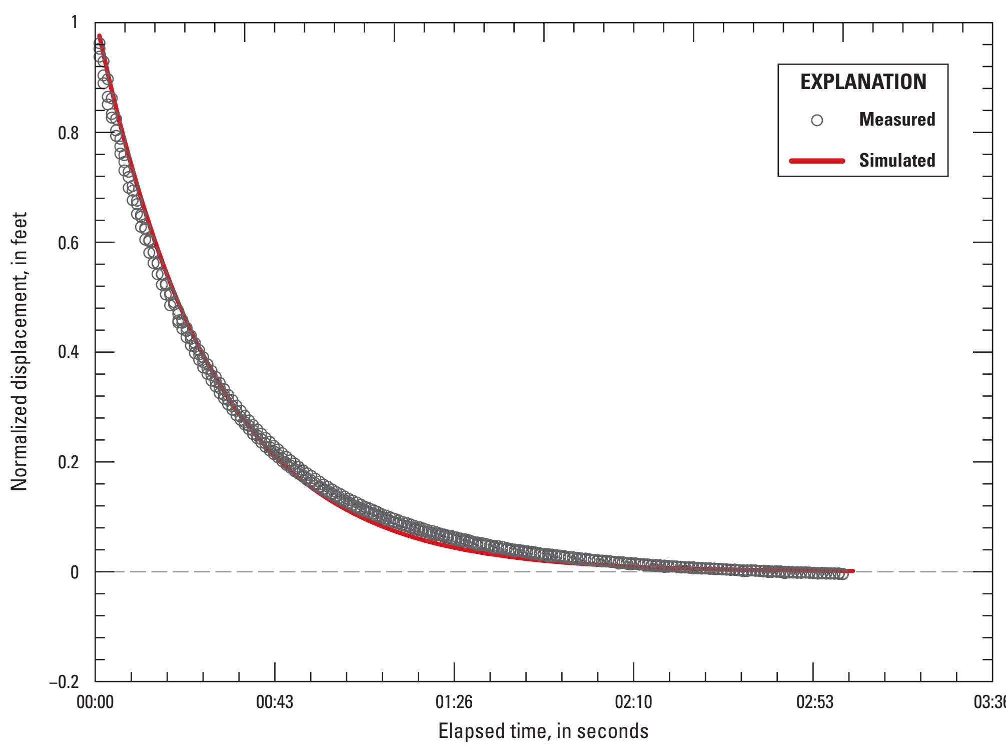
Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	20.01 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{ESTIMATED}$	=	300 feet
$L_{THEORETICAL}$	=	340 feet

MF = 3.06

K = 2.8 feet/day

Residual standard error = 0.33 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—620–640 feet
Analysis presets—All tests included

Figure 3–19. Slug-test analysis for test well NELT7 #2 (16N/02E-16P2S) for 20-foot interval of well casing (620–640 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Nelson Lake 7 #3 (NELT7 #3)

State well number: 16N/02E-16P3S **USGS site identifier:** 352806116462103

Date: 03/05/2012 **Time:** 12:14

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	279.82 feet
Top of screen	=	380.0 feet
Base of screen	=	400.0 feet
Top of aquifer	=	380 feet
Base of aquifer	=	400 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

Input is consistent

COMPUTED

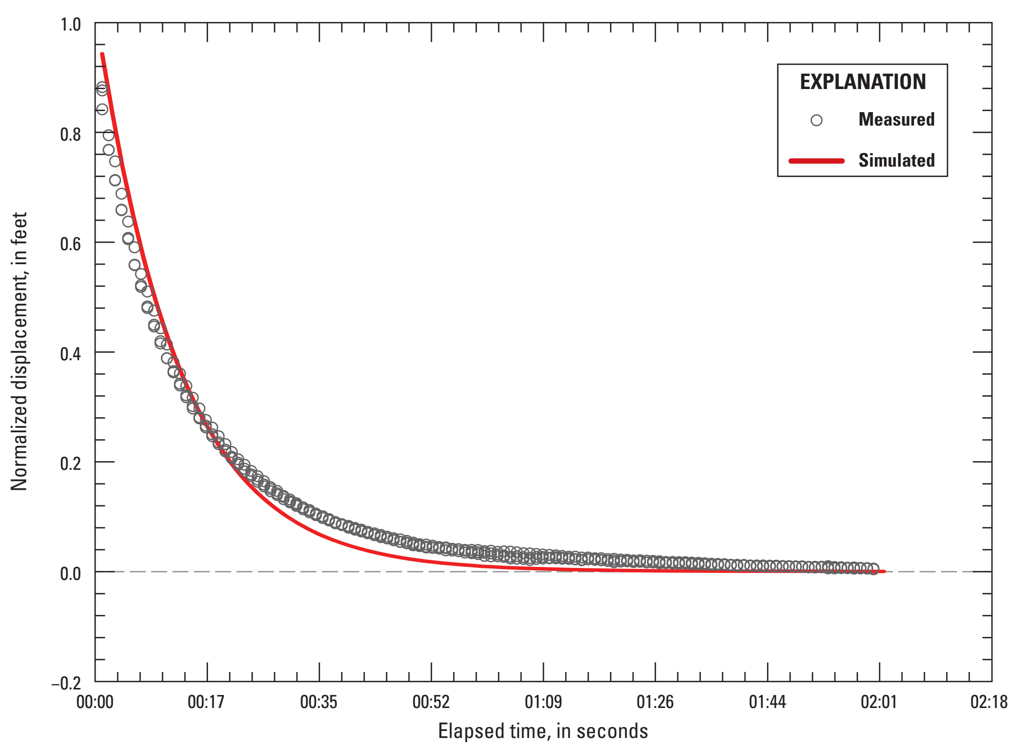
Aquifer thickness	=	20 feet
$Y_{\text{O-DISPLACEMENT}}$	=	16.50 feet
$Y_{\text{O-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	110 feet
$L_{\text{THEORETICAL}}$	=	110 feet

MF = 1.81

K = 6 feet/day

Residual standard error = 0.48 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—380–400 feet
Analysis presets—All tests included

Figure 3–20. Slug-test analysis for test well NELT7 #3 (16N/02E-16P3S) for 20-foot interval of well casing (380–400 feet below land surface), Fort Irwin National Training Center, California, March 2012. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Nelson Lake 1 #1 (NELT1 #1)

State well number: 16N/02E-34Q1S **USGS site identifier:** 352535116451001

Date: 10/26/2011 **Time:** 09:38

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	207.52 feet
Top of screen	=	740.0 feet
Base of screen	=	760.0 feet
Top of aquifer	=	740 feet
Base of aquifer	=	760 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

Input is consistent

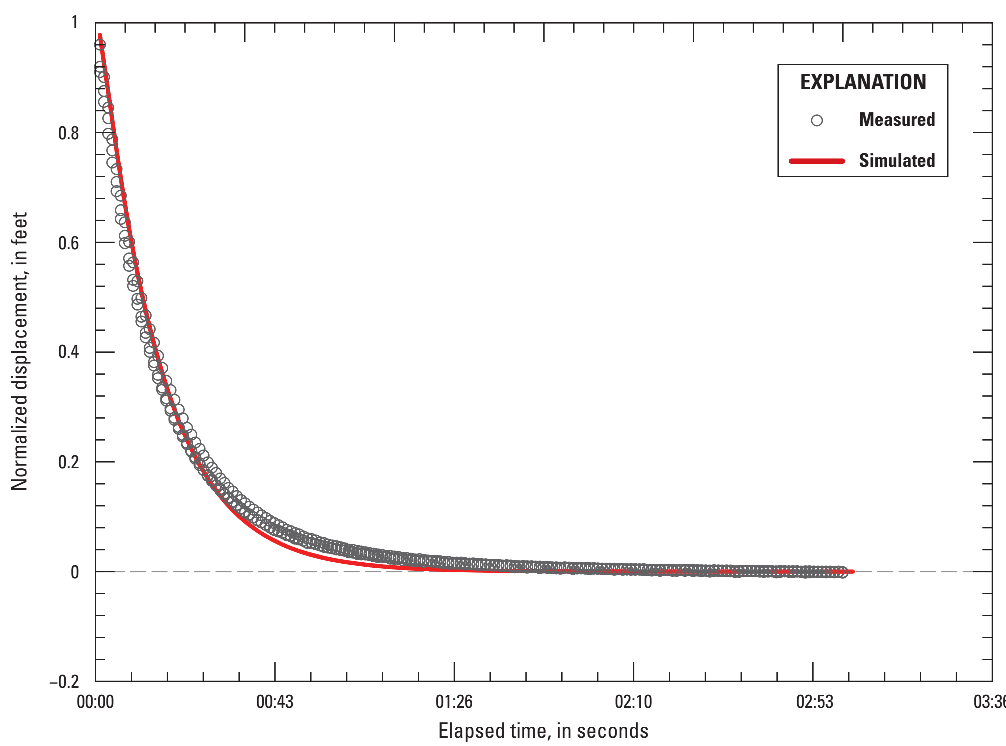
COMPUTED

Aquifer thickness	=	20 feet
$Y_{0\text{-DISPLACEMENT}}$	=	18.71 feet
$Y_{0\text{-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	530 feet
$L_{\text{THEORETICAL}}$	=	540 feet

MF	**=**	**4.07**
K	**=**	**5 feet/day**

Residual standard error **=** **0.36 feet**

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—740–760 feet
Analysis presets—All tests included

Figure 3–21. Slug-test analysis for test well NELT1 #1 (16N/02E-34Q1S) for 20-foot interval of well casing (740–760 feet below land surface), Fort Irwin National Training Center, California, October 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

Nelson Lake 1 #2 (NELT1 #2)

State well number: 16N/02E-34Q2S **USGS site identifier:** 352535116451002

Date: 11/01/2011 **Time:** 15:46

INPUT

Construction

Casing diameter (dc)	=	1.94 inches
Annulus diameter (dw)	=	1.94 inches

Depth to

Water level	=	202.99 feet
Top of screen	=	280.0 feet
Base of screen	=	300.0 feet
Top of aquifer	=	280 feet
Base of aquifer	=	300 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

Input is consistent

COMPUTED

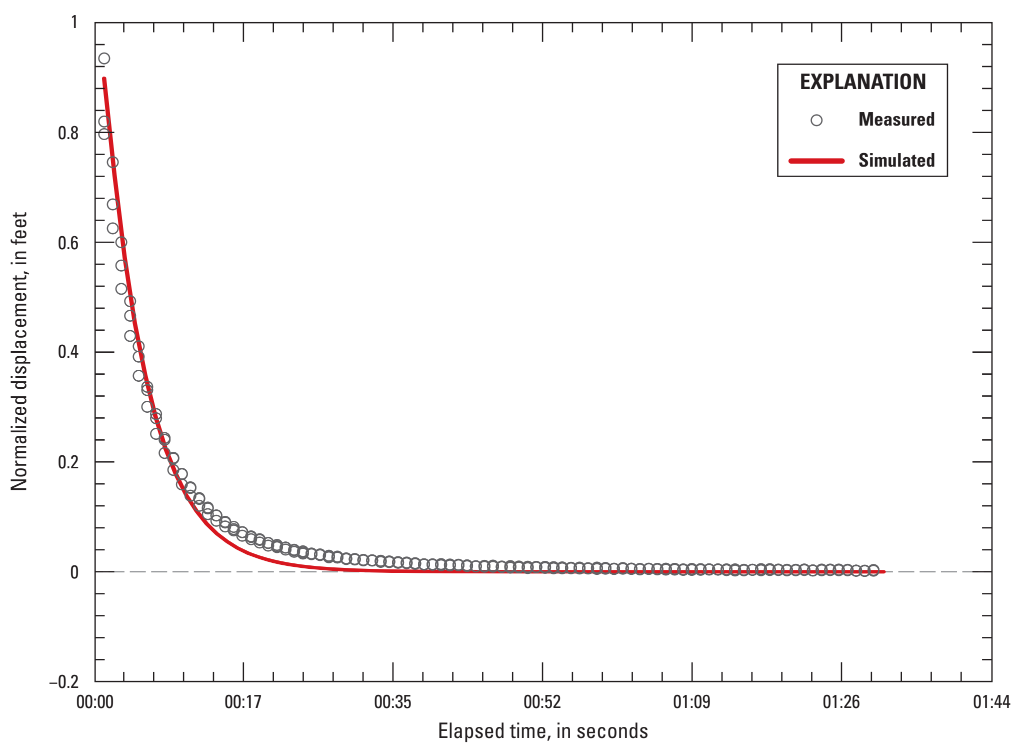
Aquifer thickness	=	20 feet
$Y_{\text{O-DISPLACEMENT}}$	=	15.54 feet
$Y_{\text{O-SLUG}}$	=	11.53 feet
$L_{\text{ESTIMATED}}$	=	86 feet
$L_{\text{THEORETICAL}}$	=	87 feet

MF = 1.63

K = 14 feet/day

Residual standard error = 0.34 feet

Kansas Geological Survey—high conductivity



Remarks: Butler, Garnett, and Healey, 2003, Ground Water 41(5)
Pneumatic slug test—280–300 feet
Analysis presets—All tests included

Figure 3–22. Slug-test analysis for test well NELT1 #2 (16N/02E-34Q2S) for 20-foot interval of well casing (280–300 feet below land surface), Fort Irwin National Training Center, California, November 2011. (Abbreviations: MF, dampening coefficient; K, hydraulic conductivity; feet/day, feet per day; RMS, residual standard error; KGS_High-K, Kansas Geological Survey method for analysis of slug tests in formations of high hydraulic conductivity; USGS, U.S. Geological Survey).

References Cited

Butler, J.J., Jr., Garnett, E.J., and Healey, J.M., 2003, Analysis of slug tests in formations of high hydraulic conductivity: Groundwater, v. 41, no. 5, p. 620–631, https://doi.org/10.1111/j.1745-6584.2003.tb02400.x.

Halford, K.J., and Kuniansky, E.L., 2002, Documentation of spreadsheets for the analysis of aquifer-test and slug-test data: U.S. Geological Survey Open-File Report 2002–197, 54 p., https://doi.org/10.3133/ofr02197.

Appendix 4. Aquifer-Test Hydrographs

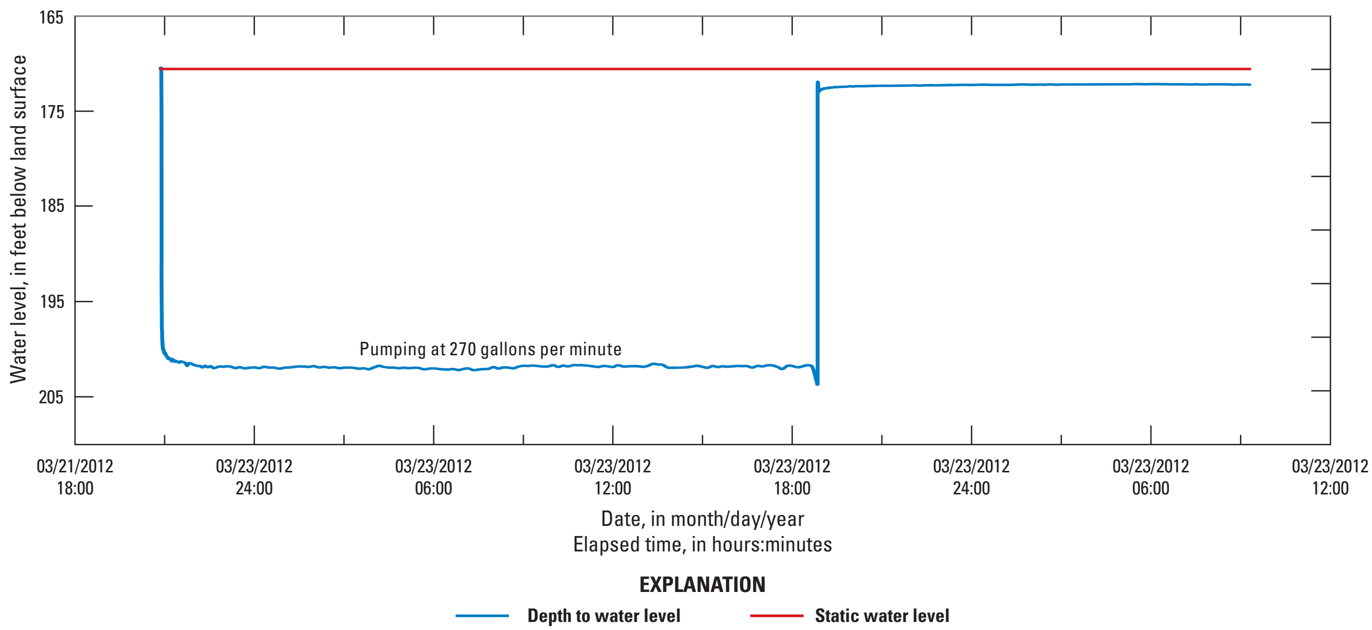


Figure 4–1. Aquifer-test water-level hydrograph for test well GOLD1-T #1 (15N/01E-28R4S) for constant pumping rate followed by initial recovery, Fort Irwin National Training Center, California, March 2012.

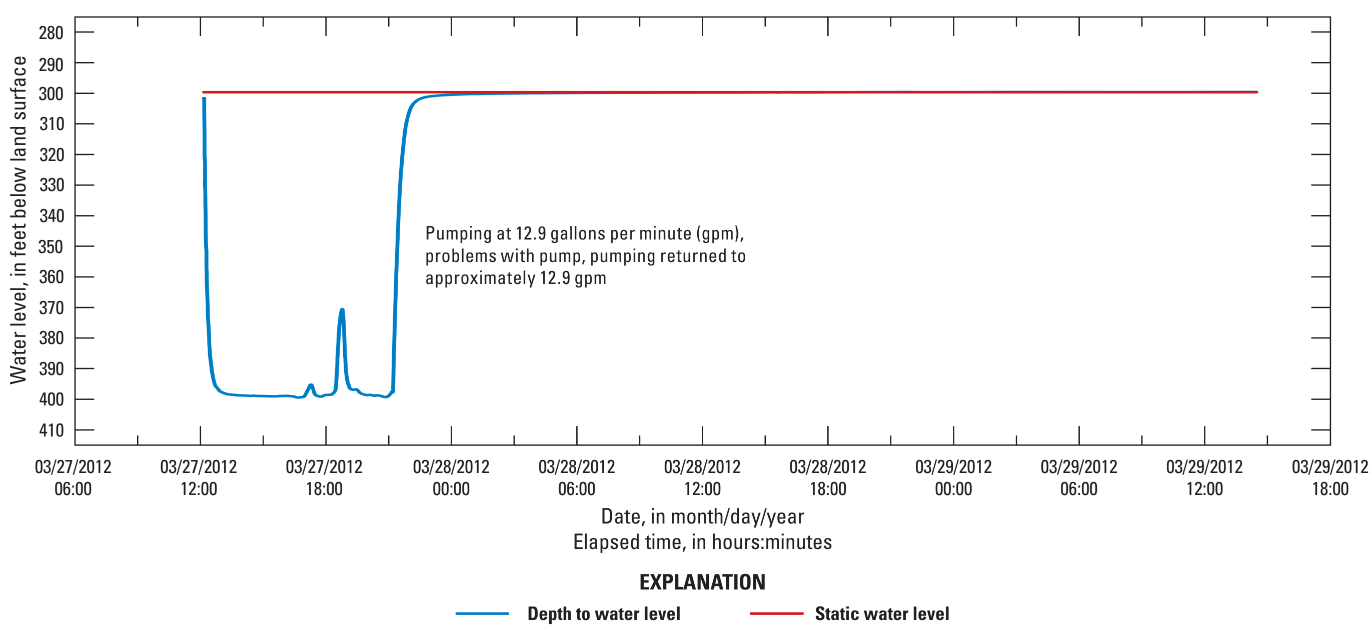


Figure 4–2. Aquifer-test water-level hydrograph for test well NELT6 #1 (15N/02E-05N1S) for constant pumping rate followed by initial recovery, Fort Irwin National Training Center, California, March 2012.

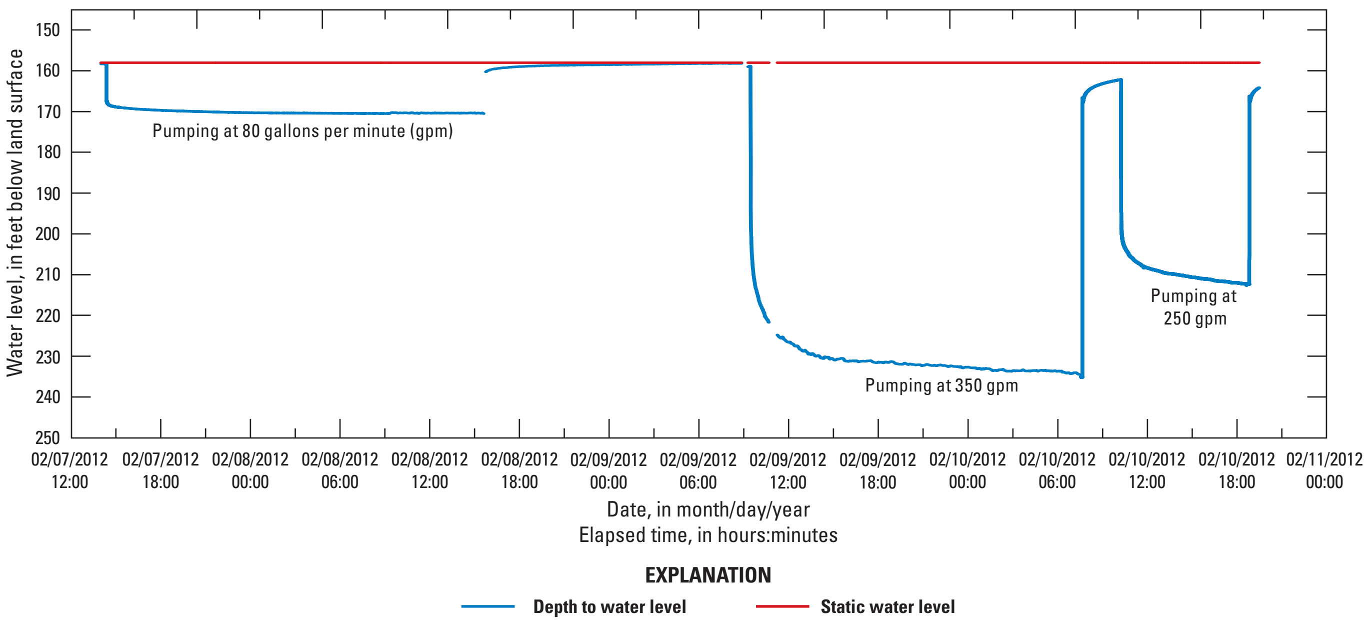


Figure 4–3. Aquifer-test water-level hydrograph for test well NELT4 #1 (15N/03E-08L1S) for variable pumping rate followed by initial recovery, Fort Irwin National Training Center, California, February 2012.

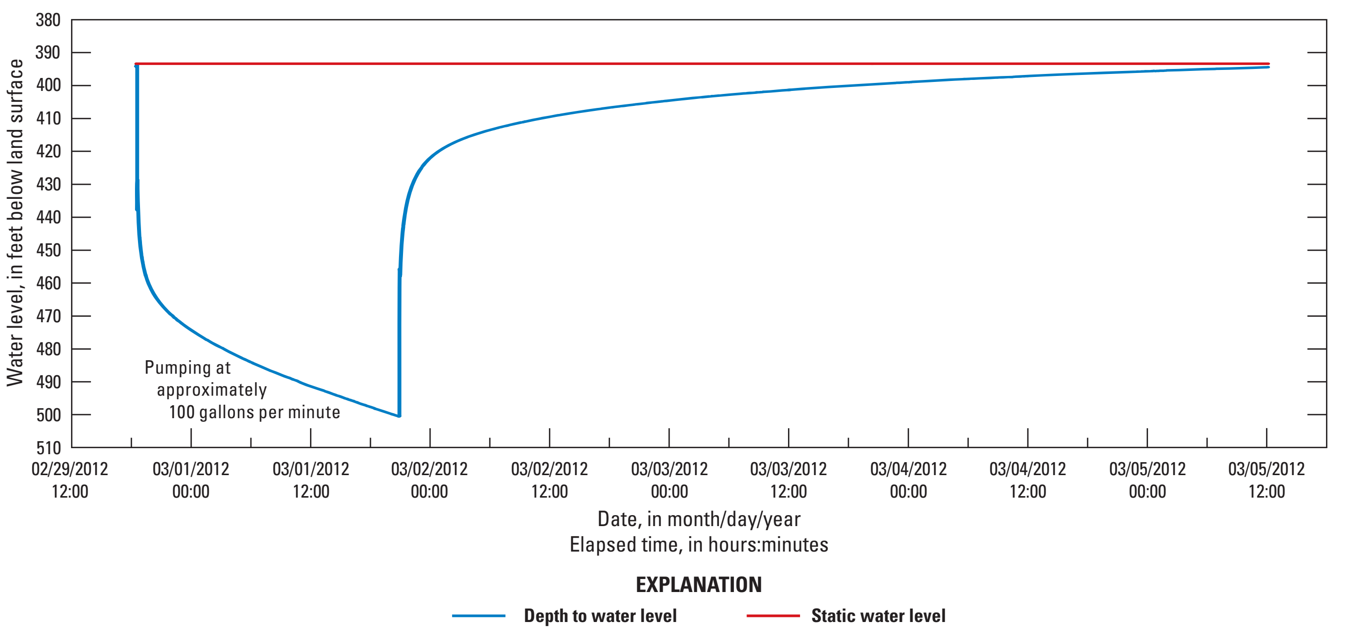


Figure 4–4. Aquifer-test water-level hydrograph for test well NELT5 #1 (16N/01E-35P1S) for constant pumping rate followed by initial recovery, Fort Irwin National Training Center, California, February 2012.

Appendix 5. Aquifer-Test Modeling (Curve Matching)

Goldstone 1-Test (GOLD1-T #1)

State well number: 15N/01E-28R4S **USGS site identifier:** 352145116522401

Date: 03/21/2012 **Time:** 20:53

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	14.75 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	170.56 feet
Top of aquifer	=	260 feet
Base of aquifer	=	680 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Permeable basalt

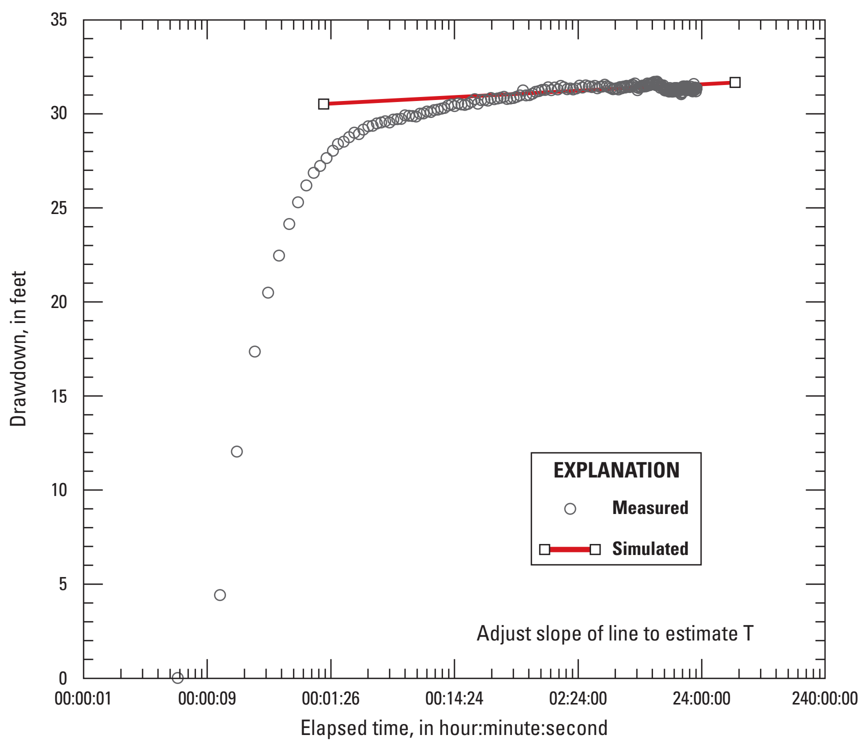
Flow rate: 270 gallons per minute

COMPUTED

Aquifer thickness	=	420 feet
Slope	=	0.342445 feet per $\log_{10}$

Input is consistent

K	**=**	**66 feet/day**
T	**=**	**28,000 feet²/day**



Remarks:

Cooper-Jacob analysis of single-well aquifer test

Total Depth: 700 feet

Screen Intervals: 260–280 feet, 300–420 feet, 620–680 feet

Figure 5–1. Cooper-Jacob analysis of drawdown for test well GOLD1-T #1 (15N/01E-28R4S), Fort Irwin National Training Center, California, March 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity).

Table 5–1. Reduced data from Cooper-Jacob analysis of drawdown for test well GOLD1-T #1 (15N/01E-28R4S) for constant pumping rate, Fort Irwin National Training Center, California, March 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time (mm/dd/yy)	Reduced data time (Hr:Min:Sec)	Water level (feet)
1	3/21/12	20:53:19	170.49
2	3/21/12	20:53:24	170.49
3	3/21/12	20:53:30	174.90
4	3/21/12	20:53:34	182.53
5	3/21/12	20:53:40	187.84
6	3/21/12	20:53:46	190.98
7	3/21/12	20:53:52	192.95
8	3/21/12	20:53:59	194.62
9	3/21/12	20:54:06	195.78
10	3/21/12	20:54:14	196.69
11	3/21/12	20:54:22	197.35
12	3/21/12	20:54:30	197.71
13	3/21/12	20:54:39	198.14
14	3/21/12	20:54:49	198.53
15	3/21/12	20:54:58	198.88
16	3/21/12	20:55:09	199.01
17	3/21/12	20:55:21	199.25
18	3/21/12	20:55:33	199.48
19	3/21/12	20:55:45	199.41
20	3/21/12	20:55:58	199.64
21	3/21/12	20:56:13	199.82
22	3/21/12	20:56:28	199.86
23	3/21/12	20:56:43	199.97
24	3/21/12	20:57:00	200.02
25	3/21/12	20:57:18	200.09
26	3/21/12	20:57:37	200.03
27	3/21/12	20:57:57	200.17
28	3/21/12	20:58:18	200.21
29	3/21/12	20:58:40	200.22
30	3/21/12	20:59:04	200.40
31	3/21/12	20:59:30	200.39
32	3/21/12	20:59:56	200.37
33	3/21/12	21:00:24	200.35
34	3/21/12	21:00:54	200.49
35	3/21/12	21:01:26	200.51
36	3/21/12	21:02:00	200.61
37	3/21/12	21:02:36	200.58
38	3/21/12	21:03:12	200.68
39	3/21/12	21:03:54	200.71
40	3/21/12	21:04:36	200.76
41	3/21/12	21:05:18	200.80
42	3/21/12	21:06:06	200.93
43	3/21/12	21:07:00	200.98
44	3/21/12	21:07:48	200.91
45	3/21/12	21:08:48	201.04
46	3/21/12	21:09:48	200.99
47	3/21/12	21:10:48	200.96
48	3/21/12	21:11:54	201.01
49	3/21/12	21:13:06	201.13
50	3/21/12	21:14:24	201.27
51	3/21/12	21:15:42	201.03
52	3/21/12	21:17:06	201.21
53	3/21/12	21:18:36	201.22
54	3/21/12	21:20:12	201.18
55	3/21/12	21:21:48	201.32
56	3/21/12	21:23:36	201.26
57	3/21/12	21:25:30	201.30
58	3/21/12	21:27:30	201.34
59	3/21/12	21:29:36	201.39
60	3/21/12	21:31:48	201.28
61	3/21/12	21:34:12	201.31
62	3/21/12	21:36:42	201.32
63	3/21/12	21:39:18	201.39
64	3/21/12	21:42:06	201.47
65	3/21/12	21:45:06	201.74
66	3/21/12	21:48:12	201.47
67	3/21/12	21:51:36	201.48
68	3/21/12	21:55:06	201.55
69	3/21/12	21:58:48	201.65
70	3/21/12	22:02:48	201.69
71	3/21/12	22:07:00	201.76
72	3/21/12	22:11:24	201.76
73	3/21/12	22:16:06	201.90
74	3/21/12	22:21:06	201.74
75	3/21/12	22:26:24	201.88
76	3/21/12	22:32:00	201.78
77	3/21/12	22:38:00	201.97
78	3/21/12	22:44:00	201.90
79	3/21/12	22:51:00	201.80

Table 5–1. Reduced data from Cooper-Jacob analysis of drawdown for test well GOLD1-T #1 (15N/01E-28R4S) for constant pumping rate, Fort Irwin National Training Center, California, March 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	3/21/12	22:58:00	201.83
81	3/21/12	23:05:00	201.79
82	3/21/12	23:13:00	201.83
83	3/21/12	23:22:00	201.98
84	3/21/12	23:30:00	201.88
85	3/21/12	23:40:00	202.00
86	3/21/12	23:50:00	201.94
87	3/22/12	0:00:00	201.91
88	3/22/12	0:10:00	201.97
89	3/22/12	0:20:00	201.84
90	3/22/12	0:30:00	201.93
91	3/22/12	0:40:00	201.93
92	3/22/12	0:50:00	202.04
93	3/22/12	1:00:00	201.94
94	3/22/12	1:10:00	201.90
95	3/22/12	1:20:00	201.85
96	3/22/12	1:30:00	201.80
97	3/22/12	1:40:00	201.82
98	3/22/12	1:50:00	201.84
99	3/22/12	2:00:00	201.78
100	3/22/12	2:10:00	201.91

Goldstone 1-Test (GOLD1-T #1) recovery curve

State well number: 15N/01E-28R4S **USGS site identifier:** 352145116522401

Date: 03/22/2012 **Time:** 20:53

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	14.75 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	170.56 feet
Top of aquifer	=	260 feet
Base of aquifer	=	680 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

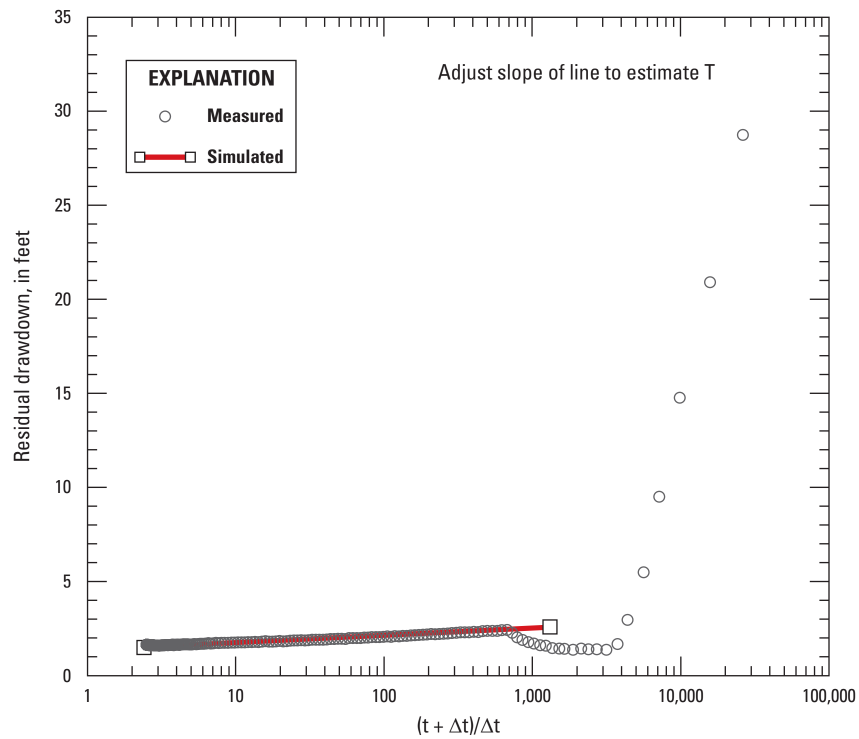
Aquifer material: Permeable basalt
Flow rate: 270 gallons per minute

COMPUTED

Aquifer thickness	=	420 feet
Slope	=	0.3882784 feet per $\log_{10}$

Input is consistent

K	**=**	**58 feet/day**
T	**=**	**25,000 feet²/day**



Remarks:
Cooper-Jacob recovery analysis of single-well aquifer test
Total Depth: 700 feet
Screen Intervals: 260–280 feet, 300–420 feet, 620–680 feet

Figure 5–2. Cooper-Jacob analysis of recovery for test well GOLD1-T #1 (15N/01E-28R4S), Fort Irwin National Training Center, California, March 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity; t, time, in seconds; Dt, time difference, in seconds).

Table 5–2. Reduced data from Cooper-Jacob recovery analysis for test well GOLD1-T #1 (15N/01E-28R4S), Fort Irwin National Training Center, California, March 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time (mm/dd/yy)	Reduced data time (Hr:Min:Sec)	Water level (feet)
1	3/21/12	20:53:00	170.56
2	3/22/12	18:50:42	203.67
3	3/22/12	18:50:45	199.30
4	3/22/12	18:50:47	191.46
5	3/22/12	18:50:50	185.33
6	3/22/12	18:50:53	180.06
7	3/22/12	18:50:56	176.05
8	3/22/12	18:51:00	173.52
9	3/22/12	18:51:03	172.24
10	3/22/12	18:51:07	171.93
11	3/22/12	18:51:11	171.96
12	3/22/12	18:51:15	171.96
13	3/22/12	18:51:19	172.00
14	3/22/12	18:51:24	171.93
15	3/22/12	18:51:30	171.98
16	3/22/12	18:51:34	171.99
17	3/22/12	18:51:40	172.02
18	3/22/12	18:51:46	172.14
19	3/22/12	18:51:52	172.17
20	3/22/12	18:51:59	172.26
21	3/22/12	18:52:06	172.34
22	3/22/12	18:52:14	172.46
23	3/22/12	18:52:22	172.60
24	3/22/12	18:52:30	172.84
25	3/22/12	18:52:39	172.99
26	3/22/12	18:52:49	172.97
27	3/22/12	18:52:58	172.94
28	3/22/12	18:53:09	172.93
29	3/22/12	18:53:21	172.94
30	3/22/12	18:53:33	172.93
31	3/22/12	18:53:45	172.88
32	3/22/12	18:53:58	172.89
33	3/22/12	18:54:13	172.86
34	3/22/12	18:54:28	172.86
35	3/22/12	18:54:43	172.86
36	3/22/12	18:55:00	172.83
37	3/22/12	18:55:18	172.82
38	3/22/12	18:55:37	172.80
39	3/22/12	18:55:57	172.78
40	3/22/12	18:56:18	172.77
41	3/22/12	18:56:40	172.76
42	3/22/12	18:57:04	172.77
43	3/22/12	18:57:30	172.74
44	3/22/12	18:57:56	172.74
45	3/22/12	18:58:24	172.72
46	3/22/12	18:58:54	172.71
47	3/22/12	18:59:26	172.69
48	3/22/12	19:00:00	172.67
49	3/22/12	19:00:36	172.67
50	3/22/12	19:01:12	172.65
51	3/22/12	19:01:54	172.66
52	3/22/12	19:02:36	172.62
53	3/22/12	19:03:18	172.64
54	3/22/12	19:04:06	172.62
55	3/22/12	19:05:00	172.61
56	3/22/12	19:05:48	172.60
57	3/22/12	19:06:48	172.60
58	3/22/12	19:07:48	172.58
59	3/22/12	19:08:48	172.58
60	3/22/12	19:09:54	172.55
61	3/22/12	19:11:06	172.55
62	3/22/12	19:12:24	172.55
63	3/22/12	19:13:42	172.56
64	3/22/12	19:15:06	172.51
65	3/22/12	19:16:36	172.52
66	3/22/12	19:18:12	172.51
67	3/22/12	19:19:48	172.51
68	3/22/12	19:21:36	172.50
69	3/22/12	19:23:30	172.47
70	3/22/12	19:25:30	172.46
71	3/22/12	19:27:36	172.46
72	3/22/12	19:29:48	172.47
73	3/22/12	19:32:12	172.46
74	3/22/12	19:34:42	172.45
75	3/22/12	19:37:18	172.43
76	3/22/12	19:40:06	172.44
77	3/22/12	19:43:06	172.43
78	3/22/12	19:46:12	172.43
79	3/22/12	19:49:36	172.41

Table 5–2. Reduced data from Cooper-Jacob recovery analysis for test well GOLD1-T #1 (15N/01E-28R4S), Fort Irwin National Training Center, California, March 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	3/22/12	19:53:06	172.39
81	3/22/12	19:56:48	172.38
82	3/22/12	20:00:48	172.41
83	3/22/12	20:05:00	172.38
84	3/22/12	20:09:24	172.37
85	3/22/12	20:14:06	172.37
86	3/22/12	20:19:06	172.38
87	3/22/12	20:24:24	172.37
88	3/22/12	20:30:00	172.35
89	3/22/12	20:36:00	172.35
90	3/22/12	20:42:00	172.34
91	3/22/12	20:49:00	172.35
92	3/22/12	20:56:00	172.33
93	3/22/12	21:03:00	172.32
94	3/22/12	21:11:00	172.32
95	3/22/12	21:20:00	172.32
96	3/22/12	21:28:00	172.32
97	3/22/12	21:38:00	172.30
98	3/22/12	21:48:00	172.31
99	3/22/12	21:58:00	172.30
100	3/22/12	22:08:00	172.29

Nelson Lake 6 (NELT6 #1)

State well number: 15N/02E-05N1S **USGS site identifier:** 352436116474001

Date: 03/27/2012 **Time:** 12:11

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	15 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	301.76 feet
Top of aquifer	=	400 feet
Base of aquifer	=	840 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

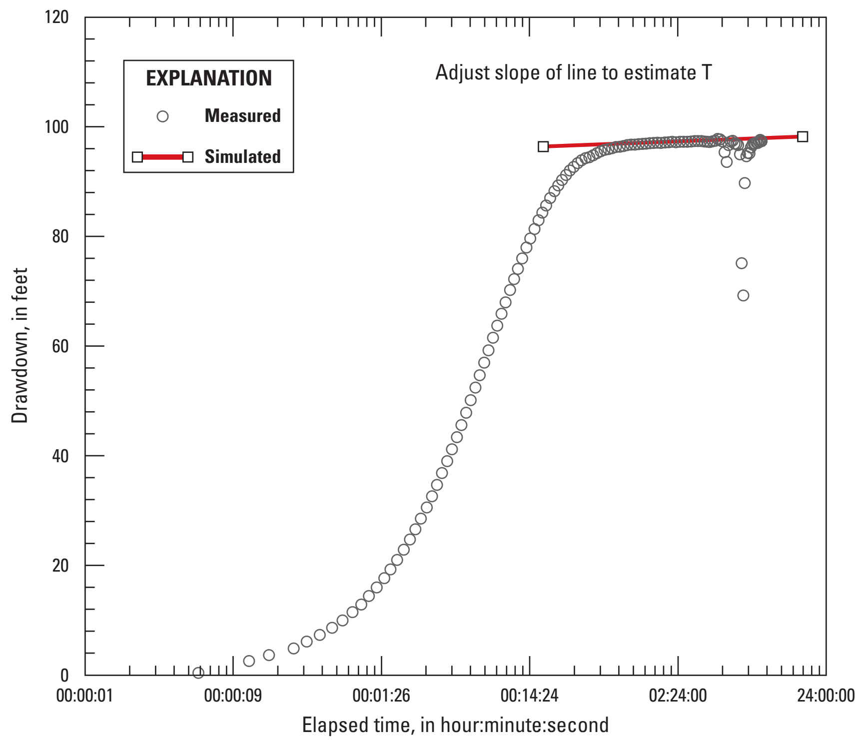
Aquifer material: Medium-grained sand
Flow rate: 12.9 gallons per minute

COMPUTED

Aquifer thickness	=	440 feet
Slope	=	1.028571 feet per $\log_{10}$

Input is consistent

K	**=**	**1 feet/day**
T	**=**	**440 feet²/day**



Remarks:
Cooper-Jacob recovery analysis of single-well aquifer test
Total Depth: 903 feet
Screen Intervals: 400–460 feet, 500–560 feet, 760–840 feet

Figure 5–3. Cooper-Jacob analysis of drawdown for test well NELT6 #1 (15N/02E-05N1S), Fort Irwin National Training Center, California, March 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity).

Table 5–3. Reduced data from Cooper-Jacob analysis of drawdown for test well NELT6 #1 (15N/02E-05N1S) for constant pumping rate, Fort Irwin National Training Center, California, March 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
1	3/27/12	12:11:19	301.69
2	3/27/12	12:11:24	302.04
3	3/27/12	12:11:30	304.25
4	3/27/12	12:11:34	305.31
5	3/27/12	12:11:41	306.52
6	3/27/12	12:11:46	307.77
7	3/27/12	12:11:52	308.98
8	3/27/12	12:11:59	310.29
9	3/27/12	12:12:06	311.65
10	3/27/12	12:12:14	313.13
11	3/27/12	12:12:22	314.53
12	3/27/12	12:12:30	316.07
13	3/27/12	12:12:39	317.66
14	3/27/12	12:12:49	319.33
15	3/27/12	12:12:58	320.91
16	3/27/12	12:13:09	322.66
17	3/27/12	12:13:21	324.51
18	3/27/12	12:13:33	326.39
19	3/27/12	12:13:45	328.26
20	3/27/12	12:13:58	330.19
21	3/27/12	12:14:13	332.25
22	3/27/12	12:14:28	334.27
23	3/27/12	12:14:43	336.34
24	3/27/12	12:15:00	338.53
25	3/27/12	12:15:18	340.66
26	3/27/12	12:15:37	342.85
27	3/27/12	12:15:57	345.04
28	3/27/12	12:16:18	347.25
29	3/27/12	12:16:40	349.52
30	3/27/12	12:17:04	351.82
31	3/27/12	12:17:30	354.10
32	3/27/12	12:17:56	356.33
33	3/27/12	12:18:24	358.65
34	3/27/12	12:18:54	360.90
35	3/27/12	12:19:26	363.17
36	3/27/12	12:20:00	365.40
37	3/27/12	12:20:36	367.56
38	3/27/12	12:21:12	369.63
39	3/27/12	12:21:54	371.87
40	3/27/12	12:22:36	373.89
41	3/27/12	12:23:18	375.74
42	3/27/12	12:24:06	377.65
43	3/27/12	12:25:00	379.65
44	3/27/12	12:25:48	381.27
45	3/27/12	12:26:48	383.02
46	3/27/12	12:27:48	384.60
47	3/27/12	12:28:48	386.01
48	3/27/12	12:29:54	387.28
49	3/27/12	12:31:06	388.70
50	3/27/12	12:32:24	389.93
51	3/27/12	12:33:42	390.98
52	3/27/12	12:35:06	391.97
53	3/27/12	12:36:36	392.89
54	3/27/12	12:38:12	393.72
55	3/27/12	12:39:48	394.33
56	3/27/12	12:41:36	395.04
57	3/27/12	12:43:30	395.56
58	3/27/12	12:45:30	395.97
59	3/27/12	12:47:36	396.13
60	3/27/12	12:49:48	396.49
61	3/27/12	12:52:12	396.85
62	3/27/12	12:54:42	397.22
63	3/27/12	12:57:18	397.48
64	3/27/12	13:00:06	397.61
65	3/27/12	13:03:06	397.79
66	3/27/12	13:06:12	397.97
67	3/27/12	13:09:36	398.04
68	3/27/12	13:13:06	398.17
69	3/27/12	13:16:48	398.34
70	3/27/12	13:20:48	398.40
71	3/27/12	13:25:00	398.42
72	3/27/12	13:29:24	398.51
73	3/27/12	13:34:06	398.55
74	3/27/12	13:39:06	398.60
75	3/27/12	13:44:24	398.70
76	3/27/12	13:50:00	398.72
77	3/27/12	13:56:00	398.75
78	3/27/12	14:02:00	398.74
79	3/27/12	14:09:00	398.82

Table 5–3. Reduced data from Cooper-Jacob analysis of drawdown for test well NELT6 #1 (15N/02E-05N1S) for constant pumping rate, Fort Irwin National Training Center, California, March 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	3/27/12	14:16:00	398.85
81	3/27/12	14:23:00	398.92
82	3/27/12	14:31:00	398.84
83	3/27/12	14:40:00	398.93
84	3/27/12	14:48:00	398.95
85	3/27/12	14:58:00	398.93
86	3/27/12	15:08:00	398.99
87	3/27/12	15:18:00	399.06
88	3/27/12	15:28:00	399.05
89	3/27/12	15:38:00	399.07
90	3/27/12	15:48:00	398.97
91	3/27/12	15:58:00	398.94
92	3/27/12	16:08:00	398.91
93	3/27/12	16:18:00	399.01
94	3/27/12	16:28:00	399.12
95	3/27/12	16:38:00	399.44
96	3/27/12	16:48:00	399.35
97	3/27/12	16:58:00	399.04
98	3/27/12	17:08:00	397.02
99	3/27/12	17:18:00	395.24
100	3/27/12	17:28:00	398.31

Nelson Lake 6 (NELT6 #1) recovery curve

State well number: 15N/02E-05N1S **USGS site identifier:** 352436116474001

Date: 03/27/2012 **Time:** 12:11

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	15 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	301.76 feet
Top of aquifer	=	400 feet
Base of aquifer	=	840 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

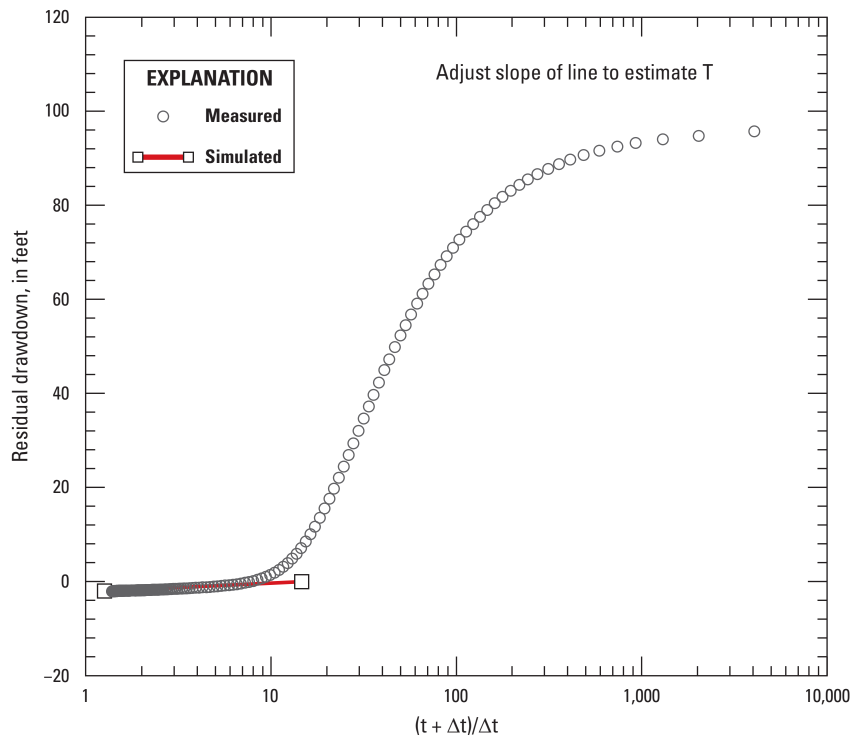
Aquifer material: Clay soils (surface)
Flow rate: 12.9 gallons per minute

COMPUTED

Aquifer thickness	=	440 feet
Slope	=	1.879699 feet per $\log_{10}$

Input is consistent

K	**=**	**0.55 feet/day**
T	**=**	**240 feet^2/day**



Remarks:
Cooper-Jacob recovery analysis of single-well aquifer test
Total Depth: 903 feet
Screen Intervals: 400–460 feet, 500–560 feet, 760–840 feet

Figure 5–4. Cooper-Jacob analysis of recovery for test well NELT6 #1 (15N/02E-05N1S), Fort Irwin National Training Center, California, March 2012. (Abbreviations: feet^2/day, feet squared per day; K, hydraulic conductivity; T, transmissivity; t, time, in seconds; Dt, time difference, in seconds).

Table 5–4. Reduced data from Cooper-Jacob recovery analysis for test well NELT6 #1 (15N/02E-05N1S), Fort Irwin National Training Center, California, March 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time (mm/dd/yy)	Reduced data time (Hr:Min:Sec)	Water level (feet)
1	3/27/12	12:11:00	301.76
2	3/27/12	21:12:22	397.50
3	3/27/12	21:12:39	395.81
4	3/27/12	21:12:58	394.23
5	3/27/12	21:13:21	392.45
6	3/27/12	21:13:45	390.51
7	3/27/12	21:14:13	388.39
8	3/27/12	21:14:43	386.10
9	3/27/12	21:15:18	383.53
10	3/27/12	21:15:57	380.75
11	3/27/12	21:16:40	377.74
12	3/27/12	21:17:30	374.43
13	3/27/12	21:18:24	370.91
14	3/27/12	21:19:26	367.06
15	3/27/12	21:20:36	362.91
16	3/27/12	21:21:54	358.51
17	3/27/12	21:23:18	354.06
18	3/27/12	21:25:00	348.97
19	3/27/12	21:26:48	344.03
20	3/27/12	21:28:48	338.97
21	3/27/12	21:31:06	333.77
22	3/27/12	21:33:42	328.66
23	3/27/12	21:36:36	323.81
24	3/27/12	21:39:48	319.38
25	3/27/12	21:43:30	315.30
26	3/27/12	21:47:36	311.79
27	3/27/12	21:52:12	308.86
28	3/27/12	21:57:18	306.64
29	3/27/12	22:03:06	304.91
30	3/27/12	22:09:36	303.62
31	3/27/12	22:16:48	302.76
32	3/27/12	22:25:00	302.10
33	3/27/12	22:34:06	301.66
34	3/27/12	22:44:24	301.32
35	3/27/12	22:56:00	301.08
36	3/27/12	23:09:00	300.91
37	3/27/12	23:23:00	300.72
38	3/27/12	23:40:00	300.60
39	3/27/12	23:58:00	300.51
40	3/28/12	0:18:00	300.42
41	3/28/12	0:38:00	300.32
42	3/28/12	0:58:00	300.28
43	3/28/12	1:18:00	300.25
44	3/28/12	1:38:00	300.17
45	3/28/12	1:58:00	300.16
46	3/28/12	2:18:00	300.10
47	3/28/12	2:38:00	300.08
48	3/28/12	2:58:00	300.06
49	3/28/12	3:18:00	300.02
50	3/28/12	3:38:00	300.02
51	3/28/12	3:58:00	300.01
52	3/28/12	4:18:00	299.98
53	3/28/12	4:38:00	299.95
54	3/28/12	4:58:00	299.96
55	3/28/12	5:18:00	299.94
56	3/28/12	5:38:00	299.89
57	3/28/12	5:58:00	299.91
58	3/28/12	6:18:00	299.89
59	3/28/12	6:38:00	299.86
60	3/28/12	6:58:00	299.89
61	3/28/12	7:18:00	299.86
62	3/28/12	7:38:00	299.88
63	3/28/12	7:58:00	299.86
64	3/28/12	8:18:00	299.84
65	3/28/12	8:38:00	299.84
66	3/28/12	8:58:00	299.86
67	3/28/12	9:18:00	299.84
68	3/28/12	9:38:00	299.82
69	3/28/12	9:58:00	299.80
70	3/28/12	10:18:00	299.82
71	3/28/12	10:38:00	299.81
72	3/28/12	10:58:00	299.80
73	3/28/12	11:18:00	299.79
74	3/28/12	11:38:00	299.81
75	3/28/12	11:58:00	299.81
76	3/28/12	12:18:00	299.79
77	3/28/12	12:38:00	299.79
78	3/28/12	12:58:00	299.81
79	3/28/12	13:18:00	299.80

Table 5–4. Reduced data from Cooper-Jacob recovery analysis for test well NELT6 #1 (15N/02E-05N1S), Fort Irwin National Training Center, California, March 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	3/28/12	13:38:00	299.78
81	3/28/12	13:58:00	299.77
82	3/28/12	14:18:00	299.76
83	3/28/12	14:38:00	299.79
84	3/28/12	14:58:00	299.73
85	3/28/12	15:18:00	299.76
86	3/28/12	15:38:00	299.76
87	3/28/12	15:58:00	299.74
88	3/28/12	16:18:00	299.72
89	3/28/12	16:38:00	299.76
90	3/28/12	16:58:00	299.76
91	3/28/12	17:18:00	299.72
92	3/28/12	17:38:00	299.73
93	3/28/12	17:58:00	299.70
94	3/28/12	18:18:00	299.70
95	3/28/12	18:38:00	299.69
96	3/28/12	18:58:00	299.71
97	3/28/12	19:18:00	299.69
98	3/28/12	19:38:00	299.67
99	3/28/12	19:58:00	299.66
100	3/28/12	20:18:00	299.63

Nelson Lake 4 (NELT4 #1)

State well number: 15N/03E-08L1S **USGS site identifier:** 352354116411201

Date: 02/09/2012 **Time:** 09:26

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	13 inches
Screen length (L)	=	200 feet

Depth to

Water level (DTW)	=	158.86 feet
Top of aquifer	=	320 feet
Base of aquifer	=	580 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

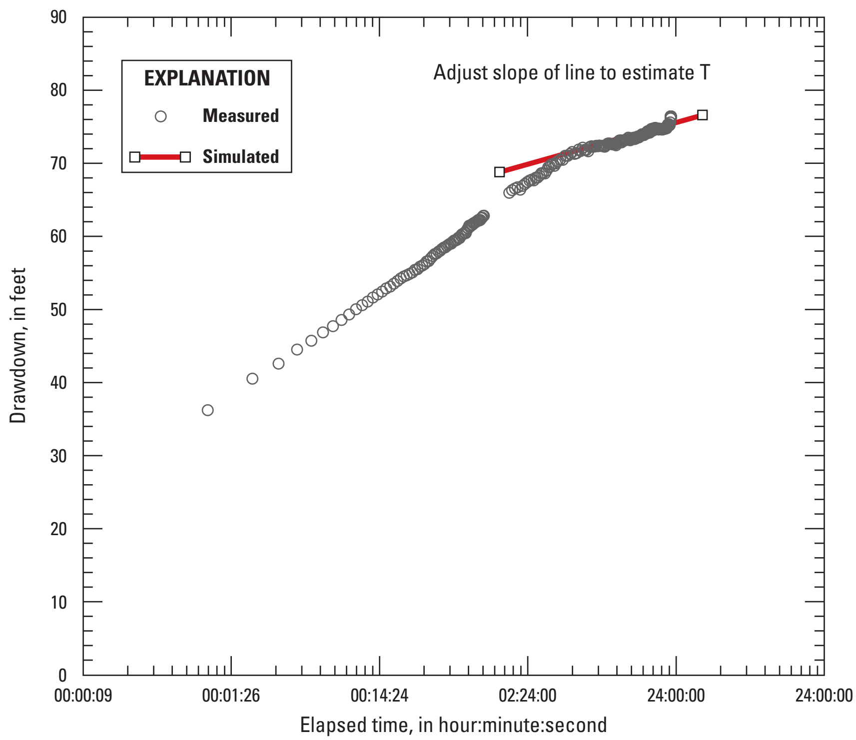
Flow rate: 350 gallons per minute

COMPUTED

Aquifer thickness	=	260 feet
Slope	=	5.6834307 feet per $\log_{10}$

Input is consistent

K	**=**	**8.3 feet/day**
T	**=**	**2,200 feet^2/day**



Remarks:

Cooper-Jacob recovery analysis of single-well aquifer test

Total Depth: 580 feet

Screen Intervals: 320–480 feet, 500–520 feet, 560–580 feet

Figure 5–5. Cooper-Jacob analysis of drawdown for test well NELT4 #1 (15N/03E-08L1S), Fort Irwin National Training Center, California, February 2012. (Abbreviations: feet^2/day, feet squared per day; K, hydraulic conductivity; T, transmissivity).

Table 5–5. Reduced data from Cooper-Jacob analysis of drawdown for test well NELT4 #1 (15N/03E-08L1S) for constant pumping rate, Fort Irwin National Training Center, California, February 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
1	2/9/12	9:26:54	158.86
2	2/9/12	9:29:54	201.43
3	2/9/12	9:32:54	205.71
4	2/9/12	9:35:54	208.17
5	2/9/12	9:38:54	209.92
6	2/9/12	9:41:54	211.28
7	2/9/12	9:44:54	212.36
8	2/9/12	9:47:54	213.36
9	2/9/12	9:50:54	213.92
10	2/9/12	9:53:54	214.70
11	2/9/12	9:56:54	215.40
12	2/9/12	9:59:54	216.15
13	2/9/12	10:02:54	216.76
14	2/9/12	10:05:54	217.31
15	2/9/12	10:08:54	217.70
16	2/9/12	10:11:54	218.12
17	2/9/12	10:14:54	218.38
18	2/9/12	10:17:54	218.93
19	2/9/12	10:20:54	219.37
20	2/9/12	10:23:54	219.93
21	2/9/12	10:26:54	220.44
22	2/9/12	10:29:54	220.66
23	2/9/12	10:32:54	220.98
24	2/9/12	10:35:54	221.09
25	2/9/12	10:38:54	221.65
26	2/9/12	11:20:00	225.17
27	2/9/12	11:35:00	225.26
28	2/9/12	11:50:00	226.30
29	2/9/12	12:05:00	226.51
30	2/9/12	12:20:00	227.17
31	2/9/12	12:35:00	227.45
32	2/9/12	12:50:00	228.38
33	2/9/12	13:05:00	228.52
34	2/9/12	13:25:00	229.34
35	2/9/12	13:55:00	229.87
36	2/9/12	14:25:00	230.14
37	2/9/12	14:55:00	230.55
38	2/9/12	15:25:00	230.67
39	2/9/12	15:55:00	231.20
40	2/9/12	16:25:00	231.24
41	2/9/12	16:55:00	231.21
42	2/9/12	17:25:00	231.12
43	2/9/12	17:55:00	231.59
44	2/9/12	18:25:00	231.45
45	2/9/12	18:55:00	231.31
46	2/9/12	19:25:00	231.97
47	2/9/12	19:55:00	231.95
48	2/9/12	20:25:00	232.07
49	2/9/12	20:55:00	232.37
50	2/9/12	21:25:00	232.19
51	2/9/12	21:55:00	232.35
52	2/9/12	22:25:00	232.26
53	2/9/12	22:55:00	232.40
54	2/9/12	23:25:00	232.68
55	2/9/12	23:55:00	232.73
56	2/10/12	0:25:00	232.88
57	2/10/12	0:55:00	233.25
58	2/10/12	1:25:00	233.06
59	2/10/12	1:55:00	233.57
60	2/10/12	2:25:00	233.46
61	2/10/12	2:55:00	233.70
62	2/10/12	3:25:00	233.57
63	2/10/12	3:55:00	233.61
64	2/10/12	4:25:00	233.49
65	2/10/12	4:55:00	233.46
66	2/10/12	5:25:00	233.54
67	2/10/12	5:55:00	233.70
68	2/10/12	6:25:00	233.90
69	2/10/12	6:55:00	234.22
70	2/10/12	7:25:00	234.46
71	2/10/12	7:34:04	235.07
72	2/10/12	7:34:10	235.05
73	2/10/12	7:34:16	235.04
74	2/10/12	7:34:22	235.07
75	2/10/12	7:34:28	235.11
76	2/10/12	7:34:34	235.12
77	2/10/12	7:34:40	235.10
78	2/10/12	7:34:46	235.10
79	2/10/12	7:34:52	235.14

Table 5–5. Reduced data from Cooper-Jacob analysis of drawdown for test well NELT4 #1 (15N/03E-08L1S) for constant pumping rate, Fort Irwin National Training Center, California, February 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	2/10/12	7:34:58	235.11
81	2/10/12	7:35:04	235.14
82	2/10/12	7:35:10	235.19
83	2/10/12	7:35:16	235.16
84	2/10/12	7:35:22	235.12
85	2/10/12	7:35:28	235.15
86	2/10/12	7:35:34	235.17
87	2/10/12	7:35:40	235.21
88	2/10/12	7:35:46	235.21
89	2/10/12	7:35:52	235.21
90	2/10/12	7:35:58	235.23
91	2/10/12	7:36:04	235.23
92	2/10/12	7:36:10	235.28
93	2/10/12	7:36:16	235.27
94	2/10/12	7:36:22	235.24
95	2/10/12	7:36:28	235.23
96	2/10/12	7:36:34	235.25
97	2/10/12	7:36:40	235.27
98	2/10/12	7:36:46	235.23
99	2/10/12	7:36:52	235.23
100	2/10/12	7:36:58	235.26

Nelson Lake 4 (NELT4 #1) recovery curve

State well number: 15N/03E-08L1S **USGS site identifier:** 352354116411201

Date: 02/09/2012 **Time:** 09:26

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	13 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	158.86 feet
Top of aquifer	=	320 feet
Base of aquifer	=	580 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

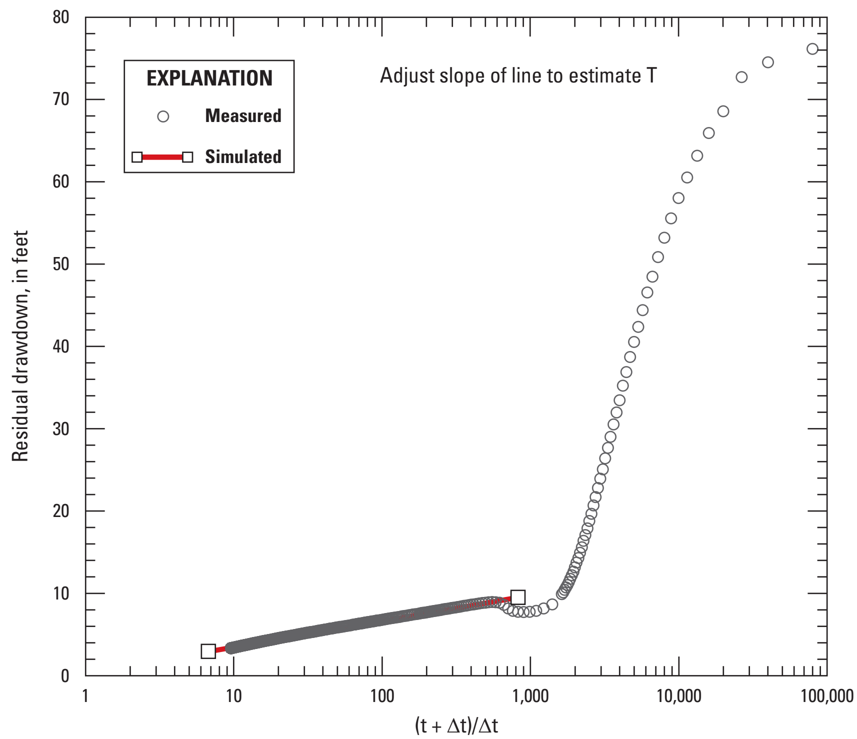
Aquifer material: Fine-grained sand
Flow rate: 350 gallons per minute

COMPUTED

Aquifer thickness	=	260 feet
Slope	=	3.1578947 feet per $\log_{10}$

Input is consistent

K	**=**	**15 feet/day**
T	**=**	**3,900 feet²/day**



Remarks:
Cooper-Jacob recovery analysis of single-well aquifer test
Total Depth: 580 feet
Screen Intervals: 320–480 feet, 500–520 feet, 560–580 feet

Figure 5–6. Cooper-Jacob analysis of recovery for test well NELT4 #1 (15N/03E-08L1S), Fort Irwin National Training Center, California, February 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity; t, time, in seconds; Dt, time difference, in seconds).

Table 5–6. Reduced data from Cooper-Jacob recovery analysis for test well NELT4 #1 (15N/03E-08L1S), Fort Irwin National Training Center, California, February 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
1	2/9/12	9:26:00	158.86
2	2/10/12	7:38:57	231.57
3	2/10/12	7:39:01	219.37
4	2/10/12	7:39:05	209.68
5	2/10/12	7:39:09	201.22
6	2/10/12	7:39:13	194.06
7	2/10/12	7:39:17	187.84
8	2/10/12	7:39:21	182.75
9	2/10/12	7:39:25	178.50
10	2/10/12	7:39:29	175.22
11	2/10/12	7:39:33	172.58
12	2/10/12	7:39:37	170.61
13	2/10/12	7:39:41	169.26
14	2/10/12	7:39:59	166.98
15	2/10/12	7:40:31	166.59
16	2/10/12	7:41:03	167.69
17	2/10/12	7:41:35	167.70
18	2/10/12	7:42:07	167.49
19	2/10/12	7:42:39	167.30
20	2/10/12	7:43:11	167.12
21	2/10/12	7:43:43	166.97
22	2/10/12	7:44:15	166.83
23	2/10/12	7:44:47	166.71
24	2/10/12	7:45:19	166.59
25	2/10/12	7:45:51	166.49
26	2/10/12	7:46:23	166.39
27	2/10/12	7:47:27	166.22
28	2/10/12	7:48:31	166.06
29	2/10/12	7:49:35	165.92
30	2/10/12	7:50:39	165.81
31	2/10/12	7:51:43	165.68
32	2/10/12	7:52:47	165.58
33	2/10/12	7:53:51	165.48
34	2/10/12	7:54:55	165.40
35	2/10/12	7:55:59	165.31
36	2/10/12	7:57:03	165.23
37	2/10/12	7:58:07	165.15
38	2/10/12	7:59:11	165.08
39	2/10/12	8:00:47	164.97
40	2/10/12	8:02:55	164.85
41	2/10/12	8:05:03	164.74
42	2/10/12	8:07:11	164.64
43	2/10/12	8:09:19	164.54
44	2/10/12	8:11:27	164.45
45	2/10/12	8:13:35	164.36
46	2/10/12	8:15:43	164.28
47	2/10/12	8:17:51	164.20
48	2/10/12	8:19:59	164.13
49	2/10/12	8:22:07	164.05
50	2/10/12	8:24:15	164.00
51	2/10/12	8:26:23	163.94
52	2/10/12	8:28:31	163.87
53	2/10/12	8:30:39	163.81
54	2/10/12	8:32:47	163.75
55	2/10/12	8:34:55	163.70
56	2/10/12	8:37:03	163.64
57	2/10/12	8:39:11	163.59
58	2/10/12	8:41:19	163.54
59	2/10/12	8:43:27	163.50
60	2/10/12	8:45:35	163.46
61	2/10/12	8:47:43	163.41
62	2/10/12	8:49:51	163.36
63	2/10/12	8:51:59	163.32
64	2/10/12	8:54:07	163.27
65	2/10/12	8:56:15	163.23
66	2/10/12	8:58:23	163.19
67	2/10/12	9:00:31	163.16
68	2/10/12	9:02:39	163.11
69	2/10/12	9:04:47	163.09
70	2/10/12	9:06:55	163.05
71	2/10/12	9:09:03	163.01
72	2/10/12	9:11:11	162.98
73	2/10/12	9:13:19	162.94
74	2/10/12	9:15:27	162.90
75	2/10/12	9:17:35	162.87
76	2/10/12	9:19:43	162.83
77	2/10/12	9:21:51	162.80
78	2/10/12	9:23:59	162.78
79	2/10/12	9:26:07	162.75

Table 5–6. Reduced data from Cooper-Jacob recovery analysis for test well NELT4 #1 (15N/03E-08L1S), Fort Irwin National Training Center, California, February 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	2/10/12	9:28:15	162.72
81	2/10/12	9:30:23	162.69
82	2/10/12	9:32:31	162.66
83	2/10/12	9:34:39	162.63
84	2/10/12	9:36:47	162.60
85	2/10/12	9:38:55	162.57
86	2/10/12	9:41:03	162.54
87	2/10/12	9:43:11	162.51
88	2/10/12	9:45:19	162.48
89	2/10/12	9:47:27	162.47
90	2/10/12	9:49:35	162.43
91	2/10/12	9:51:43	162.42
92	2/10/12	9:53:51	162.39
93	2/10/12	9:55:59	162.37
94	2/10/12	9:58:07	162.34
95	2/10/12	10:00:15	162.31
96	2/10/12	10:02:23	162.29
97	2/10/12	10:04:31	162.26
98	2/10/12	10:06:39	162.24
99	2/10/12	10:08:47	162.22
100	2/10/12	10:10:55	162.21

Nelson Lake 5 (NELT5 #1)

State well number: 16N/01E-35P1S **USGS site identifier:** 352530116503601

Date: 02/29/2012 **Time:** 18:34

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	14.75 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	394.23 feet
Top of aquifer	=	480 feet
Base of aquifer	=	840 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

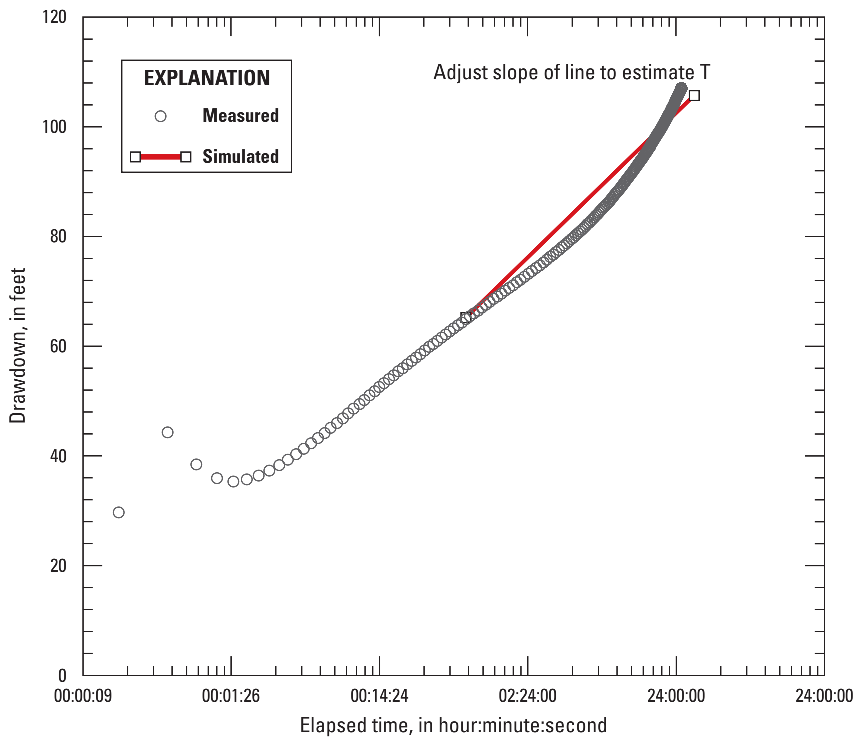
Aquifer material: Clay soils (surface)
Flow rate: 100 gallons per minute

COMPUTED

Aquifer thickness	=	360 feet
Slope	=	26.2987 feet per $\log_{10}$

Input is consistent

K	**=**	**0.37 feet/day**
T	**=**	**130 feet²/day**



Remarks:
Cooper-Jacob recovery analysis of single-well aquifer test
Total Depth: 905 feet
Screen Intervals: 480–520 feet, 640–780 feet, 820–840 feet

Figure 5–7. Cooper-Jacob analysis of drawdown for test well NELT5 #1 (16N/01E-35P1S), Fort Irwin National Training Center, California, February 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity).

Table 5–7. Reduced data from Cooper-Jacob analysis of drawdown for test well NELT5 #1 (16N/01E-35P1S) for constant pumping rate, Fort Irwin National Training Center, California, February 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)	Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)			(mm/dd/yy)	(Hr:Min:Sec)	
1	2/29/12	18:34:28	393.37	41	3/1/12	0:08:00	474.58
2	2/29/12	18:35:00	437.64	42	3/1/12	0:28:00	475.27
3	2/29/12	18:35:37	429.26	43	3/1/12	0:48:00	475.86
4	2/29/12	18:36:18	429.06	44	3/1/12	1:08:00	476.51
5	2/29/12	18:37:04	430.66	45	3/1/12	1:28:00	477.13
6	2/29/12	18:37:56	432.65	46	3/1/12	1:48:00	477.68
7	2/29/12	18:38:54	434.64	47	3/1/12	2:08:00	478.25
8	2/29/12	18:40:00	436.59	48	3/1/12	2:28:00	478.82
9	2/29/12	18:41:12	438.47	49	3/1/12	2:48:00	479.31
10	2/29/12	18:42:36	440.20	50	3/1/12	3:08:00	479.79
11	2/29/12	18:44:06	441.95	51	3/1/12	3:28:00	480.35
12	2/29/12	18:45:48	443.51	52	3/1/12	3:48:00	480.91
13	2/29/12	18:47:48	445.13	53	3/1/12	4:08:00	481.44
14	2/29/12	18:49:54	446.59	54	3/1/12	4:28:00	481.89
15	2/29/12	18:52:24	448.03	55	3/1/12	4:48:00	482.39
16	2/29/12	18:55:06	449.33	56	3/1/12	5:08:00	482.91
17	2/29/12	18:58:12	450.65	57	3/1/12	5:28:00	483.35
18	2/29/12	19:01:36	451.88	58	3/1/12	5:48:00	483.83
19	2/29/12	19:05:30	453.21	59	3/1/12	6:08:00	484.24
20	2/29/12	19:09:48	454.31	60	3/1/12	6:28:00	484.73
21	2/29/12	19:14:42	455.47	61	3/1/12	6:48:00	485.19
22	2/29/12	19:20:06	456.59	62	3/1/12	7:08:00	485.60
23	2/29/12	19:26:12	457.66	63	3/1/12	7:28:00	486.02
24	2/29/12	19:33:06	458.79	64	3/1/12	7:48:00	486.45
25	2/29/12	19:40:48	459.82	65	3/1/12	8:08:00	486.85
26	2/29/12	19:49:24	460.89	66	3/1/12	8:28:00	487.25
27	2/29/12	19:59:06	461.95	67	3/1/12	8:48:00	487.65
28	2/29/12	20:10:00	462.91	68	3/1/12	9:08:00	488.08
29	2/29/12	20:22:00	463.97	69	3/1/12	9:28:00	488.46
30	2/29/12	20:36:00	465.01	70	3/1/12	9:48:00	488.82
31	2/29/12	20:51:00	465.97	71	3/1/12	10:08:00	489.24
32	2/29/12	21:08:00	467.03	72	3/1/12	10:28:00	489.59
33	2/29/12	21:28:00	468.07	73	3/1/12	10:48:00	490.00
34	2/29/12	21:48:00	469.12	74	3/1/12	11:08:00	490.46
35	2/29/12	22:08:00	470.01	75	3/1/12	11:28:00	490.85
36	2/29/12	22:28:00	470.86	76	3/1/12	11:48:00	491.24
37	2/29/12	22:48:00	471.68	77	3/1/12	12:08:00	491.57
38	2/29/12	23:08:00	472.48	78	3/1/12	12:28:00	491.91
39	2/29/12	23:28:00	473.18	79	3/1/12	12:48:00	492.21
40	2/29/12	23:48:00	473.93				

Table 5–7. Reduced data from Cooper-Jacob analysis of drawdown for test well NELT5 #1 (16N/01E-35P1S) for constant pumping rate, Fort Irwin National Training Center, California, February 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	3/1/12	13:08:00	492.59
81	3/1/12	13:28:00	492.94
82	3/1/12	13:48:00	493.26
83	3/1/12	14:08:00	493.66
84	3/1/12	14:28:00	493.98
85	3/1/12	14:48:00	494.36
86	3/1/12	15:08:00	494.72
87	3/1/12	15:28:00	495.07
88	3/1/12	15:48:00	495.43
89	3/1/12	16:08:00	495.74
90	3/1/12	16:28:00	496.12
91	3/1/12	16:48:00	496.46
92	3/1/12	17:08:00	496.84
93	3/1/12	17:28:00	497.13
94	3/1/12	17:48:00	497.48
95	3/1/12	18:08:00	497.83
96	3/1/12	18:28:00	498.23
97	3/1/12	18:48:00	498.54
98	3/1/12	19:08:00	498.88
99	3/1/12	19:28:00	499.21
100	3/1/12	19:48:00	499.52

Nelson Lake 5 (NELT5 #1) recovery curve

State well number: 16N/01E-35P1S **USGS site identifier:** 352530116503601

Date: 03/01/2012 **Time:** 18:34

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	14.75 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	394.23 feet
Top of aquifer	=	480 feet
Base of aquifer	=	840 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Clay soils (surface)

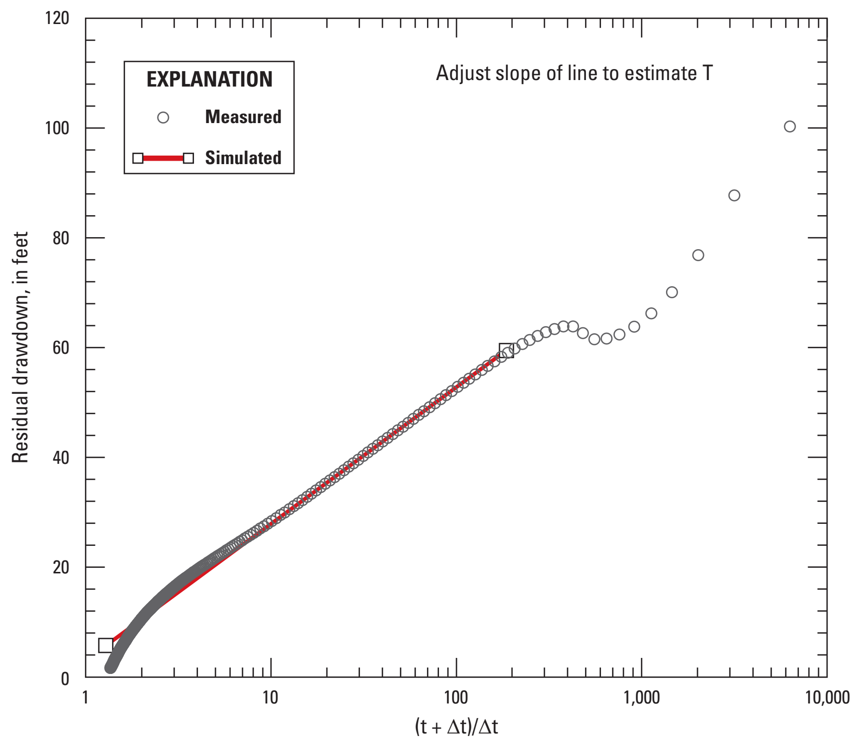
Flow rate: 100 gallons per minute

COMPUTED

Aquifer thickness	=	360 feet
Slope	=	24.88437 feet per $\log_{10}$

Input is consistent

K	**=**	**0.39 feet/day**
T	**=**	**140 feet²/day**



Remarks:

Cooper-Jacob recovery analysis of single-well aquifer test

Total Depth: 905 feet

Screen Intervals: 480–520 feet, 640–780 feet; 820–840 feet

Figure 5–8. Cooper-Jacob analysis of recovery for test well NELT5 #1 (16N/01E-35P1S), Fort Irwin National Training Center, California, March 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity; t, time, in seconds; Dt, time difference, in seconds).

Table 5–8. Reduced data from Cooper-Jacob recovery analysis for test well NELT5 #1 (16N/01E-35P1S), Fort Irwin National Training Center, California, March 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
1	2/29/12	18:34:00	394.23
2	3/1/12	20:55:00	471.06
3	3/1/12	20:56:18	456.58
4	3/1/12	20:57:56	458.06
5	3/1/12	21:00:00	456.32
6	3/1/12	21:02:36	453.25
7	3/1/12	21:05:48	450.15
8	3/1/12	21:09:54	447.05
9	3/1/12	21:15:06	444.08
10	3/1/12	21:21:36	441.22
11	3/1/12	21:29:48	438.45
12	3/1/12	21:40:06	435.77
13	3/1/12	21:53:06	433.15
14	3/1/12	22:09:24	430.64
15	3/1/12	22:30:00	428.18
16	3/1/12	22:56:00	425.88
17	3/1/12	23:28:00	423.73
18	3/2/12	0:08:00	421.68
19	3/2/12	0:48:00	420.11
20	3/2/12	1:28:00	418.83
21	3/2/12	2:08:00	417.75
22	3/2/12	2:48:00	416.83
23	3/2/12	3:28:00	416.00
24	3/2/12	4:08:00	415.27
25	3/2/12	4:48:00	414.61
26	3/2/12	5:28:00	414.00
27	3/2/12	6:08:00	413.41
28	3/2/12	6:48:00	412.89
29	3/2/12	7:28:00	412.37
30	3/2/12	8:08:00	411.91
31	3/2/12	8:48:00	411.46
32	3/2/12	9:28:00	411.01
33	3/2/12	10:08:00	410.61
34	3/2/12	10:48:00	410.22
35	3/2/12	11:28:00	409.81
36	3/2/12	12:08:00	409.45
37	3/2/12	12:48:00	409.07
38	3/2/12	13:28:00	408.74
39	3/2/12	14:08:00	408.41
40	3/2/12	14:48:00	408.08
41	3/2/12	15:28:00	407.80
42	3/2/12	16:08:00	407.49
43	3/2/12	16:48:00	407.22
44	3/2/12	17:28:00	406.94
45	3/2/12	18:08:00	406.66
46	3/2/12	18:48:00	406.43
47	3/2/12	19:28:00	406.18
48	3/2/12	20:08:00	405.93
49	3/2/12	20:48:00	405.70
50	3/2/12	21:28:00	405.45
51	3/2/12	22:08:00	405.22
52	3/2/12	22:48:00	404.98
53	3/2/12	23:28:00	404.75
54	3/3/12	0:08:00	404.53
55	3/3/12	0:48:00	404.32
56	3/3/12	1:28:00	404.10
57	3/3/12	2:08:00	403.89
58	3/3/12	2:48:00	403.68
59	3/3/12	3:28:00	403.52
60	3/3/12	4:08:00	403.32
61	3/3/12	4:48:00	403.13
62	3/3/12	5:28:00	402.95
63	3/3/12	6:08:00	402.78
64	3/3/12	6:48:00	402.61
65	3/3/12	7:28:00	402.43
66	3/3/12	8:08:00	402.27
67	3/3/12	8:48:00	402.10
68	3/3/12	9:28:00	401.94
69	3/3/12	10:08:00	401.80
70	3/3/12	10:48:00	401.65
71	3/3/12	11:28:00	401.48
72	3/3/12	12:08:00	401.32
73	3/3/12	12:48:00	401.15
74	3/3/12	13:28:00	401.01
75	3/3/12	14:08:00	400.84
76	3/3/12	14:48:00	400.69
77	3/3/12	15:28:00	400.59
78	3/3/12	16:08:00	400.46
79	3/3/12	16:48:00	400.30

Table 5–8. Reduced data from Cooper-Jacob recovery analysis for test well NELT5 #1 (16N/01E-35P1S), Fort Irwin National Training Center, California, March 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	3/3/12	17:28:00	400.19
81	3/3/12	18:08:00	400.06
82	3/3/12	18:48:00	399.94
83	3/3/12	19:28:00	399.82
84	3/3/12	20:08:00	399.72
85	3/3/12	20:48:00	399.58
86	3/3/12	21:28:00	399.49
87	3/3/12	22:08:00	399.34
88	3/3/12	22:48:00	399.21
89	3/3/12	23:28:00	399.09
90	3/4/12	0:08:00	399.00
91	3/4/12	0:48:00	398.87
92	3/4/12	1:28:00	398.74
93	3/4/12	2:08:00	398.62
94	3/4/12	2:48:00	398.49
95	3/4/12	3:28:00	398.38
96	3/4/12	4:08:00	398.29
97	3/4/12	4:48:00	398.16
98	3/4/12	5:28:00	398.07
99	3/4/12	6:08:00	397.97
100	3/4/12	6:48:00	397.87

Nelson Lake 3 (NELT3 #1)

State well number: 16N/02E-31H1S **USGS site identifier:** 352556116475501

Date: 02/13/2015 **Time:** 11:22

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	13 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	208.26 feet
Top of aquifer	=	260 feet
Base of aquifer	=	740 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

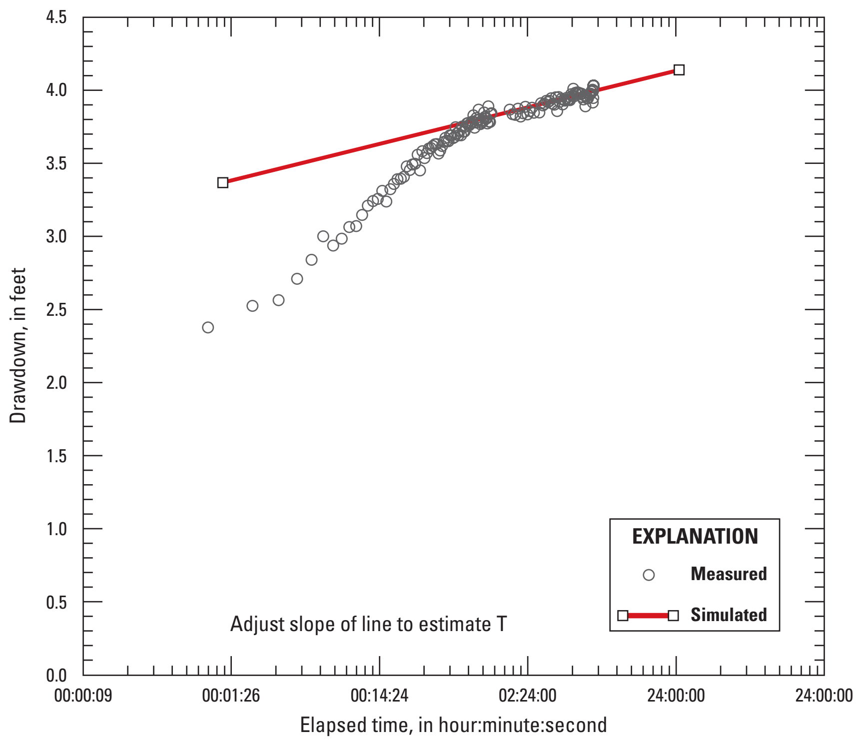
Aquifer material: Medium-grained sand
Flow rate: 85 gallons per minute

COMPUTED

Aquifer thickness	=	480 feet
Slope	=	0.250081 feet per $\log_{10}$

Input is consistent

K	**=**	**25 feet/day**
T	**=**	**12,000 feet²/day**



Remarks:
Cooper-Jacob recovery analysis of single-well aquifer test
Total Depth: 740 feet
Screen Intervals: 260–300 feet, 360–460 feet, 540–580 feet, 720–740 feet

Figure 5–9. Cooper-Jacob analysis of drawdown for test well NELT3 #1 (16N/02E-31H1S), Fort Irwin National Training Center, California, February 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity).

Table 5–9. Reduced data from Cooper-Jacob analysis of drawdown for test well NELT3 #1 (16N/02E-31H1S) for constant pumping rate, Fort Irwin National Training Center, California, February 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)	Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)			(mm/dd/yy)	(Hr:Min:Sec)	
1	2/13/15	11:22:48	208.26	41	2/13/15	12:02:48	211.93
2	2/13/15	11:23:48	210.64	42	2/13/15	12:03:48	211.92
3	2/13/15	11:24:48	210.79	43	2/13/15	12:04:48	211.91
4	2/13/15	11:25:48	210.82	44	2/13/15	12:05:48	211.95
5	2/13/15	11:26:48	210.97	45	2/13/15	12:06:48	211.95
6	2/13/15	11:27:48	211.10	46	2/13/15	12:07:48	211.93
7	2/13/15	11:28:48	211.26	47	2/13/15	12:08:48	211.94
8	2/13/15	11:29:48	211.20	48	2/13/15	12:09:48	212.01
9	2/13/15	11:30:48	211.25	49	2/13/15	12:10:48	211.97
10	2/13/15	11:31:48	211.33	50	2/13/15	12:11:48	211.95
11	2/13/15	11:32:48	211.33	51	2/13/15	12:12:48	211.98
12	2/13/15	11:33:48	211.41	52	2/13/15	12:13:48	211.95
13	2/13/15	11:34:48	211.47	53	2/13/15	12:14:48	212.01
14	2/13/15	11:35:48	211.50	54	2/13/15	12:15:48	211.98
15	2/13/15	11:36:48	211.52	55	2/13/15	12:16:48	211.98
16	2/13/15	11:37:48	211.57	56	2/13/15	12:17:48	212.01
17	2/13/15	11:38:48	211.50	57	2/13/15	12:18:48	212.03
18	2/13/15	11:39:48	211.58	58	2/13/15	12:19:48	212.04
19	2/13/15	11:40:48	211.62	59	2/13/15	12:20:48	212.02
20	2/13/15	11:41:48	211.65	60	2/13/15	12:21:48	212.03
21	2/13/15	11:42:48	211.66	61	2/13/15	12:22:48	212.04
22	2/13/15	11:43:48	211.67	62	2/13/15	12:23:48	212.05
23	2/13/15	11:44:48	211.74	63	2/13/15	12:24:48	212.09
24	2/13/15	11:45:48	211.72	64	2/13/15	12:25:48	212.01
25	2/13/15	11:46:48	211.75	65	2/13/15	12:26:48	212.04
26	2/13/15	11:47:48	211.76	66	2/13/15	12:27:48	212.07
27	2/13/15	11:48:48	211.82	67	2/13/15	12:28:48	212.06
28	2/13/15	11:49:48	211.71	68	2/13/15	12:29:48	212.13
29	2/13/15	11:50:48	211.84	69	2/13/15	12:30:48	212.06
30	2/13/15	11:51:48	211.80	70	2/13/15	12:31:48	212.03
31	2/13/15	11:52:48	211.83	71	2/13/15	12:32:48	212.04
32	2/13/15	11:53:48	211.86	72	2/13/15	12:33:48	212.05
33	2/13/15	11:54:48	211.87	73	2/13/15	12:34:48	212.05
34	2/13/15	11:55:48	211.88	74	2/13/15	12:35:48	212.11
35	2/13/15	11:56:48	211.89	75	2/13/15	12:36:48	212.08
36	2/13/15	11:57:48	211.89	76	2/13/15	12:37:48	212.07
37	2/13/15	11:58:48	211.83	77	2/13/15	12:38:48	212.07
38	2/13/15	11:59:48	211.85	78	2/13/15	12:39:48	212.03
39	2/13/15	12:00:48	211.88	79	2/13/15	12:40:48	212.15
40	2/13/15	12:01:48	211.91				

Table 5–9. Reduced data from Cooper-Jacob analysis of drawdown for test well NELT3 #1 (16N/02E-31H1S) for constant pumping rate, Fort Irwin National Training Center, California, February 2012.—Continued

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	2/13/15	12:41:48	212.05
81	2/13/15	12:42:48	212.04
82	2/13/15	12:43:48	212.10
83	2/13/15	12:44:48	212.10
84	2/13/15	13:11:28	212.13
85	2/13/15	13:16:28	212.10
86	2/13/15	13:21:28	212.09
87	2/13/15	13:26:28	212.13
88	2/13/15	13:31:28	212.08
89	2/13/15	13:36:28	212.10
90	2/13/15	13:41:28	212.15
91	2/13/15	13:46:28	212.10
92	2/13/15	13:51:28	212.12
93	2/13/15	13:56:28	212.14
94	2/13/15	14:01:28	212.11
95	2/13/15	14:15:00	212.11
96	2/13/15	14:20:00	212.17
97	2/13/15	14:25:00	212.16
98	2/13/15	14:30:00	212.17
99	2/13/15	14:35:00	212.19
100	2/13/15	14:40:00	212.18

Nelson Lake 3 (NELT3 #1) recovery curve

State well number: 16N/02E-31H1S **USGS site identifier:** 352556116475501

Date: 02/13/2015 **Time:** 11:22

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	13 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	208.26 feet
Top of aquifer	=	260 feet
Base of aquifer	=	740 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

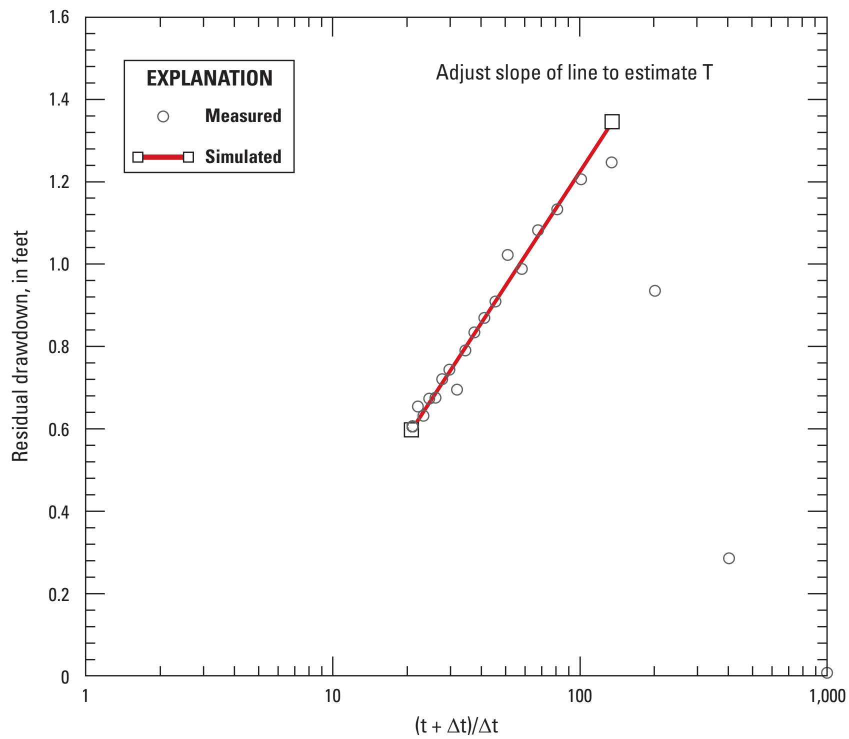
Aquifer material: Fine-grained sand
Flow rate: 85 gallons per minute

COMPUTED

Aquifer thickness	=	480 feet
Slope	=	0.921279 feet per $\log_{10}$

Input is consistent

K	**=**	**6.8 feet/day**
T	**=**	**3,300 feet²/day**



Remarks:
Cooper-Jacob recovery analysis of single-well aquifer test
Total Depth: 740 feet
Screen Intervals: 260–300 feet, 360–460 feet, 540–580 feet, 720–740 feet

Figure 5–10. Cooper-Jacob analysis of recovery for test well NELT3 #1 (16N/02E-31H1S), Fort Irwin National Training Center, California, February 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity; t, time, in seconds; Dt, time difference, in seconds).

Table 5–10. Reduced data from Cooper-Jacob recovery analysis for test well NELT5 #1 (16N/02E-35P1S), Fort Irwin National Training Center, California, February 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
1	2/13/15	11:22:48	208.26
2	2/13/15	18:03:06	212.19
3	2/13/15	18:04:06	208.55
4	2/13/15	18:05:06	209.20
5	2/13/15	18:06:06	209.51
6	2/13/15	18:07:06	209.47
7	2/13/15	18:08:06	209.39
8	2/13/15	18:09:06	209.34
9	2/13/15	18:10:06	209.25
10	2/13/15	18:11:06	209.28
11	2/13/15	18:12:06	209.17
12	2/13/15	18:13:06	209.13
13	2/13/15	18:14:06	209.09
14	2/13/15	18:15:06	209.05
15	2/13/15	18:16:06	208.96
16	2/13/15	18:17:06	209.00
17	2/13/15	18:18:06	208.98
18	2/13/15	18:19:06	208.94
19	2/13/15	18:20:06	208.93
20	2/13/15	18:21:06	208.89
21	2/13/15	18:22:06	208.91
22	2/13/15	18:23:06	208.87

Superior Basin Test Well (SBTW)

State well number: 31S/46E-05B1M **USGS site identifier:** 351619117041301

Date: 02/23/2015 **Time:** 12:11

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	14.75 inches
Screen length (L)	=	220 feet

Depth to

Water level	=	119.36 feet
Top of aquifer	=	140 feet
Base of aquifer	=	380 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

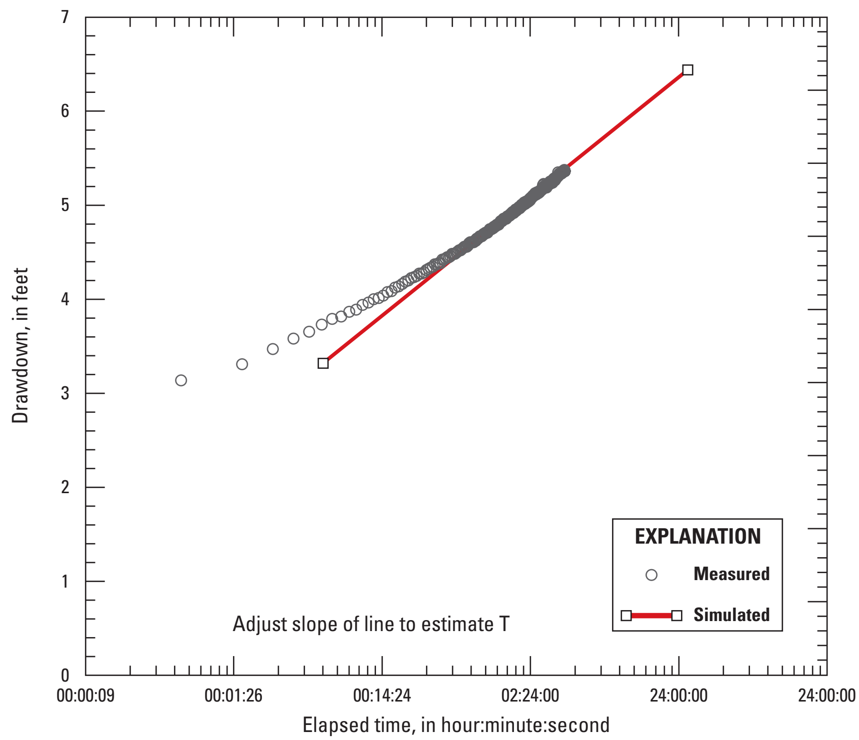
Aquifer material: Fine-grained sand
Flow rate: 111 gallons per minute

COMPUTED

Aquifer thickness	=	240 feet
Slope	=	1.268293 feet per $\log_{10}$

Input is consistent

K	**=**	**13 feet/day**
T	**=**	**3,100 feet²/day**



Remarks:
Cooper-Jacob recovery analysis of single-well aquifer test
Total Depth: 600 feet
Screen Intervals: 140–200 feet, 220–380 feet

Figure 5–11. Cooper-Jacob analysis of drawdown for test well SBTW #1 (31S/46E-05B1M), Fort Irwin National Training Center, California, February 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity).

Table 5–11. Reduced data from Cooper-Jacob analysis of drawdown for test well SBTW #1 (31S/46E-05B1M) for constant pumping rate, Fort Irwin National Training Center, California, February 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
1	2/23/15	12:11:22	119.53
2	2/23/15	12:13:00	122.84
3	2/23/15	12:15:00	123.11
4	2/23/15	12:17:00	123.26
5	2/23/15	12:19:00	123.34
6	2/23/15	12:21:00	123.42
7	2/23/15	12:23:00	123.49
8	2/23/15	12:25:00	123.54
9	2/23/15	12:27:00	123.60
10	2/23/15	12:29:00	123.65
11	2/23/15	12:31:00	123.69
12	2/23/15	12:33:00	123.73
13	2/23/15	12:35:00	123.77
14	2/23/15	12:37:00	123.80
15	2/23/15	12:39:00	123.81
16	2/23/15	12:41:00	123.85
17	2/23/15	12:43:00	123.88
18	2/23/15	12:45:00	123.90
19	2/23/15	12:47:00	123.91
20	2/23/15	12:49:00	123.95
21	2/23/15	12:51:00	123.98
22	2/23/15	12:53:00	123.99
23	2/23/15	12:55:00	124.01
24	2/23/15	12:57:00	124.03
25	2/23/15	12:59:00	124.05
26	2/23/15	13:01:00	124.06
27	2/23/15	13:03:00	124.09
28	2/23/15	13:05:00	124.09
29	2/23/15	13:07:00	124.12
30	2/23/15	13:09:00	124.14
31	2/23/15	13:11:00	124.14
32	2/23/15	13:13:00	124.15
33	2/23/15	13:15:00	124.17
34	2/23/15	13:17:00	124.20
35	2/23/15	13:19:00	124.20
36	2/23/15	13:21:07	124.22
37	2/23/15	13:23:07	124.24
38	2/23/15	13:25:07	124.24
39	2/23/15	13:27:07	124.26
40	2/23/15	13:29:07	124.27
41	2/23/15	13:31:07	124.29
42	2/23/15	13:33:07	124.30
43	2/23/15	13:35:07	124.31
44	2/23/15	13:37:07	124.32
45	2/23/15	13:39:07	124.32
46	2/23/15	13:41:07	124.35
47	2/23/15	13:43:07	124.36
48	2/23/15	13:45:07	124.37
49	2/23/15	13:47:07	124.38
50	2/23/15	13:49:07	124.38
51	2/23/15	13:51:07	124.40
52	2/23/15	13:53:07	124.41
53	2/23/15	13:55:07	124.42
54	2/23/15	13:57:07	124.43
55	2/23/15	13:59:07	124.45
56	2/23/15	14:01:07	124.46
57	2/23/15	14:03:07	124.46
58	2/23/15	14:05:07	124.47
59	2/23/15	14:07:07	124.47
60	2/23/15	14:09:07	124.48
61	2/23/15	14:11:07	124.50
62	2/23/15	14:13:07	124.50
63	2/23/15	14:15:07	124.51
64	2/23/15	14:17:07	124.53
65	2/23/15	14:19:07	124.53
66	2/23/15	14:21:07	124.55
67	2/23/15	14:23:07	124.55
68	2/23/15	14:25:07	124.56
69	2/23/15	14:27:07	124.57
70	2/23/15	14:29:07	124.57
71	2/23/15	14:31:07	124.57
72	2/23/15	14:33:07	124.60
73	2/23/15	14:35:07	124.60
74	2/23/15	14:37:07	124.61
75	2/23/15	14:39:07	124.62
76	2/23/15	14:41:07	124.63
77	2/23/15	14:43:07	124.63
78	2/23/15	14:45:07	124.64
79	2/23/15	14:47:07	124.64

Table 5–11. Reduced data from Cooper-Jacob analysis of drawdown for test well SBTW #1 (31S/46E-05B1M) for constant pumping rate, Fort Irwin National Training Center, California, February 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time		Water level (feet)
	(mm/dd/yy)	(Hr:Min:Sec)	
80	2/23/15	14:49:07	124.64
81	2/23/15	14:51:07	124.67
82	2/23/15	14:53:07	124.67
83	2/23/15	14:55:07	124.67
84	2/23/15	14:57:07	124.67
85	2/23/15	14:59:07	124.68
86	2/23/15	15:01:07	124.69
87	2/23/15	15:03:07	124.69
88	2/23/15	15:05:07	124.71
89	2/23/15	15:07:07	124.71
90	2/23/15	15:09:07	124.73
91	2/23/15	15:11:07	124.72
92	2/23/15	15:13:07	124.73
93	2/23/15	15:15:07	124.74
94	2/23/15	15:17:07	124.73
95	2/23/15	15:19:07	124.76
96	2/23/15	15:21:07	124.76
97	2/23/15	15:23:07	124.76
98	2/23/15	15:25:07	124.76
99	2/23/15	15:27:07	124.78
100	2/23/15	15:29:07	124.77

Superior Basin Test Well (SBTW) recovery curve

State well number: 31S/46E-05B1M **USGS site identifier:** 351619117041301

Date: 02/24/2015 **Time:** 09:34

INPUT

Construction

Casing diameter (dc)	=	8 inches
Annulus diameter (dw)	=	14.75 inches
Screen length (L)	=	200 feet

Depth to

Water level	=	119.36 feet
Top of aquifer	=	140 feet
Base of aquifer	=	380 feet

Annular fill

Across screen	=	Coarse sand
Above screen	=	Bentonite

Aquifer material: Fine-grained sand

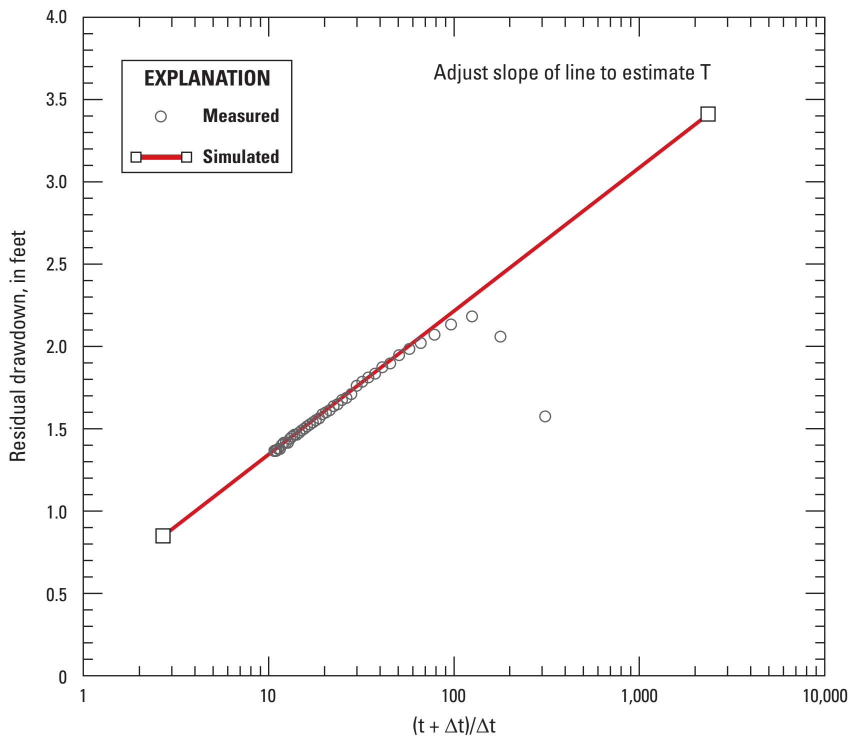
Flow rate: 111 gallons per minute

COMPUTED

Aquifer thickness	=	240 feet
Slope	=	0.871176 feet per $\log_{10}$

Input is consistent

K	**=**	**19 feet/day**
T	**=**	**4,500 feet²/day**



Remarks:

Cooper-Jacob recovery analysis of single-well aquifer test

Total Depth: 600 feet

Screen Intervals: 140–200 feet, 220–380 feet

Figure 5–12. Cooper-Jacob analysis of recovery for test well SBTW #1 (31S/46E-05B1M), Fort Irwin National Training Center, California, February 2012. (Abbreviations: feet²/day, feet squared per day; K, hydraulic conductivity; T, transmissivity; t, time, in seconds; Dt, time difference, in seconds).

Table 5–12. Reduced data from Cooper-Jacob recovery analysis for test well SBTW #1 (31S/46E-05B1M), Fort Irwin National Training Center, California, February 2012.

[mm/dd/yy, month/day/year; Hr:Min:Sec, hours:minutes:seconds]

Entry	Reduced data time (mm/dd/yy)	Reduced data time (Hr:Min:Sec)	Water level (feet)
1	2/24/15	9:34:00	119.36
2	2/24/15	16:27:33	121.75
3	2/24/15	16:28:53	120.93
4	2/24/15	16:29:53	121.42
5	2/24/15	16:30:53	121.54
6	2/24/15	16:31:53	121.49
7	2/24/15	16:32:53	121.43
8	2/24/15	16:33:53	121.38
9	2/24/15	16:34:53	121.34
10	2/24/15	16:35:53	121.31
11	2/24/15	16:36:53	121.26
12	2/24/15	16:37:53	121.23
13	2/24/15	16:38:53	121.19
14	2/24/15	16:39:53	121.17
15	2/24/15	16:40:53	121.15
16	2/24/15	16:41:53	121.12
17	2/24/15	16:42:53	121.07
18	2/24/15	16:43:53	121.05
19	2/24/15	16:44:53	121.03
20	2/24/15	16:45:53	121.01
21	2/24/15	16:46:53	121.00
22	2/24/15	16:47:53	120.97
23	2/24/15	16:48:53	120.96
24	2/24/15	16:49:53	120.95
25	2/24/15	16:50:53	120.92
26	2/24/15	16:51:53	120.91
27	2/24/15	16:52:53	120.90
28	2/24/15	16:53:53	120.89
29	2/24/15	16:54:53	120.87
30	2/24/15	16:55:53	120.86
31	2/24/15	16:56:53	120.85
32	2/24/15	16:57:53	120.84
33	2/24/15	16:58:53	120.82
34	2/24/15	16:59:53	120.82
35	2/24/15	17:00:53	120.81
36	2/24/15	17:01:53	120.80
37	2/24/15	17:02:53	120.77
38	2/24/15	17:03:53	120.77
39	2/24/15	17:04:53	120.77
40	2/24/15	17:05:53	120.76
41	2/24/15	17:06:53	120.74
42	2/24/15	17:07:53	120.74
43	2/24/15	17:08:53	120.72
44	2/24/15	17:09:53	120.72

Appendix 6. Unpumped Flow Log Data and Calibration

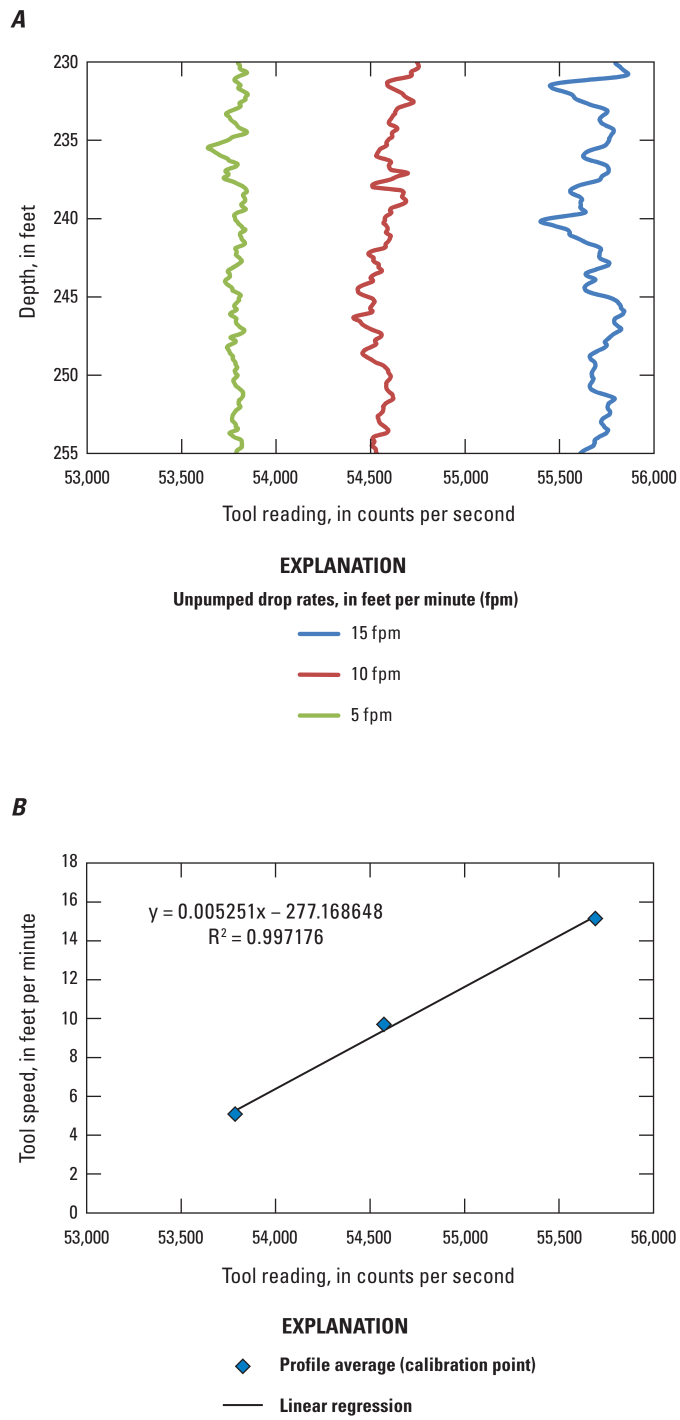


Figure 6–1. Wellbore-flow test results for test well GOLD1-T #1 (15N/01E-28R4S), Fort Irwin National Training Center, California, January 2015, of *A*, vertical profiles of wellbore flow reading by tool transit rate in 25-foot interval of well casing, raw data for unpumped conditions, and *B*, calibration relation and regression equation for wellbore flow, unpumped conditions.

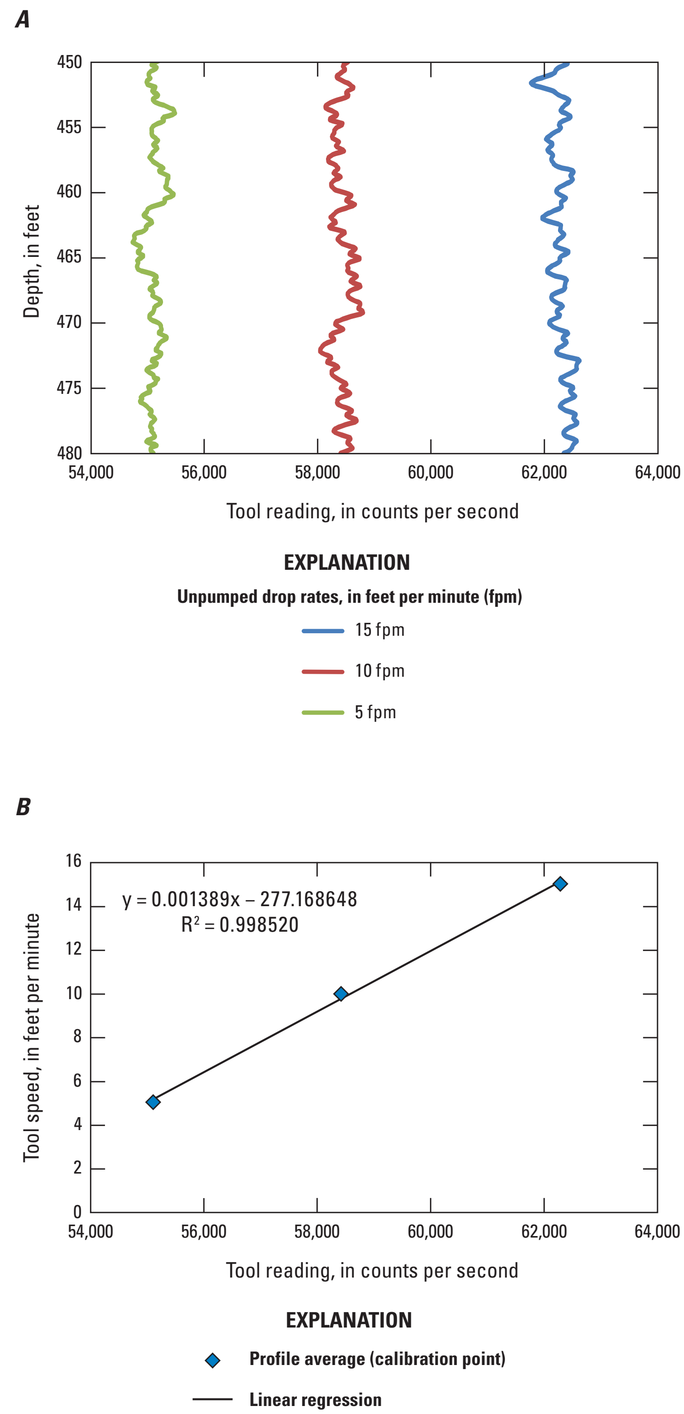


Figure 6–2. Wellbore-flow test results for test well NELT5 #1 (16N/01E-35P1S), Fort Irwin National Training Center, California, January 2015, of *A*, vertical profiles of wellbore flow reading by tool transit rate in 30-foot interval of well casing, raw data for unpumped conditions, and *B*, calibration relation and regression equation for wellbore flow, unpumped conditions.

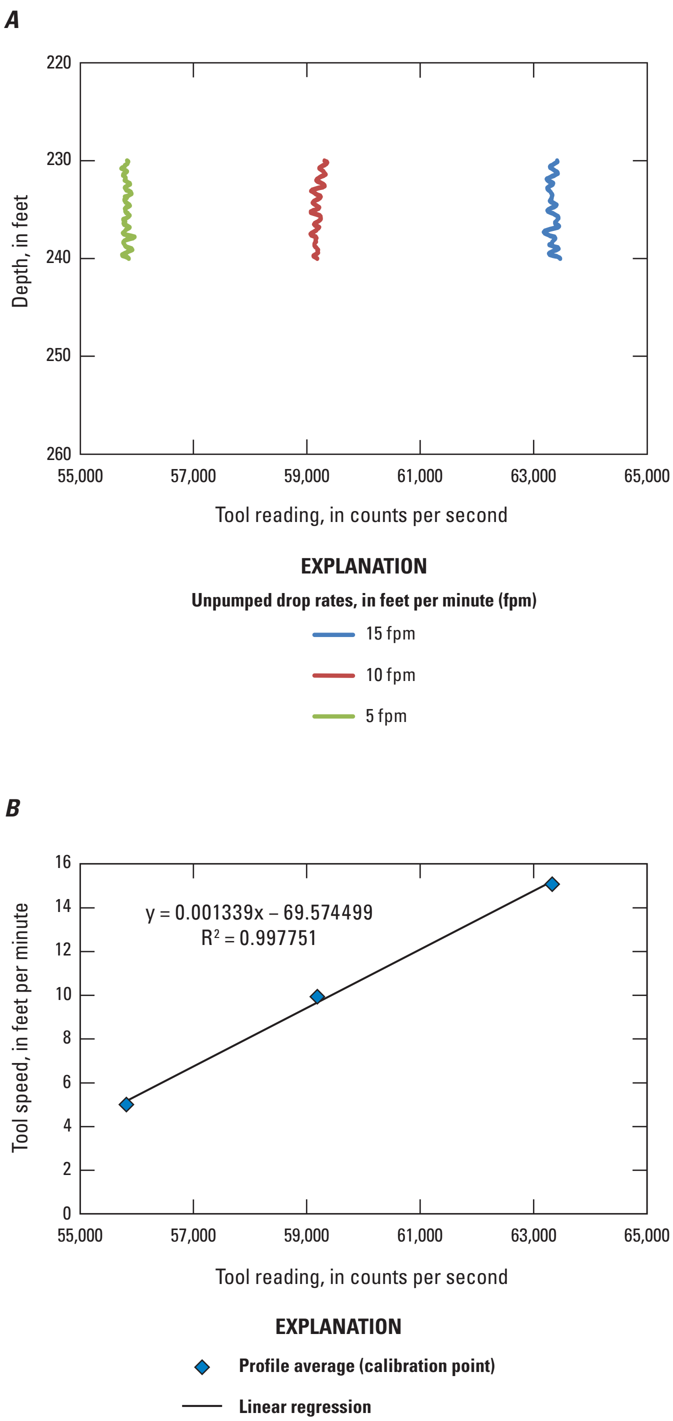


Figure 6–3. Wellbore-flow test results for test well NELT3 #1 (16N/02E-31H1S), Fort Irwin National Training Center, California, July 2015, of *A*, vertical profiles of wellbore flow reading by tool transit rate in 10-foot interval of well casing, raw data for unpumped conditions, and *B*, calibration relation and regression equation for wellbore flow, unpumped conditions.

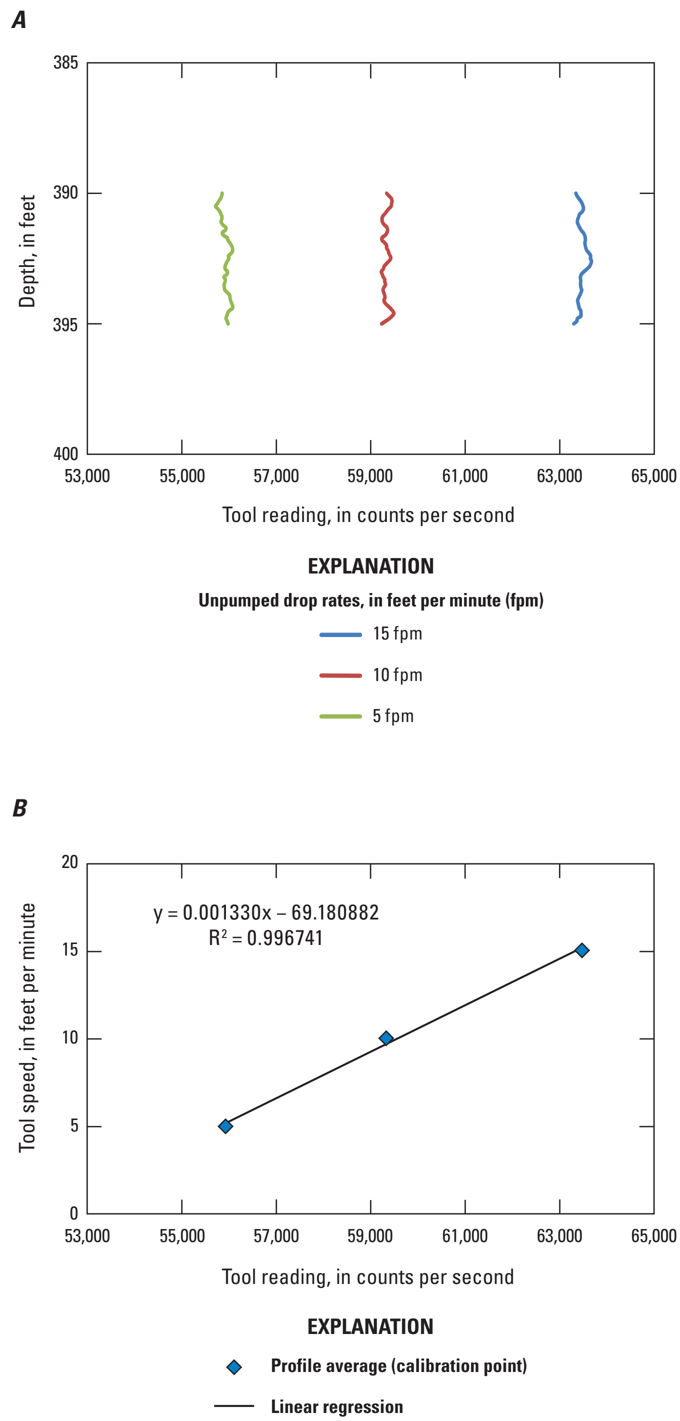


Figure 6–4. Wellbore-flow test results for test well NELT6 #1 (15N/02E-05N1S), Fort Irwin National Training Center, California, July 2015, of *A*, vertical profiles of wellbore flow reading by tool transit rate in 25-foot interval of well casing, raw data for unpumped conditions, and *B*, calibration relation and regression equation for wellbore flow, unpumped conditions.

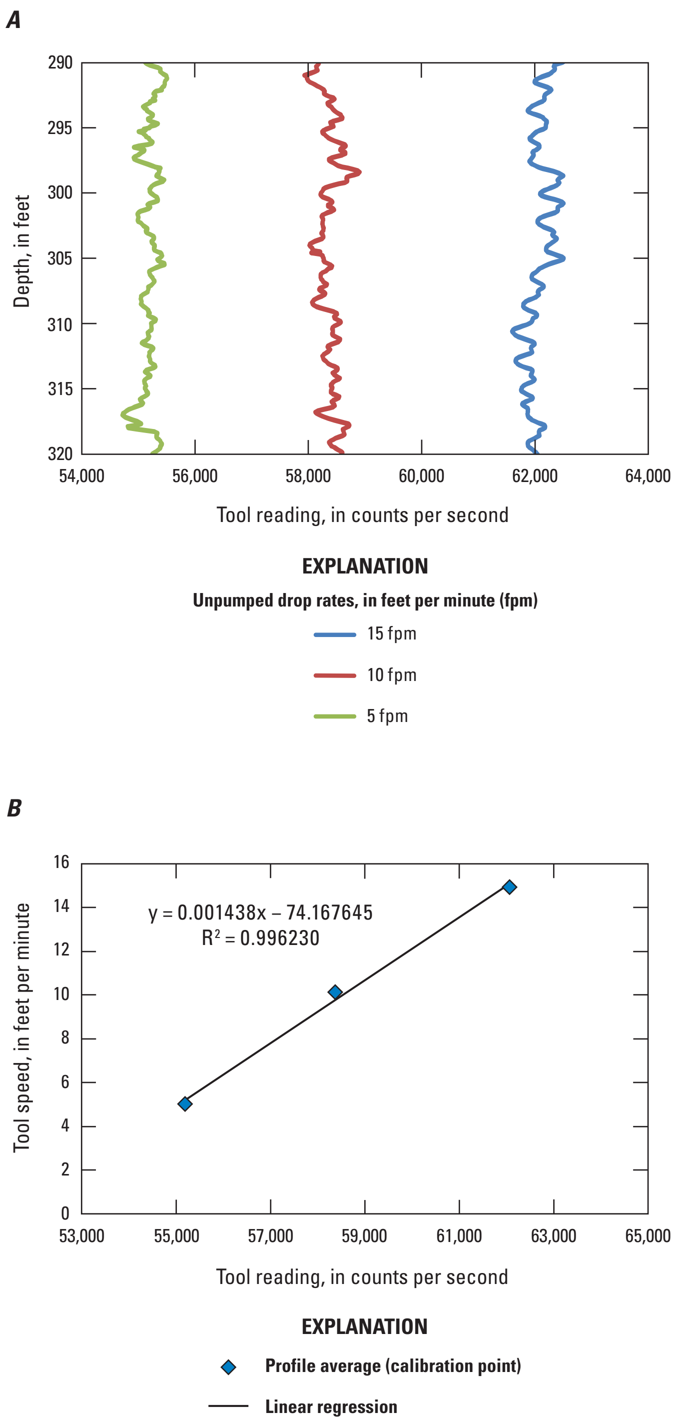


Figure 6–5. Wellbore-flow test results for test well NELT4 #1 (15N/03E-08L1S), Fort Irwin National Training Center, California, January 2015, of *A*, vertical profiles of wellbore flow reading by tool transit rate in 5-foot interval of well casing, raw data for unpumped conditions, and *B*, calibration relation and regression equation for wellbore flow, unpumped conditions.

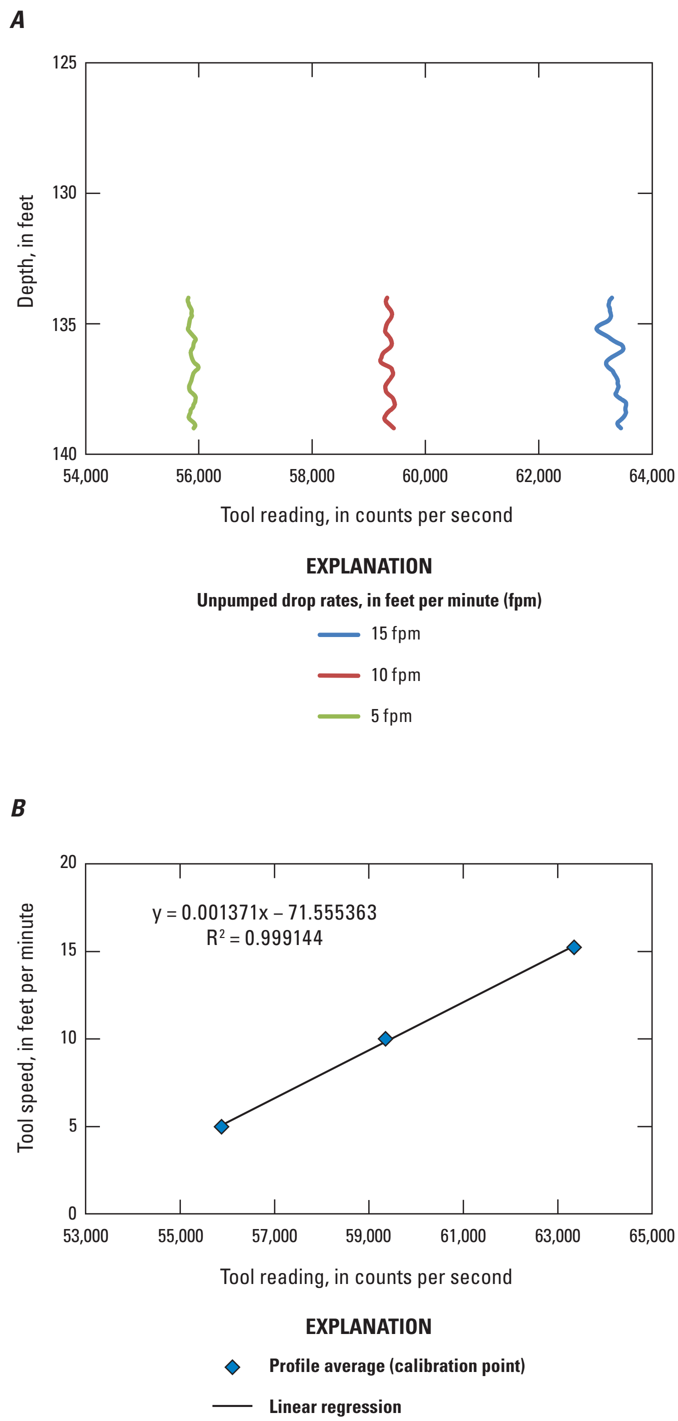


Figure 6–6. Wellbore-flow test results for test well SBTW #1 (31S/46E-05B1M), Fort Irwin National Training Center, California, June 2016, of *A*, vertical profiles of wellbore flow reading by tool transit rate in 30-foot interval of well casing, raw data for unpumped conditions, and *B*, calibration relation and regression equation for wellbore flow, unpumped conditions.

Appendix 7. Pumped Flow Log Data and Calibration

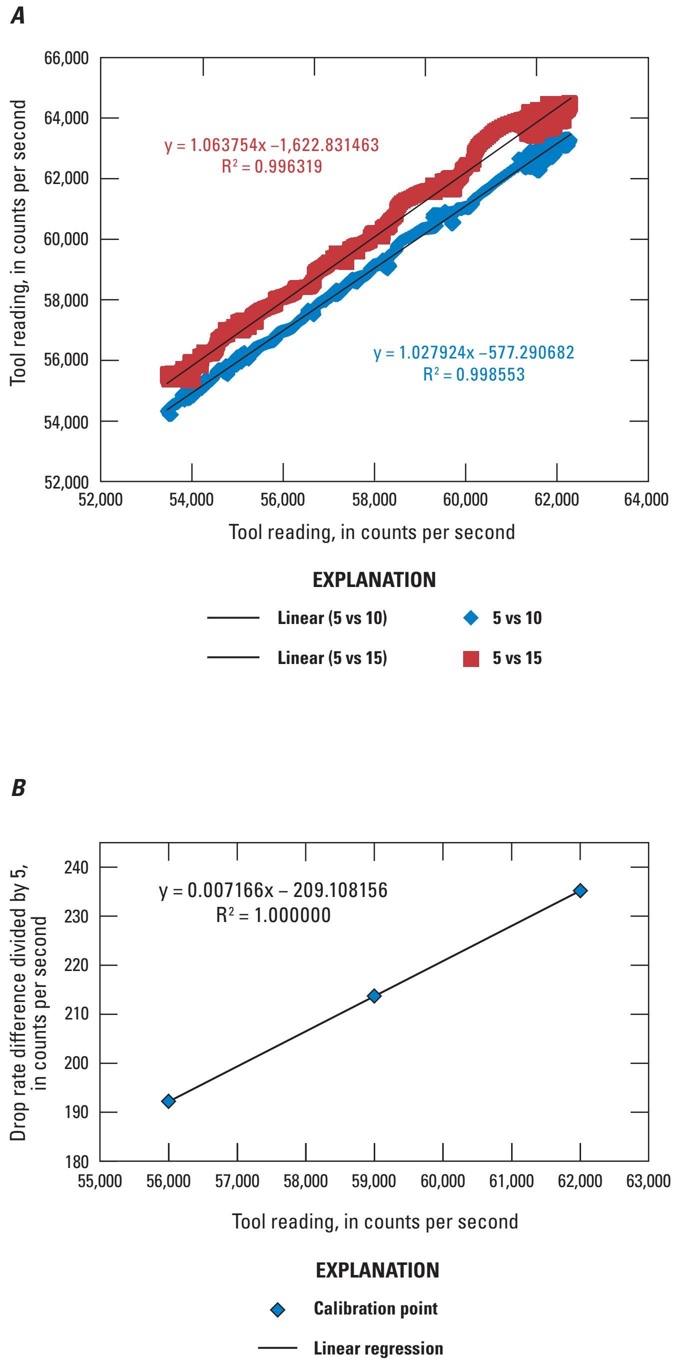


Figure 7–1. Wellbore-flow test results for test well NELT3 #1 (16N/02E-31H1S), Fort Irwin National Training Center, California, February 2015, of *A*, relations between wellbore flow readings by paired transit rates, raw data for pumped conditions, and *B*, calibration relation and regression equation for wellbore flow, pumped conditions. (Transit rates were 5, 10, and 15 feet per minute.)

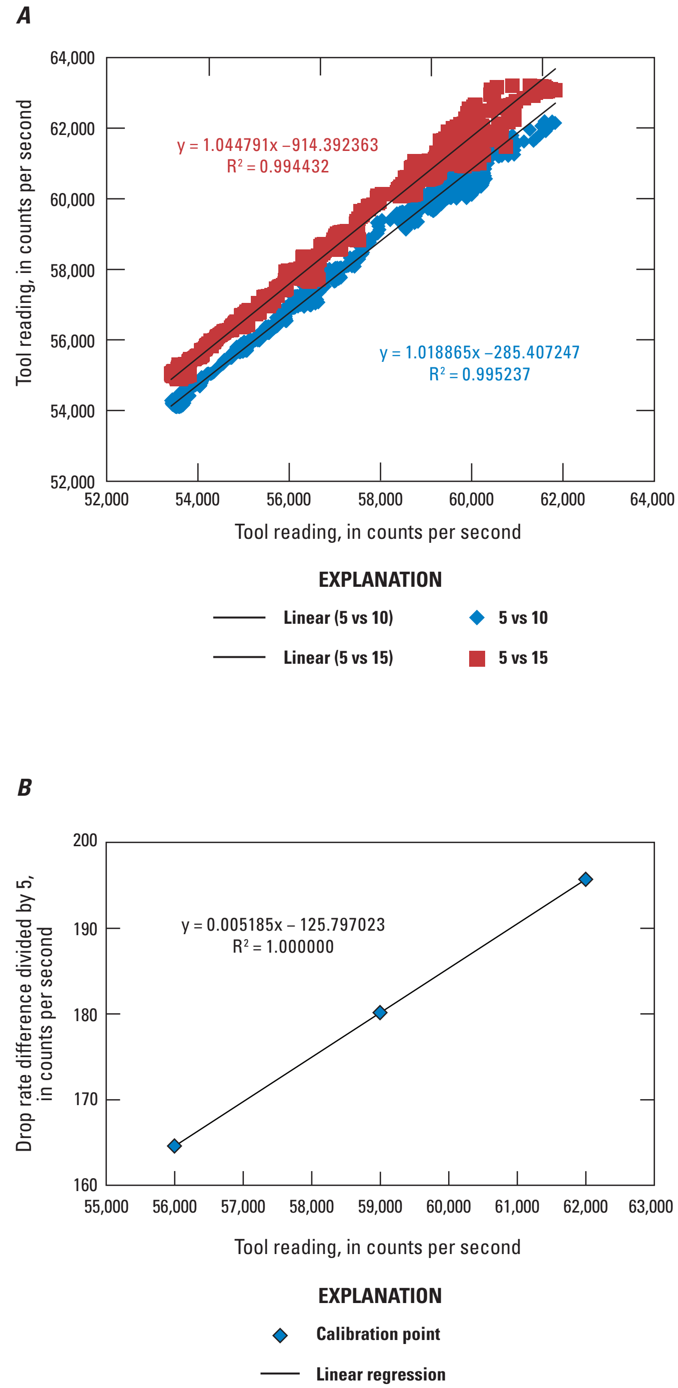


Figure 7–2. Wellbore-flow test results for test well SBTW #1 (31S/46E-05B1M), Fort Irwin National Training Center, California, February 2015, of *A*, relations between wellbore flow readings by paired transit rates, raw data for pumped conditions, and *B*, calibration relation and regression equation for wellbore flow, pumped conditions. (Transit rates were 5, 10, and 15 feet per minute.)

For more information concerning the research in this report, contact the
Director, California Water Science Center
U.S. Geological Survey
6000 J Street, Placer Hall
Sacramento, California 95819
https://ca.water.usgs.gov

Publishing support provided by the U.S. Geological Survey
Science Publishing Network, Sacramento Publishing Service Center

USGS

Navikas and others—**Summary of Hydrologic Testing, Wellbore-Flow Data, and Expanded Water-Level and Water-Quality Data, 2011–15, Fort Irwin National Training Center, San Bernardino County, California**—Scientific Investigations Report 2019–5091

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20195091