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Analysis of Ground-Water Levels and Associated Trends in Yucca Flat, Nevada Test Site, Nye County, Nevada, 1951–2003

Scientific Investigations Report 2005-5175

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

(Back of Cover)

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By Joseph M. Fenelon

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SCIENTIFIC INVESTIGATIONS REPORT 2005-5175

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

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director

U.S. Geological Survey, Carson City, Nevada, 2005

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Volume	
barrel (42 gal)	159.0	liter (L)
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meter (m^3)
million gallons (Mgal)	3.069	acre-foot (acre-ft)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Energy	
kiloton	4.184×10^{12}	joules (J)
	Pressure	
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)
	Specific capacity	
gallons per minute per foot of drawdown (gal/min per foot)	17.88	cubic meter per day per meter of drawdown (m^2/d)
	Flow rate	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Volumetric rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year m^3/yr)
gallon per minute (gal/min)	0.06309	liter per second per meter (L/s)

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

Datum: Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD83) unless otherwise stated.

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = (1.8 x °C) + 32.

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.

Analysis of Ground-Water Levels and Associated Trends in Yucca Flat, Nevada Test Site, Nye County, Nevada, 1951–2003

By Joseph M. Fenelon

Abstract

Almost 4,000 water-level measurements in 216 wells in the Yucca Flat area from 1951 to 2003 were quality assured and analyzed. An interpretative database was developed that describes water-level conditions for each water level measured in Yucca Flat. Multiple attributes were assigned to each water-level measurement in the database to describe the hydrologic conditions at the time of measurement. General quality, temporal variability, regional significance, and hydrologic conditions are attributed for each water-level measurement. The database also includes narratives that discuss the water-level history of each well.

Water levels in 34 wells were analyzed for variability and for statistically significant trends. An attempt was made to identify the cause of many of the water-level fluctuations or trends. Potential causes include equilibration following well construction or development, pumping in the monitoring well, withdrawals from a nearby supply well, recharge from precipitation, earthquakes, underground nuclear tests, land subsidence, barometric pressure, and Earth tides.

Some of the naturally occurring fluctuations in water levels may result from variations in recharge. The magnitude of the overall water-level change for these fluctuations generally is less than 2 feet. Long-term steady-state hydrographs for most of the wells open to carbonate rock have a very similar pattern. Carbonate-rock wells without the characteristic pattern are directly west of the Yucca and Topgallant faults in the southwestern part of Yucca Flat. Long-term steady-state hydrographs from wells open to volcanic tuffs or the Eleana confining unit have a distinctly different pattern from the general water-level pattern of the carbonate-rock aquifers.

Anthropogenic water-level fluctuations were caused primarily by water withdrawals and nuclear testing. Nuclear tests affected water levels in many wells. Trends in these wells are attributed to test-cavity infilling or the effects of depressurization following nuclear testing. The magnitude of the overall water-level change for wells with anthropogenic trends can be large, ranging from several feet to hundreds of feet.

Vertical water-level differences at 27 sites in Yucca Flat with multiple open intervals were compared. Large vertical differences were noted in volcanic rocks and in boreholes where water levels were affected by nuclear tests. Small vertical differences were noted within the carbonate-rock and valley-fill aquifers. Vertical hydraulic gradients generally are downward in volcanic rocks and from pre-Tertiary clastic rocks toward volcanic- or carbonate-rock units.

Introduction

Yucca Flat is in the northeastern part of the Nevada Test Site (NTS) in Nye County, southern Nevada (fig. 1). During the period 1951–1992, 659 underground nuclear tests were detonated in Yucca Flat as well as 3 to the north of Yucca Flat (U.S. Department of Energy, 2000); 138 of these tests were considered certain or probable of introducing radionuclide contaminants into the ground water (Laczniak and others, 1996, table 4).

The U.S. Department of Energy (DOE), National Nuclear Security Administration, Nevada Site Office, under its Environmental Restoration Program, has a long-term program to investigate and remediate radionuclide contaminants generated on the NTS. As part of the program, DOE is evaluating the risk that these contaminants pose to the public. To accomplish this objective, a reasonable conceptual model of the ground-water flow system must be constructed. A necessary part of developing a model of the flow system is to compile and analyze available ground-water levels. This report is the third in a series of studies by the U.S. Geological Survey (USGS), in cooperation with DOE, to analyze and quality assure historic water-level measurements in areas of testing on the NTS (Fenelon, 2000; Bright and others, 2001).

As part of the water-level analysis in Yucca Flat, all water-level measurements need to be quality assured for accuracy and reliability. Additionally, the hydrologic conditions at the time of each water-level measurement must be determined. For example, determining whether an abrupt water-level rise

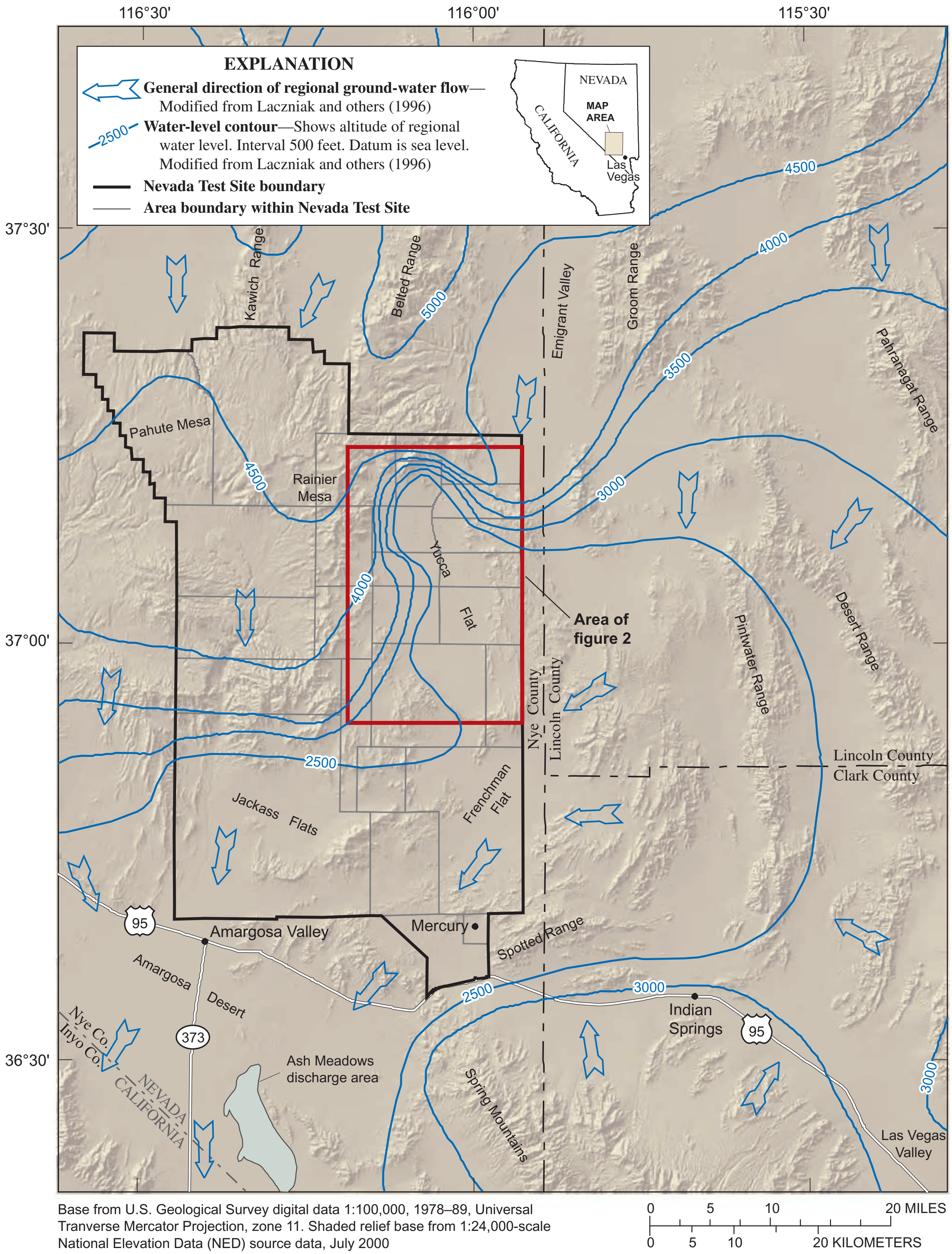

Figure 1. Map showing regional features and ground-water flow in the area near Yucca Flat, Nevada Test Site.

was caused by a well slug test or by a nearby nuclear test is essential for correctly interpreting the water level. Finally, an analysis of the fluctuations or trends in ground-water levels is needed to identify long-term patterns and changes in water levels. Determining the causes of these trends can help identify what factors influence the flow system.

Purpose and Scope

This report documents the analysis of almost 4,000 water levels measured in 216 wells in Yucca Flat and vicinity from 1951 to 2003. As part of the analysis, a systematic quality-assurance review of the USGS National Water Information System (NWIS) database was done to remove or correct erroneous water-level data, remove duplicate sites, and add missing water-level measurements. Additionally, ancillary data necessary for computing hydraulic heads in wells were compiled. These data include well-completion records, borehole deviations, measuring points, and water temperatures, as well as information on lithologic units contributing water to the well. Reported ground-water withdrawals within the study area and precipitation data from major recharge areas near the Spring Mountains, Rainier Mesa, and Pahranagat Valley also were compiled.

An interpretive Microsoft® Access database of Yucca Flat water-level measurements was constructed that consists of several components. First, each water-level measurement was assigned multiple attributes to describe the hydrologic condition at the time of measurement. Second, each well hydrograph has a written narrative, which consists of comments or explanations about the well or about one or more measured water levels in the well. Third, water-level and site information from the NWIS database were merged into the Access water-level database to provide a comprehensive database of water-level measurements in Yucca Flat.

Water levels in wells with sufficient long-term data were analyzed for variability and for significant trends. Trends were analyzed statistically to detect significant upward or downward changes and graphically to compare trends among wells. An attempt was made to identify the cause of many of the water-level fluctuations or trends. Potential causes include equilibration following well construction or development, pumping or hydraulic testing in the monitoring well, withdrawals from a nearby supply well, recharge from precipitation, earthquakes, underground nuclear tests, land subsidence, barometric pressure, and Earth tides.

Acknowledgments

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Hydrogeology

Yucca Flat is a topographically closed drainage basin that ranges from about 3,920 ft above sea level in Yucca Lake to about 4,500 ft above sea level on the perimeters of the basin floor. Yucca Flat is surrounded by CP Hills to the south, Halfpint Range to the east, Rhyolite Hills and Quartzite Ridge to the north, and Eleana Range to the west (fig. 2). These adjacent highlands typically reach altitudes of 5,000–7,000 ft above sea level.

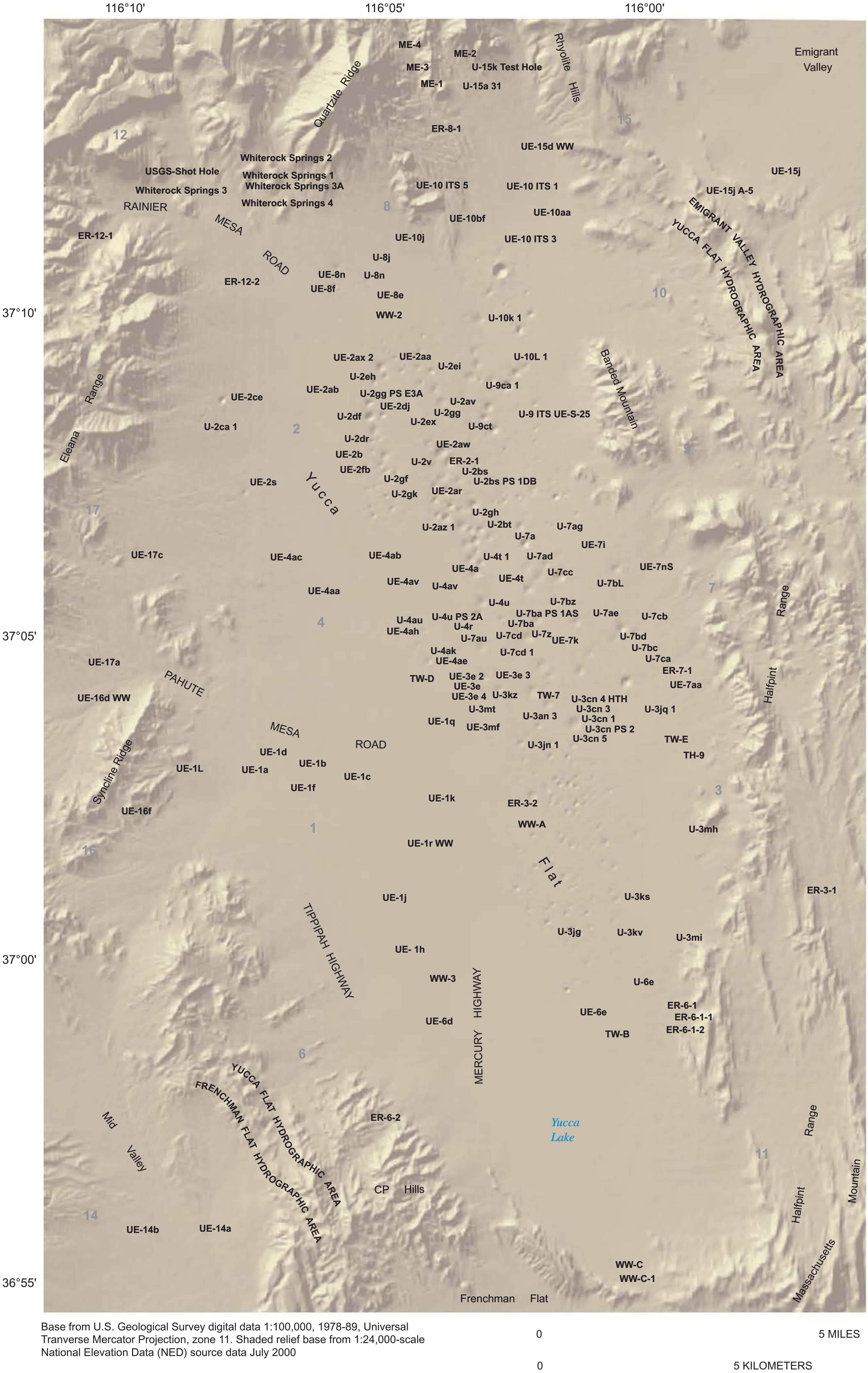
Hydrogeologic units in Yucca Flat were defined by Laczniak and others (1996, table 2; pl. 3). They include the quartzite confining unit, lower carbonate-rock aquifer, Eleana confining unit, upper carbonate-rock aquifer, granite, tuff confining unit, welded-tuff aquifer, and valley-fill aquifer. The distribution of these units at the water table is shown in figure 3. Interpretations from recent (post-1994) geologic and geophysical investigations in Yucca Flat are not incorporated into this map.

The quartzite confining unit is composed of Cambrian and Eocambrian quartzite, siltstone and shale. Minor intrusions of Cretaceous granite on the north side of Yucca Flat also are grouped with the quartzite confining unit. The confining unit defines the lower boundary of the flow system and is exposed at the water table in northeastern Yucca Flat (fig. 3). The unit is believed to restrict the southerly flow of ground water on the northern edge of Yucca Flat, as evidenced by a steep ground-water gradient in that area (fig. 1; Winograd and Thordarson, 1975, p. 63–66).

The principal regional aquifer in Yucca Flat is the lower carbonate-rock aquifer. It consists of dolomite and limestone of Cambrian through Devonian age. The lower carbonate-rock aquifer predominates in the eastern part of Yucca Flat (fig. 3). In this area, water-level altitudes are about 2,500 ft or less above sea level and ground-water gradients are small (fig. 1).

The Eleana confining unit underlies the west side of Yucca Flat (fig. 3). The unit consists of Devonian through Pennsylvanian siliceous siltstone (argillite), shale, conglomerate, and sandstone of the Eleana Formation and Chainman Shale. Steep ground-water gradients occur on the west side of Yucca Flat (fig. 1), where the confining unit restricts the movement of ground water.

The upper carbonate-rock aquifer, on the west side of Yucca Flat, is separated from the lower carbonate-rock aquifer by the Eleana confining unit. The upper carbonate-rock aquifer consists of Pennsylvanian Tippipah Limestone and Cambrian through Devonian carbonate rocks that have been thrust faulted over the Eleana confining unit. The upper carbonate-



Base from U.S. Geological Survey digital data 1:100,000, 1978-89, Universal Tranverse Mercator Projection, zone 11. Shaded relief base from 1:24,000-scale National Elevation Data (NED) source data July 2000

EXPLANATION

11 **Area number and boundary within Nevada Test Site**

ER-6-2 **Borehole with water-level data and name—**
Yellow highlight indicates borehole with ground-water withdrawal

Figure 2. Map showing location of boreholes with water-level measurements and boreholes having ground-water withdrawals in Yucca Flat, Nevada Test Site, 1951–2003.

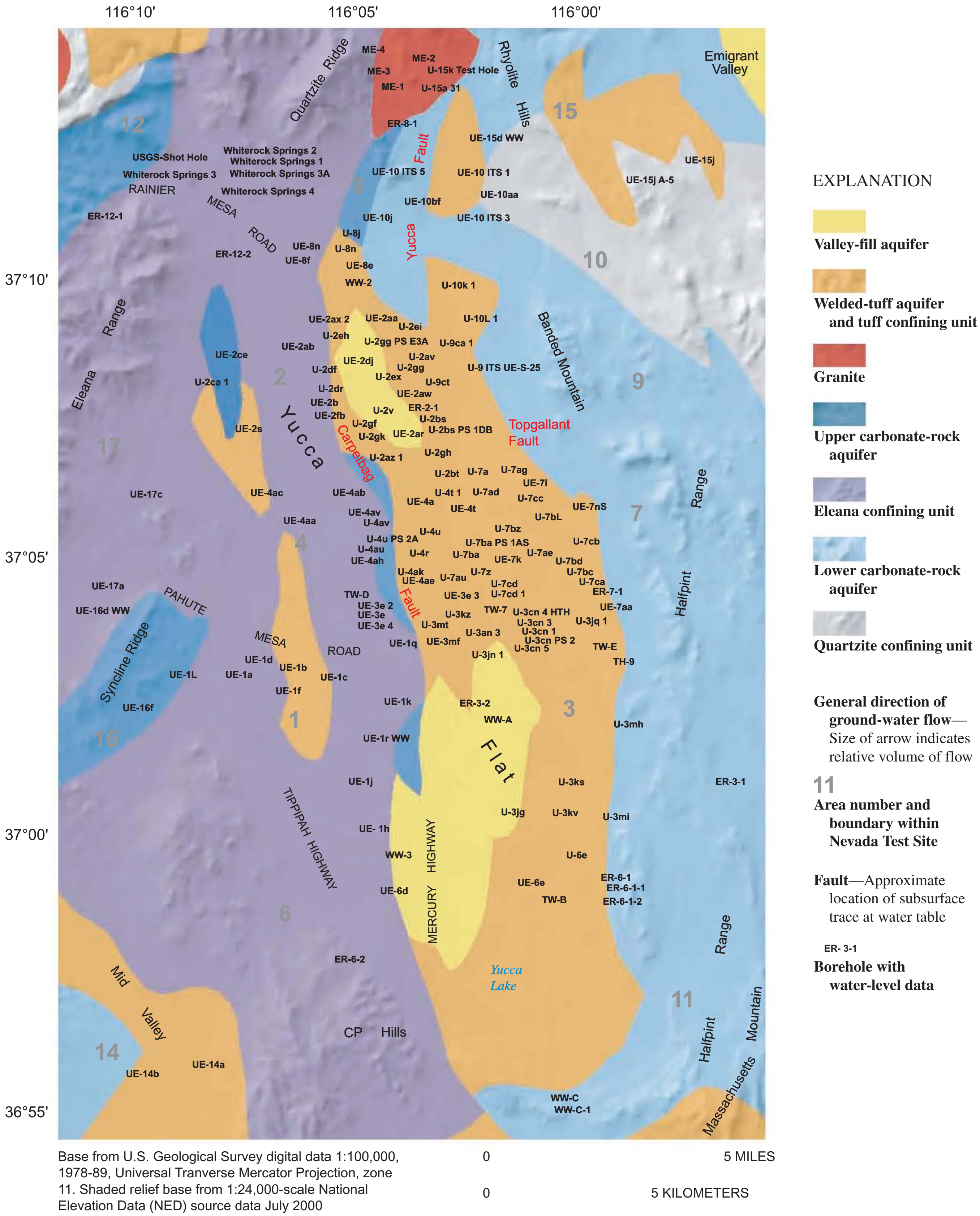


Figure 3. Map showing distribution of hydrogeologic units and major faults at the water table in Yucca Flat, Nevada Test Site. Modified from Laczniak and others, 1996, plate 3.

rock aquifer is limited in extent but may be locally important to flow transport.

Tertiary volcanic rocks and valley-fill alluvium are basin-filling deposits in Yucca Flat that overlie the pre-Tertiary rocks discussed above. Most of the underground nuclear tests in Yucca Flat occurred in these units. The volcanic rocks, deposited as tuffs from volcanoes to the west and northwest, are present at the water table in the eastern half of Yucca Flat (fig. 3). The lower sequence of volcanic rocks forms a tuff confining unit. It consists of bedded and reworked, nonwelded, commonly zeolitized tuffs. The tuff confining unit ranges in thickness from 0 to about 1,800 ft; saturated thickness can exceed 1,000 ft. The upper sequence of volcanic units forms a welded-tuff aquifer that is saturated only to a limited extent at the water table. Much of the alluvium in Yucca Flat is unsaturated. Where saturated in the deepest parts of the fault-controlled depressions in central Yucca Flat, the alluvium forms valley-fill aquifers (fig. 3). The alluvium consists of variably cemented, moderately sorted, gravel and sand.

Tectonic activity has complicated the hydrogeology of Yucca Flat. Major folding has brought the quartzite confining unit near land surface where it juxtaposes the lower carbonate-rock aquifer (Winograd and Thordarson, 1975, p. 63). Pre-Tertiary thrust faults have moved sections of older carbonate rocks over the Eleana confining unit. Late Tertiary and more recent, high-angle, extensional faults cut north-south through Yucca Flat. These faults, which include the Yucca and Carpetbag faults (fig. 3), have vertical offsets of 500 to more than 1,000 ft at depth (Phelps and McKee, 1999). Folds and faults in Yucca Flat have compartmentalized the flow system and restricted regional ground-water flow in areas where aquifers juxtapose confining units. Faults also have been hypothesized to juxtapose shallow and deep aquifers, creating vertical pathways for water to short-circuit confining units (Winograd and Thordarson, 1975, p. 55).

Yucca Flat is within the Death Valley regional ground-water flow system (Harrill and others, 1988, sheet 1) and, more specifically, within the Ash Meadows ground-water subbasin (Laczniak and others, 1996, p. 21). Regional ground-water flow generally is from north to south through the lower carbonate-rock aquifer (fig. 1). Less than 350 acre-ft/yr is estimated to flow through the lower carbonate-rock aquifer beneath Yucca Flat (Winograd and Thordarson, 1975, p. 94). Flow is limited because the basin is bounded by confining units on the west, north, northeast, and from above (Laczniak and others, 1996, p. 26). Horizontal hydraulic gradients are large on the north and west sides of Yucca Flat, but relatively small east of the Carpetbag fault (Doty and Thordarson, 1983; Hale and others, 1995). Natural vertical hydraulic gradients generally are downward from the volcanic rocks to the lower carbonate-rock aquifer (Winograd and Thordarson, 1975, p. 54).

Several notable hydraulic features have been mapped in the potentiometric surface of the valley-fill and volcanic rocks. Areas of high hydraulic head, referred to as "ground-water mounds," were mapped in the water table east of the Carpetbag fault (Hale and others, 1995). Some of these areas of high hydraulic head, between the Carpetbag and Yucca faults in the northern half of Yucca Flat, are caused by underground nuclear tests. In areas where valley-fill deposits are at the water table (fig. 3), ground-water mounding may occur following a nuclear test because of decreases in the porosity and permeability of the saturated deposits. In other areas, high-pressure zones occur in the tuff confining unit, a unit that was used extensively for underground nuclear tests.

Most of the recharge to Yucca Flat is subsurface inflow through the lower carbonate-rock aquifer from the northeast and west (Winograd and Thordarson, 1975, p. 94). This inflow is derived from precipitation that occurs on the mountain ranges to the west, north or northeast, such as the Belted Range (fig. 1). Precipitation in the surrounding highlands of Yucca Flat also may contribute small amounts of recharge to the basin, especially through ephemeral drainages from the highlands. Some recharge may reach the lower carbonate-rock aquifer from the shallow Cenozoic rocks within central Yucca Flat through a hydraulic sink at the Yucca/Carpetbag fault system (Winograd and Thordarson, 1975, p. 54–57). Other potential pathways for recharge are through fissures in Yucca Lake (fig. 2; Doty and Rush, 1985) and through subsidence craters from underground nuclear tests (Hokett and others, 2000).

Ground water discharges from Yucca Flat through the lower carbonate-rock aquifer by lateral flow into Frenchman Flat and ultimately to Ash Meadows or other downgradient discharge areas (fig. 1; Laczniak and others, 1996, p. 26). Since 1952, ground water also has been withdrawn from wells throughout Yucca Flat (fig. 2).

Water-Level Measurements

The USGS collects and maintains water-level data on the Nevada Test Site. As part of this data-collection program, current and historic water-level data are compiled, reviewed, and stored in the USGS NWIS database. In Yucca Flat and vicinity, the database has almost 4,000 water-level measurements from 216 wells where data were collected periodically from 1951 to 2003 (fig. 2; table 1). A well, for the purposes of the NWIS database and this report, describes a discrete open interval in a borehole. Therefore, a single borehole may be referenced to multiple wells. As an example, water-level measurements were made in some boreholes as the hole was progressively deepened. In these cases, a unique well identification number and name were established in the database for each depth in which levels were measured. In other cases, multiple piezometers, open at different intervals and hydraulically isolated from one another, were placed in a single borehole. In these cases, each piezometer is considered a distinct well. Wells from the same borehole typically are distinguished from each other by a parenthetical expression at the end of the well name—for example, ER-2-1 (2079 ft).

Table 1. Characteristics of wells with at least one water-level measurement through 2003 in the Yucca Flat area, Nevada Test Site

Latitude and longitude: Referenced to North American Datum of 1983 (NAD83).

Land-surface altitude: Altitude relative to sea level.

Open interval: Area of well that is open to aquifer and where, if saturated, ground water may enter well. Open interval consists of open borehole and(or) well screen, including gravel packs. Where multiple open intervals occur, depths are in feet below land surface to top of uppermost interval and bottom of lowermost interval.

Contributing units: Lithologic units contributing water to well. Multiple units for single well listed in order of their likely importance in contributing water to well. Abbreviations: C, pre-Tertiary carbonate rock; F, valley fill; P, Paleocolluvium; S, pre-Tertiary clastic rock; V, volcanic tuffs; (V), volcanic tuffs within valley fill; X, igneous or metamorphic rocks; *, hole was dry and contributing unit listed is the unit at bottom of hole.

[Symbol: --, not available]

U.S. Geological Survey well name (see fig. 2)	U.S. Geological Survey site identification number[1]	Nevada Test Site hole name[2]	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet)	Depth drilled (feet)	Open interval		Contributing units
							Depth to top (feet)	Depth to bottom (feet)	
ER-2-1 (2079 ft)	370725116033901	ER-2-1	37.125230	116.062768	4,216	2,600	1,642	2,177	V
ER-2-1 (2559 ft)	370725116033902	ER-2-1	37.125230	116.062768	4,216	2,600	2,313	2,600	V
ER-3-1-1 (deep)	370116115561301	ER-3-1	37.019251	115.936776	4,407	2,807	2,512	2,807	C
ER-3-1-2 (shallow)	370116115561302	ER-3-1	37.019251	115.936776	4,407	2,807	2,208	2,310	C
ER-3-2-1 (deep)	370214116021001	ER-3-2	37.037130	116.037071	4,010	3,000	2,860	3,000	V
ER-3-2-2 (middle)	370214116021002	ER-3-2	37.037130	116.037071	4,010	3,000	2,588	2,636	F, V
ER-3-2-3 (shallow)	370214116021003	ER-3-2	37.037130	116.037071	4,010	3,000	1,550	1,890	F
ER-6-1 (piezometer))	365904115593403	ER-6-1	36.984409	115.993733	3,937	2,129	1,435	1,542	V
ER-6-1 main (2129 ft)	365904115593404	ER-6-1	36.984400	115.993730	3,935	2,129	1,819	2,129	C
ER-6-1 main (2243 ft)	365904115593405	ER-6-1	36.984409	115.993730	3,937	3,206	1,819	2,243	C
ER-6-1 main (3206 ft)	365904115593401	ER-6-1	36.984409	115.993730	3,937	3,206	1,819	3,206	C
ER-6-1-1	365904115593402	ER-6-1 #1	36.984272	115.993697	3,937	2,085	1,835	2,052	C
ER-6-1-2 (1587 ft)	365901115593502	ER-6-1 #2	36.983853	115.993919	3,935	3,200	120	1,587	V
ER-6-1-2 (3200 ft)	365901115593501	ER-6-1 #2	36.983853	115.993919	3,935	3,200	1,775	3,200	C, X
ER-6-2	365740116043501	ER-6-2	36.960983	116.077128	4,231	3,430	1,746	3,430	C, S
ER-7-1	370424115594301	ER-7-1	37.073278	115.996131	4,246	2,500	1,775	2,500	C
ER-8-1	371248116032101	ER-8-1	37.213158	116.056541	4,818	2,863	1,895	2,863	X
ER-12-1 (1641-1846 ft)	371106116110401	ER-12-1	37.184856	116.185093	5,817	3,588	1,641	1,846	C, S, X
ER-12-1 (3309-3414 ft)	371106116110402	ER-12-1	37.184856	116.185093	5,817	3,588	3,309	3,442	C
ER-12-2 (2964-5203 ft)	371019116072103	ER-12-2	37.171479	116.123385	4,705	6,883	2,964	5,203	S, X
ER-12-2 (2964-6883 ft)	371019116072101	ER-12-2	37.171479	116.123385	4,705	6,883	2,964	6,883	S, X
ER-12-2 (5203-6883 ft)	371019116072102	ER-12-2	37.171479	116.123385	4,705	6,883	5,203	6,883	S, X
ER-12-2 (579 ft)	371019116072104	ER-12-2	37.171479	116.123385	4,705	6,883	120	650	V, F, S
ME-1	371340116035201	Marble #1 [ME-1]	37.227802	116.065314	5,210	378	32	378	X
ME-2	371352116034601	Marble #2 [ME-2]	37.231094	116.063522	5,246	274	14	274	X
ME-3	371346116035801	Marble #3 [ME-3]	37.229508	116.066883	5,316	978	20	978	X
ME-4	371400116041101	Marble #4 [ME-4]	37.233338	116.070672	5,490	1,187	7	1,187	X
TH-9	370311115591901	Test Hole #9	37.053014	115.989347	4,176	1,953	80	1,953	C, V
TW-7	370353116020201	Test Well #7 [HTH]	37.064817	116.034644	4,058	2,272	0	2,272	V

Table 1. Characteristics of wells with at least one water-level measurement through 2003 in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	U.S. Geological Survey site identification number[1]	Nevada Test Site hole name[2]	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet)	Depth drilled (feet)	Open interval: Depth to top (feet)	Open interval: Depth to bottom (feet)	Contributing units
TW-B	365849116002101	USGS Test Well B Ex.	36.979150	116.014617	3,932	1,675	1,432	1,675	V
TW-D	370418116044501	USGS Test Well D	37.074391	116.075887	4,150	1,950	1,700	1,950	C, S
TW-E (1970 ft)	370321115594201	USGS HTH E	37.055797	115.995834	4,172	1,970	580	1,970	V
TW-E (2430 ft)	370321115594202	USGS HTH E	37.055797	115.995834	4,172	2,430	0	2,430	C, V
TW-E (2620 ft)	370321115594203	USGS HTH E	37.055797	115.995834	4,172	2,620	0	2,620	C, V
U-2av	370836116035001	U-2av	37.143269	116.064715	4,298	2,193	79	2,193	V
U-2az 1	370648116034401	U-2az #1	37.113319	116.063204	4,192	1,820	58	1,820	V
U-2bs	370723116033101	U-2bs	37.123000	116.059384	4,226	2,000	79	1,920	V
U-2bs PS 1DB	370722116032252	U-2bs PS #1DB	37.122844	116.056912	4,221	2,250	2,165	2,175	V
U-2bt	370641116030501	U-2bt	37.111450	116.052278	4,182	1,800	77	1,800	V
U-2ca 1	370822116082701	U-2ca #1 [UE-2u]	37.139510	116.141772	4,871	1,473	68	1,473	C, V
U-2df	370822116051501	U-2df	37.139466	116.088314	4,354	1,865	78	1,865	V, F
U-2dr	370802116050301	U-2dr	37.133963	116.085116	4,313	2,020	117	2,000	F
U-2eh	370900116045601	U-2eh	37.149827	116.083133	4,368	2,250	117	2,250	V, F
U-2ei	370904116040301	U-2ei	37.151116	116.068430	4,327	2,100	117	2,100	V
U-2ex	370826116041901	U-2ex	37.140400	116.072938	4,311	2,009	118	2,009	V
U-2gf	370728116042001	U-2gf	37.124386	116.072996	4,249	1,810	118	1,810	V
U-2gg	370834116040101	U-2gg	37.142791	116.067807	4,289	1,821	117	1,821	V*
U-2gg PS E3A	370837116040901	U-2gg PSE #3A	37.143602	116.070166	4,311	2,383	939	2,383	V
U-2gh	370645116031901	U-2gh	37.112455	116.056048	4,177	1,801	117	1,801	V
U-2gk	370720116041601	U-2gk	37.122305	116.072082	4,242	1,809	116	1,809	F
U-2v	370737116035901	U-2v	37.126802	116.067249	4,256	2,530	73	2,530	V
U-3an 3	370353116021401	U-3an #3	37.064908	116.038047	4,061	3,555	3,262	3,555	C
U-3cn 1	370338116011801	U-3cn #1	37.060453	116.022635	4,074	2,460	2,000	2,460	V
U-3cn 3	370339116011901	U-3cn #3	37.060706	116.022938	4,075	2,460	2,005	2,460	V
U-3cn 4 HTH	370355116013001	U-3cn #4 HTH	37.065192	116.025924	4,084	2,295	1,697	2,295	V
U-3cn 5	370320116012001	U-3cn #5 [BILBY Hydrologic Test Hole]	37.059433	116.023232	4,009	3,030	2,832	3,030	C, X
U-3cn PS 2	370338116011901	U-3cn PS #2	37.060372	116.022638	3,994	2,603	600	2,603	V
U-3jg	370017116014201	U-3jg	37.004786	116.029335	3,962	1,650	118	1,650	F
U-3jn 1	370326116021101	U-3jn Ex. #1/Inst.	37.057144	116.037369	4,046	2,000	1,354	2,000	V
U-3jq 1	370353116000601	U-3jq Ex. #1/Inst.	37.064656	116.002442	4,174	2,224	118	2,224	V, S, C

Table 1. Characteristics of wells with at least one water-level measurement through 2003 in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	U.S. Geological Survey site identification number[1]	Nevada Test Site hole name[2]	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet)	Depth drilled (feet)	Open interval		Contributing units
							Depth to top (feet)	Depth to bottom (feet)	
U-3ks	370053116002901	U-3ks	37.014700	116.008873	3,966	1,613	117	1,610	V
U-3kv	370020116003701	U-3kv	37.005372	116.011009	3,956	1,600	117	1,600	V
U-3kz	370409116025901	U-3kz	37.069033	116.050561	4,084	2,250	117	2,198	V
U-3mh	370157115591401	U-3mh	37.032436	115.988169	4,092	1,742	268	1,742	V*
U-3mi	370020115593001	U-3mi	37.005661	115.992650	4,006	1,794	372	1,794	V, C
U-3mt	370348116024301	U-3mt	37.063383	116.046158	4,067	1,550	110	1,550	V
U-4ak	370435116040701	U-4ak	37.076272	116.069359	4,130	1,630	120	1,630	V
U-4au	370509116040301	U-4au	37.085883	116.069387	4,144	1,750	117	1,750	V
U-4av	370547116041103	U-4av	37.096438	116.070482	4,178	1,700	117	1,700	V
U-4r	370506116031001	U-4r	37.085180	116.053673	4,119	2,250	119	2,250	V
U-4t 1	370601116025301	U-4t #1	37.100380	116.049075	4,144	2,100	118	2,100	V
U-4u (2112 ft)	370520116025703	U-4u	37.088950	116.050134	4,120	2,112	118	2,112	V
U-4u PS 2A	370513116025101	U-4u PS #2A	37.086928	116.050153	4,117	2,280	1,610	2,280	V
U-6e	365934116001601	U-6e	36.992789	116.005364	3,942	1,500	117	1,500	V*
U-7a	370626116015601	U-7a	37.107161	116.033111	4,255	2,699	2,438	2,699	C, V
U-7ad (1853 ft)	370613116013601	U-7ad	37.103544	116.027599	4,286	1,853	113	1,853	V
U-7ad (1965 ft)	370613116013602	U-7ad	37.103544	116.027599	4,286	1,965	113	1,965	V
U-7ae (2056 ft)	370512116002501	U-7ae	37.086522	116.007737	4,266	2,056	675	2,056	V
U-7ag	370632116014401	U-7ag	37.108806	116.029666	4,286	1,975	565	1,975	V
U-7au	370447116030501	U-7au	37.079755	116.052192	4,111	2,440	117	1,609	V
U-7ba	370514116024101	U-7ba	37.087041	116.045620	4,129	2,000	117	1,504	V
U-7ba PS 1AS	370517116023301	U-7ba PS #1AS	37.088022	116.043283	4,137	2,333	1,935	1,993	V
U-7bc	370444116001801	U-7bc	37.078936	116.005990	4,229	2,250	117	2,250	V
U-7bd	370454116003201	U-7bd	37.081572	116.009621	4,224	2,000	117	2,000	V
U-7bL	370554116005601	U-7bL	37.098242	116.016379	4,317	1,810	397	1,810	V*
U-7bz (817-2188 ft)	370530116015501	U-7bz	37.091744	116.032722	4,176	2,188	817	2,188	V, C
U-7ca	370436116000201	U-7ca	37.076736	116.001481	4,244	1,800	268	1,800	V
U-7cb	370514116000601	U-7cb	37.087286	116.002656	4,286	1,850	299	1,850	V
U-7cc	370605116012401	U-7cc	37.101311	116.024244	4,286	1,600	556	1,600	V
U-7cd	370451116024101	U-7cd	37.080819	116.045669	4,115	1,625	117	1,625	V
U-7cd 1	370451116024102	U-7cd #1	37.080825	116.045564	4,114	1,700	114	1,700	V
U-7z	370455116021201	U-7z	37.082011	116.037436	4,108	1,903	116	1,903	V
U-8j	371048116052001	U-8j	37.179927	116.089828	4,556	2,000	119	2,000	V, S, X
U-8n	371031116053001	U-8n	37.175271	116.092609	4,542	1,893	118	1,893	V
U-9 ITS UE-S-25	370819116022901	U-9 ITS UE-S-25	37.138455	116.042126	4,222	2,028	79	2,028	V

Table 1. Characteristics of wells with at least one water-level measurement through 2003 in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	U.S. Geological Survey site identification number[1]	Nevada Test Site hole name[2]	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet)	Depth drilled (feet)	Open interval: Depth to top (feet)	Open interval: Depth to bottom (feet)	Contributing units
U-9ca 1	370846116030851	U-9ca #1	37.145958	116.053037	4,244	3,210	1,800	3,210	V, C
U-9ct	370815116032701	U-9ct	37.137472	116.058415	4,264	1,710	117	1,710	V*
U-10k 1	370953116030801	U-10k #1 Expl./Inst.	37.164566	116.053118	4,272	2,289	1,983	2,275	V
U-10L 1	370917116023701	U-10L #1	37.154753	116.044520	4,264	2,208	1,375	2,208	C, V
U-15a 31 (1200 ft)	371335116033401	U-15a #31 [Granite Hole]	37.226216	116.060186	5,112	1,200	88	1,200	X
U-15k Test Hole	371346116032601	U-15k Test Hole (Granite Bit)	37.229450	116.057991	5,168	857	404	857	X
UE-1a	370254116070601	UE-1a	37.048227	116.119270	4,304	957	78	957	C, S
UE-1b	370254116064201	UE-1b	37.048196	116.112417	4,273	1,254	76	1,254	S, V
UE-1c	370253116055201	UE-1c	37.048130	116.098710	4,207	1,880	74	1,880	C, V
UE-1d	370301116065301	UE-1d	37.050127	116.115656	4,296	857	79	857	C, V
UE-1f	370246116064901	UE-1f	37.046035	116.114581	4,277	703	59	703	S, X
UE-1h	370005116040301	UE-1h	37.001286	116.068242	3,995	3,358	2,134	3,358	C
UE-1j	370049116042401	UE-1j	37.013669	116.074131	4,030	1,632	108	1,632	C
UE-1k	370218116033101	UE-1k	37.038316	116.059378	4,051	2,338	110	2,338	V, F
UE-1L (5339 ft)	370254116082001	UE-1L	37.048324	116.139826	4,457	5,339	716	5,339	S
UE-1L (recompleted)	370254116082002	UE-1L	37.048324	116.139826	4,457	5,339	716	2,284	S
UE-1q (2437 ft)	370337116033001	UE-1q	37.060294	116.059203	4,081	2,437	78	2,437	V, C
UE-1q (2600 ft)	370337116033002	UE-1q	37.060294	116.059203	4,081	2,600	2,459	2,600	C
UE-1r WW	370142116033301	UE-1r	37.028302	116.060145	4,042	4,182	2,319	4,182	C, V, X
UE-2aa (2207 ft)	370909116041951	UE-2aa	37.152375	116.072880	4,348	2,317	77	2,207	V
UE-2aa (2317 ft)	370909116041901	UE-2aa	37.152375	116.072880	4,348	2,317	77	2,317	C, V
UE-2ab	370849116054301	UE-2ab	37.146996	116.096256	4,413	1,270	80	1,270	C*
UE-2ar	370726116040302	UE-2ar Inst.	37.123769	116.068452	4,241	2,351	81	2,351	V, F
UE-2aw	370758116040601	UE-2aw/Inst.	37.132638	116.069329	4,272	2,328	77	2,328	V
UE-2ax 2	370910116045901	UE-2ax #2	37.152591	116.083927	4,396	2,450	72	2,450	V
UE-2b	370748116051201	UE-2b	37.129994	116.087441	4,310	3,512	120	3,512	V, C
UE-2ce	370831116080701	UE-2ce Water Well	37.141968	116.136094	4,765	1,650	1,377	1,650	C
UE-2dj	370823116050001	UE-2dj/Inst.	37.139797	116.084300	4,341	2,350	77	2,350	V, S
UE-2fb	370736116050301	UE-2fb	37.126616	116.084916	4,274	2,790	83	2,790	C, V
UE-2s	370712116073901	UE-2s/Inst.	37.119816	116.128465	4,583	1,970	1,050	1,970	C
UE-3e (1707 ft)	370411116025901	UE-3e	37.069580	116.050614	4,083	1,707	117	1,707	V
UE-3e (2105 ft)	370411116025902	UE-3e	37.069580	116.050614	4,083	2,105	117	2,105	V
UE-3e (2110 ft)	370411116025905	UE-3e	37.069580	116.050614	4,083	2,510	117	2,110	V
UE-3e (2118-2510 ft)	370411116025906	UE-3e	37.069580	116.050614	4,083	2,510	2,118	2,510	V
UE-3e (2410 ft)	370411116025903	UE-3e	37.069580	116.050614	4,083	2,410	117	2,410	V
UE-3e (2510 ft)	370411116025904	UE-3e	37.069580	116.050614	4,083	2,510	117	2,510	V

Table 1. Characteristics of wells with at least one water-level measurement through 2003 in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	U.S. Geological Survey site identification number[1]	Nevada Test Site hole name[2]	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet)	Depth drilled (feet)	Open interval		Contributing units
							Depth to top (feet)	Depth to bottom (feet)	
UE-3e 2 (2372 ft)	370411116025907	UE-3e #2	37.069689	116.050617	4,082	2,372	1,950	2,372	V
UE-3e 3 (2221 ft)	370411116025908	UE-3e #3	37.070114	116.048325	4,082	2,221	115	2,221	V*
UE-3e 4 (2300 ft)	370411116025909	UE-3e #4	37.069555	116.050558	4,081	2,300	1,436	2,300	V
UE-3e 4-1 (2181 ft)	370411116025910	UE-3e #4	37.069555	116.050558	4,081	2,300	2,094	2,192	V
UE-3e 4-2 (1919 ft)	370411116025911	UE-3e #4	37.069555	116.050558	4,081	2,300	1,832	1,926	V
UE-3e 4-3 (1661 ft)	370411116025912	UE-3e #4	37.069555	116.050556	4,081	2,300	1,540	1,668	V
UE-3mf (119-1692 ft)	370339116024206	UE-3mf/Inst.	37.060816	116.046111	4,066	2,395	119	1,692	V
UE-3mf (119-1894 ft)	370339116024204	UE-3mf/Inst.	37.060816	116.046111	4,066	2,395	119	1,894	V
UE-3mf (1692-2395 ft)	370339116024205	UE-3mf/Inst.	37.060816	116.046111	4,066	2,395	1,692	2,395	V
UE-3mf (1700 ft)	370339116024201	UE-3mf/Inst.	37.060816	116.046111	4,066	1,700	119	1,700	V
UE-3mf (1894-2395 ft)	370339116024203	UE-3mf/Inst.	37.060816	116.046111	4,066	2,395	1,894	2,395	V
UE-3mf (2100 ft)	370339116024202	UE-3mf/Inst.	37.060816	116.046111	4,066	2,100	119	2,100	V
UE-4a (2655 ft)	370601116030103	UE-4a (HTH)	37.100189	116.051200	4,155	3,028	856	2,655	V
UE-4a (3028 ft)	370601116030102	UE-4a (HTH)	37.100189	116.051200	4,155	3,028	2,886	3,028	C, P, V
UE-4aa	370543116054101	UE-4aa	37.095205	116.095636	4,254	1,224	76	1,224	C*
UE-4ab (2396 ft)	370608116043102	UE-4ab/Inst.	37.102263	116.076185	4,201	2,650	71	2,396	V
UE-4ab (2650 ft)	370608116043101	UE-4ab/Inst.	37.102263	116.076185	4,201	2,650	71	2,650	C, V, S
UE-4ac (1522 ft)	370601116071402	UE-4ac	37.100282	116.121468	4,471	1,677	74	1,522	V
UE-4ac (1677 ft)	370601116071401	UE-4ac	37.100282	116.121468	4,471	1,680	74	1,667	C
UE-4ae (2290 ft)	370434116040702	UE-4ae/Inst.	37.075997	116.069362	4,130	2,457	79	2,290	V
UE-4ae (2457 ft)	370434116040701	UE-4ae/Inst.	37.075997	116.069362	4,130	2,457	79	2,457	C, V
UE-4ah	370501116041301	UE-4ah/Inst.	37.083697	116.071015	4,142	2,851	79	2,851	C, V
UE-4av (1724-2815 ft)	370547116041102	UE-4av	37.096441	116.070651	4,177	2,815	1,724	2,815	V, P, S
UE-4av (1758 ft)	370547116041101	UE-4av	37.096441	116.070651	4,177	1,758	125	1,758	V
UE-4av (2815 ft)	370547116041104	UE-4av	37.096441	116.070651	4,177	2,815	125	2,815	V, P, S
UE-4t (1619-1721 ft)	370556116025404	UE-4t	37.098878	116.049128	4,141	2,413	1,619	1,721	V
UE-4t (1701 ft)	370556116025401	UE-4t	37.098878	116.049128	4,141	1,701	119	1,701	V
UE-4t (1947 ft)	370556116025402	UE-4t	37.098878	116.049128	4,141	1,947	119	1,947	V
UE-4t (2413 ft)	370556116025403	UE-4t	37.098878	116.049128	4,141	2,413	119	2,413	V
UE-4t 1 (1906-2010 ft)	370556116025405	UE-4t	37.098878	116.049128	4,141	2,413	1,906	2,010	V
UE-4t 2 (1564-1754 ft)	370556116025406	UE-4t	37.098878	116.049128	4,141	2,413	1,564	1,754	V
UE-6d	365905116033201	UE-6d	36.984758	116.059811	3,947	3,896	2,125	3,896	F, V
UE-6e (2090-2230 ft)	365905116012002	UE-6e	36.984564	116.023170	3,938	4,209	2,090	2,230	V
UE-6e (2090-4209 ft)	365905116012001	UE-6e	36.984564	116.023170	3,938	4,209	2,090	4,209	C, V

Table 1. Characteristics of wells with at least one water-level measurement through 2003 in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	U.S. Geological Survey site identification number[1]	Nevada Test Site hole name[2]	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet)	Depth drilled (feet)	Open interval		Contributing units
							Depth to top (feet)	Depth to bottom (feet)	
UE-7aa	370412115593601	UE-7aa	37.069961	115.994173	4,259	2,154	345	2,154	C
UE-7i	370619116011701	UE-7i	37.105281	116.022321	4,330	2,930	79	2,930	C, V
UE-7k	370453116015201	UE-7k	37.081297	116.031952	4,126	2,548	74	2,548	C, V
UE-7nS	370556116000901	UE-7nS	37.098722	116.003351	4,367	2,205	1,707	2,205	C
UE-8e (2295 ft)	371014116051601	UE-8e/Inst.	37.170580	116.088525	4,488	2,295	71	2,121	V
UE-8e (2470 ft)	371014116051602	UE-8e/Inst.	37.170580	116.088525	4,488	2,470	71	2,470	C, V
UE-8f	371022116054901	UE-8f	37.172785	116.097712	4,560	2,248	--	--	--
UE-8n	371029116053601	UE-8n	37.174730	116.094331	4,549	2,372	73	2,372	C, V
UE-10 ITS 1	371154116024601	UE-10 ITS #1	37.198389	116.047112	4,486	2,289	82	2,289	V, S
UE-10 ITS 1 (2040 ft)	371154116024602	UE-10 ITS #1	37.198389	116.047112	4,486	2,300	82	2,040	V
UE-10 ITS 3 (1926 ft)	371109116024702	UE-10 ITS #3	37.185758	116.047215	4,353	2,160	85	1,926	V
UE-10 ITS 3 (2160 ft)	371109116024701	UE-10 ITS #3	37.185758	116.047215	4,353	2,160	84	2,160	C, V
UE-10 ITS 5	371155116031401	UE-10 ITS #5/Inst.	37.198427	116.054666	4,522	2,334	89	2,334	C, V
UE-10 ITS 5 (2180 ft)	371155116031402	UE-10 ITS #5/Inst.	37.198427	116.054666	4,522	2,350	89	2,180	V
UE-10aa	371131116021501	UE-10aa/Inst.	37.192025	116.038237	4,401	1,380	76	1,380	S, X
UE-10bf	371123116025201	UE-10bf/Inst.	37.189744	116.048726	4,387	2,266	77	2,266	C, V
UE-10bf (2144 ft)	371123116025202	UE-10bf/Inst.	37.189744	116.048726	4,387	2,266	77	2,144	V
UE-10j (2232-2297 ft)	371108116045303	UE-10j	37.185477	116.082394	4,574	2,613	2,232	2,297	C
UE-10j (2232-2613 ft)	371108116045302	UE-10j	37.185477	116.082394	4,574	2,613	2,232	2,613	C
UE-10j (2380 ft)	371108116045301	UE-10j	37.185477	116.082394	4,574	2,380	55	2,380	C
UE-14a	365550116084201	UE-14a	36.930502	116.145773	4,339	3,300	80	3,300	V
UE-14b	365550116091101	UE-14b	36.930538	116.153948	4,353	3,680	2,051	3,680	V
UE-15d WW (1735-6001 ft)	371230116021500	UE-15d Water Well	37.209100	116.042271	4,586	6,001	1,735	6,001	C, X
UE-15d WW (5400-6001 ft)	371230116021501	UE-15d Water Well	37.209100	116.042271	4,586	6,001	5,400	6,001	C
UE-15j	371201115573601	UE-15j	37.200354	115.960826	4,763	1,248	15	1,248	X
UE-15j A-5	371158115574701	UE-15j A-5	37.199420	115.964023	4,772	745	6	745	V
UE-16d WW	370412116095101	UE-16d Eleana Water Well (Sidetrack)	37.070063	116.165158	4,684	3,000	81	1,944	C, S, X
UE-16d WW (830 ft)	370406116095600	UE-16d Eleana Water Well (Sidetrack)	37.070063	116.165158	4,684	830	81	830	C, S, X
UE-16d WW (2117-2293 ft)	370412116095102	UE-16d Eleana Water Well (Sidetrack)	37.070063	116.165158	4,684	2,350	2,117	2,293	S, X
UE-16f (1261 ft)	370208116092401	UE-16f Eleana	37.035635	116.157588	4,651	1,261	213	1,261	X, S
UE-16f (1479 ft)	370208116092402	UE-16f Eleana	37.035635	116.157588	4,651	1,479	1,293	1,479	X, S
UE-17a	370425116095801	UE-17a Eleana	37.073532	116.167108	4,696	1,214	745	1,214	S, X
UE-17c	370616116090801	UE-17c Eleana	37.104527	116.152997	4,835	586	38	586	F, S
USGS - Shot Hole	371205116080201	USGS Shot Hole	37.201285	116.134647	5,065	105	--	--	V
Whiterock Springs 1	371204116075501	Whiterock Springs-1	37.201004	116.132933	5,065	72	2	72	V
Whiterock Springs 2	371210116075001	Whiterock Springs-2	37.202646	116.131547	5,080	84	--	--	V

Table 1. Characteristics of wells with at least one water-level measurement through 2003 in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	U.S. Geological Survey site identification number[1]	Nevada Test Site hole name[2]	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet)	Depth drilled (feet)	Open interval		Contributing units
							Depth to top (feet)	Depth to bottom (feet)	
Whiterock Springs 3	371158116075501	Whiterock Springs-3	37.199354	116.132944	5,030	41	--	--	V
Whiterock Springs 3A	371159116075201	Whiterock Springs-3A	37.199624	116.131911	4,995	10	--	--	V
Whiterock Springs 4	371148116074801	Whiterock Springs-4	37.196599	116.130902	4,959	71	--	--	V
WW-2 (2045 ft)	370958116051501	Water Well 2 [USGS HTH-2]	37.166185	116.088494	4,470	2,045	1,465	2,045	V
WW-2 (2535 ft)	370958116051503	Water Well 2 [USGS HTH-2]	37.166185	116.088494	4,470	2,535	2,121	2,535	V
WW-2 (2896 ft)	370958116051508	Water Well 2 [USGS HTH-2]	37.166185	116.088494	4,470	2,896	2,550	2,896	C
WW-2 (3422 ft)	370958116051512	Water Well 2 [USGS HTH-2]	37.166185	116.088494	4,470	3,422	2,700	3,412	C
WW-2 (3422 ft, uncased)	370958116051511	Water Well 2 [USGS HTH-2]	37.166185	116.088494	4,470	3,422	2,550	3,422	C
WW-3 (1575 ft)	365942116032900	Well 3 Water Well	36.995183	116.058828	3,969	1,575	1,209	1,575	F, (V)
WW-3 (1800 ft)	365942116032901	Well 3 Water Well	36.995183	116.058828	3,969	1,800	1,209	1,800	F, V
WW-A (1730 ft)	370142116021100	USGS Water Well A	37.036828	116.037107	4,006	1,730	1,555	1,730	F
WW-A (1870 ft)	370142116021101	USGS Water Well A	37.036828	116.037107	4,006	1,870	1,555	1,870	F
WW-C (recompleted)	365508116003502	USGS Water Well C	36.918798	116.010513	3,924	1,701	1,373	1,701	C
WW-C (1373-1701 ft)	365508116003501	USGS Water Well C	36.918798	116.010513	3,924	1,701	1,373	1,701	C
WW-C-1	365500116003901	Water Well C-1 [U-6 Well D]	36.918600	116.010275	3,924	1,707	914	1,707	C

[1]The U.S. Geological Survey site identification is based on the latitude-longitude grid. Each site is identified by a unique 15-digit number. The first six digits denote degrees, minutes, and seconds of latitude; the next seven digits denote degrees, minutes, and seconds of longitude; and the last two digits are the sequence number of the well or test hole within the 1-second grid of latitude and longitude. The assigned number is retained as a permanent identifier even if a more precise latitude and longitude are later determined. To determine the geographic location of a well or test hole, the latitude and longitude coordinates should be used rather than the site identifier.

[2]Official Nevada Test Site (NTS) hole names are assigned to test holes according to the type of hole drilled, site location (NTS area number), and sequence code for consecutive order in which the hole was drilled or redrilled. Most of the holes drilled on the NTS begin with the letter "U." Exploratory holes, drilled to assess material properties within a defined area, are designated with an "E" following the "U." The "U" or "UE" are followed by a dash (-), NTS area number, and sequence code (letters "a-z, aa-az, ba-bz, ..., za-zz"). The suffix "PS" indicates a post-shot hole, the suffix "Inst.," indicates an instrumented hole, the suffix "#" followed by a number indicates a satellite hole, and "HTH" indicates a hydrologic test hole. Exceptions to the standard naming convention are wells beginning with "ER," which indicates a well drilled for the Environmental Restoration Program.

A single number in the parenthetical expression refers to the depth of the well; two numbers separated by a dash refer to the depth of the top and bottom of the open interval in a well. Table 1 lists all 216 wells with water-level measurements in Yucca Flat; figure 2 shows the location of the boreholes where these wells are completed.

Periodic water-level measurements were made manually by the USGS using calibrated electric-cable units (also known as iron-horse and wire-line devices), calibrated electric tapes, or rarely, a steel tape (Garber and Koopman, 1968). Most measurements prior to 1996 were made with an electric-cable unit, whereas, more recent measurements typically were made using electric tapes. The tapes and cable units are calibrated annually at different water-level depths with a USGS 2,000-ft steel reference tape. At the time of measurement, a correction factor is applied to the depth-to-water reading based on the annual calibration. Recent measurements generally are considered more accurate (±0.1 ft) than older measurements (±0.5 to 1 ft).

In addition to the USGS water-level measurements, supplemental water-level measurements from private contractors working at the NTS are stored in the NWIS database. Most of the contractor data collected prior to 1992 were determined from fluid-density geophysical logs, which are considered accurate to 1–2 ft. Recent contractor water-level measurements made for the DOE Environmental Restoration Program used electric tapes. These tapes, which are calibrated annually with the USGS 2,000-ft steel reference tape, are considered accurate to ±0.1 ft.

Water-level fluctuations were monitored by the USGS in eight wells in Yucca Flat using pressure transducers and electronic data loggers. Water levels were measured hourly in these wells from 1- to 6-year periods between 1990 and 1998 (fig. 4). The water-level data are maintained in the NWIS database. Transducer data were checked periodically with manual water-level measurements using a calibrated tape. The general procedure used to calibrate the pressure transducers is outlined in Locke and La Camera (2003, p. 16–18).

Additional continuous water-level data, collected by NTS contractors since 1992, are available for many wells. These data were collected for various purposes using pressure transducers and electronic data loggers. The data were used to monitor water levels for aquifer tests and to monitor water levels during or following well construction and development activities. Wells with 1 to 6 months of continuous data through 2003 include ER-2-1 (2079 ft), ER-2-1 (2559 ft), ER-6-1 main (3206 ft), ER-6-1 (piezometer), ER-6-1-1, ER-6-1-2 (1587 ft), ER-6-1-2 (3200 ft), ER-7-1, ER-12-2 (2964-6883 ft), and ER-12-2 (579 ft) (Jeffrey Wurtz, Stoller-Navarro Joint Venture, written commun., 2004).

A systematic quality-assurance review of the NWIS database for the wells in Yucca Flat was done for this study for the period 1951–2003. This included removing or correcting duplicate sites or erroneous water-level data, and adding missing water-level measurements and construction information. A summary of water-level measurements from the 216 wells is listed in table 2. The earliest measurement was made in 1951 and 48 wells were measured in 2003. The shallowest measured depth to water was 8 ft in wells Whiterock Springs 3 and 3A and the deepest measured depth to water was 2,762 ft in well ER-12-1 (3309-3414 ft). Water-level depths of greater than 1,500 ft were measured in 149 wells (table 2).

Description of Water-Level Database

An interpretative database using Microsoft® Access format was constructed that describes the external conditions influencing each water level that was measured in Yucca Flat. The database contains site information for each well, well-construction records, borehole lithology and aquifer data, and water-level data (app. 1). Information in this database was derived by merging data sets created for this study with site and water-level data from NWIS. All tables are linked by the USGS well name and site identification number, a unique 15-digit number used to identify the well site (table 1). Several of the tables also are linked by water-level date. The structure of the water-level database is shown in figure 5. An effort was made to maintain a database structure that is consistent with the structure of the NWIS database. For example, the four well-construction tables from NWIS are preserved in the water-level database.

Hydrographs and well locations in Yucca Flat are interactively presented with a Microsoft® Excel workbook. The workbook is designed to be an easy-to-use tool to obtain a quick understanding of the water-level history for any well in Yucca Flat. It also can be used to filter water-level data by restricting the data to certain wells, dates, or hydrologic conditions.

An example page from the workbook (fig. 6) shows well UE-10bf, which was selected using the Excel built-in AutoFilter. Selected water-level information from the water-level database is shown for this well. Additionally, a short narrative is displayed that discusses the well and hydrograph.

Site, Well-Construction, and Lithology Information

Site, well-construction, and lithology information for the Yucca Flat water-level wells are stored in NWIS as well as the Access water-level database. This information can be used as supporting data to understand and interpret the water levels and water-level trends.

Site information for the 216 wells in Yucca Flat is stored in four tables in the Access database (fig. 5; app. 1). Basic site data are in the table YF_sitefile. These data include the DOE name for referencing the borehole where a well is completed, location coordinates (latitude/longitude and Universal Transverse Mercator projection), general location information (hydrographic area number, hydrologic unit code, and NTS area number), and land-surface altitude. Land-surface altitudes and dates of surveys are reported for selected

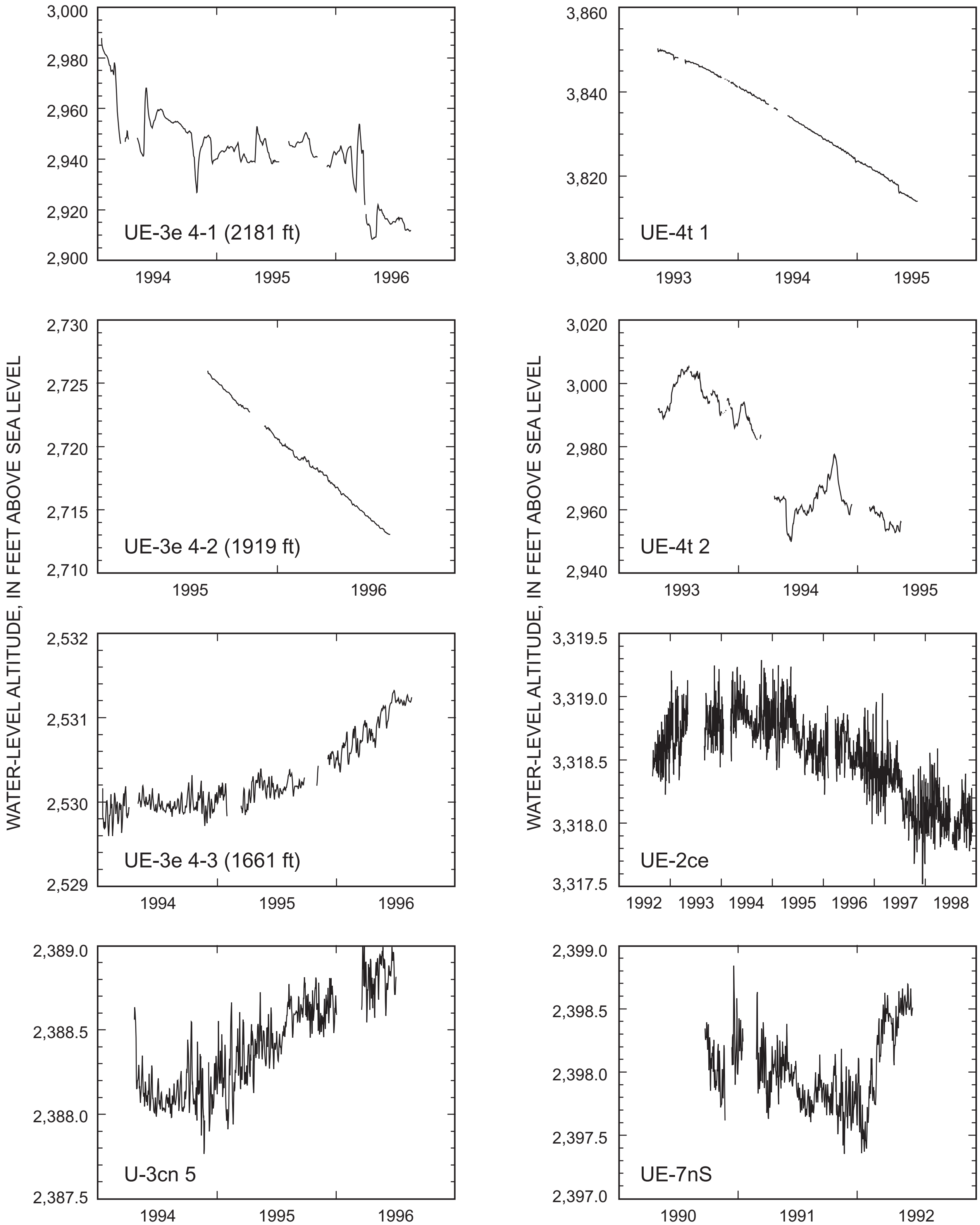


Figure 4. Graphs showing daily mean water levels from wells in Yucca Flat with continuous water levels measured by the U.S. Geological Survey. Horizontal and vertical scales are variable.

Table 2. Summary of water-level measurements from wells in the Yucca Flat area, Nevada Test Site

Number of measurements: Includes measurements indicating well was dry or obstructed.

Minimum and maximum water level: --, A measurement of the water surface was not made in the well because the well was dry or obstructed.

U.S. Geological Survey well name (see fig. 2)	Water level			
	Period of record	Number of measurements	Minimum, shallowest (feet below land surface)	Maximum, deepest (feet below land surface)
ER-2-1 (2079 ft)	2003	8	1,722	1,768
ER-2-1 (2559 ft)	2003	10	599	677
ER-3-1-1 (deep)	1994–1995	2	2,016	2,016
ER-3-1-2 (shallow)	1994–2003	37	2,015	2,017
ER-3-2-1 (deep)	1994–1995	3	1,606	1,609
ER-3-2-2 (middle)	1994–2003	37	1,600	1,608
ER-3-2-3 (shallow)	1994–1995	3	--	--
ER-6-1 main (2129 ft)	1992–1994	3	1,545	1,550
ER-6-1 main (2243 ft)	1995–2003	34	1,546	1,548
ER-6-1 main (3206 ft)	1994–1995	3	1,548	1,548
ER-6-1 (piezometer)	1992–2003	35	1,470	1,475
ER-6-1-1	1994–2003	27	1,546	1,548
ER-6-1-2 (1587 ft)	2002–2003	10	1,471	1,472
ER-6-1-2 (3200 ft)	2002–2003	9	1,545	1,546
ER-6-2	1994–2003	39	1,784	1,787
ER-7-1	2003	3	1,853	1,853
ER-8-1	2003	1	--	--
ER-12-1 (1641-1846 ft)	1993–2003	36	1,526	1,542
ER-12-1 (3309-3414 ft)	1992	1	2,762	2,762
ER-12-2 (2964-5203 ft)	2003	8	187	216
ER-12-2 (2964-6883 ft)	2003	9	205	818
ER-12-2 (5203-6883 ft)	2003	8	186	216
ER-12-2 (579 ft)	2003	10	414	418
ME-1	1959–2001	4	334	336
ME-2	1959–2001	2	--	--
ME-3	1959–2001	12	477	482
ME-4	1959–2001	2	--	--
TH-9	1969	1	1,785	1,785
TW-7	1958–2003	167	1,580	1,668
TW-B	1961–2003	111	1,503	1,509
TW-D	1961–2003	46	1,722	1,732
TW-E (1970 ft)	1960	4	1,716	1,716
TW-E (2430 ft)	1961	5	1,731	1,732
TW-E (2620 ft)	1962–2003	12	1,769	1,788
U-2av	1969	6	1,780	1,872
U-2az 1	1970	1	1,801	1,801
U-2bs	1971–1972	37	1,721	1,911
U-2bs PS 1DB	1973–1975	12	1,940	1,975
U-2bt	1971	7	1,626	1,780
U-2ca 1	1965	24	1,281	1,326
U-2df	1969	1	1,858	1,858
U-2dr	1972–1974	15	1,849	1,860
U-2eh	1974	2	1,870	1,898
U-2ei	1977	6	1,898	1,921
U-2ex	1982–1983	5	1,840	1,847
U-2gf	1987	13	1,769	1,779

Table 2. Summary of water-level measurements from wells in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	Water level			
	Period of record	Number of measurements	Minimum, shallowest (feet below land surface)	Maximum, deepest (feet below land surface)
U-2gg PS E3A	1995–1996	3	1,821	1,822
U-2gh	1988–1989	21	1,572	1,578
U-2gk	1992–2003	44	1,778	1,803
U-2v	1966	1	1,825	1,825
U-3an 3	1963	1	1,685	1,685
U-3cn 1	1963	2	1,670	1,671
U-3cn 3	1963	3	1,672	1,683
U-3cn 4 HTH	1963	15	1,195	1,689
U-3cn 5	1966–2003	67	1,619	1,623
U-3cn PS 2	1963–1977	151	1,550	1,905
U-3jg	1972	7	1,546	1,554
U-3jn 1	1971	3	1,644	1,649
U-3jq 1	1972	6	1,712	1,714
U-3ks	1977	5	1,547	1,590
U-3kv	1979–1991	27	1,532	1,536
U-3kz	1984–1986	89	1,141	2,189
U-3mh	1986–1987	4	1,590	1,664
U-3mi	1987–2003	53	1,558	1,598
U-3mt	1990–1991	7	1,537	1,538
U-4ak	1981	2	1,615	1,617
U-4au	1987–1988	16	1,638	1,644
U-4av	1990–1991	16	1,582	1,686
U-4r	1983–1984	17	1,523	2,190
U-4t 1	1986	13	1,034	1,058
U-4u (2112 ft)	1987	1	1,463	1,463
U-4u PS 2A	1990–1998	60	1,492	1,642
U-6e	1984–1986	2	--	--
U-7a	1963	4	1,812	1,868
U-7ad (1853 ft)	1972	28	1,810	1,850
U-7ad (1965 ft)	1972	3	1,806	1,820
U-7ae (2056 ft)	1976	3	1,786	1,802
U-7ag	1973	12	1,894	1,972
U-7au	1978	1	1,603	1,603
U-7ba	1980	1	1,504	1,504
U-7ba PS 1AS	1994–1996	4	1,171	1,178
U-7bc	1981	4	1,744	1,855
U-7bd	1978	3	1,749	1,754
U-7bL	1985	1	--	--
U-7bz (817-2188 ft)	1989–2002	3	1,658	1,659
U-7ca	1985–1988	16	1,702	1,707
U-7cb	1986–1991	54	1,784	1,798
U-7cc	1988–2002	7	1,577	1,581
U-7cd	1992–2003	58	1,426	1,614
U-7cd 1	1992–1993	16	1,419	1,675

Table 2. Summary of water-level measurements from wells in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	Water level			
	Period of record	Number of measurements	Minimum, shallowest (feet below land surface)	Maximum, deepest (feet below land surface)
U-7z	1971	1	1,635	1,635
U-8j	1983–1984	6	1,768	1,867
U-8n	1984–1988	5	1,772	1,843
U-9 ITS UE-S-25	1971	3	1,793	1,794
U-9ca 1	1964–1997	17	1,620	1,783
U-9ct	1981–2002	4	1,677	1,682
U-10k 1	1964–1965	6	1,858	1,867
U-10L 1	1964–1997	7	1,840	1,860
U-15a 31 (1200 ft)	1962	1	187	187
U-15k Test Hole	1997–2003	20	655	787
UE-1a	1964–2003	47	543	547
UE-1b	1964–2003	46	643	646
UE-1c	1964–2003	42	1,289	1,298
UE-1d	1964–1967	2	536	536
UE-1f	1964–1977	2	628	628
UE-1h	1982–2003	33	1,555	1,559
UE-1j	1968–1988	2	1,538	1,538
UE-1k	1969–1973	5	1,603	1,605
UE-1L (5339 ft)	1976–1977	10	504	508
UE-1L (recompleted)	1978–2003	38	499	520
UE-1q (2437 ft)	1980–1991	12	1,553	1,569
UE-1q (2600 ft)	1992–2003	41	1,655	1,656
UE-1r WW	1984	3	1,626	1,769
UE-2aa (2207 ft)	1970–1977	17	1,915	1,926
UE-2aa (2317 ft)	1970	1	1,939	1,939
UE-2ab	1997	1	--	--
UE-2ar	1975	1	1,791	1,791
UE-2aw	1973–1974	5	1,813	1,822
UE-2ax 2	1973	8	1,968	1,970
UE-2b	1968	1	1,888	1,888
UE-2ce	1977–2003	194	1,398	1,478
UE-2dj	1971	6	1,878	1,896
UE-2fb	1977	10	1,721	1,772
UE-2s	1964	23	1,825	1,944
UE-3e (1707 ft)	1986	4	1,555	1,557
UE-3e (2105 ft)	1986	15	1,488	1,968
UE-3e (2110 ft)	1986	5	1,512	1,543
UE-3e (2118-2510 ft)	1986	22	838	1,649
UE-3e (2410 ft)	1986	30	1,540	1,826
UE-3e (2510 ft)	1986	2	1,542	1,609
UE-3e 2 (2372 ft)	1987–1988	16	517	673
UE-3e 3 (2221 ft)	1988	1	--	--
UE-3e 4 (2300 ft)	1990	6	1,537	1,991
UE-3e 4-1 (2181 ft)	1990–2003	99	1,024	1,304
UE-3e 4-2 (1919 ft)	1990–2003	109	1,234	1,420
UE-3e 4-3 (1661 ft)	1990–2003	98	1,548	1,560

Table 2. Summary of water-level measurements from wells in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	Water level			
	Period of record	Number of measurements	Minimum, shallowest (feet below land surface)	Maximum, deepest (feet below land surface)
UE-3mf (119-1692 ft)	1987	5	1,482	1,546
UE-3mf (119-1894 ft)	1986	22	1,428	1,477
UE-3mf (1692-2395 ft)	1987	6	1,414	1,458
UE-3mf (1700 ft)	1986	4	1,601	1,630
UE-3mf (1894-2395 ft)	1986	34	1,359	1,590
UE-3mf (2100 ft)	1986	25	1,440	2,099
UE-4a (2655 ft)	1961–1963	16	1,461	1,620
UE-4a (3028 ft)	1961	1	1,740	1,740
UE-4aa	1973	3	1,219	1,219
UE-4ab (2396 ft)	1973–1982	9	1,624	1,807
UE-4ab (2650 ft)	1973	1	1,874	1,874
UE-4ac (1522 ft)	1983	1	--	--
UE-4ac (1677 ft)	1974	1	--	--
UE-4ae (2290 ft)	1974–1981	4	1,620	1,634
UE-4ae (2457 ft)	1974	1	1,628	1,628
UE-4ah	1978–1979	8	1,543	1,656
UE-4av (1724-2815 ft)	1989–1990	22	1,626	2,211
UE-4av (1758 ft)	1989	5	1,564	1,728
UE-4av (2815 ft)	1990–1991	4	1,564	1,571
UE-4t (1619-1721 ft)	1989–1990	7	865	888
UE-4t (1701 ft)	1987	1	1,600	1,600
UE-4t (1947 ft)	1987	6	1,068	1,428
UE-4t (2413 ft)	1987–1989	33	867	1,746
UE-4t 1 (1906–2010 ft)	1990–2003	114	288	493
UE-4t 2 (1564-1754 ft)	1990–2003	98	361	1,196
UE-6d	1968–2003	51	1,514	1,528
UE-6e (2090-2230 ft)	1994–2003	38	1,509	1,514
UE-6e (2090-4209 ft)	1980–1992	15	1,507	1,510
UE-7aa	1969–1971	16	1,860	2,114
UE-7i	1983–1984	3	1,783	1,788
UE-7k	1981–1997	2	--	--
UE-7nS	1976–2003	148	1,959	1,976
UE-8e (2295 ft)	1970–1972	6	1,904	2,006
UE-8e (2470 ft)	1973–1976	6	1,910	2,060
UE-8f	1997	1	--	--
UE-8n	1988	2	--	--
UE-10 ITS 1	1969–1972	16	1,213	1,238
UE-10 ITS 1 (2040 ft)	1972–1986	7	1,221	1,250
UE-10 ITS 3 (1926 ft)	1973–1989	12	1,849	1,860
UE-10 ITS 3 (2160 ft)	1969–1972	16	1,867	2,023
UE-10 ITS 5	1970–1972	6	2,034	2,071
UE-10 ITS 5 (2180 ft)	1973–1977	4	1,985	1,990
UE-10aa	1973–1980	4	1,134	1,151
UE-10bf	1978	8	1,890	1,911

Table 2. Summary of water-level measurements from wells in the Yucca Flat area, Nevada Test Site—Continued

U.S. Geological Survey well name (see fig. 2)	Water level			
	Period of record	Number of measurements	Minimum, shallowest (feet below land surface)	Maximum, deepest (feet below land surface)
UE-10bf (2144 ft)	1978–1982	8	1,873	1,906
UE-10j (2232-2297 ft)	1997–2003	25	2,157	2,158
UE-10j (2232-2613 ft)	1995–1996	9	2,157	2,159
UE-10j (2380 ft)	1965–1978	8	2,157	2,163
UE-14a	1983–1984	7	1,294	1,647
UE-14b	1984–2003	41	1,664	1,671
UE-15d WW (1735-6001 ft)	1962	2	668	673
UE-15d WW (5400-6001 ft)	1963–1983	4	667	694
UE-15j	1969	1	444	444
UE-15j A-5	1969	1	452	452
UE-16d WW	1981	1	753	753
UE-16d WW (830 ft)	1977	1	753	753
UE-16d WW (2117-2293 ft)	1977	45	303	593
UE-16f (1261 ft)	1977	1	798	798
UE-16f (1479 ft)	1985–2003	40	366	369
UE-17a	1976–2003	55	380	639
UE-17c	1976–1978	7	508	511
USGS-Shot Hole	1958	1	87	87
Whiterock Springs 1	1959	1	21	21
Whiterock Springs 2	1959	1	50	50
Whiterock Springs 3	1959	1	8	8
Whiterock Springs 3A	1959	1	8	8
Whiterock Springs 4	1959	1	49	49
WW-2 (2045 ft)	1961	1	1,915	1,915
WW-2 (2535 ft)	1961	4	1,958	1,980
WW-2 (2896 ft)	1962	1	2,056	2,056
WW-2 (3422 ft)	1962–2003	42	2,053	2,066
WW-2 (3422 ft, uncased)	1962	1	2,053	2,053
WW-3 (1575 ft)	1951	1	1,530	1,530
WW-3 (1800 ft)	1952–2003	68	1,532	1,630
WW-A (1730 ft)	1960	1	1,604	1,604
WW-A (1870 ft)	1960–2003	59	1,601	1,643
WW-C (recompleted)	1969–1975	6	1,542	1,545
WW-C (1373-1701 ft)	1961–1962	7	1,537	1,545
WW-C-1	1962–1998	18	1,538	1,594

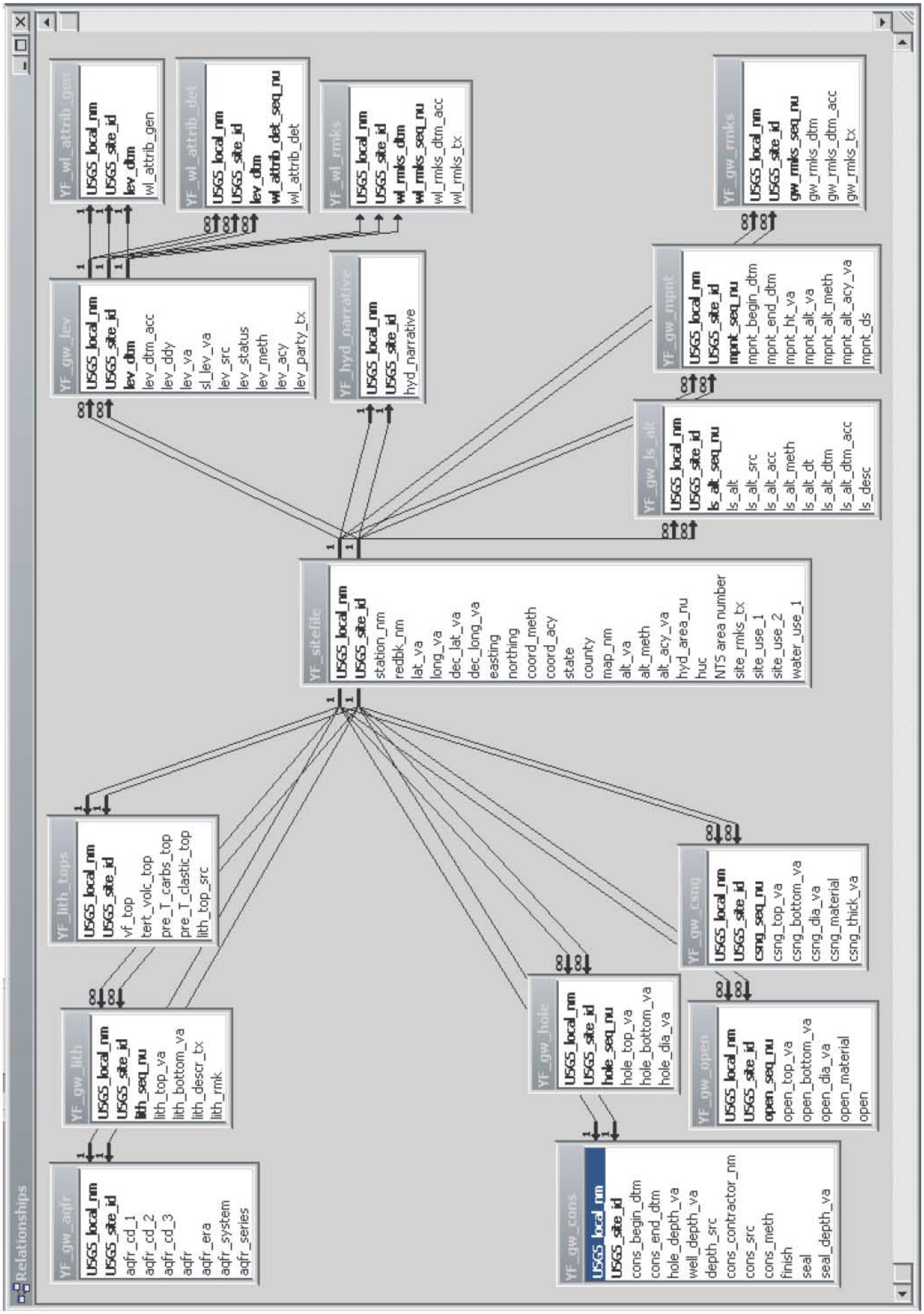


Figure 5. Diagram showing relations among Microsoft® Access files in the Yucca Flat water-level database.

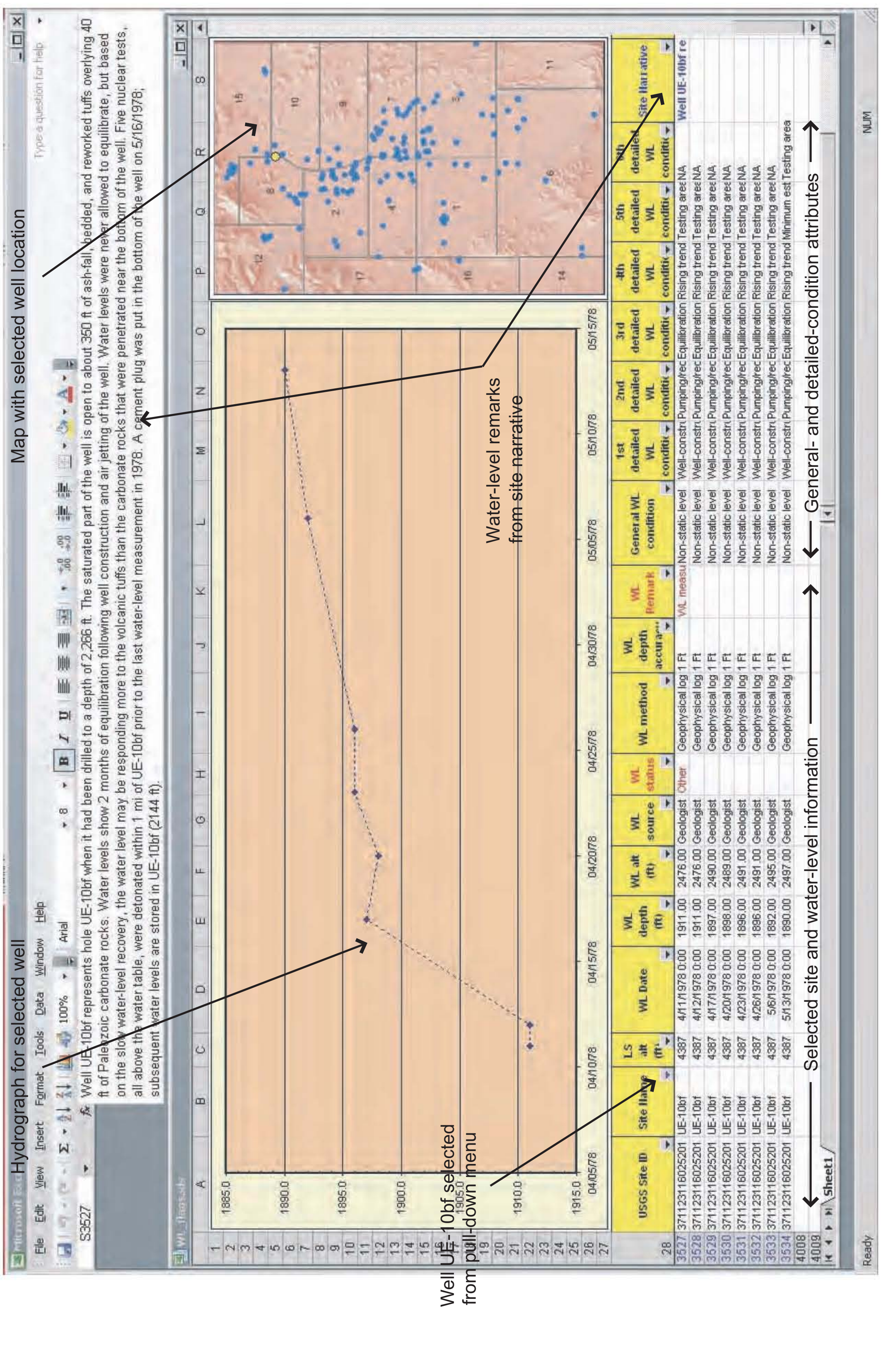


Figure 6. Diagram example of water-level output from Microsoft® Excel workbook.

wells in the table YF_gw_ls_alt. A third table, YF_gw_mpnt, contains fields that describe the measuring point for many of the wells that are actively measured as part of the DOE NTS water-level network. The last table, YF_gw_rmks, has miscellaneous remarks related to the site, well, or water levels. These remarks are derived from a variety of sources including published reports, drilling records, or field notes.

Well-construction records are stored in four tables in the Access database (fig. 5; app. 1). General construction information, such as construction dates, borehole and well depth, and construction method, are in the table YF_gw_cons. The remaining three tables, YF_gw_hole, YF_gw_csng, and YF_gw_open, provide information on borehole diameter, casing, and open intervals for each well.

Lithology information for each borehole and names of lithologic unit(s) contributing water to each well are stored in three tables in the Access database (fig. 5; app. 1). Detailed lithologic descriptions of cuttings or cores for most boreholes are in the table YF_gw_lith. These original descriptions were written by many different geologists and workers over the past 50 years and compiled primarily by H.R. Covington and D.B. Wood of the USGS. The second Access table, YF_lith_tops, provides the depths to the top of the valley fill, Tertiary volcanic rocks, pre-Tertiary carbonate rocks, and pre-Tertiary clastic rocks for each well in the database. The third table, YF_gw_aqfr, identifies the aquifers or lithologic units contributing water to each well. The designations for aquifers or water-bearing units in this table are lithostratigraphic based rather than hydrostratigraphic based, as is commonly used for the NTS (Laczniak and others, 1996, table 1).

Water-Level Data

Water-level measurement source, method, and accuracy, as well as hydrologic conditions during water-level measurements, are attributed in the Access database. Interpretations for individual water-level measurements and for the period of record from a well have been incorporated into the attributes. Abrupt water-level changes and long-term water-level declines are examples of typical phenomena that were interpreted.

Hydrologic-condition attributes were used to describe the state of each water level that was measured in Yucca Flat. They also describe the external factors that caused a water level to be at the depth reported. Some of the attributes are subjective interpretations made by the author. Hydrologic-condition attributes were categorized as either general or detailed (table 3). General-condition attributes describe the state of a water level. Examples are steady state, transient, nonstatic level, and localized conditions. Detailed-condition attributes can either denote the factor affecting a water level or describe the effect that a factor has on a water level. Factors affecting water levels include nuclear tests, climate, pumping, and recent well construction. Water-level effects include abrupt change, anomalous-high, equilibration, and rising trend. One general-condition attribute and 0–6 detailed-condition attributes were assigned to each water-level measurement in Yucca Flat.

An example of how water levels from well TW-7 were attributed is shown in figure 7. In this example, initial water-level measurements were relatively consistent and considered representative of regional steady-state conditions. However, after the Aardvark nuclear test in 1962, localized hydrologic conditions prevailed as water levels were altered by multiple underground nuclear tests that caused abrupt rises in water levels. Subsequent to each rise, a declining trend occurred as water levels equilibrated from the nuclear test.

The water-level history of each well also is documented as a narrative. The narrative consists of comments or explanations about the well or about one or more measured water levels in the well. An interpretation of the hydrograph and its hydrologic significance usually is provided. The narrative may include information about the open interval, testing done in the well, the well productivity, specific influences near the well that may have affected water levels (such as a nuclear test), and any other details that may provide insight into the condition of the water levels. Most of the basic information included in the narrative was derived from published reports or USGS data files archived in Henderson, Nev.

Data pertaining to water-level measurements in Yucca Flat are stored in five tables in the Access database (fig. 5; app. 1). The table YF_gw_lev contains the basic data pertaining to the water-level measurement. These data include the water-level date, depth, source, status, method, and accuracy. The accuracy pertains to the depth-to-water measurement and not the water-level altitude. The table YF_wl_rmks contains remarks related to specific water-level measurements. The general- and detailed-condition attributes for each water-level measurement are stored in the Access tables YF_wl_attrib_gen and YF_wl_attrib_det. The hydrograph narratives are stored in the table YF_hyd_narrative.

Borehole Deviation

Estimates of borehole deviation were available for many of the boreholes used in this study. In most cases, deviation was minimal and bottom-hole vertical corrections were less than 0.5 ft. As a general rule, water levels were not corrected for borehole deviation unless the correction was greater than 0.5 ft. Corrections smaller than 0.5 ft were not applied to water levels because the uncertainty in the deviation correction may be as great or greater than the magnitude of the correction.

Water-level corrections for selected depth intervals (table 4) were developed using linear equations based on cumulative measured borehole deviations. Within the selected depth interval, the angle of deviation is assumed constant. The true vertical water-level depth was determined by substituting the measured water-level depth, and measured and true vertical borehole interval depths from a deviation survey into a linear

Table 3. Description of general- and detailed-condition attributes assigned to water levels in Yucca Flat

Number of water levels: Number of water levels in Yucca Flat assigned with this attribute. Each water level was assigned only one general-condition attribute but may have multiple detailed-condition attributes.

Attribute name	Description	Number of water levels
General-condition attribute		
Insufficient data	Water level does not have sufficient supporting information to determine its general condition.	63
Localized conditions	Water level represents localized, typically transient, hydrologic conditions in aquifer (for example, nuclear-test effect or localized pumping).	928
None	Hole is dry or obstructed, or site was visited but water level was not measured.	53
Nonstatic level	Water level is affected by activities in the well such as aquifer testing, well construction, or pumping. Water level does not represent conditions within the aquifer.	1,166
Steady state–LOCAL	Water level approximates predevelopment, steady-state, hydrologic conditions in a well that monitors a local-scale flow system, such as a perched aquifer.	19
Steady state–REGIONAL	Water level approximates predevelopment, steady-state hydrologic conditions in a well that monitors the regional ground-water flow system.	1,459
Suspect	Water level is suspect or in error, and cannot be attributed to any known hydrologic cause.	161
Transient–REGIONAL	Water level represents changes from pumping in the regional ground-water flow system.	128
Detailed-condition attribute		
Abrupt change	Water level rapidly shifted or changed from previous measurements.	75
Anomalous - high	Water-level altitude is unusually high relative to other measurements at the site or at nearby sites.	858
Anomalous - low	Water-level altitude is unusually low relative to other measurements at the site or at nearby sites.	27
Borehole deviation	Water level is corrected for borehole deviation.	350
Consistent	Water level appears to be part of a reasonably consistent trend representative of general water-level conditions in the area.	1,173
Declining trend	Water level appears to be part of a discernable, overall downward trend. Possible causes include nearby pumping, decreased recharge, equilibration following drilling, or depressurization after a nuclear test.	787
Dry	Site was dry at time of measurement.	13
Elevated	Water level is elevated appreciably above the regional ground-water system, probably because of natural conditions.	136
Equilibration	Water level appears to be part of a discernable, overall trend that is approaching an equilibrium level, either higher or lower than the initial measurement. Equilibration commonly occurs following well construction, pumping, or nearby nuclear testing.	1,820
Erratic/Unstable	Water level is erratic and unstable.	79
Injection/recovery	Water level appears to be affected by recent injection of water, mud, or other fluid into the well or hole.	95
Limited data	Water level is one of a limited number. Therefore general-condition attribute assigned to water level is tentative.	100

Table 3. Description of general- and detailed-condition attributes assigned to water levels in Yucca Flat—Continued

Attribute name	Description	Number of water levels
Detailed-condition attribute—Continued		
Maximum estimate	Water level or depth to bottom of hole (where hole is dry) represents a maximum estimate of the equilibrated water-level altitude in the monitored hydrologic unit.	10
Minimum estimate	Water level represents a minimum estimate of the equilibrated water-level altitude in the monitored hydrologic unit.	33
Nearby drilling effect	Water level is affected by drilling activities in a nearby hole.	24
Nuclear-test effect	Water level appears to be or is suspected of being affected by nearby nuclear tests.	1,406
Obstruction	Water-level measurement was attempted but not made because of an obstruction in the hole.	35
Packer test	Water level was measured during a packer test.	152
Pumping area	Site is in an area that may be impacted by ground-water withdrawals.	254
Pumping/recovery	Water level appears to be responding to current or past pumping at the site or at a nearby site. If water-level measurement is missing, well was actively pumping at time of measurement.	529
Rising trend	Water level appears to be part of a discernable, overall rising trend. Possible causes include a decrease in nearby pumping, equilibration following drilling, and above-normal precipitation.	1,602
Suspected perched water	Water level appears to represent perched-water conditions.	21
Testing area	Site is within 1 mile of one or more underground nuclear tests. Water level possibly is affected.	1,817
Undeveloped	Water level may not accurately represent hydrologic conditions because of insufficient or no well development.	94
Well-construction effect	Water level appears to be equilibrating from, or is suspected of being affected by, prior well-construction and development activities.	853

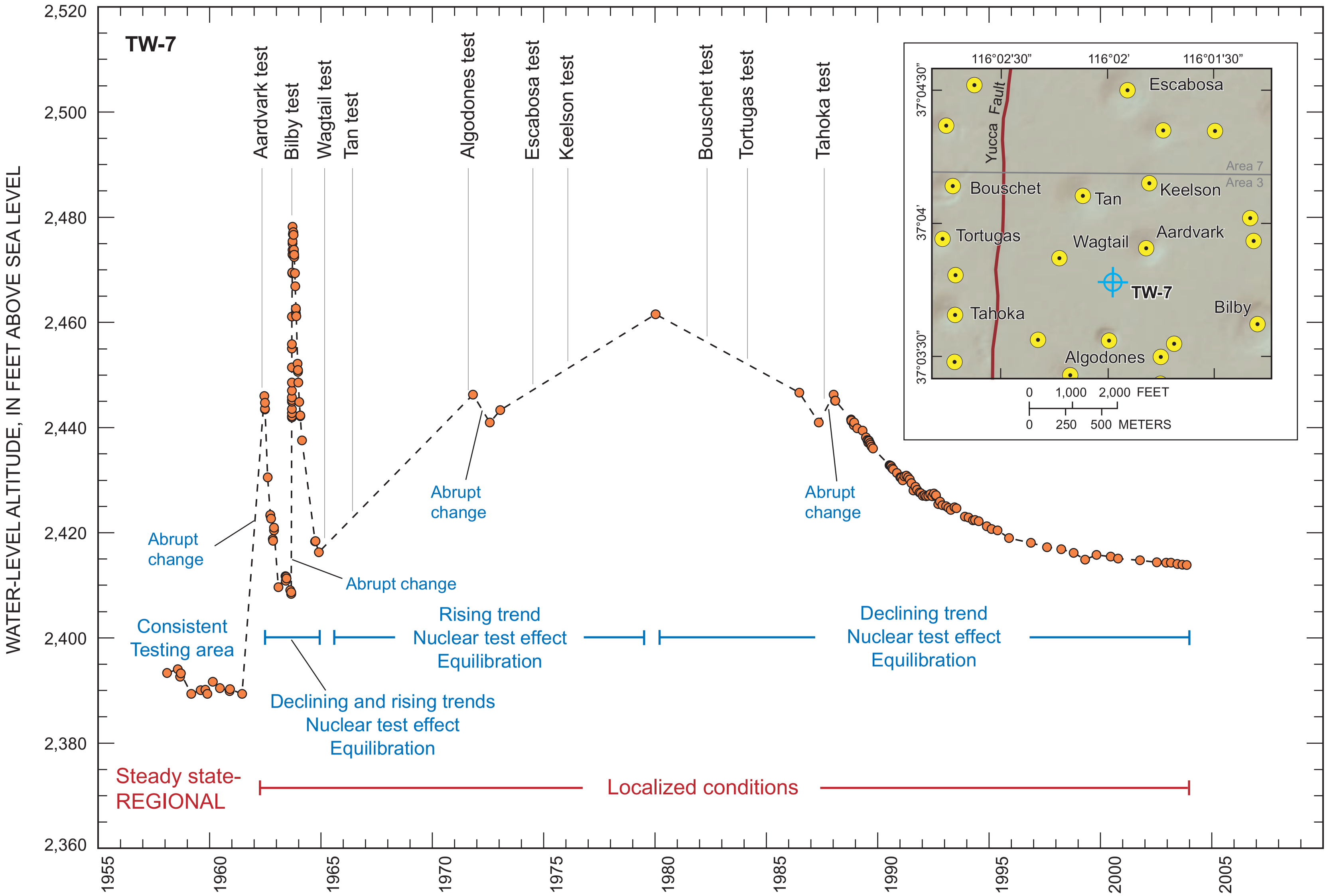


Figure 7. Hydrograph of well TW-7 showing (1) example of general (red) and detailed (blue) condition attributes that were assigned to water levels, and (2) relation between water levels and nearby underground nuclear tests. Map inset shows all nearby nuclear tests. The water-level attributes for this well are stored in the Microsoft® Access database accompanying this report.

Table 4. Water-level corrections for borehole deviations in selected boreholes in Yucca Flat

Source of data: BDS, borehole-deviation survey run along length of borehole. Slant hole, the angle of the borehole, which was assumed to be constant along its length, was obtained from a drilling report or well diagram.

Depth interval over which correction applies: Interval, which bounds the minimum and maximum depths of historic water-level measurements, was used to determine equation for borehole-deviation correction.

Equation used for correction: V_d, corrected vertical water-level depth; M_d, measured water-level depth in borehole.

Water-level mean measured depth: Mean measured depth to water in borehole before borehole-deviation correction was applied. --, no water level measured for depth interval.

Water-level adjustment: Amount of adjustment subtracted from mean measured water level (M_d) to obtain corrected mean vertical water-level measurement (V_d); --, no adjustment applied.

Borehole name (see fig. 2)	Source of data	Depth interval over which correction applies, in feet	Equation used for correction	Water level	
				Mean measured depth, in feet	Adjustment, in feet
ER-6-2	BDS	1,701–1,877	$V_d = M_d * 0.99771 + 2.12$	1,787.2	2.0
ME-2	Slant hole	0–274	$V_d = M_d * 0.6984$	152.0	45.8
U-2bs PS 1DB	Slant hole	1,838–2,188	$V_d = M_d * 0.8038 + 239.62$	2,138.0	179.9
U-2gg PS E3A	Slant hole	0–2,060	$V_d = M_d * 0.95106$	1,915.0	93.7
U-3cn 5	BDS	1,429–1,970	$V_d = M_d * 0.9954 + 5.42$	1,622.6	2.0
U-4u PS 2A	BDS	1,485–1,665	$V_d = M_d * 0.94500 - 4.46$	1,702.3	98.1
U-7ba PS 1AS	BDS[1]	926–1,476	$V_d = M_d * 0.92489 + 24.99$	1,242.9	68.4
UE-10j[2]	BDS	2,100–2,200	$V_d = M_d * 0.9927 + 13.32$	2,160.2	2.4
WW-2[3]	BDS	1,775–2,175	$V_d = M_d - 0.52$	2,044.4	0.5
WW-A[4]	BDS	1,575–1,850	$V_d = M_d - 3.00$	1,608.8	3.0
WW-C-1	BDS	1,525–1,550	$V_d = M_d * 0.9848 + 19.21$	1,544.0	4.3
		1,550–1,575	$V_d = M_d * 0.9772 + 30.99$	--	--
		1,575–1,600	$V_d = M_d * 0.966 + 48.63$	1,599.4	5.7

[1] Sporadic borehole-deviation measurements were obtained from drilling records.

[2] Includes wells UE-10j (2232-2613 ft), UE-10j (2232-2297 ft), and UE-10j (2380 ft).

[3] Includes wells WW-2 (2045 ft), WW-2 (2535 ft), WW-2 (2896 ft), WW-2 (3422 ft), and WW-2 (3422 ft, uncased).

[4] Includes wells WW-A (1730 ft) and WW-A (1870 ft).

equation of the form:

$$V_d = (M_d - M_{top})*(\Delta V_{int}/\Delta M_{int}) + V_{top} \quad (1)$$

where

V_d is corrected vertical water-level depth, in feet below land surface;

M_d is measured water-level depth, in feet below land surface;

M_{top} is measured depth to top of depth interval over which correction applies, in feet below land surface;

ΔV_{int} is difference in true vertical depths between top and bottom of depth interval, in feet below land surface;

ΔM_{int} is difference in measured depths between top and bottom of depth interval, in feet below land surface; and

V_{top} is true vertical depth to top of depth interval, in feet below land surface.

As an example, a borehole deviation survey for well UE-10j (U.S. Geological Survey data files, Henderson, Nev.) shows that a measured depth interval of 2,100–2,200 ft below land surface can be used to bound historic water-level measurements in this borehole (table 2). The corresponding true-vertical depths from the deviation survey at the top and the bottom of this interval are 2,097.99 ft and 2,197.26 ft, respectively. Substituting these values into equation 1 gives the linear water-level adjustment for the depth interval that bounds historic water levels (table 4):

$$V_d = (M_d - 2{,}100 \text{ ft})*(99.27 \text{ ft}/100.00 \text{ ft}) + 2{,}097.99 \text{ ft}. \quad (2)$$

In reduced form, equation (2) becomes:

$$V_d = M_d * 0.9927 + 13.32 \text{ ft}. \quad (3)$$

Water levels in 18 wells from 11 boreholes in Yucca Flat were corrected for borehole deviation (table 4). The mean water-level adjustment for borehole deviation in slant holes (boreholes intentionally drilled at an angle) ranged from 46 to 180 ft. In the remaining boreholes, water-level adjustments were less than 6 ft.

Land-Surface Altitude

Land-surface altitudes for most of the wells in Yucca Flat were determined from surveys by NTS contractors as part of well construction, either shortly before drilling or shortly after initial well completion. Prior to 1990, most of these altitudes were obtained using standard leveling surveys. More recent altitudes were determined by differential Global Positioning System (DGPS) surveys (Rick Remington, Bechtel Nevada, written commun., 2004). The accuracies of the surveyed altitudes are recorded as ±0.1 ft, but true errors could be greater depending on the accuracy of the benchmark(s) on which a survey is based. Altitudes for a few of the wells in Yucca Flat were estimated from topographic maps.

In 2003, the USGS used high-precision DGPS methods to resurvey 41 of the active water-level monitoring wells in Yucca Flat. High-precision control points were established at four existing benchmarks on the west and east sides of Yucca Flat. Altitudes for the control points were obtained from two 24-hour occupations at each point using dual-frequency GPS receivers. The altitudes are tied into the national Continuously Operating Reference Stations (CORS) network, which is coordinated by the National Geodetic Survey of the National Oceanic and Atmospheric Administration. A Real Time Kinematic (RTK) system was set up using these control points to run DGPS surveys to each of the 41 wells. The measuring-point (MP) altitude of each well was measured directly from the GPS survey. The land-surface altitude was calculated by subtracting the height of the MP above land surface from the MP altitude. The altitudes are assumed to be accurate to ±0.2 ft based on the repeatability of measurements over multiple setups.

The land-surface altitudes were resurveyed by the USGS to confirm or improve the accuracy of the altitudes measured during well construction. Additionally, at some wells in Yucca Flat, land-surface altitudes may be changing with time because of subsidence. Subsidence has been documented in the underground testing area of Yucca Flat using interferometric synthetic aperture radar (InSAR). Subsidence was reported to extend about 0.6 mi in diameter around individual underground nuclear tests (Vincent and others, 2003). These subsidence zones around individual tests can overlap to form larger oval-shaped subsidence areas, which are concentrated primarily between the Yucca and Topgallant faults (fig. 3; Laczniak and others, 2003). Between 1992 and 1997, subsidence of as much as 0.5 ft in Yucca Flat was documented with InSAR (Laczniak and others, 2003).

Where subsidence occurs, the measured depth to water can decrease with time solely because of a changing land-surface datum. Because land-surface datums were not adjusted with time to account for subsidence, artificial rising trends in water-level altitudes at wells affected by subsidence may be incorporated into the water-level record. Assuming the water-level altitude remains unchanged, the rate of apparent rise in water level will be directly proportional to the rate of subsidence in land surface. Distinguishing changes in water-level depth that are caused by subsidence is difficult without regular monitoring of land-surface altitude.

The original land-surface altitudes measured at the time of well construction and altitudes from the 2003 USGS surveys are listed in table 5. Altitudes established at the time of well construction, for the wells in table 5, were determined during a period of more than 40 years. The differences in land-surface altitude between the well-construction surveys and the USGS 2003 surveys range from +2.84 to -5.64 ft (table 5).

The differences in land-surface altitudes are attributed to errors in altitude measurements during surveying, the use of different land-surface datums between surveys, or an actual change in land-surface altitude. Because the exact point on the ground used as land-surface datum during the well-construc-

Table 5. Survey estimates of land-surface and measuring-point altitudes for water-level monitoring wells in Yucca Flat

[Surveys were done at the time of well construction and in 2003. Altitudes in feet above sea level; MP height in feet above land surface. Abbreviations: LS, land surface; MP, measuring point for water-level measurement]

U.S. Geological Survey well name (see fig. 2)	Measurement at time of well construction		USGS 2003 measurement			Difference between LS altitudes, in feet
	LS altitude, in feet	Date established	MP altitude, in feet	MP height, in feet	LS altitude, in feet	
ER-2-1 (2079 ft)	4,216.2	1/3/2002	4,218.81	2.95	4,215.86	-0.34
ER-2-1 (2559 ft)	4,216.2	1/3/2002	4,217.93	2.07	4,215.86	-0.34
ER-3-1-2 (shallow)	4,408.1	3/14/1994	4,408.74	2.00	4,406.74	-1.36
ER-3-2-2 (middle)	4,007.9	4/17/1995	4,011.99	1.90	4,010.09	2.19
ER-6-1 main (2243 ft)	3,934.65	2/25/1994	3,939.05	1.80	3,937.25	2.60
ER-6-1 (piezometer)	3,934.65	2/25/1994	3,939.85	2.60	3,937.25	2.60
ER-6-1-1	3,934.52	8/26/2003	3,938.54	1.40	3,937.14	2.62
ER-6-1-2 (1587 ft)	3,932.78	2/15/2002	3,937.28	1.95	3,935.33	2.55
ER-6-1-2 (3200 ft)	3,932.78	2/15/2002	3,937.85	2.50	3,935.33	2.55
ER-6-2	4,230.9	3/22/1993	4,231.96	0.70	4,231.26	0.36
ER-7-1	4,246.7	8/4/2003	4,249.80	3.59	4,246.21	-0.49
ER-8-1	4,819.95	2/14/2002	4,821.58	3.34	4,818.24	-1.71
ER-12-2 (2964-5203 ft)	4,705.3	2/19/2002	4,707.71	3.06	4,704.65	-0.65
ER-12-2 (5203-6883 ft)	4,705.3	2/19/2002	4,707.68	3.03	4,704.65	-0.65
ER-12-2 (579 ft)	4,705.3	2/19/2002	4,706.33	1.68	4,704.65	-0.65
TW-7	4,063.4	1954–1958	4,060.06	2.30	4,057.76	-5.64
TW-B	3,929.0	1961	3,933.02	1.18	3,931.84	2.84
TW-D	4,152.0	1961	4,151.97	1.50	4,150.47	-1.53
U-2gk	4,240.78	1992	4,241.71	0.00	4,241.71	0.93
U-3cn 5	4,012.2	12/10/1965	4,010.92	1.70	4,009.22	-2.98
U-3mi	4,003.5	1986	4,005.77	0.00	4,005.77	2.27
UE-1a	4,303.2	1/26/1964	4,306.14	2.55	4,303.59	0.39
UE-1b	4,272.8	1/28/1964	4,275.36	2.00	4,273.36	0.56
UE-1c	4,205.8	1/28/1964	4,208.88	2.23	4,206.65	0.85
UE-1h	3,995	4/2/1968	3,996.92	2.00	3,994.92	-0.08
UE-1L (recompleted)	4,454.4	4/12/1972	4,459.01	2.03	4,456.98	2.58
UE-1q (2600 ft)	4,081.6	11/5/1980	4,082.46	1.04	4,081.42	-0.18
UE-2ce	4,764.4	1977	4,766.03	1.50	4,764.53	0.13
UE-3e 4-1 (2181 ft)	4,082.3	12/18/1989	4,083.64	2.30	4,081.34	-0.96
UE-3e 4-2 (1919 ft)	4,082.3	12/18/1989	4,083.64	2.30	4,081.34	-0.96
UE-3e 4-3 (1661 ft)	4,082.3	12/18/1989	4,083.64	2.30	4,081.34	-0.96
UE-4t 1 (1906-2010 ft)	4,143.6	1/5/1987	4,142.89	1.80	4,141.09	-2.51
UE-4t 2 (1564-1754 ft)	4,143.6	1/5/1987	4,142.89	1.80	4,141.09	-2.51
UE-6d	3,947	4/1/1968	3,949.05	2.10	3,946.95	-0.05
UE-6e (2090-2230 ft)	3,935.6	3/27/1973	3,939.85	1.71	3,938.14	2.54
UE-7nS	4,369.79	6/3/1976	4,368.71	2.00	4,366.71	-3.08
UE-10j (2232-2297 ft)	4,573.7	5/4/1965	4,574.92	1.25	4,573.67	-0.03
UE-16f (1479 ft)	4,651.5	8/1/1977	4,654.15	3.17	4,650.98	-0.52
WW-2 (3422 ft)	4,470	1962	4,471.86	2.22	4,469.64	-0.36
WW-3 (1800 ft)	3,969.3	1951–1961	3,969.75	0.70	3,969.05	-0.25
WW-A (1870 ft)	4,006	1960	4,007.13	0.71	4,006.42	0.42

tion survey is not known, it could not be duplicated during the 2003 USGS survey. Therefore, even at wells where survey-measurement errors may be negligible, land-surface altitudes cannot be directly compared because of potentially inconsistent land-surface datums. Water levels were not corrected for changes in land-surface datum because of these potential errors.

Some of the wells with large negative differences in land-surface altitude may be affected by subsidence at the well site. Of the 11 wells in 8 boreholes where relatively large (from -0.96 to -5.64 ft) potential downward movement of land surface is indicated, most of these wells are in areas where subsidence is expected to have occurred. For example, the land-surface altitude at well TW-7 shows an apparent downward shift of more than 5 ft. Some of this change is directly related to underground nuclear tests (Garber, 1963, p. 3; Hale and others, 1963, p. 14-17).

Water Temperature

Water levels in a well can be affected by the temperature of the water in the well. An anomalously high water temperature will result in water that has a relatively low density. For a given pressure head, warm (low density) water causes the water level in a well to rise higher than it would with "normal-temperature" water; likewise, cool (high density) water will cause the water level to be lower.

In some cases, water levels may need to be corrected for spatial and temporal variations in water temperature. Correcting for spatial differences in temperature among wells can be important when comparing heads for hydraulic-gradient calculations. Where ground-water gradients are low relative to the magnitude of temperature corrections, uncorrected hydraulic heads in wells may result in determinations of erroneous directions of ground-water flow. Temporal variations of water temperature in a well should be considered when determining the cause of a water-level trend in the well. A decreasing or increasing water temperature with time will cause an apparent decreasing or increasing water-level trend. Water temperature can change temporally because of the effects of a nearby nuclear test or from circulation of thermal water in a borehole during well construction, development, and aquifer testing.

Adjusting water levels for temperature effects, or more precisely, density effects, requires information that is not available for most wells in Yucca Flat. Although temperature is likely to be the most important factor affecting borehole fluid density in these wells, other factors such as dissolved and suspended solids, nonaqueous phase liquids (most likely associated with drilling of a well or leakage of oil from pumps), the compressibility of water caused by pressure from the overlying water column, and gravitational effects can influence the density. To adjust water levels for temperature effects, the zone or zones of inflow to the well must be known. Additionally, a temperature distribution from the point of lowest inflow in the well to the top of the water column is needed. Determining the zone(s) of inflow is critical in wells with several thousand feet of open interval because density corrections are applied only to the length of the water column above the lowest zone of inflow.

The effect that water temperature in a well has on the estimate of hydraulic head can be determined if the mean water temperature and length of the water column above the point of inflow in a well are known. The following equation, described by Winograd (1970), can be used to calculate a water-level correction resulting from a temperature adjustment:

$$n' = \frac{s}{s'} * n, \quad (4)$$

where

n' is the temperature-corrected length of water column above the point of inflow for a given temperature adjustment;

n is the measured water-column length above the point of inflow (assumed to be the middle of the open interval, in this report);

s is the specific weight (or density) of water in the column at the mean measured water-column temperature and hydrostatic pressure; and

s' is the specific weight (or density) of water at the adjusted temperature and identical hydrostatic pressure.

The Thiesen-Scheel-Diesselhorst equation (McCutcheon and others, 1993) can be used to calculate the density of pure water for a specified temperature:

$$\rho = 1,000\left[1 - \frac{(T + 288.9414)}{508,929.2 * (T + 68.12963)}(T - 3.9863)^2\right], \quad (5)$$

where

ρ is density of water, in kilograms per cubic meter; and

T is temperature of water, in degrees Celsius.

A cursory examination of 44 wells in Yucca Flat with available water-level and temperature data indicates that water-level corrections in most wells would be less than 2 ft if all water temperatures were adjusted to a temperature of 30°C (table 6). Wells with the largest corrections are influenced either by long water-column lengths (greater than about 1,000 ft) or, to a lesser degree, by mean water-column temperatures that differ by more than 10°C from 30°C. Wells with potential corrections of more than 2 ft are ER-12-2 (5203-6883 ft), ER-12-2 (2964-5203 ft), ER-6-1-2 (3200 ft), U-3cn 5, and UE-4t 1 (1906-2010 ft).

Table 6 only should be used to illustrate the approximate magnitude of the effects of water temperature on hydraulic-head estimates. Each of the assumptions used in determining water-level corrections—a constant geothermal gradient of 0.7°C per 100 ft, a water-column length extending from the

Table 6. Approximate effects of temperature on hydraulic-head estimates for selected wells in the Yucca Flat area

Length of saturated open interval: Length is measured from bottom of open interval in well to top of open interval or top of water surface, whichever length is less.

Water-level depth: Depth to water at time of water-temperature measurement.

Water temperature at surface: Measured in 2003, 5 feet below surface of water in well.

Estimated average water temperature: Average water-column temperature, assuming geothermal gradient of 0.7 degrees Celsius (˚C) per 100 feet.

Measured water-column length: Length of water column in well from mid-point of saturated open interval to top of water.

Temperature-adjusted water-column length: Length of water column in well if water temperature is adjusted to 30 degrees Celsius.

Water-level adjustment: Approximate adjustment to measured water level that is needed to account for effects of spatially variable water temperatures on hydraulic heads in wells. Water levels were adjusted to a common water temperature of 30 degrees Celsius.

U.S. Geological Survey well name (see fig. 2)	Length of saturated open interval, in feet	Water-level depth, in feet below land surface	Water temperature at surface, in ˚C	Estimated average water temperature, in ˚C	Measured water-column length, in feet	Temperature-adjusted water-column length, in feet	Water-level adjustment, in feet
ER-12-2 (5203-6883 ft)	1,680	193	19.6	40.1	5,850.17	5,829.82	-20.35
ER-12-2 (2964-5203 ft)	2,239	193	19.5	34.3	3,890.47	3,885.12	-5.35
ER-6-1-2 (3200 ft)	1,425	1,545	38.0	41.6	942.50	938.67	-3.83
U-3cn 5	198	1,620	33.3	38.2	1,310.62	1,306.97	-3.65
ER-7-1	647	1,853	45.3	46.6	323.39	321.41	-1.98
ER-6-2	1,646	1,784	33.5	36.7	823.00	821.18	-1.82
ER-3-1-2 (shallow)	102	2,016	48.6	49.6	243.15	241.34	-1.81
ER-6-1 main (2243 ft)	424	1,547	38.2	40.1	484.08	482.40	-1.68
ER-6-1-1	217	1,547	37.8	39.3	396.85	395.59	-1.26
UE-7nS	235	1,970	41.4	41.9	117.69	117.20	-0.49
U-3mi	236	1,558	41.4	41.8	118.01	117.52	-0.49
WW-2 (3422 ft)	712	2,054	27.4	31.2	1,002.12	1,001.75	-0.37
ER-6-1-2 (1587 ft)	115	1,472	37.7	38.0	57.61	57.46	-0.15
UE-2ce	202	1,448	32.9	33.3	101.06	100.96	-0.10
UE-10j (2232-2297 ft)	65	2,160	32.1	32.5	104.65	104.57	-0.08
ER-6-1 (piezometer)	68	1,474	36.6	36.7	34.04	33.96	-0.08
U-2gk	31	1,778	27.8	27.9	15.62	15.62	0.01
U-15k Test Hole	62	762	21.3	21.4	30.77	30.84	0.07
TW-D	227	1,723	26.4	26.9	113.30	113.40	0.10
TW-B	171	1,504	24.8	25.1	85.49	85.61	0.12
UE-3e 4-3 (1661 ft)	120	1,548	20.4	20.6	59.77	59.92	0.15
U-7cd	199	1,426	23.2	23.6	99.48	99.65	0.17
WW-A (1870 ft)	269	1,601	24.7	25.2	134.61	134.79	0.18
UE-1c	583	1,297	26.1	27.2	291.32	291.55	0.23
ER-2-1 (2079 ft)	454	1,723	24.9	25.8	227.16	227.43	0.27
WW-3 (1800 ft)	268	1,532	19.4	19.9	134.21	134.56	0.35
UE-1a	412	545	22.6	23.4	205.94	206.31	0.37
ER-12-1 (1641-1846 ft)	205	1,527	22.9	23.7	216.81	217.18	0.37
UE-1b	610	644	23.7	24.8	304.76	305.20	0.44
ER-3-2-2 (middle)	48	1,606	24.4	28.2	1,006.02	1,006.55	0.53
UE-4t 2 (1564-1754 ft)	190	1,188	24.0	25.8	471.27	471.83	0.56
TW-7	628	1,644	22.3	23.5	314.14	314.70	0.56
UE-17a	469	630	22.3	23.6	349.96	350.57	0.61
UE-14b	1,629	1,667	23.6	28.2	1,198.96	1,199.60	0.64
UE-1q (2600 ft)	141	1,656	23.8	27.2	873.96	874.68	0.72
UE-6e (2090-2230 ft)	140	1,510	22.2	24.7	650.48	651.44	0.96
UE-3e 4-2 (1919 ft)	94	1,418	20.1	21.8	461.29	462.29	1.00
UE-1h	1,224	1,555	22.2	26.7	1,191.17	1,192.31	1.14
UE- 1L (recompleted)	1,568	519	21.4	25.2	981.48	982.81	1.33
UE-6d	1,771	1,514	20.4	26.0	1,496.31	1,498.00	1.69
UE-3e 4-1 (2181 ft)	98	1,189	19.3	22.9	953.56	955.39	1.83
UE-16f (1479 ft)	186	367	19.3	23.2	1,019.29	1,021.18	1.89
ER-2-1 (2559 ft)	287	609	19.2	26.2	1,847.50	1,849.49	1.99
UE-4t 1 (1906-2010 ft)	104	485	19.0	24.6	1,473.26	1,475.46	2.20

middle of the open interval to the water surface, and adjustment of all water temperatures to 30°C—have an effect on the estimated water-level corrections. Information on zones of inflow to the well in combination with an adequate vertical temperature profile of the water column are needed to determine accurate hydraulic heads in wells. An adequate temperature profile in a well must extend from the top of the water column to the lowest zone of inflow and must be made after the water in the well equilibrates with formation-water temperatures.

Causes of Water-Level Fluctuations

Water levels in wells at Yucca Flat fluctuate because of natural and anthropogenic causes. Natural causes include barometric pressure, Earth tides, and recharge from precipitation. Anthropogenic causes include ground-water withdrawals, equilibration following drilling activities, land subsidence, and underground nuclear testing. Some of these factors, such as recharge, can have relatively slow response times that may cause long-term changes in regional water levels. Other factors, such as barometric pressure, may be relatively instantaneous and have only a short-term effect on water levels.

Barometric Pressure and Earth Tides

Changes in barometric pressure and Earth tides cause water-level fluctuations in wells throughout Yucca Flat. These fluctuations typically are largest in wells open to confined aquifers. The combined water-level response from barometric pressure and Earth tides is less than 1 ft and may result in daily to annual fluctuations. Barometric pressure and Earth tides are not likely to have an effect on long-term water-level trends.

Barometric-induced fluctuations commonly are caused by instantaneous responses to atmospheric loads transferred directly to the aquifer and to the water column in an open well (Brassington, 1998, p. 102). However, water-level responses also can lag because of drainage effects and the time necessary for air moving through the unsaturated zone to transfer the load to the water table (Rojstaczer, 1988; Weeks, 1979). Instantaneous changes in water level that result from atmospheric loading are the balance of two opposing effects. The load associated with an increase in barometric pressure will (1) push down on the water column in an open well, resulting in a relatively large drop in water level, and (2) pressurize the aquifer, resulting in a relatively small rise in water level. Typically, in a well open to the atmosphere, an increase in barometric pressure causes an instantaneous drop in water level, and a decrease causes an instantaneous rise. Water levels will respond to daily and seasonal fluctuations in barometric pressure related to heating of the atmosphere as well as changes in barometric pressure caused by changing weather fronts.

The effects of barometric pressure and Earth tides on water levels for selected Yucca Flat wells were estimated by a linear-optimization process using the Solver tool in Microsoft® Excel. Theoretical Earth-tide responses were generated using computer programs from Harrison (1971). Time series of measured barometric pressure and theoretical Earth tides at a well were fitted to measured water levels at the well by adjusting the amplitude and phase of each time series. Simulated water levels were generated that were a best fit between measured water levels and the barometric pressure and Earth-tide responses. The best fit was obtained by minimizing the sum-of-square differences between the simulated and measured water levels.

The response of water levels to barometric pressure is shown in figure 8. In this figure, measured water levels show an inverse response to barometric pressure (fig. 8*A*). However, only some of the short-term, water-level fluctuations in this well are attributed to changes in barometric pressure. Most of the residual water-level fluctuations that exist after removing the barometric-pressure signal are attributed to Earth tides (figs. 8*B* and 8*C*). Most of the small fluctuations that remain after removal of Earth-tide effects likely result from imperfect removal of these effects from the record.

Precipitation

Precipitation in southern Nevada ranges from less than 4 in/yr in low-lying valleys to more than 20 in/yr in the Spring Mountains. In Yucca Flat, precipitation averages 6–7 in/yr on the valley floor and 8–14 in/yr on the nearby upland areas to the west and northwest (Air Resources Laboratory, Special Operations and Research Division, 2004). About two-thirds to three-quarters of annual precipitation falls during winter storms, which are usually of low intensity and areally extensive.

Precipitation data from 1964 to 2003 were compiled and trends in the data were analyzed for selected precipitation stations within the region surrounding Yucca Flat. Location and altitude information for all precipitation sites used for this report are listed in table 7. The sites were selected to represent three general areas of recharge near Yucca Flat: the Spring Mountains to the south, Rainier Mesa to the northwest, and Pahranagat Valley to the northeast (fig. 1).

A Spring Mountains precipitation index was created from three high-altitude precipitation stations within the Spring Mountains: Kyle Canyon (7,500 ft), Lee Canyon (8,400 ft), and Adams Ranch (9,050 ft). Precipitation is measured at these stations once each year around June by the Nevada Division of Water Resources. Annual data for the three stations were averaged to create the precipitation index. An index using the mean from multiple stations minimizes errors in data collection as well as data estimation.

Monthly data from three precipitation stations in recharge areas to the west and northwest of Yucca Flat were averaged to create the Rainier Mesa precipitation index (table 7). The data were obtained from the Air Resources Laboratory (ARL),

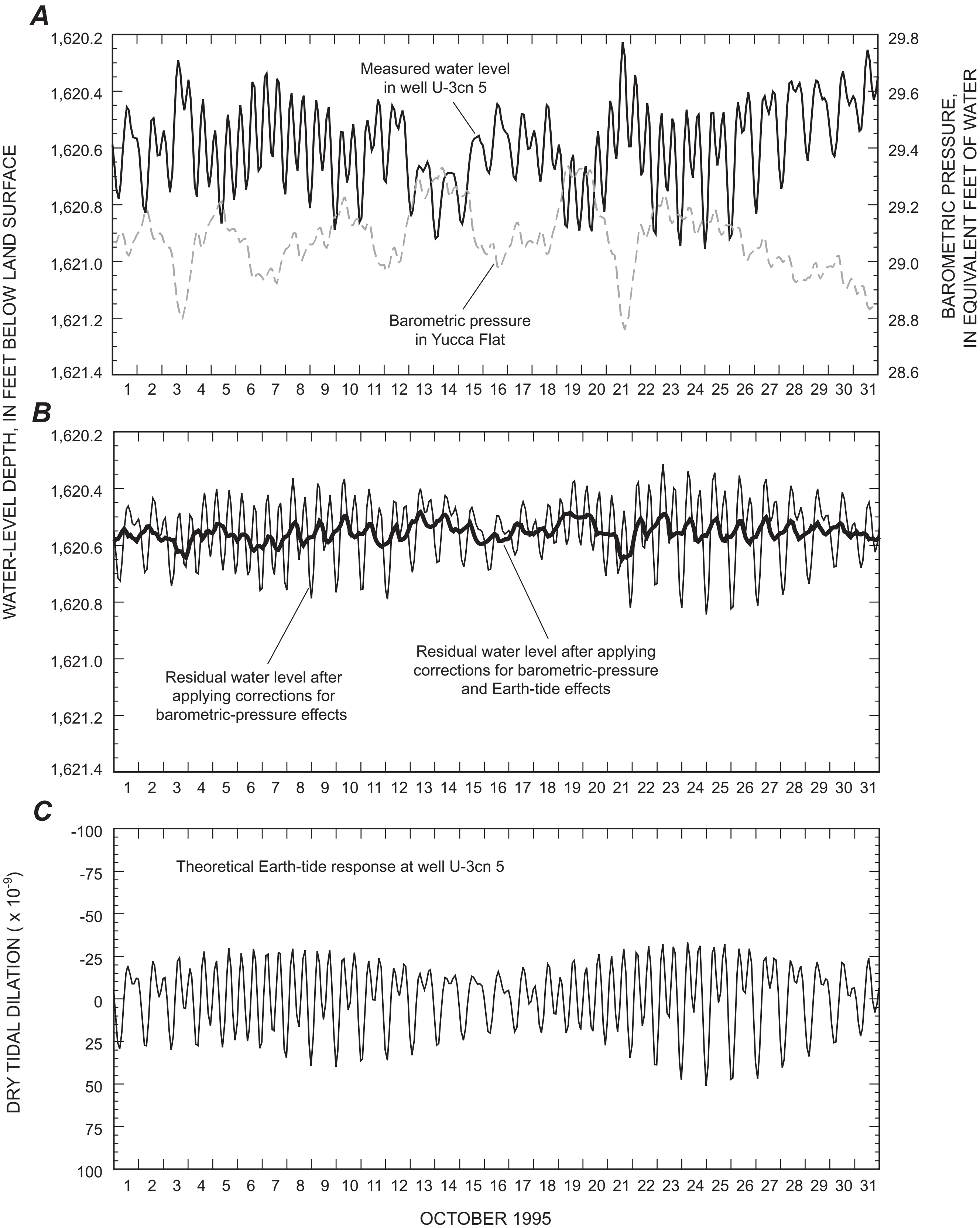


Figure 8. Graphs showing short-term response of water levels in well U-3cn 5 to barometric pressure and Earth tides, October 1995.

Table 7. Information for precipitation sites used to create precipitation indices for Yucca Flat

Precipitation index: Name of precipitation index in which precipitation station is included.

Mean annual precipitation: Mean based on period 1964-2003.

Reporting agency: NDWR, Nevada Division of Water Resources; ARL/DOE, Air Resources Laboratory/U.S. Department of Energy; NOAA/NWS, National Oceanic and Atmospheric Administration/National Weather Service.

[Abbreviation: NWR, National Wildlife Refuge]

Precipitation station name	Precipitation index	Latitude, in degrees, minutes	Longitude, in degrees, minutes	Altitude, in feet above sea level	Mean annual precipitation, in inches	Reporting agency
Lee Canyon	Spring Mountains	36°18′	115°41′	8,400	22.8	NDWR
Kyle Canyon	Spring Mountains	36°16′	115°37′	7,500	20.7	NDWR
Adams Ranch	Spring Mountains	36°19′	115°44′	9,050	19.5	NDWR
			Precipitation index mean:		21.0	
Rainier Mesa	Rainier Mesa	37°11′	116°13′	7,490	12.8	ARL/DOE
Pahute Mesa 1	Rainier Mesa	37°15′	116°26′	6,550	7.7	ARL/DOE
Tippipah Springs 2	Rainier Mesa	37°03′	116°11′	4,980	8.7	ARL/DOE
			Precipitation index mean:		9.7	
Pahranagat NWR	Pahranagat Valley	37°16′	115°07′	3,400	6.4	NOAA/NWS
Pioche	Pahranagat Valley	37°56′	114°27′	6,180	13.8	NOAA/NWS
			Precipitation index mean:		10.1	

Special Operations and Research Division (SORD). SORD conducts basic and applied research on problems of mutual interest to DOE and National Oceanic and Atmospheric Administration (NOAA) that relate to the NTS.

Monthly data from two precipitation stations, selected to represent recharge patterns occurring northeast of Yucca Flat, were averaged to create a Pahranagat Valley index (table 7). The stations are part of the NOAA–National Weather Service cooperative observer network. The stations are about 50 and 110 mi northeast of the study area and were selected based on a period of record of at least 30 years, active to the year 2003.

A plot of cumulative departure from mean annual precipitation was constructed for each of the three precipitation indices. The mean for each index was determined from the 40-year period, 1964–2003. The cumulative departure plot is useful for identifying precipitation trends over a number of years that are either drier or wetter than average (fig. 9). If the curve slopes upward, regardless of its position in relation to the zero line, the trend indicates a wetter-than-average period; whereas, a downward-trending slope represents a drier-than-average period relative to the period of record. A steep slope represents a greater departure from the mean than a shallow slope, and, therefore, an extreme wet or dry period relative to the period of record.

A LOcally WEighted Scatterplot Smooth (LOWESS) line was fitted to the cumulative-departure data to identify significant and relatively long-term (greater than 5 years) trends in precipitation that might affect regional ground-water levels. The locally weighted regression smoothing function in the S-Plus 6.1 software package (Insightful Corporation, 2001) was used in this study to generate LOWESS trends. LOWESS is a nonparametric method of fitting a curved line to data (Helsel and Hirsch, 1992, p. 288–291). At each data point, a predicted value is computed using a weighted linear regression. Predicted values are then connected to create a smoothed line. Weights were determined through trial and error to create a smooth that reflected relatively long-term patterns. LOWESS trend lines are preferable to linear regression for determining cyclic or nonlinear trends in data. A LOWESS trend line is helpful for identifying similarities and differences in trends between sites. The line can be useful for discerning a pattern or trend in data with scatter.

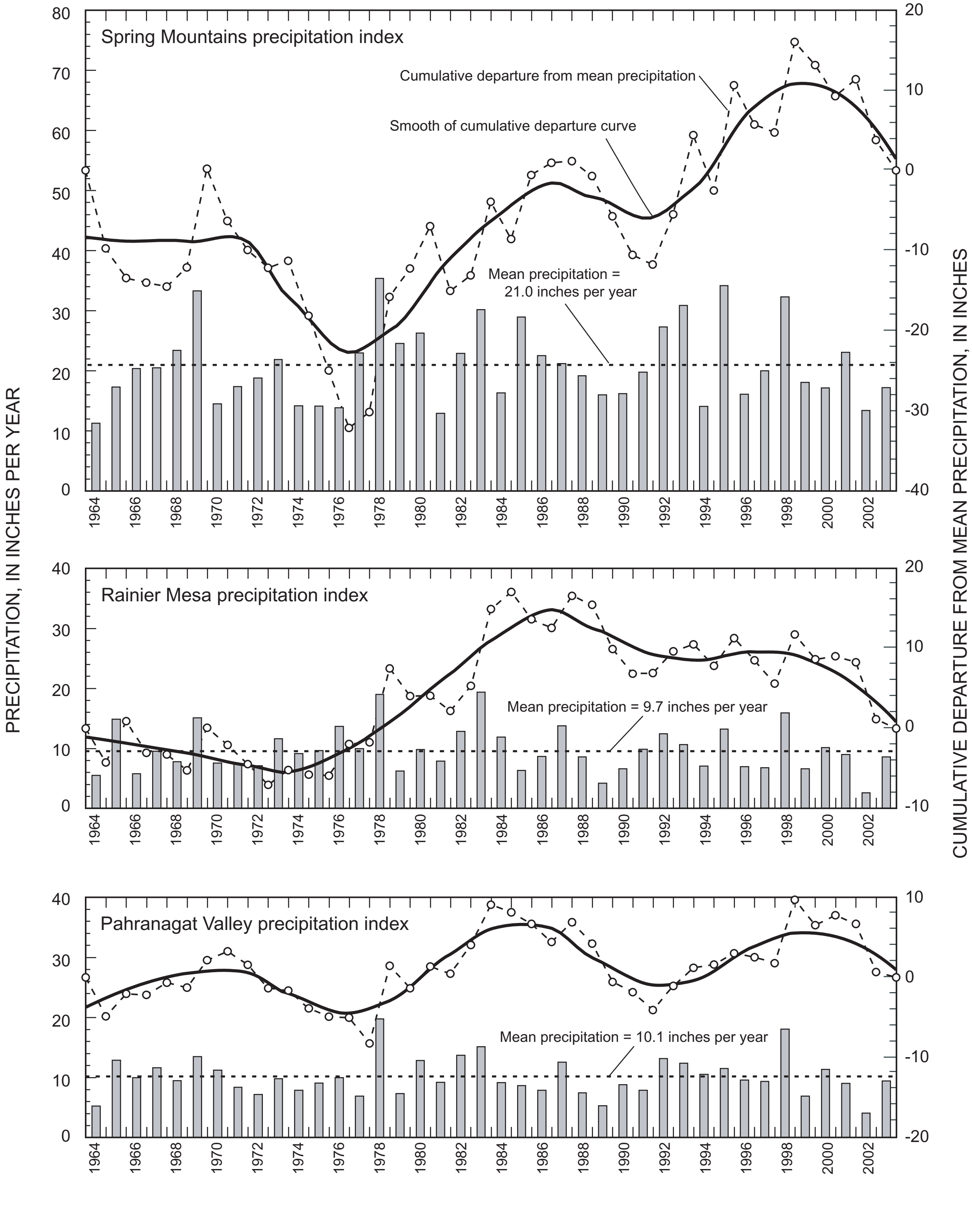


Figure 9. Graphs showing annual precipitation and cumulative departure from mean precipitation at index sites in the Spring Mountains, Rainier Mesa, and Pahranagat Valley, 1964–2003. Wet periods are shown by increasing slope in cumulative departure curve, dry periods by decreasing slope. Scales on all plots are the same.

The plots of cumulative departure from mean precipitation for the Spring Mountains, Rainier Mesa, and Pahranagat Valley (fig. 9) show annual variations and regional, long-term trends in precipitation. The trends are somewhat similar for all three indices. However, for the period 1987–2003, the Spring Mountains index had an overall rising trend (wetter-than-average period), despite dry periods for 1988–1991 and 1999–2003. In contrast, the Rainier Mesa index had a declining trend for the period 1987–2003.

Long-term changes in precipitation are likely to affect regional ground-water levels. In shallow alluvial aquifers in east-central Nevada, water levels responded to long-term (10 years) drier- or wetter-than-normal periods of precipitation (Dettinger and Schaefer, 1995). In deeper aquifers (greater than 1,000 ft below land surface), water levels also may show evidence of responding to drier- or wetter-than-normal periods of precipitation. On the east side of the NTS, water levels in the regional Paleozoic carbonate-rock aquifer may correlate, after a lag time of about 3–4 years, to departures from normal precipitation (Bright and others, 2001; Fenelon and Moreo, 2002). At Yucca Mountain, Lehman and Brown (1996) suggested precipitation as a possible cause of apparent cyclic water-level fluctuations in wells penetrating volcanic rocks at depths from 1,200 to 4,000 ft below land surface.

Ground-Water Withdrawals

About 17,000 acre-ft of water were withdrawn from nine wells in Yucca Flat between 1952 and 2003; five of these wells have total withdrawals of more than 2,000 acre-ft each (fig. 10). Ninety-nine percent of the withdrawals from Yucca Flat occurred after 1960, which coincides with widespread nuclear testing in Yucca Flat. Total annual withdrawals in Yucca Flat peaked in 1969 at about 860 acre-ft/yr and then slowly declined to about 140 acre-ft/yr in 2003 (fig. 11). Eighty percent of the water withdrawn in Yucca Flat was from carbonate-rock aquifers; the remaining water was derived from the valley-fill aquifer (fig. 11).

From 1961 to 2003, an average of 390 acre-ft/yr of water was withdrawn from wells in Yucca Flat. An average withdrawal of this magnitude implies that slightly more water is withdrawn from Yucca Flat than naturally flows into the basin, as estimated by Winograd and Thordarson (1975, p. 94). Water Well C and Water Well C-1, which produce from the lower carbonate-rock aquifer on the downgradient end of Yucca Flat, accounted for 44 percent of all water withdrawn from Yucca Flat through 2003.

Underground Nuclear Tests and Earthquakes

Underground nuclear tests have a large effect on water levels in Yucca Flat, whereas earthquakes probably do not. No change in periodic or continuous water levels in Yucca Flat could be attributed to an earthquake, despite documented effects in nearby areas (Fenelon and Moreo, 2002; O'Brien, 1992). Earthquakes likely affect water levels in Yucca Flat, but the effects probably are short-lived and are not apparent in quarterly water-level measurements. Although continuous water-level data is expected to show a response to earthquakes, almost none of the continuous data available in Yucca Flat (fig. 4) coincided with major earthquakes that occurred in 1992, 1994, and 1999. These earthquakes—the Landers, Northridge, and Hector Mine—were centered in California, more than 100 mi from Yucca Flat.

Through 1992, 828 underground nuclear tests were conducted at the NTS, of which 659 were beneath Yucca Flat (U.S. Department of Energy, 2000). The last nuclear device was tested in September 1992, prior to the United States declaring a moratorium on nuclear testing. Some of the underground tests consisted of multiple simultaneous nuclear detonations in the same or nearby boreholes. In Yucca Flat, 747 nuclear devices were detonated during the 659 tests; 3 additional tests were done to the north of Yucca Flat (fig. 12; app. 2).

Nuclear tests affect water levels in Yucca Flat by four processes: seismic response, pore-water pressurization, pore-water depressurization, and cavity infilling. The magnitude and duration of changes in water levels are affected by the size of, and distance from, a test. Close to a detonation, changes in water levels sometimes persist for years before equilibrium is reestablished. A brief description of the response of water levels to underground nuclear tests, summarized from Laczniak and others (1996, p. 42-44), is given below. Other published reports describing the effects of underground testing on water levels in Yucca Flat include Hale and others, 1963; Hawkins and others, 1987; Hoover and Trudeau, 1987; Hawkins and others, 1990; and Hale and others, 1995.

Following an underground nuclear detonation, a large amount of energy is released. A small part of this energy goes out in a seismic wave. When this wave propagates through the earth, ground-water levels at relatively large distances may be affected briefly by the ground motion (for example, see Dudley and Larson, 1976, p. 11). However, long-term effects on water levels from seismic responses are considered negligible.

At the site of the detonation, a test cavity is formed as the rock matrix is vaporized or compressed outward following the shock blast. Water levels are lowered instantaneously in the area of the cavity as water is expelled or vaporized by the blast. Shortly after the blast, the cavity may fill with rubble from above, but is devoid of water.

Within a few feet to several thousand feet of the edge of the cavity, water levels may rise rapidly in response to the shock wave from a nuclear detonation. The shock wave changes the matrix of nearby geologic deposits. Materials such as alluvium can compact, whereas low-permeability, air-fall and bedded tuffs can compress and deform (Hale and others, 1963). Each test pressurizes the alluvium or tuffs. Multiple detonations cumulatively can elevate water levels (Hoover and Trudeau, 1987).

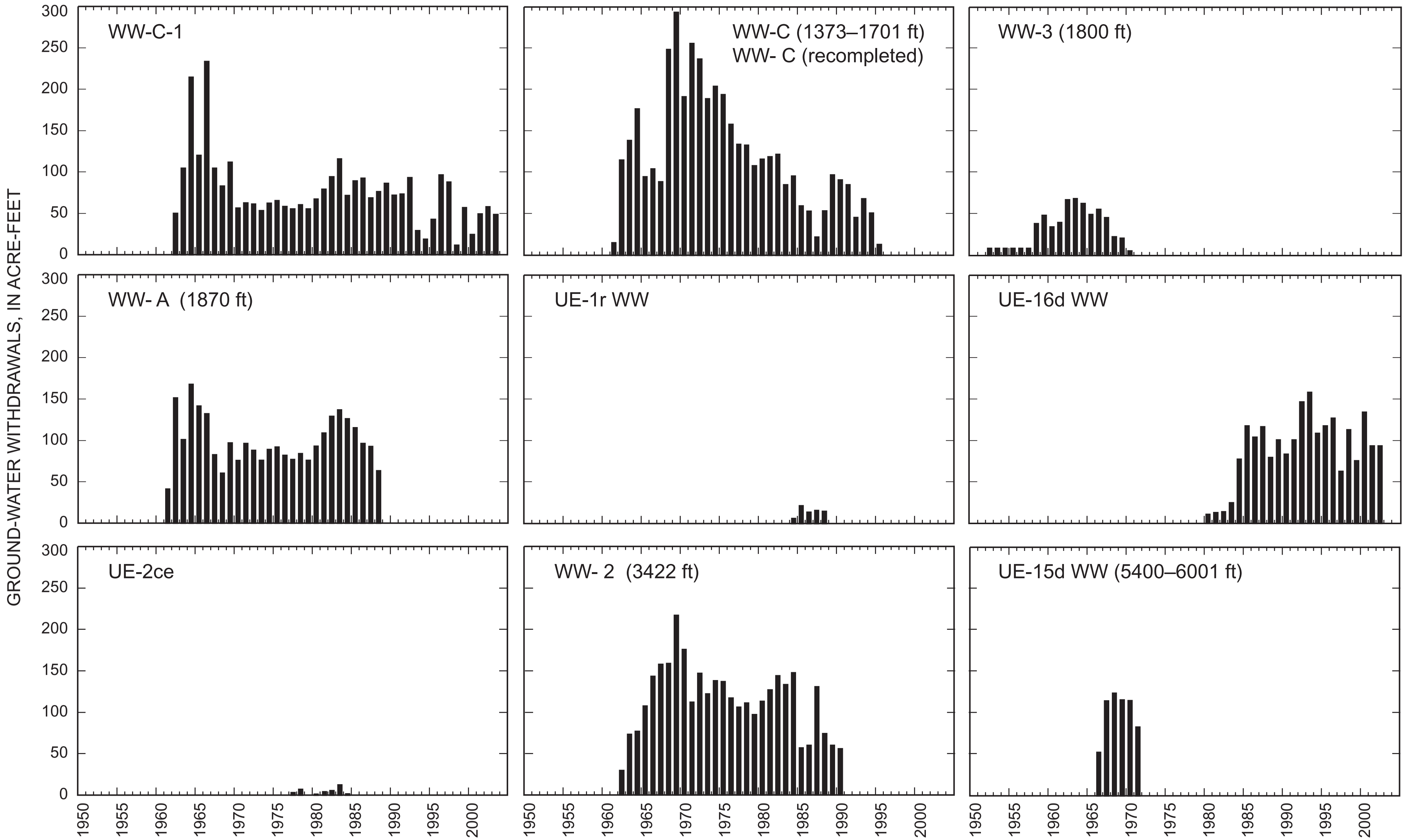


Figure 10. Graphs showing ground-water withdrawals by well in Yucca Flat, 1950–2003. Withdrawals from 1972–82 (with the exception of well UE-2ce) are estimates based on NTS annual workforce populations (Moreo and others, 2003). For well location see figure 2.

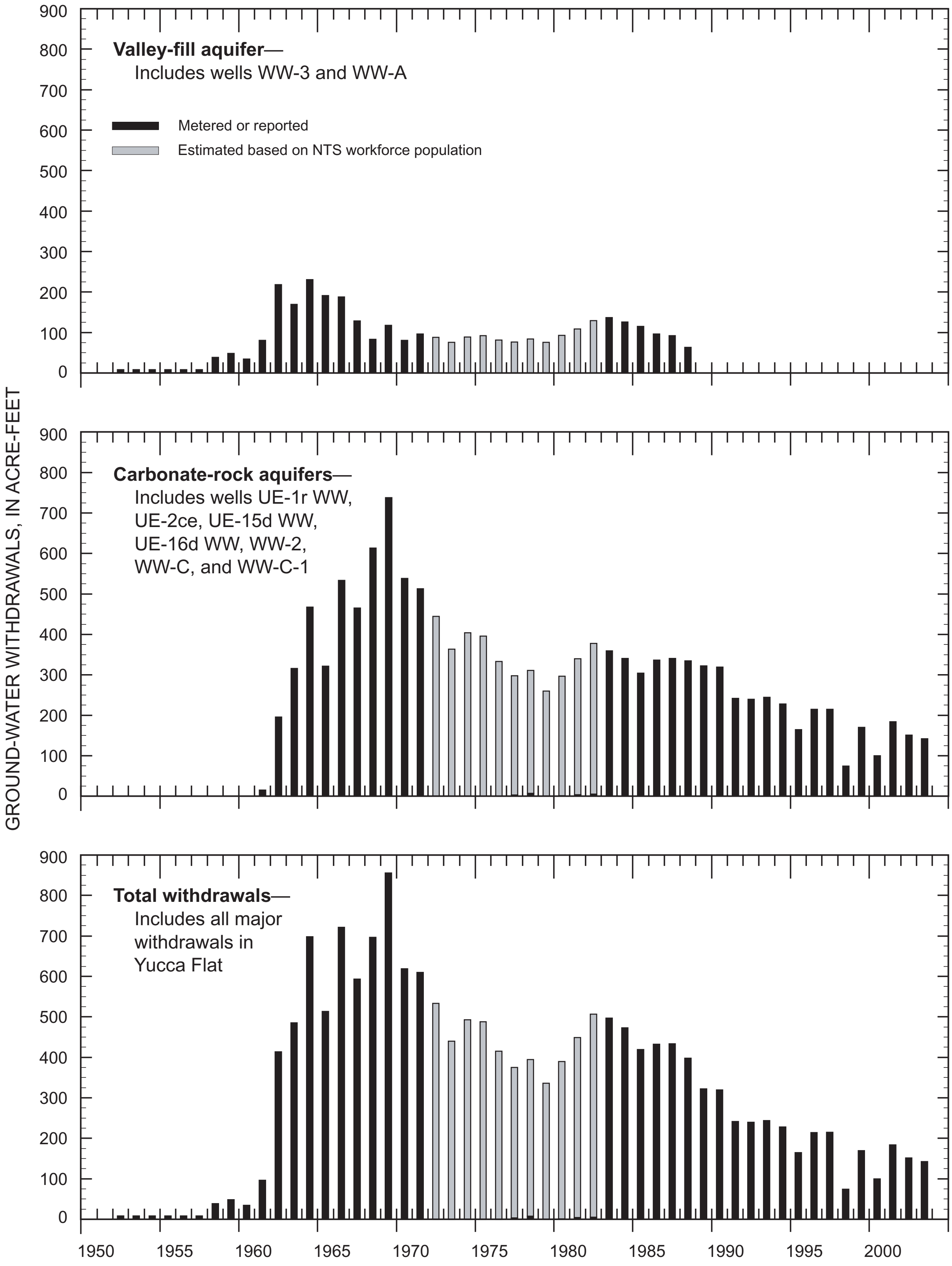


Figure 11. Graphs showing total annual withdrawals and withdrawals by aquifer type in Yucca Flat, 1950–2003. Withdrawals from carbonate-rock aquifers include the lower and upper carbonate-rock aquifers. For well location see figure 2.

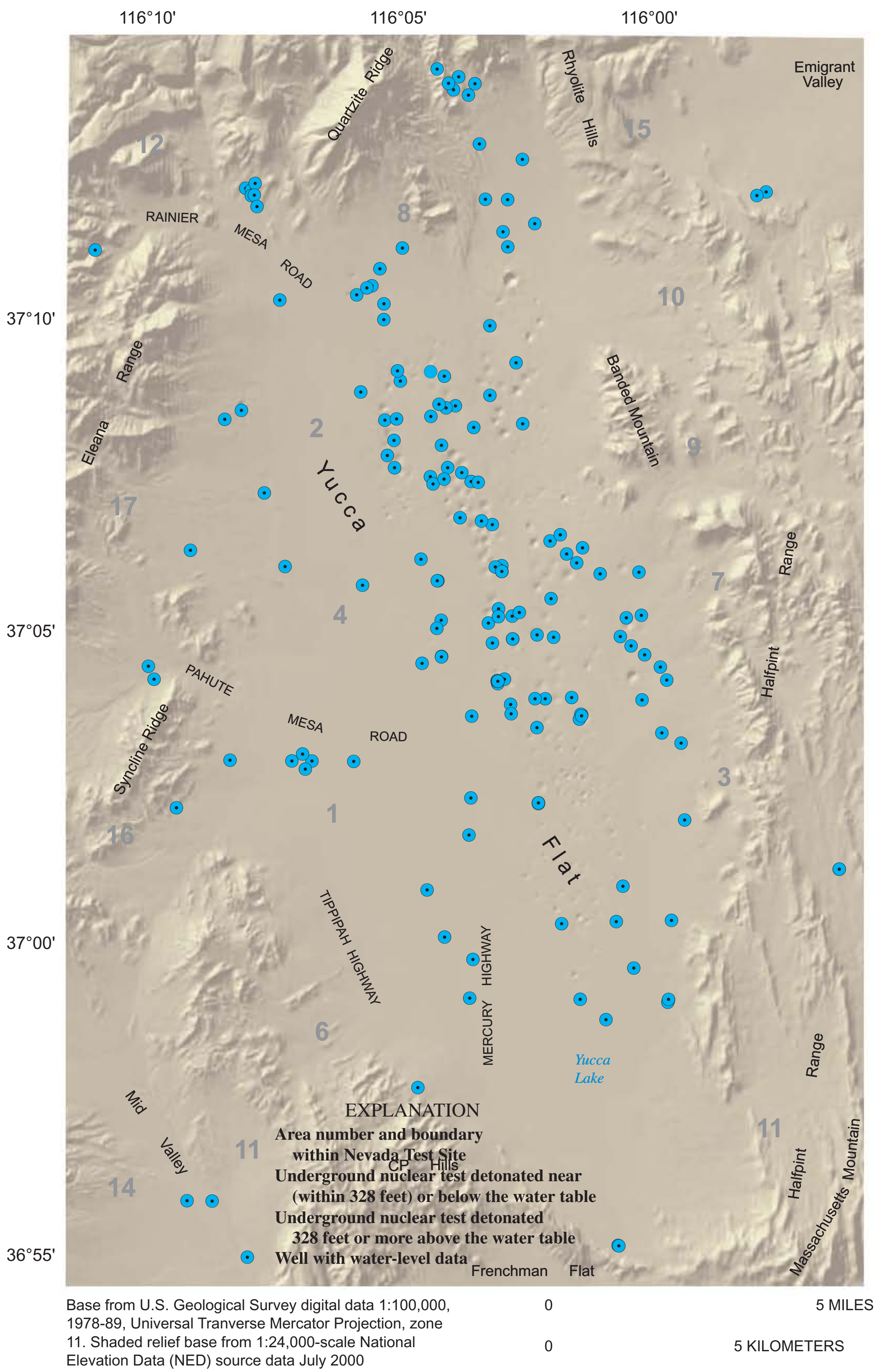


Figure 12. Map showing distribution of underground nuclear tests in the Yucca Flat area, Nevada Test Site.

In the months to years after a test, water levels decline as water flows from areas of high hydraulic head to areas of low head. In the confined tuffs, this results in upward movement of water to the water table, downward movement of water to the lower carbonate-rock aquifer (Hale and others, 1963, p. 20), and lateral movement of water into the test cavity or away from the pressurized zone. Water levels in the cavity will rise as a result of infilling of the test cavity.

The effects on water levels in close proximity to a nuclear test can be large and long-lasting. For this study, a nuclear test is considered unlikely to affect water levels if the test is greater than a lateral distance of 1 mi and a vertical distance of 328 ft from the water level. The largest reported yield in Yucca Flat for a nuclear test above the water table is less than or equal to 200 kilotons. A test of this magnitude is expected to create a test cavity with a radius of almost 328 ft (U.S. Congress, Office of Technology Assessment, 1989, p. 37). Therefore, tests that were conducted more than 328 ft above the water table were assumed, in general, to have minimal effect on water levels in Yucca Flat. The lateral and vertical distribution of underground nuclear tests in Yucca Flat is shown in figure 12.

Analysis of Water Levels

Water levels from 34 wells were analyzed for trends (table 8). Some of the trends were compared to potential factors causing the trends to better understand influences on the ground-water system. The wells selected for statistical trend analysis have at least 6 years of periodic water-level record. For most data sets, the 10-year period, 1994–2003, was used for trend analysis. This period was selected because the data sets had consistent semiannual or quarterly data; whereas, prior to 1994, water levels in many wells were measured sporadically or not at all. Water levels with general-condition attributes of "nonstatic level" or "suspect" (table 3) were excluded from the analysis. Nonstatic levels accounted for about 29 percent of the measured water levels in Yucca Flat. Most of these nonstatic levels were measured when water levels in a well were equilibrating following well construction or development.

Water-level data were statistically analyzed using the Mann-Kendall trend test (Helsel and Hirsch, 1992, p. 326–328). The Mann-Kendall method is a nonparametric test that determines whether a statistically significant upward or downward change in water level has occurred over the period of record analyzed. The method, which tests for a monotonic change, does not imply anything about the magnitude of the change or whether the change is linear. Because the Mann-Kendall trend test is robust with respect to outliers, each data point is given equal treatment. Where data are irregularly spaced in time, specific time periods may be overrepresented or underrepresented on the overall trend. A 99-percent confidence level was used in the test for the statistical significance of an upward or downward change in water level.

Water-level data were analyzed further with LOWESS trend lines. Trend lines help display underlying patterns in data; especially where data scatter is high relative to the trend. LOWESS trend lines also were used because fitting a straight line through the data generally is not appropriate. Most causes of water-level fluctuations do not result in a linear or monotonic trend in one direction for long periods. For example, water levels can rise and fall with time because of the cyclic nature of recharge, changing rates of pumping in water-supply wells, and episodic nuclear testing.

Correlations of water levels with factors influencing trends were analyzed graphically. Graphical analysis was used to provide a visual indication of the overall strengths and weaknesses of a relation between two variables. In some cases, such as the effect of pumping on water levels, a mathematical correlation may not be evident. For example, following a sustained decrease in pumping, water levels may rise or they may continue to decline at a lesser rate. In this type of situation, the relation between pumping and water levels is difficult to analyze statistically but may be apparent in graphical form.

Naturally Occurring Trends

Water-level measurements that represent long-term, regional, steady-state conditions accounted for 37 percent of the water levels measured in Yucca Flat. Trends for these water levels are assumed to be caused by natural factors, such as changes in recharge from precipitation. Hydrographs of these water levels were grouped by the following hydrologic units: carbonate-rock aquifer, volcanic tuff, and Eleana confining unit (figs. 13–15, respectively). Long-term fluctuations in recharge may cause some of the naturally occurring trends. The magnitude of the overall water-level change for these trends typically is less than 2 ft.

Six of the 10 wells open to the carbonate-rock aquifer have significant upward water-level trends, one has a significant downward trend, and three have no significant upward or downward trend (table 8). Of the eight wells with data from 1994 to 2003, all but one well, UE-1q (2600 ft), had a higher mean water level in 2003 than in 1994. Six of the 10 hydrographs have very similar LOWESS trends, which are characterized by a relatively rapid rise in the mid-1990's followed by a gentle rise or a gentle decline after 2000 (fig. 13). Well UE-10j (2232-2297 ft), which is missing data from 1994 to 1996, probably also has the characteristic pattern of the carbonate-rock hydrographs. Water levels in this well from 1997 to 2003 strongly correlate with levels in well WW-2 (3422 ft). Three of the wells in figure 13 have hydrographs without the characteristic pattern. Hydrographs from two of the wells, UE-1h and ER-6-2, have a strong upward trend from 1994 to 2003. The third well, UE-1q (2600 ft), has a slightly downward trending hydrograph that appears similar

Table 8. Analysis of water-level trends, using the Mann-Kendall test, for selected wells in the Yucca Flat area

Level of significance (p): Probability that water-level changes are due to chance rather than a trend; <, less than.

Maximum change in water level: A measure of the amount of variation in water level for the period analyzed. The change is the difference between the maximum and minimum water-level values using a LOWESS smooth (figs. 13-15 and 18).

Statistically significant trend: Considered significant if the level of significance is less than 0.01; up, water level rising; down, water level declining; none, no significant monotonic trend for period analyzed.

U.S. Geological Survey well name (see fig. 2)	Period of record analyzed	Number of observations	Level of significance (p)	Kendall's tau	Maximum change in water level, in feet	Statistically significant trend
Carbonate-rock aquifer water levels						
ER-3-1-2 (shallow)	1994–2003	38	0.002	-0.35	1	up
ER-6-1 main (2243 ft)	1995–2003	32	0.002	-0.40	0.9	up
ER-6-1-1	1994–2003	25	<0.001	-0.52	1	up
ER-6-2	1994–2003	39	<0.001	-0.81	2.8	up
U-3cn 5	1994–2003	23	<0.001	-0.57	0.8	up
UE-1h	1994–2003	21	<0.001	-0.86	2.3	up
UE-1q (2600 ft)	1994–2003	36	0.001	0.38	0.3	down
UE-7nS	1994–2003	25	0.02	-0.33	0.6	none
UE-10j (2232-2297 ft)	1997–2003	25	0.16	0.20	0.4	none
WW-2 (3422 ft)	1994–2003	35	0.11	-0.19	1.4	none
Volcanic-tuff water levels						
ER-6-1 (piezometer)	1995–2003	33	<0.001	0.65	0.7	down
TW-B	1994–2003	34	0.04	0.25	0.3	none
UE-1c	1994–2003	22	0.76	0.05	0.2	none
UE-6e (2090-2230 ft)	1994–2003	32	0.05	-0.24	1.5	none
UE-14b	1994–2003	20	0.28	0.17	0.3	none
Eleana confining unit water levels						
ER-12-1 (1641-1846 ft)	1998–2003	23	<0.001	-0.60	1.3	up
TW-D	1994–2003	20	0.019	0.38	0.6	none
UE-1a	1994–2003	22	0.5	-0.10	0.1	none
UE-1b	1994–2003	26	0.48	0.10	0.1	none
UE-1L (recompleted)	1994–2003	21	<0.001	-0.76	1.1	up
UE-16f (1479 ft)	1994–2003	25	0.002	-0.44	0.2	up
Water levels affected by withdrawals						
UE-2ce	1994–2003	28	<0.001	0.88	2.5	down
UE-6d	1985–2003	33	<0.001	-0.72	2.2	up
WW-3 (1800 ft)	1992–2003	42	<0.001	-0.52	1.3	up
WW-A (1870 ft)	1994–2003	36	<0.001	-0.87	3.1	up
Water levels likely affected by nuclear tests						
TW-7	1980–2003	48	<0.001	0.98	47	down
U-2gk	1994–2003	30	<0.001	-0.98	4.6	up
U-3cn PS 2	1963–1977	29	<0.001	-0.98	350	up
U-4u PS 2a	1991–1998	31	<0.001	-1.00	142	up
U-9ca 1	1964–1978	16	<0.001	0.98	161	down
UE-3e 4-1 (2181 ft)	1990–2003	32	<0.001	0.73	149	down
UE-3e 4-2 (1919 ft)	1990–2003	37	<0.001	1.00	152	down
UE-3e 4-3 (1661 ft)	1990–2003	32	<0.001	-0.85	3.8	up
UE-4t 1 (1906-2010 ft)	1992–2003	41	<0.001	1.00	208	down

to hydrographs in volcanic tuffs (fig. 14). All three of these wells are in the southwestern part of Yucca Flat, west of the Yucca and Topgallant faults; wells UE-1h and ER-6-2 also are west of the Carpetbag fault (fig. 3). The location of these three wells and their dissimilar hydrographs may indicate that the faults create a flow barrier in the carbonate-rock flow system.

Wells open to volcanic tuffs, and with naturally occurring water-level trends, are in the southern part of the Yucca Flat area. Hydrographs from these wells have a distinctly different pattern from the general water-level pattern of the carbonate-rock aquifers. LOWESS trends of hydrographs from wells open to volcanic tuffs generally are characterized by flat to slight-downward trends from 1994 to 2003 (fig. 14). The exception to this pattern, well UE-6e (2090-2230 ft), is characterized by greater measurement variation and an upward trend beginning around 2000. Water levels in four of the wells have no significant upward or downward trend (table 8). Well ER-6-1 (piezometer) is the only well open to volcanic tuffs with a significant downward trend. A possible reason for this downward trend is a suspected breach in the casing that could permit water from the volcanic-tuff open interval in ER-6-1 (piezometer) to drain down to the deeper carbonate-rock open interval in well ER-6-1 main (2243 ft) (Jeffrey Wurtz, Stoller-Navarro Joint Venture, written commun., 2005).

Wells open to the Eleana confining unit, and with naturally occurring water-level trends, are in the western part of the Yucca Flat area. Hydrographs from these wells are characterized by flat to slight upward trends (fig. 15) and are similar in appearance to water-level trends in the volcanic tuffs. Three wells have statistically significant upward trends (table 8). The somewhat anomalous water-level trend in well ER-12-1 (1641-1846 ft) may result from the unique hydrogeologic setting of this well relative to the other wells in the Eleana confining unit. Although well ER-12-1 (1641-1846 ft) is grouped with wells open to the Eleana confining unit, the well actually is open to thrust-faulted Paleozoic dolomite sandwiched between rocks of the Eleana Formation (Russell and others, 1996). The well also is at a high altitude (5,817 ft above sea level) and lies on the east slope of Rainier Mesa, an area of recharge to Yucca Flat.

Deviations in recharge patterns (wet and dry periods) are a potential cause of some of the long-term changes in water levels. LOWESS trends of annual mean water levels in Yucca Flat were compared to LOWESS trends of cumulative departure from mean annual precipitation (fig. 16). Only wells with more than 20 years of water-level measurements were compared. The Rainier Mesa, Pahranagat Valley, and Spring Mountains precipitation indices represented potential recharge from areas surrounding Yucca Flat. Graphical comparison of water levels to precipitation indicates that water levels in some wells may respond to precipitation with a lag of about 3 years. Hydrographs from wells in the carbonate-rock aquifer (U-3cn 5, UE-7nS, and UE-1h) show a stronger apparent correspondence to precipitation patterns than other hydrographs. The remaining hydrographs have more subtle fluctuations, which may or may not correspond with precipitation. Water-level data collected prior to 1990 did not compare as well with the precipitation curves because water levels were measured sporadically with less accurate devices. In some cases, one or two water levels are all that define the earliest 5 years on the hydrographs (fig. 16). Because of this, the shape of the water-level curve during the 1980's was sometimes difficult to define.

The water-level trend in well UE-1h, in the southwestern part of Yucca Flat, appears different from most of the other trends in figure 16. This well had an upward-trending hydrograph from 1982 to 2003. The water-level fluctuations in this well might be caused by a combination of two different factors. One factor could be causing a linear rise in water level. This linear rise might be caused by recovery from past pumping in nearby well WW-3 or a local source of recharge from ephemeral streams to the west. Once this linear trend is removed from the hydrograph, the remainder of the fluctuations could be explained by a second factor—a response to recharge from northwestern or northeastern sources (fig. 16).

Alternatively, water levels in well UE-1h could be responding to a precipitation source that is different than the source for most of the other wells in Yucca Flat. The UE-1h hydrograph appears very similar to the cumulative departure curve, shifted forward 4 years, for the Spring Mountains precipitation index (fig. 9). This does not imply that the well is receiving recharge water from the Spring Mountains. Rather, water levels may be responding to a closer precipitation source that has a precipitation pattern similar to the Spring Mountains. As discussed earlier, the water-level response in well UE-1h may indicate that the ground water in the southwestern part of Yucca Flat responds differently from the rest of Yucca Flat.

The approximate 3-year lag time between periods of excess precipitation and a response in water levels seems relatively quick given the long distances (miles) from recharge areas to the measured wells. The apparent discrepancy between lag time and distance might be explained as follows. For precipitation falling in highland areas some distance from Yucca Flat, the lag time includes two components: (1) the time necessary for precipitation to travel through the unsaturated zone and enter the ground-water system, and (2) the time necessary for changes in hydraulic head in recharge areas to be observed in a well as a pressure response in a confined aquifer system (Davis and DeWiest, 1966, p. 46). In many high-altitude areas of southern Nevada, precipitation may infiltrate rapidly through the unsaturated zone because soils are thin, bedrock is fractured, and evapotranspiration rates are low (Flint and others, 2002, p. 194). Even in high-altitude areas where the unsaturated zone is relatively thick, ground-water recharge through fractured volcanic or carbonate rocks may occur in a few years or less (Clebsch, 1961, p. 124; Winograd and others, 1998, p. 90; and Guerin, 2001). In comparison, precipitation in desert basins that typically are not recharge areas may take thousands of years to infiltrate the unsaturated

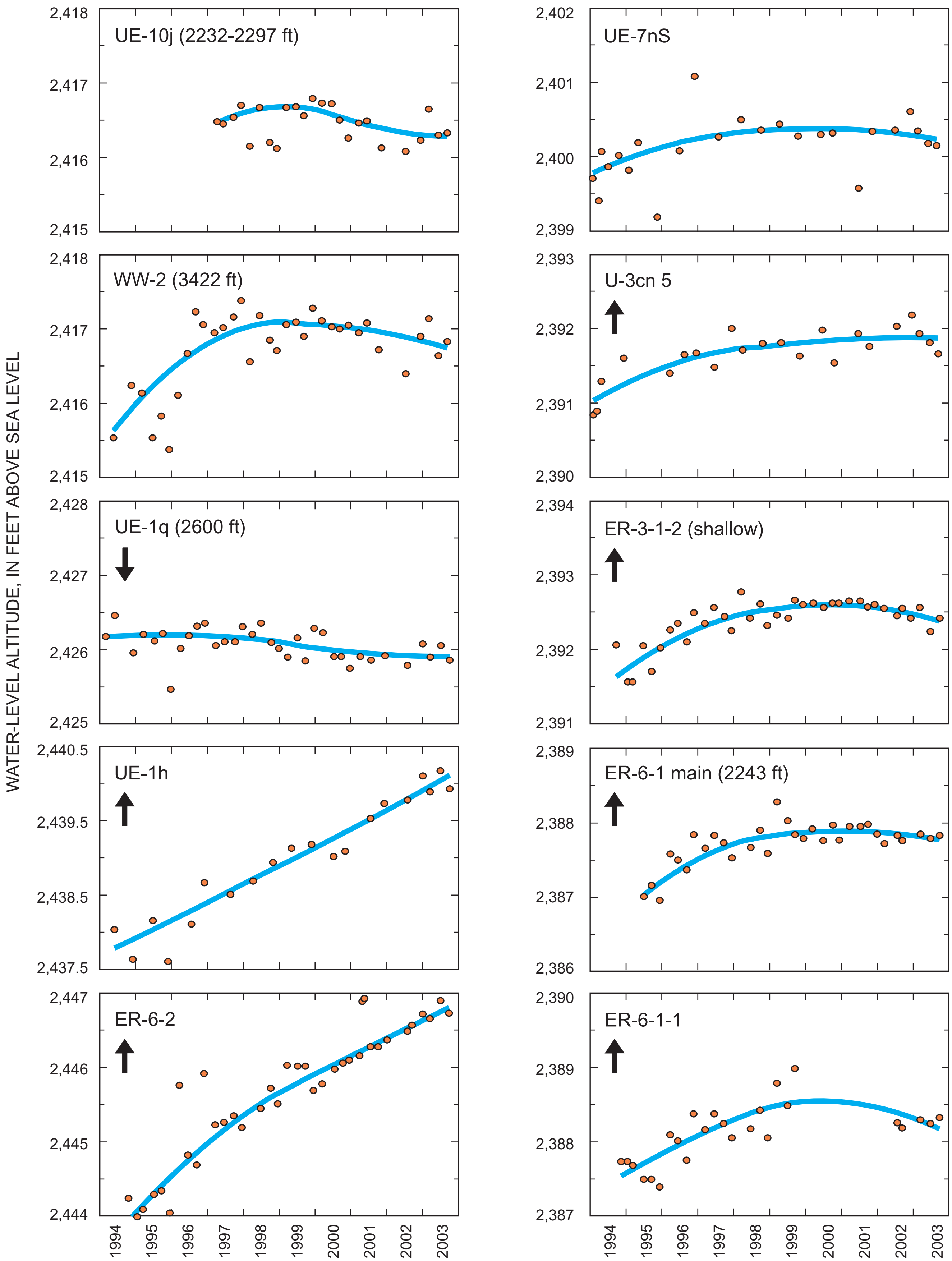


Figure 13. Graphs showing relation among water levels with naturally occurring trends from selected wells in carbonate-rock aquifers, Yucca Flat area, 1994–2003. Blue line is LOWESS trend and arrow indicates direction of statistically significant trend.

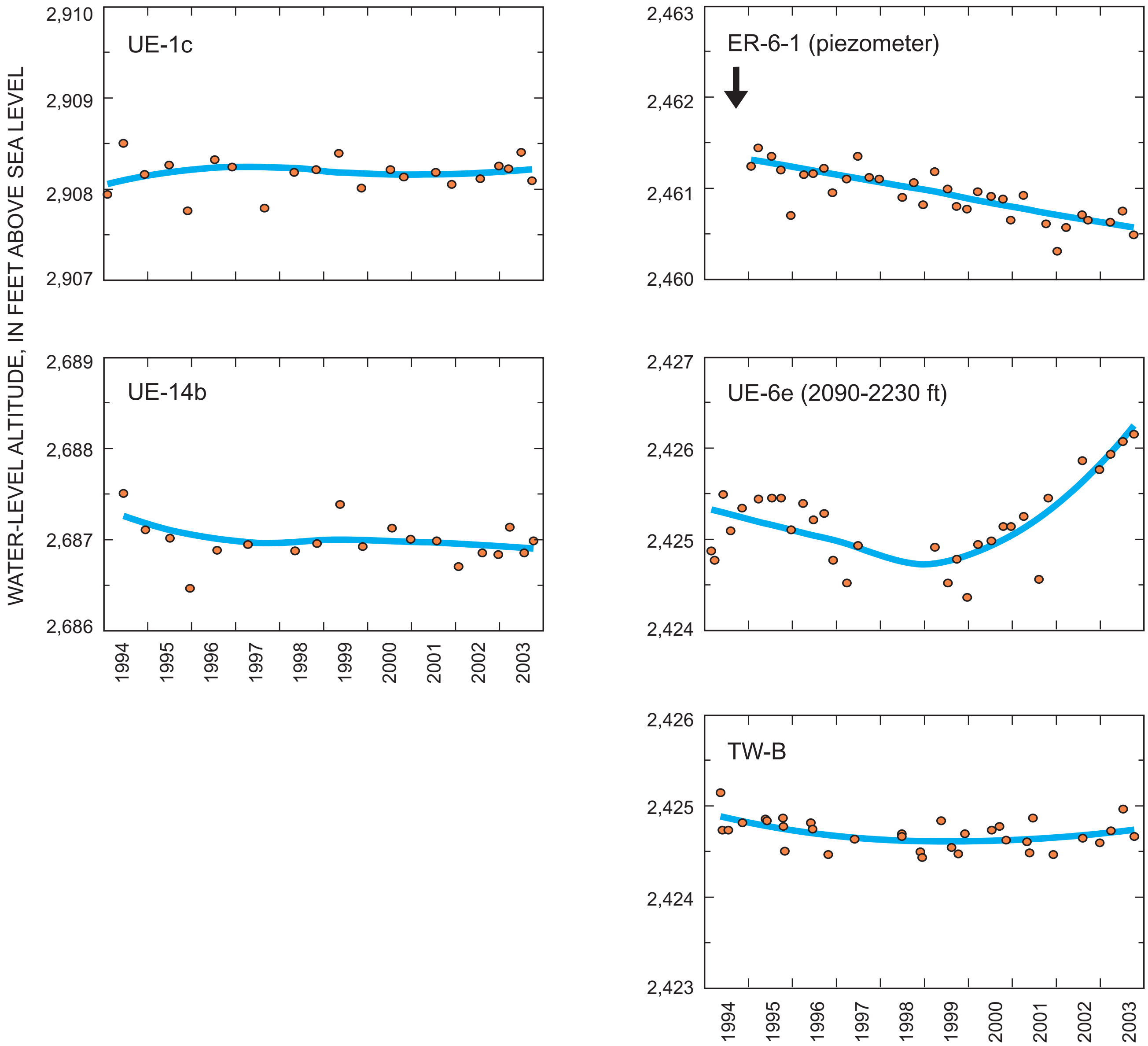


Figure 14. Graphs showing relation among water levels with naturally occurring trends from selected wells in volcanic tuffs, Yucca Flat area, 1994–2003. Blue line is LOWESS trend and arrow indicates direction of statistically significant trend.

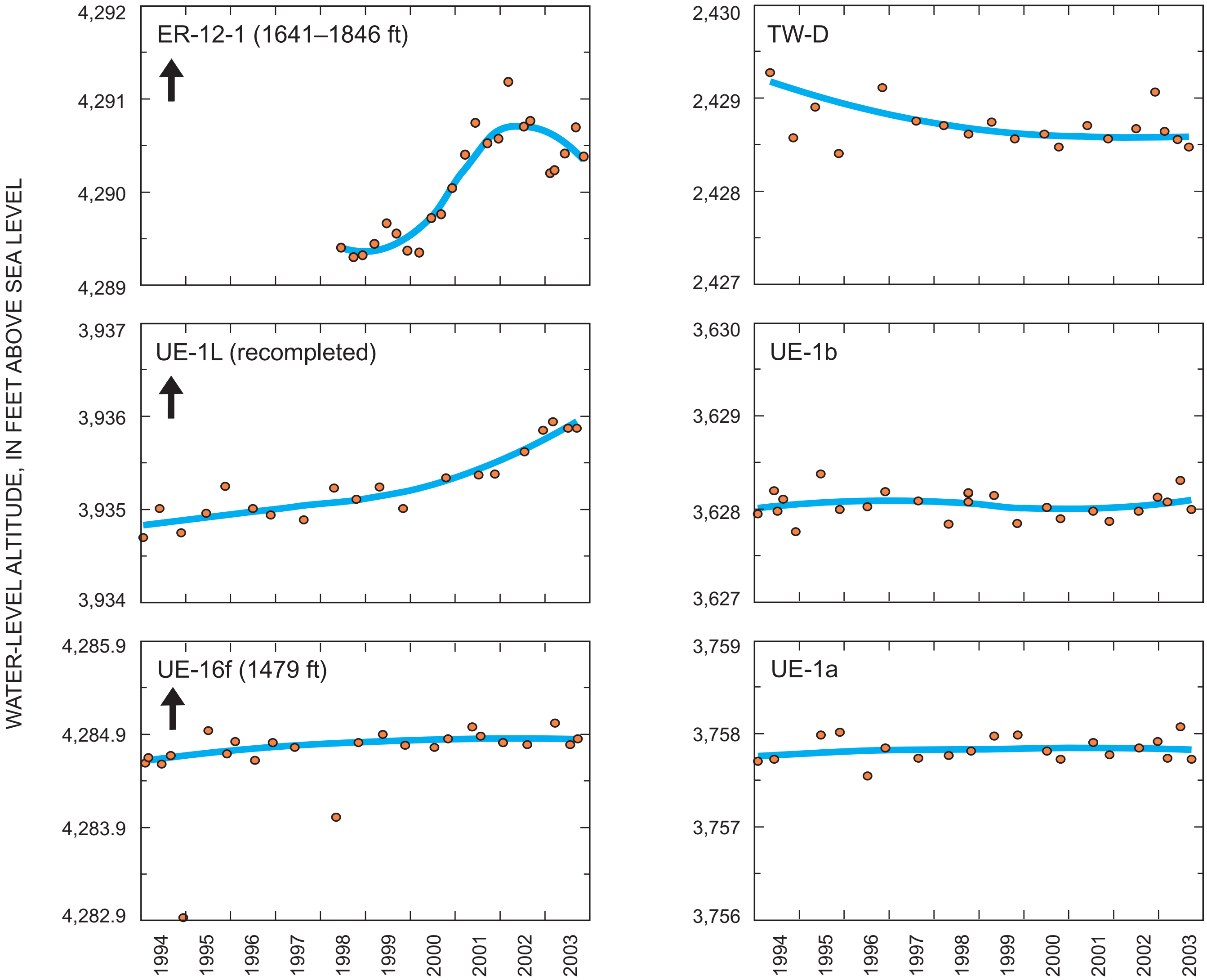


Figure 15. Graphs showing relation among water levels with naturally occurring trends from selected wells in the Eleana confining unit, Yucca Flat area, 1994–2003. Blue line is LOWESS trend and arrow indicates direction of statistically significant trend.

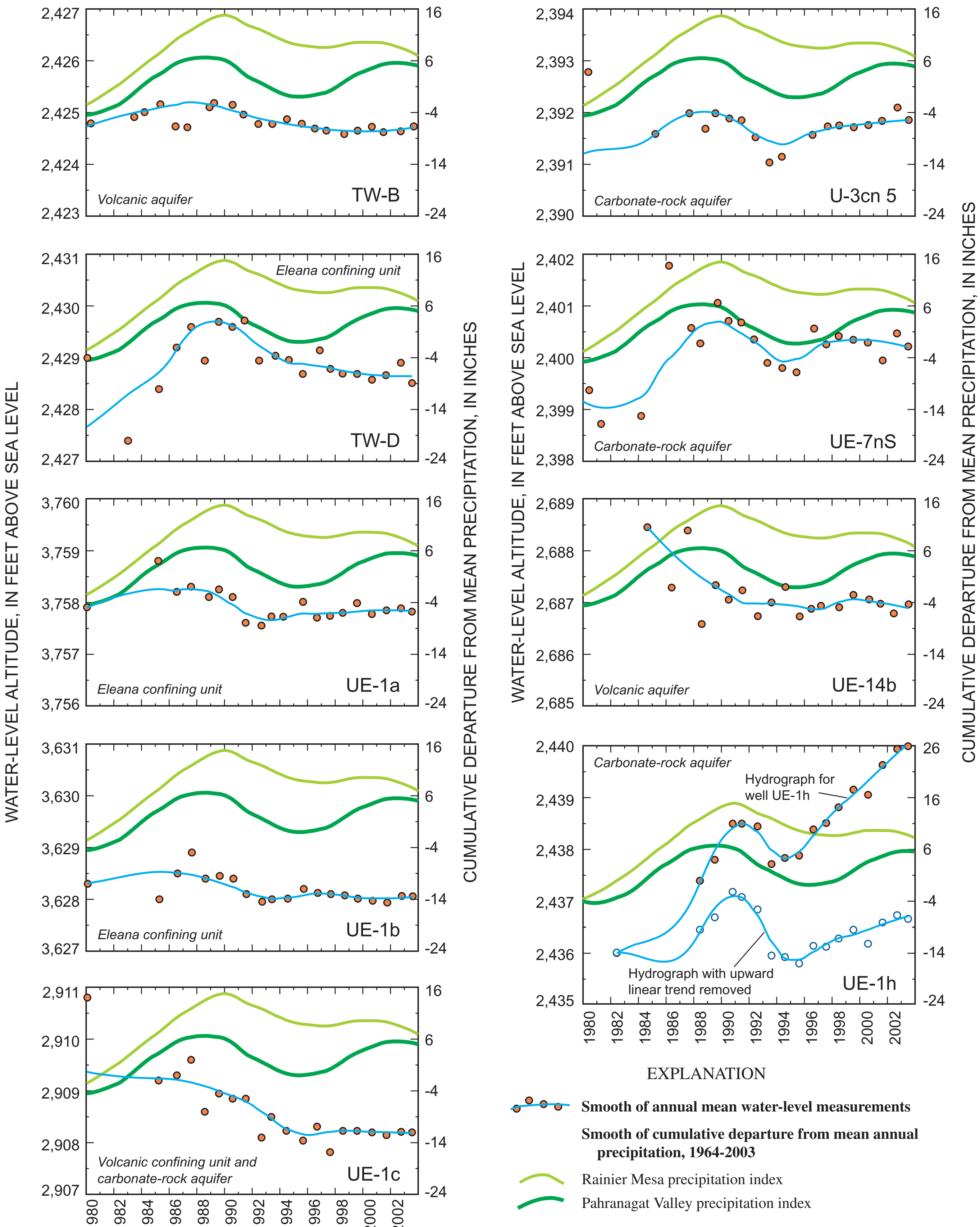


Figure 16. Graphs showing relation between trends in precipitation and steady-state water levels from selected wells in the Yucca Flat area, 1980–2003. All precipitation trend lines were shifted forward 3 years except those on plot UE-1h, which were shifted forward 4 years.

zone (Blout and others, 1995; Tyler and others, 1996). After precipitation reaches the ground-water system, the pressure response in a confined aquifer system may propagate quickly through permeable fractured rocks or slowly through less-permeable confining units. For example, a pressure response in the carbonate-rock aquifer in Yucca Flat was shown to propagate more than 6 mi in about a day during an aquifer test in well ER-6-1-2 (Stoller-Navarro Joint Venture, written commun., 2005).

The apparent correspondence between precipitation and water-level trends (fig. 16) should be viewed with caution. This is especially true for water-level trends in the volcanic tuffs and Eleana confining unit. Although a plausible case could be made that water levels in the carbonate-rock aquifer are responding to precipitation 3 years after it falls, a short response time in less-permeable units is unlikely. Additionally, water-level trends assumed to be caused by natural climatic processes may be affected by unknown factors, such as distant pumping, problems related to well construction, subsidence, and changing water temperature. Changes in water levels from these unknown factors may be attributed, incorrectly, to a precipitation response. Longer-term water-level records are needed to determine with more certainty whether precipitation is the primary cause of many of the fluctuating water levels in Yucca Flat.

Anthropogenic Trends

Trends in water levels caused by anthropogenic activities were grouped by the cause of the trend—water withdrawals and nuclear tests (table 8). About 3 percent of the measured water levels in Yucca Flat were affected by water withdrawals from one or more of the nine withdrawal wells in Yucca Flat (fig. 10). Nuclear tests, however, affected about 35 percent of the measured water levels in Yucca Flat. Only levels that were part of a long-term record, affected by nuclear tests, and with a general-condition attribute of "localized conditions" were analyzed for trends. The overall water-level change for wells with anthropogenic trends ranged from about 4 to 350 ft.

Water levels in withdrawal wells were measured sporadically when pumped, which limited analysis to six wells (fig. 17). Two of the wells pumping from the carbonate-rock aquifer, WW-2 (3422 ft) and WW-C-1, appear to have had relatively little drawdown despite high rates of pumping. Water levels in WW-2 (3422 ft) were interpreted to be fully recovered in 1993, when water-level monitoring in the well began on a regular basis. The quick recovery in these wells indicates a high transmissivity in the carbonate-rock aquifer. Four of the six wells in figure 17 had water-level trends computed for selected periods of the records (table 8). Periods selected for statistical analysis began after pumping had ceased and water levels were recovering or had recovered. Water levels in three of the four wells had significant upward trends, whereas, water levels in the remaining well had a significant downward trend.

The three wells with significant upward water-level trends, following cessation of pumping, were WW-3 (1800 ft), UE-6d, and WW-A (1870 ft). All three of these wells are open to the valley-fill aquifer and show a prolonged period of recovery following the cessation of pumping. This prolonged period indicates a relatively low transmissivity of the valley-fill aquifer. In WW-3 (1800 ft), about 60 ft of drawdown was recorded. Following the cessation of pumping in 1970, water levels required 27 years to recover. Well UE-6d is an observation well about 0.7 mi from WW-3 (1800 ft). About 14 ft of drawdown was recorded in this well before full recovery in 1999. A total of about 15 ft of drawdown was measured in WW-A (1870 ft). Pumping ended in 1988 and water levels were considered recovered in 2003.

The hydrograph for well UE-2ce is more difficult to explain as being affected solely by pumping. The well is open within a block of fault-thrusted Paleozoic dolomite, which may be isolated from the regional carbonate-rock aquifer (Cole and Cashman, 1999). The well was drilled about 600 ft distant from the 39-kiloton nuclear test, Nash (hole U-2ce), detonated in 1967. The working point for Nash was about 200 ft above the initial 1977 water level in well UE-2ce. The initial 1977 water level is interpreted as being elevated by the nearby nuclear test. About 34 acre-ft of water was withdrawn from well UE-2ce from 1977 to 1984. Elevated concentrations of tritium were measured repeatedly during the period of pumping (Buddemeier and Isherwood, 1985). After pumping ended in 1984, water levels recovered from pumping through 1994. "Recovered" water levels in 1994 were almost 50 ft lower than the initial water level in the well. A statistically significant water-level decline of about 2 ft occurred from 1994 to 2003 (table 8).

The causes of incomplete recovery and the current decline in well UE-2ce are not clear. The well only was able to sustain pumping rates of less than about 10 gal/min. Incomplete recovery may have been caused by the draining of perched zones during the period of pumping. A more likely explanation is that water levels were affected by the nearby nuclear test, Nash. Possibly, the initial measured water level in well UE-2ce was anomalously high because of the nuclear test, but was in a declining trend as water levels equilibrated after the test. In this scenario, water levels could decline from either (1) pore-water depressurization following the nuclear test, or (2) a drainage effect as water moved away from well UE-2ce toward the Nash test cavity (assuming it extended below the water). Because well UE-2ce was pumped immediately after completion, the hypothetical declining trend from the nuclear test would have been masked by pumping. Following recovery from pumping in 1994, the declining trend from the nuclear test would become apparent.

Nuclear tests affected water levels in many wells. Levels in nine wells that likely were affected by these tests were analyzed for trends (table 8). All wells had highly significant ($p<0.001$) trends, with four wells having upward trends and five wells having downward trends. These trends are attributed

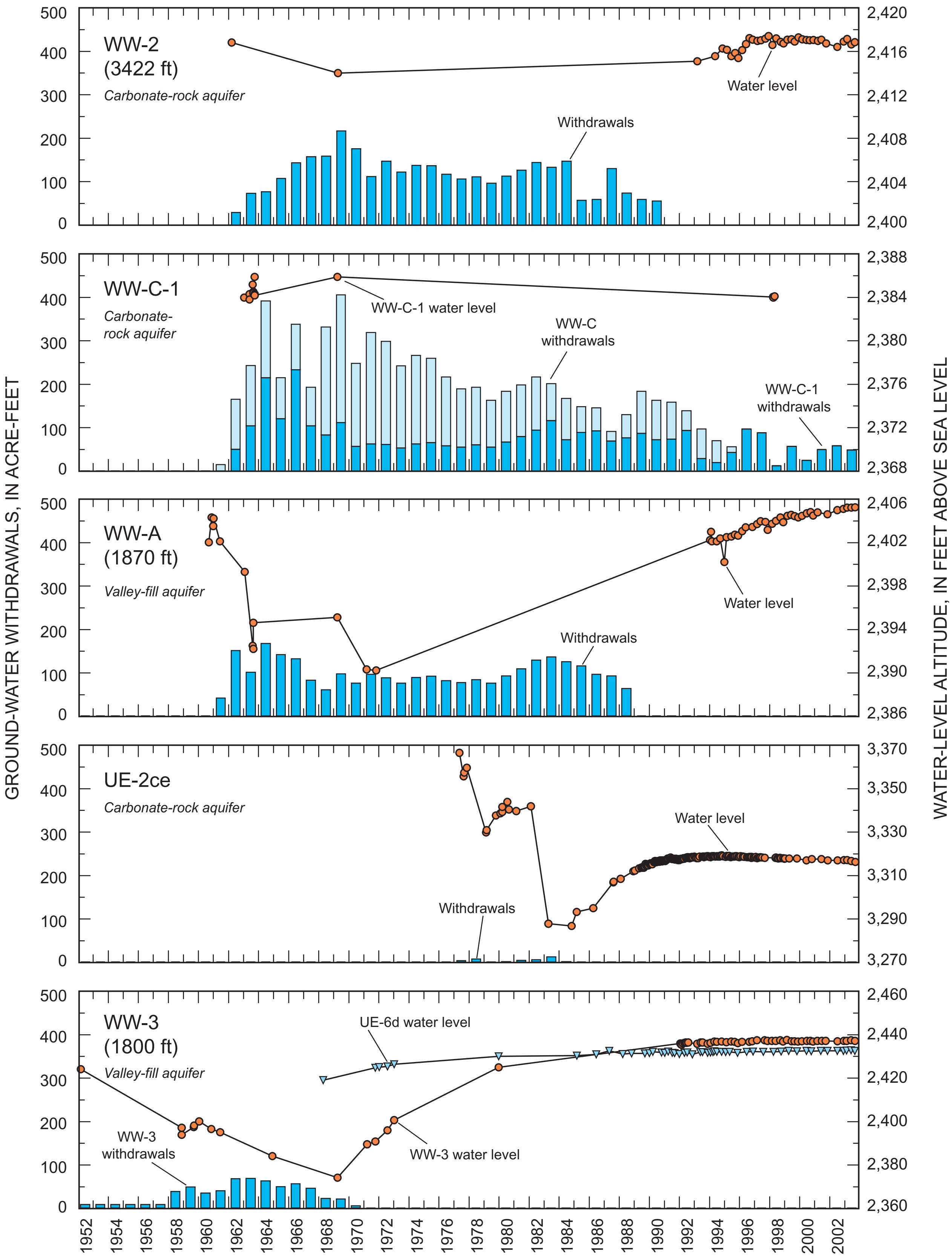


Figure 17. Graphs showing relation between ground-water withdrawals and water levels from selected wells affected by withdrawals in Yucca Flat, 1952–2003. Note that vertical scales on water-level axes are not consistent.

to test-cavity infilling or the effects of depressurization following nuclear testing.

Hydrographs for wells U-3cn PS 2 and U-4u PS 2A (fig. 18) are two examples of rising trends from cavity infilling following nuclear tests. These wells were drilled into the cavities formed by the Bilby and Dalhart nuclear tests, detonated September 13, 1963, and October 13, 1988, respectively. Water levels in the wells rose 140 to 350 ft during a period of 7–14 years. In the case of well U-3cn PS 2, the final water level measured in the well is about 40 ft higher than the pretest water levels in nearby wells U-3cn 1, U-3cn 3, and U-3cn 4 HTH.

Water levels from tuffs in well TW-7 show the effects of pore-water pressurization and depressurization caused by nearby nuclear testing. Water levels were elevated about 100 ft by multiple nearby tests (figs. 7 and 18). Fifteen years after the last nearby test, water levels still were equilibrating and appear to be stabilizing at a head that is about 15–20 ft higher than pretest heads. This higher equilibration level may result from (1) a redistribution of heads caused by a change in the local hydraulic properties from nuclear testing and (2) an unaccounted-for lowering of the measuring-point altitude through subsidence or a shifted casing.

Declining trends in wells UE-4t 1 (1906-2010 ft), U-9ca 1, UE-3e 4-1 (2181 ft), and UE-3e 4-2 (1919 ft) are interpreted as dissipations of pressures in over-pressurized zones as water moves toward zones of lower pressure (fig. 18). Water-level declines in these wells ranged from 149 to 208 ft over the periods of records. Rising trends in wells UE-3e 4-3 (1661 ft) and U-2gk may result from water migrating from confined, high-pressure zones to areas of unconfined conditions. The magnitude of the water-level rise in these water-table wells was no more than 5 ft.

Vertical Water-Level Differences

Vertical water-level differences at 27 sites in Yucca Flat with multiple open intervals were compared (fig. 19; table 9). At each site, the vertical difference in water levels between two open intervals was calculated to determine if water had the potential to move vertically at a site. Some of these sites had three or more water levels, each from a different open-interval depth, which allowed for more than one vertical difference to be analyzed at the site. Vertical hydraulic gradients were not calculated in this analysis because of uncertainties in estimating the vertical distance separating two head measurements. The top, bottom, and midpoint of each open interval and the water level that was chosen to represent each open interval are listed in table 9.

Water levels from multiple open intervals at a single site were obtained under various conditions. In some cases, water levels were measured from multiple wells at a site that were completed at different depths. At other sites, a packer was installed to measure discrete open intervals in an open borehole or in a well with multiple open intervals. Finally, at some sites, the borehole was recompleted by deepening, plugging back, or adding a bridge plug or well casing. In these boreholes, water levels were measured before and after the recompletion to obtain measurements at different open intervals.

In many cases, vertical water-level differences from two different dates were compared (table 9). However, only water levels that had equilibrated or nearly equilibrated to the conditions in the aquifer were used in the analysis. Water levels from different dates were used only if the vertical difference was greater than the temporal variability.

Results of the analysis of vertical water-level differences between open intervals are shown in figure 19. The difference commonly is shown with an approximate sign (~) or a less than (<) or greater than (>) sign. These signs are used to indicate that the water-level differences are approximate. These approximations occur in instances where the water-level measurements are from two different dates or where one of the water levels was nearly, but not fully, equilibrated. In general, figure 19 can be used to determine general areas where water has the potential to move upward or downward in Yucca Flat. Several generalizations, listed below, can be made from figure 19:

1. In boreholes where water levels were affected by nuclear tests, vertical water-level differences are large (greater than 100 ft of head difference). All five boreholes (ER-2-1, UE-3e, UE-3e 4, UE-3mf, and UE-4t) in which water levels were affected by nuclear tests had upward hydraulic gradients with large vertical water-level differences.
2. Vertical water-level differences within the carbonate-rock aquifers generally are small. Six of the seven boreholes (ER-3-1, ER-6-1, UE10j, UE-15d WW, UE-16d WW, and WW-2) that have open intervals at different depths within carbonate rocks have water-level differences of less than 5 ft. The exception is borehole TW-E, which has a relatively large vertical water-level difference and a downward hydraulic gradient.
3. The observed vertical water-level difference within the valley-fill aquifer also is small. The one borehole (WW-A) that has open intervals at different depths within valley fill has a vertical water-level difference of less than 5 ft.
4. The potential for water to move between two intervals of volcanic rocks or between volcanic rocks overlying carbonate rocks in areas not affected by nuclear tests generally is downward. Of the 14 cases that were examined, gradients were downward between 11 interval pairs (boreholes ER-6-1, ER-6-1-2, TW-E, UE-4a, UE-4av, UE-1q, UE-8e, UE-10 ITS 3, UE-10 ITS 5, and WW-2 with two intervals pairs). Most of the downward vertical water-level differences were greater than 50 ft. In the remaining three interval pairs (boreholes UE-4ae, UE-6e, and U-7ad), vertical water-level differences of less than 10 ft were too small to quantify.
5. The direction of the vertical hydraulic gradient generally is from pre-Tertiary clastic rocks toward volcanic- or carbonate-rock units. In the four boreholes with pre-Tertiary clastic rocks, gradients were upward from the clastic rocks to volcanic or carbonate rocks in three boreholes (ER-12-2,

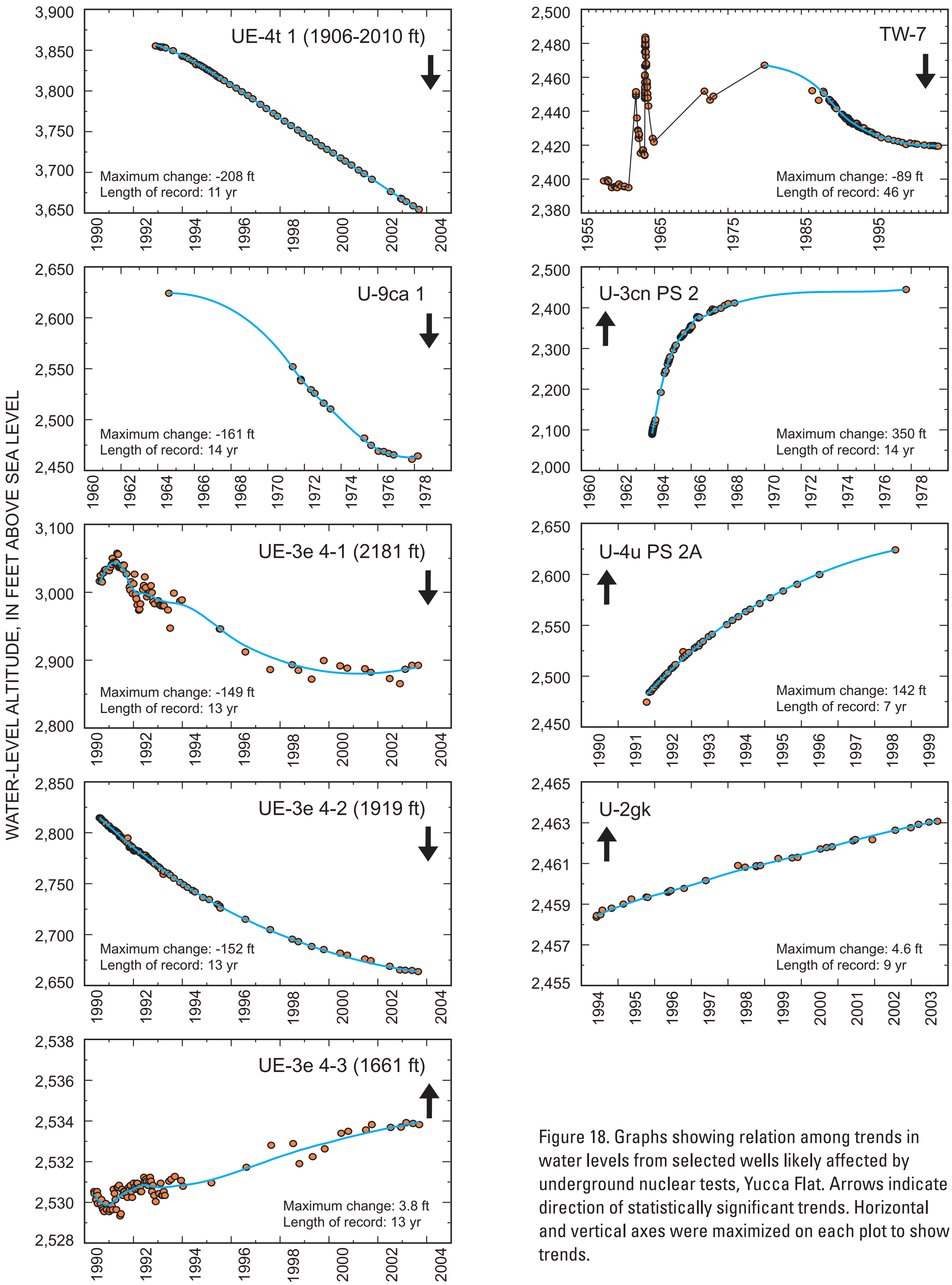


Figure 18. Graphs showing relation among trends in water levels from selected wells likely affected by underground nuclear tests, Yucca Flat. Arrows indicate direction of statistically significant trends. Horizontal and vertical axes were maximized on each plot to show trends.

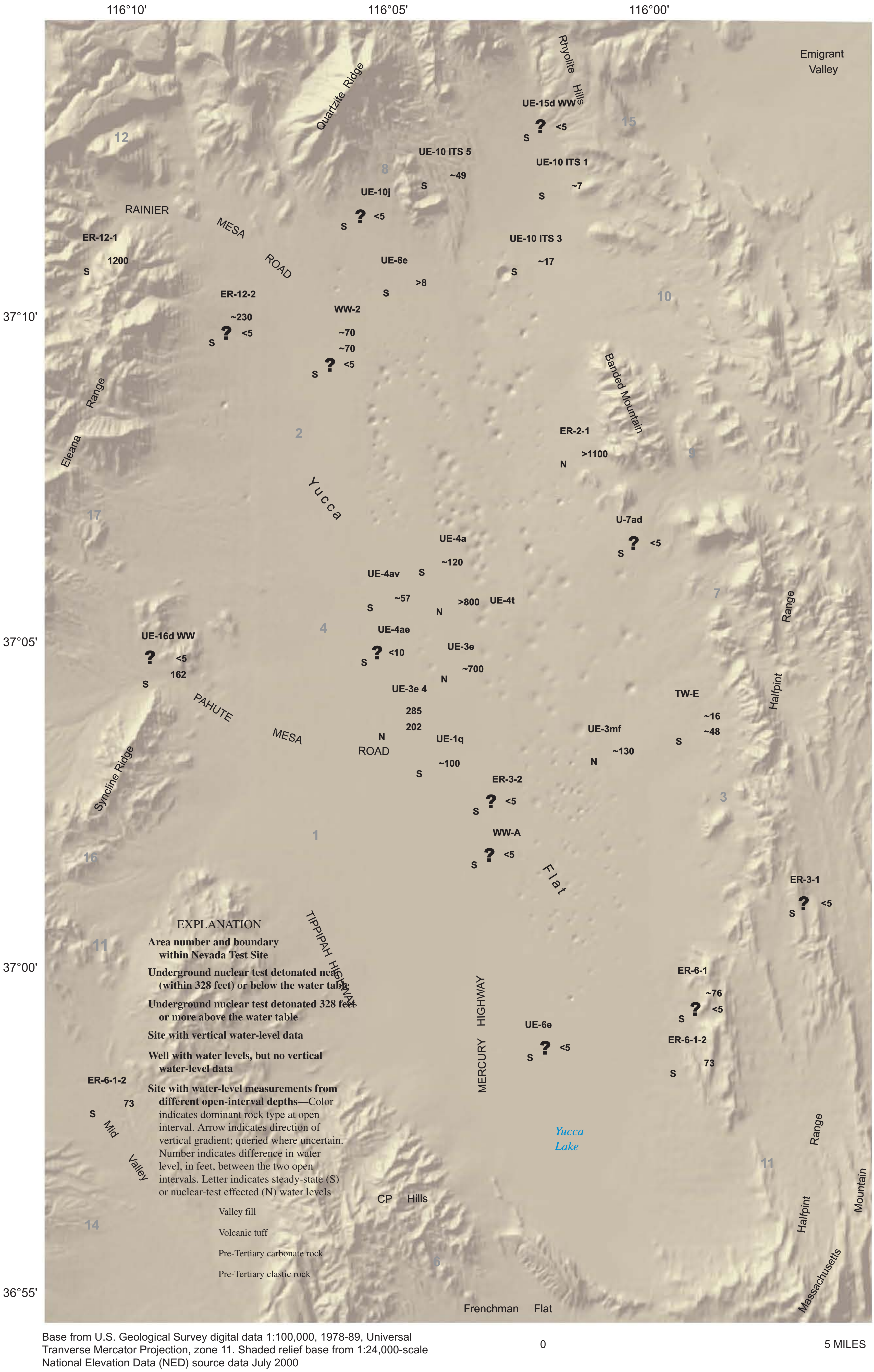


Figure 19. Map showing vertical water-level differences, direction of vertical ground-water gradients, and location of underground nuclear tests in the Yucca Flat area, Nevada Test Site. Data for vertical water-level differences are listed in table 9.

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Table 9. Open-interval and water-level data for selected wells used to analyze vertical water-level differences in the Yucca Flat area

Open interval: Area of saturated opening in well where ground water may enter. Open interval consists of open borehole and(or) well screen. Where opening extends above the water level in the well, the top of the water is considered the top of the open interval. Midpoint is calculated as the average of the top and bottom depths. Depth is in feet below land surface.

Contributing units: Lithologic unit(s) contributing water to well. Multiple units for a single well are listed in the order of their likely importance in contributing water to the well. Abbreviations: C, pre-Tertiary carbonate rock; F, valley fill; P, Paleocolluvium; S, pre-Tertiary clastic rock; V, volcanic tuffs; X, igneous or metamorphic rocks.

Water level: Water-level measurement that was used for analysis of vertical water-level differences; depth relative to land surface; altitude relative to sea level. Symbols: <, less than; > greater than; ~, approximately.

U.S. Geological Survey well name (see fig. 2)	Depth to open interval (feet)			Contributing units	Water level		
	Top	Bottom	Midpoint		Date	Depth (feet)	Altitude (feet)
ER-2-1 (2079 ft)	1,725	2,177	1,951	V	11/12/2003	1,725	2,491
ER-2-1 (2559 ft)	2,313	2,600	2,457	V	11/12/2003	601	3,614
ER-3-1-2 (shallow)	2,208	2,310	2,259	C	6/26/1995	2,016.04	2,390.70
ER-3-1-1 (deep)	2,512	2,807	2,660	C	6/26/1995	2,015.99	2,390.75
ER-3-2-2 (middle)	2,588	2,636	2,612	F, V	3/13/1997	1,605	2,405
ER-3-2-1 (deep)	2,860	3,000	2,930	V	6/26/1995	1,606	2,404
ER-6-1 (piezometer)	1,473	1,542	1,508	V	1/9/1995	1,473	2,464
ER-6-1 main (2129 ft)	1,819	2,129	1,974	C	11/19/1992	1,549	2,388
ER-6-1 main (3206 ft)	1,819	3,206	2,513	C	1/9/1995	1,548	2,389
ER-6-1-2 (1587 ft)	1,472	1,587	1,529	V	9/24/2003	1,472	2,464
ER-6-1-2 (3200 ft)	1,775	3,200	2,488	C, X	9/24/2003	1,545	2,390
ER-12-1 (1641-1846 ft)	1,641	1,846	1,744	C, S, X	3/7/1995	1,534	4,283
ER-12-1 (3309-3414 ft)	3,309	3,442	3,376	C	9/25/1992	2,762	3,055
ER-12-2 (579 ft)	415	650	533	V, F, S	11/11/2003	414	4,290
ER-12-2 (2964-5203 ft)	2,964	5,203	4,084	S, X	11/11/2003	187	4,518
ER-12-2 (5203-6883 ft)	5,203	6,883	6,043	S, X	11/11/2003	186	4,518
TW-E (1970 ft)	1,716	1,970	1,843	V	11/30/1960	1,716	2,456
TW-E (2430 ft)	1,732	2,430	2,081	C, V	6/20/1961	1,732	2,440
TW-E (2620 ft)	1,780	2,620	2,200	C, V	9/6/1963	1,780	2,392
U-7ad (1853 ft)	1,819	1,853	1,836	V	10/28/1972	1,819	2,467
U-7ad (1965 ft)	1,820	1,965	1,893	V	11/2/1972	1,820	2,466
UE-1q (2437 ft)	1,553	2,437	1,995	V, C	9/17/1991	1,553	2,528
UE-1q (2600 ft)	2,459	2,600	2,530	C	6/4/1992	1,655	2,426
UE-3e (1707 ft)	1,557	1,707	1,632	V	6/24/1986	1,557	2,526
UE-3e (2118-2510 ft)	2,118	2,510	2,314	V	8/18/1986	<838	>3,245
UE-3e 4-3 (1661 ft)	1,552	1,668	1,610	V	8/28/1990	1,552	2,529
UE-3e 4-2 (1919 ft)	1,832	1,926	1,879	V	8/28/1990	1,268	2,814
UE-3e 4-1 (2181 ft)	2,094	2,192	2,143	V	8/28/1990	1,065	3,016
UE-3mf (119-1692 ft)	1,482	1,692	1,587	V	5/21/1987	1,482	2,584
UE-3mf (1894-2395 ft)	1,894	2,395	2,145	V	11/8/1986	1,359	2,707
UE-4a (2655 ft)	1,620	2,655	2,137	V	6/4/1963	1,620	2,535
UE-4a (3028 ft)	2,886	3,028	2,957	C, P, V	11/18/1961	1,740	2,415
UE-4ae (2290 ft)	1,634	2,290	1,962	V	8/18/1976	1,634	2,496
UE-4ae (2457 ft)	1,628	2,457	2,043	C, V	5/27/1974	1,628	2,502
UE-4av (1758 ft)	1,569	1,758	1,664	V	7/7/1989	1,569	2,608
UE-4av (1724-2815 ft)	1,724	2,815	2,270	V, P, S	7/11/1990	1,626	2,551

Table 9. Open-interval and water-level data for selected wells used to analyze vertical water-level differences in the Yucca Flat area—Continued

U.S. Geological Survey well name (see fig. 2)	Depth to open interval (feet)			Contributing units	Water level		
	Top	Bottom	Midpoint		Date	Depth (feet)	Altitude (feet)
UE-4t 2 (1564-1754 ft)	1,564	1,754	1,659	V	5/19/1995	1,185	2,956
UE-4t 1 (1906-2010 ft)	1,906	2,010	1,958	V	5/1/1995	323	3,818
UE-6e (2090-2230 ft)	2,090	2,230	2,160	V	2/9/1994	1,511	2,427
UE-6e (2090-4209 ft)	2,090	4,209	3,150	C, V	5/18/1992	1,509	2,429
UE-8e (2295 ft)	1,880	2,121	2,001	V	10/20/1971	<1,904	>2,585
UE-8e (2470 ft)	1,912	2,470	2,191	C, V	4/11/1975	1,912	2,577
UE-10 ITS 1 (2040 ft)	1,222	2,040	1,631	V	1/23/1978	1,222	3,264
UE-10 ITS 1	1,215	2,289	1,752	V, S	10/28/1972	1,215	3,271
UE-10 ITS 3 (1926 ft)	1,850	1,926	1,888	V	3/19/1985	1,850	2,503
UE-10 ITS 3 (2160 ft)	1,867	2,160	2,014	C, V	12/5/1970	1,867	2,486
UE-10 ITS 5 (2180 ft)	1,990	2,180	2,085	V	3/16/1973	1,990	2,532
UE-10 ITS 5	2,039	2,334	2,187	C, V	8/4/1972	2,039	2,483
UE-10j (2232-2297 ft)	2,232	2,297	2,265	C	4/8/1997	2,157	2,416
UE-10j (2232-2613 ft)	2,232	2,613	2,423	C	11/19/1996	2,157	2,417
UE-15d WW (1735-6001 ft)	1,735	6,001	3,868	C, X	3/28/1962	669	3,918
UE-15d WW (5400-6001 ft)	5,400	6,001	5,701	C	10/2/1963	667	3,919
UE-16d WW (830 ft)	753	830	792	C, S, X	5/23/1977	753	3,931
UE-16d WW	753	1,944	1,349	C, S, X	3/4/1981	753	3,931
UE-16d WW (2117-2293 ft)	2,117	2,293	2,205	S, X	7/9/1977	591	4,093
WW-2 (2045 ft)	1,915	2,045	1,980	V	3/28/1961	1,915	2,555
WW-2 (2535 ft)	2,121	2,535	2,328	V	10/23/1961	~1,985	~2,485
WW-2 (2896 ft)	2,550	2,896	2,723	C	1/15/1962	2,056	2,414
WW-2 (3422 ft)	2,700	3,412	3,056	C	3/15/1993	2,055	2,415
WW-A (1730 ft)	1,604	1,730	1,667	F	8/28/1960	1,604	2,403
WW-A (1870 ft)	1,604	1,870	1,737	F	9/20/1960	1,604	2,402

UE-10 ITS 1, and UE-16d WW) and downward from clastic rocks to carbonate rocks in the fourth borehole (ER-12-1). In these boreholes, water-level differences generally were large; borehole ER-12-1 had a difference of about 1,200 ft between the clastic rocks and the carbonate rocks below.

Summary

Yucca Flat is in the northeastern part of the NTS in Nye County, southern Nevada. During the period 1951–92, 659 underground nuclear tests were detonated in Yucca Flat; 138 of these tests were considered certain or probable of introducing radionuclide contaminants into the ground water. The U.S. Department of Energy, National Nuclear Security Administration/Nevada Site Office, under its Environmental Restoration Program, has a long-term program to investigate and remediate radionuclide contaminants generated on the NTS. As part of the program, the USGS is compiling and analyzing available ground-water levels in Yucca Flat.

This report documents the analysis of almost 4,000 water-level measurements made in 216 wells in Yucca Flat and vicinity from 1951 to 2003. The earliest measurement was made in 1951, whereas, 48 wells were measured in 2003. The shallowest and deepest measured depths to water were 8 and 2,762 ft. Water-level depths of greater than 1,500 ft were measured in 149 wells.

As part of the water-level analysis, a systematic quality-assurance review of the USGS NWIS database was done to remove or correct erroneous water-level data, remove duplicate sites, and add missing water-level measurements. Ancillary data pertinent to computing hydraulic heads in wells also were compiled. These data include well-completion records, borehole deviations, measuring points, and water temperatures, as well as information on units contributing water to the open interval. Reported ground-water withdrawals within the study area and precipitation data from major recharge areas near the Spring Mountains, Rainier Mesa, and Pahranagat Valley also were compiled.

An interpretive Microsoft® Access database of Yucca Flat water levels was constructed. The database consists of several components, including (1) site information for each well, (2) well-construction records, (3) borehole lithology and aquifer data, and (4) water-level data. As part of the database, each water-level measurement was assigned multiple attributes to describe the hydrologic conditions at the time of measurement. Additionally, the database includes narratives that discuss the water levels and hydrograph for each well.

Water levels in 34 wells with long-term data were analyzed for variability and for significant trends. Trends were analyzed statistically to detect significant upward or downward changes. An attempt was made to identify the cause of many of the water-level fluctuations or trends. Potential causes include equilibration following well construction or development, pumping in the monitoring well, withdrawals from a nearby supply well, recharge from precipitation, earthquakes, underground nuclear tests, land subsidence, barometric pressure, and Earth tides.

Changes in barometric pressure and Earth tides cause water-level fluctuations in wells throughout Yucca Flat. These fluctuations typically are largest in wells open to confined aquifers. The combined water-level response from barometric pressure and Earth tides is less than 1 ft and causes daily to annual fluctuations.

About 17,000 acre-ft of water were pumped from nine wells in Yucca Flat between 1952 and 2003; five of these wells pumped more than 2,000 acre-ft each. Annual withdrawals in Yucca Flat peaked in 1969 at about 860 acre-ft/yr and then slowly declined to about 140 acre-ft/yr in 2003. Eighty percent of the water withdrawn in Yucca Flat was from carbonate-rock aquifers; the remaining water was derived from the valley-fill aquifer.

Water-level measurements that represent long-term, regional, steady-state conditions accounted for 37 percent of the water levels measured in Yucca Flat. Trends for these water levels are assumed to be caused by natural processes, such as changes in recharge from precipitation. The magnitude of the overall water-level change for these trends typically is less than 2 ft.

Trends were analyzed in 21 wells where water levels responded to natural processes. LOWESS trends of hydrographs from 7 of the 10 wells open to carbonate rock have a very similar pattern characterized by a relatively rapid rise in the mid-1990's followed by a gentle rise or a gentle decline after 2000. The three wells without the characteristic pattern are in the southwestern part of Yucca Flat, west of the Yucca and Topgallant faults. Hydrographs from wells open to volcanic tuffs or the Eleana confining unit have a distinctly different pattern from the general water-level pattern of the carbonate-rock aquifers. In general, LOWESS trends from these wells are characterized by flat to slight downward trends from 1994 to 2003. Graphical comparison of water levels to precipitation indicates that water levels in some wells in the carbonate-rock aquifer respond to precipitation with about a 3-year lag.

Water-level trends that result from anthropogenic activities were caused primarily by water withdrawals and nuclear testing. About 3 percent of the measured water levels in Yucca Flat were affected by water withdrawals; however, nuclear test effects accounted for 35 percent of the measured water levels. The overall water-level change for wells with anthropogenic trends ranged from about 4 to 350 ft.

Most of the water-level effects from withdrawals were noted in the withdrawal wells. Two of the wells, WW-2 (3422 ft) and WW-C-1, appear to have had relatively little drawdown despite high rates of pumping. The quick recovery in these wells indicates a high transmissivity in the carbonate-rock aquifer. In wells WW-3 and WW-A, about 60 ft and 15 ft of drawdown, respectively, were recorded.

Nuclear tests affected water levels in many wells. Levels in nine wells that likely were affected by these tests were analyzed for trends. All wells had highly significant ($p<0.001$) trends, with four wells having upward trends and five wells having downward trends. These trends are attributed to test-cavity infilling or the effects of depressurization following nuclear testing.

Vertical water-level differences at 27 sites with multiple open intervals in Yucca Flat were compared. Large vertical water-level differences (greater than 100 ft of head difference) were noted in boreholes where water levels were affected by nuclear tests. Vertical water-level differences within the carbonate-rock and valley-fill aquifers generally are small (less than 5 ft of head difference). Vertical hydraulic gradients in volcanic rocks generally are downward and water-level differences commonly are greater than 50 ft.

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Appendix 1: Water-level database for Yucca Flat, 1951–2003

The database distributed with this report is in Microsoft® Access 2000 format. It contains 17 tables with hydrologic information for 216 wells in Yucca Flat. The tables include information on well sites, well construction, borehole lithology, aquifers, and water levels. Descriptions of the types of information in the database tables are listed in table 10. These descriptions also are stored in the database. A general description of each table can be read in the Access project window by opening the database, selecting "view," and then selecting "details." Descriptions of each table column can be made to appear at the bottom of the database window screen by opening a table and moving the cursor to the column of interest.

A Microsoft® Excel workbook also is distributed with this report as an interface to the water-level database. Most of the water-level information from the database is provided in the spreadsheet. Different hydrographs from Yucca Flat can be selected using Excel's built-in AutoFilter.

Table 10. Description of Microsoft® Access database for Yucca Flat water-level measurements

[**Fixed variables**: A set of variables that applies to a column in the database. Abbreviations: NA, not applicable; HA, hydrographic area]

Site Information			
Access table name	**Table column name**	**Description**	**Fixed variables**
YF_sitefile	USGS_local_nm	USGS local well name	NA
YF_sitefile	USGS_site_id	USGS unique well identification number	NA
YF_sitefile	station_nm	USGS official NWIS site name (format is: hydrographic area, township, range, section, sequence number, USGS local name)	NA
YF_sitefile	redbk_nm	Official DOE hole name at well site	NA
YF_sitefile	lat_va	Latitude, in degrees, minutes, and decimal seconds; datum is North American Datum of 1927	NA
YF_sitefile	long_va	Longitude, in degrees, minutes, and decimal seconds; datum is North American Datum of 1927	NA
YF_sitefile	dec_lat_va	Latitude, in decimal degrees; datum is North American Datum of 1983	NA
YF_sitefile	dec_long_va	Longitude, in decimal degrees; datum is North American Datum of 1983	NA
YF_sitefile	easting	Universal Transverse Mercator Projection easting, in meters, Zone 11, North American Datum of 1927	NA
YF_sitefile	northing	Universal Transverse Mercator Projection northing, in meters, Zone 11, North American Datum of 1927	NA
YF_sitefile	coord_meth	Method used to measure horizontal coordinates	Unknown; Survey
YF_sitefile	coord_acy	Accuracy of horizontal latitude and longitude coordinates	Hndrth second; Second
YF_sitefile	state	State where well is located	NEVADA
YF_sitefile	county	County where well is located	NYE
YF_sitefile	map_nm	1:24,000 USGS topographic quadrangle on which well is located	NA
YF_sitefile	alt_va	Altitude of land surface at well, in feet; datum is National Geodetic Vertical Datum of 1929	NA
YF_sitefile	alt_meth	Method used to measure land-surface altitude	DGPS (differential GPS); Level; Reported; Map
YF_sitefile	alt_acy_va	Accuracy of land-surface altitude, in feet	NA
YF_sitefile	hyd_area_nu	Hydrographic area where well is located	HA159 (Yucca Flat); HA160 (Frenchman Flat); HA158A (Groom Lake Valley)
YF_sitefile	huc	Hydrologic Unit Code	NA
YF_sitefile	NTS area number	NTS area number	NA

Table 10. Description of Microsoft® Access database for Yucca Flat water-level measurements—Continued

Site Information—Continued			
Access table name	**Table column name**	**Description**	**Fixed variables**
YF_sitefile	site_rmks_tx	General remarks about the well site	NA
YF_sitefile	site_use_1	Primary use of well site	Destroyed; Test; Withdrawal
YF_sitefile	site_use_2	Secondary use of well site	Test; Observation; Withdrawal
YF_sitefile	water_use_1	Use of water at well site	Unused; Institutional
YF_gw_ls_alt	ls_alt_seq_nu	Sequence number of measured land-surface altitude	NA
YF_gw_ls_alt	ls_alt	Altitude of land surface at well, in feet; datum is National Geodetic Vertical Datum of 1929	NA
YF_gw_ls_alt	ls_alt_src	Source of land-surface altitude	NA
YF_gw_ls_alt	ls_alt_acc	Accuracy of land-surface altitude measurement, in feet	NA
YF_gw_ls_alt	ls_alt_meth	Method used to determine land-surface altitude	DGPS (differential GPS); L (level); U (unknown)
YF_gw_ls_alt	ls_alt_dt	Date land-surface altitude was determined, in yymmdd format	NA
YF_gw_ls_alt	ls_alt_dtm	Date land-surface altitude was determined	NA
YF_gw_ls_alt	ls_alt_dtm_acc	Accuracy of date when land-surface altitude was determined	Year; Day
YF_gw_ls_alt	ls_desc	Description of land-surface where altitude was measured	NA
YF_gw_mpnt	mpnt_seq_nu	Sequence number of well measuring point	NA
YF_gw_mpnt	mpnt_begin_dtm	Date measuring point was established	NA
YF_gw_mpnt	mpnt_end_dtm	Date measuring point was discontinued	NA
YF_gw_mpnt	mpnt_ht_va	Height of measuring point above land surface, in feet	NA
YF_gw_mpnt	mpnt_alt_va	Altitude of measuring point, in feet; datum is National Geodetic Vertical Datum of 1929	NA
YF_gw_mpnt	mpnt_alt_meth	Method used to measure measuring-point altitude	DGPS (differential GPS); L (level)
YF_gw_mpnt	mpnt_alt_acy_va	Accuracy of measuring-point altitude, in feet	NA
YF_gw_mpnt	mpnt_ds	Description of measuring point	NA
YF_gw_rmks	gw_rmks_seq_nu	Sequence number of remark	NA
YF_gw_rmks	gw_rmks_dtm	Date corresponding to remark	NA
YF_gw_rmks	gw_rmks_dtm_acc	Accuracy of date entry (“Year” means remark date only applies to the year)	Day; Month; Year

Table 10. Description of Microsoft® Access database for Yucca Flat water-level measurements—Continued

Well-Construction Records			
Access table name	**Table column name**	**Description**	**Fixed variables**
YF_gw_cons	cons_begin_dtm	Date well construction began	NA
YF_gw_cons	cons_end_dtm	Date well construction was completed	NA
YF_gw_cons	hole_depth_va	Depth of hole, in feet, that was drilled prior to establishing well site	NA
YF_gw_cons	well_depth_va	Depth of well, in feet; generally considered the depth that is accessible.	NA
YF_gw_cons	depth_src	Source of information for hole-depth and well-depth data	Driller; Other reported; Geologist
YF_gw_cons	cons_contractor_nm	Name of drilling contractor	NA
YF_gw_cons	cons_src	Source of construction data	Other reported; Geologist; Driller
YF_gw_cons	cons_meth	Drilling method	Air rotary; Hydraulic rotary; Cable tool; Reverse rotary
YF_gw_cons	finish	Type of finish around open interval	Perf or Slotted; Gravel pck, perf; Gravel pck, scrn; Open hole
YF_gw_cons	seal	Type of well seal above open interval	Cement grout
YF_gw_cons	seal_depth_va	Depth to bottom of seal, in feet below land surface	NA
YF_gw_hole	hole_seq_nu	Sequence number of hole interval	NA
YF_gw_hole	hole_top_va	Top of hole interval, in feet below land surface	NA
YF_gw_hole	hole_bottom_va	Bottom of hole interval, in feet below land surface	NA
YF_gw_hole	hole_dia_va	Diameter of hole interval, in inches	NA
YF_gw_csng	csng_seq_nu	Sequence number of casing interval	NA
YF_gw_csng	csng_top_va	Top of casing interval, in feet below land surface	NA
YF_gw_csng	csng_bottom_va	Bottom of casing interval, in feet below land surface	NA
YF_gw_csng	csng_dia_va	Diameter of casing interval, in inches	NA
YF_gw_csng	csng_material	Casing material	Steel carbon; Stainless steel; Steel; Galvanized iron; Fiberglass
YF_gw_csng	csng_thick_va	Thickness of casing, in inches	NA
YF_gw_open	open_seq_nu	Sequence number of open interval	NA
YF_gw_open	open_top_va	Top of open interval, in feet below land surface	NA
YF_gw_open	open_bottom_va	Bottom of open interval, in feet below land surface	NA
YF_gw_open	open_dia_va	Diameter of open interval, in inches	NA
YF_gw_open	open_material	Material comprising open interval	Steel; Other; Stainless steel; Steel carbon
YF_gw_open	open	Type of opening	Perforated; Open hole; Screen; Other

Table 10. Description of Microsoft® Access database for Yucca Flat water-level measurements—Continued

Borehole lithology and aquifer data			
Access table name	**Table column name**	**Description**	**Fixed variables**
YF_gw_lith	lith_seq_nu	Sequence number of lithologic interval	NA
YF_gw_lith	lith_top_va	Top of lithologic interval, in feet below land surface	NA
YF_gw_lith	lith_bottom_va	Bottom of lithologic interval, in feet below land surface	NA
YF_gw_lith	lith_descr_tx	Lithologic description of lithologic interval	NA
YF_gw_lith	lith_rmk	Other remarks pertinent to the lithology of the interval	NA
YF_lith_tops	vf_top	Depth to top of valley fill, in feet below land surface	NA
YF_lith_tops	tert_volc_top	Depth to top of Tertiary volcanics, in feet below land surface	NA
YF_lith_tops	pre_T_carbs_top	Depth to top of pre-Tertiary carbonate rocks, in feet below land surface	NA
YF_lith_tops	pre_T_clastic_top	Depth to top of pre-Tertiary clastic rocks, in feet below land surface	NA
YF_lith_tops	lith_top_src	Source of information for depth to top of lithologic unit	Reported (data reported on lithologic log or other documented source); Estimated (data estimated from nearby logs or some other source)
YF_gw_aqfr	aqfr_cd_1	Code for primary aquifer contributing water to well	C (pre-Tertiary carbonate rocks); F (valley fill); S (pre-Tertiary clastic rocks); V (volcanic rocks); X (igneous or metamorphic rocks)
YF_gw_aqfr	aqfr_cd_2	Code for secondary aquifer contributing water to well	C (pre-Tertiary carbonate rocks); F (valley fill); P (paleocolluvium); S (pre-Tertiary clastic rocks); V (volcanic rocks); X (igneous or metamorphic rocks)
YF_gw_aqfr	aqfr_cd_3	Code for tertiary aquifer contributing water to well	C (pre-Tertiary carbonate rocks); S (pre-Tertiary clastic rocks); V (volcanic rocks); X (igneous or metamorphic rocks)
YF_gw_aqfr	aqfr	Primary aquifer contributing water to well	NA
YF_gw_aqfr	aqfr_era	Geologic era of primary aquifer	NA
YF_gw_aqfr	aqfr_system	Geologic system of primary aquifer	NA
YF_gw_aqfr	aqfr_series	Geologic series of primary aquifer	NA

Table 10. Description of Microsoft® Access database for Yucca Flat water-level measurements—Continued

Water-level data			
Access table name	**Table column name**	**Description**	**Fixed variables**
YF_gw_lev	lev_dtm	Date and time water level was measured	NA
YF_gw_lev	lev_dtm_acc	Accuracy to which the water-level date was entered	Minute; Day; Month; Year
YF_gw_lev	lev_ddy	Date, as a decimal year, that water level was measured	NA
YF_gw_lev	lev_va	Depth to water, in feet below land surface	NA
YF_gw_lev	sl_lev_va	Water-level altitude, in feet above sea level; datum is National Geodetic Vertical Datum of 1929	NA
YF_gw_lev	lev_src	Source of water-level measurement	USGS; Other reported; Geologist; Driller
YF_gw_lev	lev_status	Status of water-level measurement	Dry; Nearby pumping; Obstruction; Other; Pumping; Recently pumped
YF_gw_lev	lev_meth	Method of water-level measurement	Airline; Calib. elec. Tape; Electric tape (uncalibrated); Geophysical log; Other; Pressure gage; Reported; Steel tape; Transducer; Unknown
YF_gw_lev	lev_acy	Accuracy of water-level measurement, in feet	Nearest 1/10 foot; Nearest 1/100 foot; Nearest foot; Not nearest foot
YF_gw_lev	lev_party_tx	Organization making measurement	EG&G (NTS contractor); F&S (Fenix & Scisson--NTS contractor); NTS (USGS measurements collected after about 1996 for Nevada Test Site Program); NV013 (Desert Research Institute); Shaw (Shaw Environmental, Inc.); WTP (USGS measurements collected prior to about 1996 for NTS Weapons Testing Program)
YF_wl_rmks	wl_rmks_seq_nu	Sequence number of remark	NA
YF_wl_rmks	wl_rmks_dtm	Date of water level corresponding to remark	NA
YF_wl_rmks	wl_rmks_dtm_acc	Accuracy of date entry ("Year" means remark date only applies to the year)	Day; Month; Year
YF_wl_rmks	wl_rmks_tx	Remark relating to specific water level	NA

Table 10. Description of Microsoft® Access database for Yucca Flat water-level measurements—Continued

Water-level data--Continued			
Access table name	**Table column name**	**Description**	**Fixed variables**
YF_wl_attrib_gen	wl_attrib_gen	Attribute assigned to water level to describe the general hydrologic condition at the time of measurement	Insufficient data; Localized conditions; None; Nonstatic level; Steady state—LOCAL; Steady state—REGIONAL; Suspect; Transient—REGIONAL
YF_wl_attrib_det	wl_attrib_det_seq_nu	Sequence number of detailed hydrologic condition	NA
YF_wl_attrib_det	wl_attrib_det	Attribute assigned to water level to describe the detailed hydrologic condition at the time of measurement	Abrupt change; Anomalous – high; Anomalous – low; Borehole deviation; Consistent; Declining trend; Dry; Elevated; Equilibration; Erratic/Unstable; Injection/Recovery; Limited data; Maximum estimate; Minimum estimate; Nearby drilling effect; Nuclear-test effect; Obstruction; Packer test; Pumping area; Pumping/Recovery; Rising trend; Suspected perched water; Testing area; Undeveloped; Well-construction effect
YF_hyd_narrative	hyd_narrative	Narrative discussing well site, hydrograph, and specific water levels.	NA

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
Ess Crater	10	Ess	3/23/1955	1 kt	4,259	NA	1,839	37.168286	116.044759
U-1a.01	01	Ledoux	9/27/1990	Less than 20 kt	3,996	955	617	37.007097	116.059089
U-1c Mining	01	Yerba	12/14/1971	Less than 20 kt	4,031	1,089	520	37.023211	116.059500
U-1d	01	Sundown-A	9/20/1990	Less than 20 kt	4,047	887	736	37.038169	116.057667
U-1d	01	Sundown-B	9/20/1990	Less than 20 kt	4,047	887	783	37.038169	116.057667
U-2a	02	Alpaca	2/12/1965	0.330 kt	4,402	738	1,242	37.164483	116.077416
U-2aa	02	Club	1/30/1964	Less than 20 kt	4,296	593	1,243	37.136163	116.071527
U-2ab	02	Tee	5/7/1965	7 kt	4,297	605	1,227	37.140319	116.067521
U-2ad	02	Cashmere	2/4/1965	Less than 20 kt	4,256	765	1,042	37.130697	116.062465
U-2af	02	Kennebec	6/25/1963	Low	4,275	742	1,075	37.131352	116.068935
U-2ag	02	Mullet	10/17/1963	Low	4,270	198	1,613	37.130761	116.067832
U-2ah	02	Pongee	7/22/1965	Less than 20 kt	4,270	442	1,375	37.131747	116.067724
U-2ai	02	Drill (Source-Lower)	12/5/1964	3.4 kt	4,286	718	1,110	37.134236	116.070624
U-2ai	02	Drill (Target-Upper)	12/5/1964	Less than 20 kt	4,286	618	1,211	37.134236	116.070624
U-2ak	02	Centaur	8/27/1965	Less than 20 kt	4,299	570	1,275	37.137258	116.070943
U-2aL	02	Emerson	12/16/1965	Less than 20 kt	4,289	855	996	37.140791	116.064049
U-2am	02	Commodore	5/20/1967	250 kt	4,258	2,445	-644	37.130361	116.064818
U-2an	02	Tapestry	5/12/1966	Less than 20 kt	4,291	816	1,013	37.134238	116.071988
U-2ao	09	Flotost	8/16/1977	Less than 20 kt	4,301	902	963	37.146672	116.063982
U-2ap	02	Effendi	4/27/1967	Less than 20 kt	4,284	725	1,112	37.138736	116.064074
U-2ar	02	Asiago	12/21/1976	Less than 20 kt	4,239	1,085	706	37.123863	116.068326
U-2as	02	Clarksmobile	5/17/1968	20 to 200 kt	4,218	1,550	139	37.120003	116.059701
U-2at	02	Knox	2/21/1968	20 to 200 kt	4,199	2,115	-464	37.116508	116.054568
U-2au	02	Ildrim	7/16/1969	20 to 200 kt	4,209	1,346	340	37.119383	116.055987
U-2av	02	Calabash	10/29/1969	110 kt	4,298	2,050	-182	37.143269	116.064716
U-2aw	02	Stanyan	9/26/1974	20 to 200 kt	4,271	1,880	-63	37.132580	116.069260
U-2ax	02	Portmanteau	8/30/1974	20 to 200 kt	4,397	2,150	-182	37.152433	116.084203
U-2ay #1 Zero Station	02	Yannigan-Red	2/26/1970	20 to 200 kt	4,214	1,286	380	37.116316	116.062312
U-2ay #2 Zero Station	02	Yannigan-White	2/26/1970	20 to 200 kt	4,227	1,295	420	37.118002	116.067318
U-2ay #3 Zero Station	02	Yannigan-Blue	2/26/1970	20 to 200 kt	4,214	1,193	481	37.113755	116.066668
U-2az #1	02	Flask-Green	5/26/1970	105 kt	4,192	1,734	-104	37.113319	116.063204
U-2az #2	02	Flask-Yellow	5/26/1970	90 tons	4,220	1,100	594	37.118083	116.064435
U-2az #3	02	Flask-Red	5/26/1970	35 tons	4,220	500	1,198	37.116147	116.067574
U-2b	02	St. Lawrence	11/9/1962	Low	4,384	547	1,420	37.163766	116.074163
U-2bc	02	Parnassia	11/30/1971	Less than 20 kt	4,360	1,085	856	37.160399	116.071105
U-2bd	02	Vulcan	6/25/1966	25 kt	4,354	1,059	873	37.155258	116.073030
U-2be	02	Noor	4/10/1968	20 to 200 kt	4,385	1,250	702	37.154330	116.079724
U-2bf	02	Gourd-Amber	4/24/1969	Less than 20 kt	4,418	595	1,393	37.163922	116.080511

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-2bg	02	Throw	4/10/1968	Less than 20 kt	4,408	750	1,214	37.156633	116.083141
U-2bh	02	Scuttle	11/13/1969	1.7 kt	4,394	540	1,435	37.164583	116.075702
U-2bi	02	Oakland	4/4/1967	Less than 20 kt	4,423	543	1,428	37.161930	116.083097
U-2bj	02	Imp	8/9/1968	Less than 20 kt	4,399	600	1,388	37.161741	116.078058
U-2bL	02	Gourd-Brown	4/24/1969	Less than 20 kt	4,409	744	1,225	37.159916	116.081744
U-2bm	02	Lexington	8/24/1967	Less than 20 kt	4,386	743	1,223	37.162683	116.075033
U-2bn	02	Chatty	3/18/1969	Less than 20 kt	4,394	640	1,332	37.162227	116.076752
U-2bo #1 Zero Station	02	Bowl-1	6/26/1969	Less than 20 kt	4,407	650	1,329	37.162436	116.079494
U-2bo #2 Zero Station	02	Bowl-2	6/26/1969	Less than 20 kt	4,402	750	1,217	37.160733	116.080022
U-2bp #1 Zero Station	10	Spider-A	8/14/1969	Less than 20 kt	4,326	700	1,209	37.160197	116.064477
U-2bp #2 Zero Station	10	Spider-B	8/14/1969	Less than 20 kt	4,325	747	1,158	37.158141	116.064657
U-2bq #1 Zero Station	10	Kyack-A	9/20/1969	Less than 20 kt	4,342	610	1,292	37.158699	116.068599
U-2bq #2 Zero Station	10	Kyack-B	9/20/1969	Less than 20 kt	4,331	630	1,300	37.157372	116.067041
U-2br	02	Harebell	6/24/1971	20 to 200 kt	4,312	1,702	176	37.146647	116.067710
U-2bs	02	Starwort	4/26/1973	90 kt	4,226	1,850	-127	37.123000	116.059384
U-2bu	04	Miniata	7/8/1971	83 kt	4,179	1,735	-115	37.110078	116.052289
U-2bv	02	Portulaca	6/28/1973	20 to 200 kt	4,388	1,530	411	37.148377	116.086725
U-2bw	09	Sutter	12/21/1976	Less than 20 kt	4,312	656	1,223	37.151853	116.064304
U-2bx	10	Hulsea	3/14/1974	Less than 20 kt	4,319	640	1,254	37.155083	116.064966
U-2by	02	Polygonum	10/2/1973	Less than 20 kt	4,366	700	1,243	37.158738	116.073861
U-2bz	02	Waller	10/2/1973	Less than 20 kt	4,333	1,020	888	37.153863	116.068580
U-2c	02	Kermet	11/23/1965	Less than 20 kt	4,368	644	1,306	37.161847	116.071791
U-2ca	02	Stutz	4/6/1966	Less than 20 kt	4,872	742	788	37.139471	116.141747
U-2cc	02	Saxon	7/28/1966	1.2 kt	4,719	504	1,255	37.140441	116.134038
U-2cd	02	Traveler	5/4/1966	Less than 20 kt	4,781	648	983	37.137027	116.138008
U-2ce	02	Nash	1/19/1967	39 kt	4,764	1,198	535	37.143607	116.136077
U-2cg	02	Heilman	4/6/1967	Less than 20 kt	4,699	501	1,242	37.137277	116.133552
U-2ch	02	Pod-A	10/29/1969	16.7 kt (Pod total)	4,671	875	898	37.140160	116.131374
U-2ci	02	Pod-B	10/29/1969	16.7 kt (Pod total)	4,894	816	641	37.140399	116.142708
U-2cj	02	Pod-C	10/29/1969	16.7 kt (Pod total)	4,838	560	970	37.136282	116.140838
U-2ck	02	Pod-D	10/29/1969	16.7 kt (Pod total)	4,761	1,025	656	37.135291	116.136824
U-2cm-S	02	Stoddard	9/17/1968	20 to 200 kt	4,583	1,535	178	37.119816	116.128343
U-2cn	02	Cruet	10/29/1969	11 kt	4,589	865	851	37.121466	116.128621
U-2co	02	Kryddost	5/6/1982	Less than 20 kt	4,562	1,099	592	37.116793	116.127779
U-2cp	02	Caboc	12/16/1981	Less than 20 kt	4,510	1,099	612	37.114477	116.123751
U-2cq	02	Gorbea	1/31/1984	20 to 150 kt	4,499	1,273	436	37.112649	116.122576
U-2cr	02	Wexford	8/30/1984	Less than 20 kt	4,604	1,030	802	37.143841	116.126129
U-2cs	02	Maribo	6/26/1985	Less than 20 kt	4,525	1,250	545	37.124049	116.122859

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-2cu	02	Kawich-Black	2/24/1989	Less than 20 kt	4,526	1,414	394	37.128443	116.122829
U-2cu	02	Kawich-Red	2/24/1989	Less than 20 kt	4,525	1,214	594	37.128443	116.122829
U-2db	02	Crew	11/4/1968	20 to 200 kt	4,312	0	665	37.130427	116.087380
U-2db	02	Crew-2nd	11/4/1968	Less than 20 kt	4,312	1,180	665	37.130427	116.087380
U-2db	02	Crew-3rd	11/4/1968	Less than 20 kt	4,312	1,980	-135	37.130427	116.087380
U-2dc #1e	02	Tyg-A	12/12/1968	Less than 20 kt	4,265	749	1,075	37.120774	116.081430
U-2dc #2d	02	Tyg-B	12/12/1968	Less than 20 kt	4,254	824	998	37.117544	116.080433
U-2dc #3c	02	Tyg-C	12/12/1968	Less than 20 kt	4,248	749	1,059	37.118002	116.078105
U-2dc #4a	02	Tyg-D	12/12/1968	Less than 20 kt	4,261	679	1,134	37.121233	116.079102
U-2dc #5b	02	Tyg-E	12/12/1968	Less than 20 kt	4,254	649	1,159	37.119849	116.077438
U-2dc #6f	02	Tyg-F	12/12/1968	Less than 20 kt	4,264	869	964	37.118827	116.082599
U-2dd #1	02	Can-Green	4/21/1970	20 to 200 kt	4,243	900	916	37.112322	116.082969
U-2dd #2	02	Arnica-Yellow	6/26/1970	Less than 20 kt	4,255	1,015	802	37.113880	116.087002
U-2dd #3	02	Arnica-Violet	6/26/1970	Less than 20 kt	4,261	865	966	37.117086	116.085024
U-2dd #4 [U-2dd]	02	Can-Red	4/21/1970	20 to 200 kt	4,249	1,310	508	37.115533	116.081005
U-2de	02	Coffer	3/21/1969	Less than 100 kt	4,323	1,525	343	37.133172	116.087530
U-2df	02	Hutch	7/16/1969	20 to 200 kt	4,354	1,800	108	37.139466	116.088314
U-2dg	02	Carpetbag	12/17/1970	220 kt	4,302	2,171	-358	37.129083	116.083869
U-2dh #2	02	Sappho	3/23/1972	Less than 20 kt	4,241	649	1,163	37.112999	116.081691
U-2dh #3	02	Kara	5/11/1972	Less than 20 kt	4,247	850	966	37.112444	116.085366
U-2di	02	Chantilly	9/29/1971	Less than 20 kt	4,288	1,085	759	37.124433	116.087850
U-2dj	02	Flax-Backup	12/21/1972	Less than 20 kt	4,341	1,460	434	37.139908	116.084125
U-2dj	02	Flax-Source	12/21/1972	Less than 20 kt	4,341	2,258	-364	37.139908	116.084125
U-2dj	02	Flax-Test	12/21/1972	20 to 200 kt	4,341	1,430	464	37.139908	116.084125
U-2dk	02	Zinnia	5/17/1972	Less than 20 kt	4,279	1,059	789	37.120511	116.088766
U-2dL	02	Chaenactis	12/14/1971	20 to 200 kt	4,291	1,085	768	37.123899	116.090425
U-2dm	02	Longchamps	4/19/1972	Less than 20 kt	4,275	1,071	765	37.121891	116.084713
U-2dn	02	Merida	6/7/1972	Less than 20 kt	4,258	670	1,155	37.115841	116.086199
U-2do	02	Gazook	3/23/1973	Less than 20 kt	4,268	1,070	762	37.117222	116.087902
U-2dp	02	Delphinium	9/26/1972	15 kt	4,276	970	875	37.121322	116.086602
U-2dq	02	Satz	7/7/1978	Less than 20 kt	4,232	1,033	726	37.111749	116.078002
U-2dr	02	Cabrillo	3/7/1975	20 to 200 kt	4,313	1,970	-113	37.133963	116.085116
U-2ds	02	Grove	5/22/1974	Less than 20 kt	4,236	1,030	732	37.114758	116.075574
U-2dt	02	Tanya	7/30/1968	20 to 200 kt	4,257	1,250	579	37.116719	116.083108
U-2du	02	Alviso	6/11/1975	Less than 20 kt	4,225	600	1,114	37.111733	116.074568
U-2dv	02	Fallon	5/23/1974	20 to 200 kt	4,273	1,530	267	37.124447	116.079752
U-2dw	02	Crestlake-Briar	7/18/1974	Less than 20 kt	4,269	1,226	610	37.119205	116.086002
U-2dw	02	Crestlake-Tansan	7/18/1974	Less than 20 kt	4,269	891	945	37.119205	116.086002

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-2dy	02	Edam	4/24/1975	20 to 200 kt	4,263	1,350	474	37.115638	116.088261
U-2dz	02	Banon	8/26/1976	20 to 150 kt	4,273	1,760	23	37.124961	116.082866
U-2e	02	Cumberland	4/11/1963	Low	4,352	743	1,183	37.156630	116.071835
U-2ea	02	Seafoam	12/13/1973	Less than 20 kt	4,374	650	1,303	37.161349	116.073924
U-2eb	02	Portrero	4/23/1974	Less than 20 kt	4,387	690	1,268	37.159924	116.077283
U-2ef	02	Gouda	10/6/1976	Less than 20 kt	4,260	656	1,154	37.134514	116.063146
U-2eg	02	Rivoli	5/20/1976	Less than 20 kt	4,284	656	1,178	37.137152	116.067449
U-2eh	02	Liptauer	4/3/1980	20 to 150 kt	4,368	1,368	552	37.149827	116.083133
U-2ei	02	Coulommiers	9/27/1977	20 to 150 kt	4,327	1,740	158	37.151116	116.068429
U-2ek	02	Chiberta	12/20/1975	20 to 200 kt	4,237	2,349	-578	37.127603	116.062440
U-2eL	02	Marsilly	4/5/1977	20 to 150 kt	4,220	2,264	-554	37.120186	116.063151
U-2em	02	Azul	12/14/1979	Less than 20 kt	4,273	673	1,151	37.137325	116.063943
U-2en	02	Reblochon	2/23/1978	20 to 150 kt	4,225	2,160	-407	37.123630	116.064701
U-2eo	02	Kloster	2/15/1979	20 to 150 kt	4,344	1,760	157	37.151963	116.072708
U-2ep	02	Nessel	8/29/1979	20 to 150 kt	4,221	1,522	222	37.121172	116.067457
U-2eq	02	Riola	9/25/1980	1.07 kt	4,203	1,391	277	37.115814	116.065438
U-2er	10	Islay	8/27/1981	Less than 20 kt	4,342	965	961	37.160369	116.067396
U-2es	02	Akavi	12/3/1981	20 to 150 kt	4,332	1,621	268	37.148386	116.071710
U-2et	10	Cheedam	2/17/1983	Less than 20 kt	4,332	1,125	794	37.162769	116.064218
U-2eu	02	Danablu	6/9/1983	Less than 20 kt	4,440	1,050	942	37.157569	116.090100
U-2ev	02	Agrini	3/31/1984	Less than 20 kt	4,366	1,050	866	37.146391	116.084933
U-2ew	02	Branco	9/21/1983	Less than 20 kt	4,209	961	745	37.121308	116.056454
U-2ew	02	Branco-Herkimer	9/21/1983	Less than 20 kt	4,209	1,401	305	37.121308	116.056454
U-2ex	02	Romano	12/16/1983	20 to 150 kt	4,311	1,690	152	37.140399	116.072938
U-2ey	02	Nightingale	6/22/1988	Less than 150 kt	4,384	780	1,188	37.166111	116.073116
U-2ey	02	Rhyolite	6/22/1988	Less than 150 kt	4,384	680	1,288	37.166111	116.073116
U-2f	02	Narraguagus	9/27/1963	Low	4,360	493	1,439	37.154730	116.074230
U-2fa	02	Farallones	12/14/1977	20 to 150 kt	4,322	2,192	-318	37.135822	116.086900
U-2fb	02	Quargel	11/18/1978	20 to 150 kt	4,271	1,778	-11	37.126822	116.084744
U-2fc	02	Fajy	6/28/1979	20 to 150 kt	4,364	1,759	155	37.143116	116.088389
U-2fd	02	Tarko	2/28/1980	Less than 20 kt	4,287	1,211	632	37.126499	116.089378
U-2fe	02	Crowdie	5/5/1983	Less than 20 kt	4,383	1,280	655	37.145594	116.090089
U-2ff	02	Laban	8/3/1983	Less than 20 kt	4,275	1,070	771	37.118949	116.089778
U-2g	02	Satsop	8/15/1963	Low	4,373	742	1,197	37.154044	116.077499
U-2gaS	02	Cornucopia	7/24/1986	Less than 20 kt	4,312	1,250	608	37.142699	116.071988
U-2gb	02	Panamint	5/21/1986	Less than 20 kt	4,219	1,575	159	37.124986	116.061259
U-2ge	02	Borate	10/23/1987	20 to 150 kt	4,335	1,780	99	37.141849	116.079572
U-2gf	02	Schellbourne	5/13/1988	Less than 150 kt	4,249	1,519	255	37.124386	116.072996

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-2gg	02	Ingot	3/9/1989	20 to 150 kt	4,289	1,640	209	37.142791	116.067807
U-2gh	02	Metropolis	3/10/1990	20 to 150 kt	4,177	1,540	32	37.112455	116.056048
U-2h	02	Carmel	2/21/1963	Low	4,390	539	1,428	37.154761	116.080755
U-2j Shaft	02	Alva	8/19/1964	4.4 kt	4,420	545	1,429	37.158969	116.083969
U-2L	02	Ahtanum	9/13/1963	Low	4,419	742	1,238	37.163322	116.081511
U-2m #1 Emplacement Hole	02	Fenton	4/23/1966	1.4 kt	4,423	549	1,423	37.160491	116.083744
U-2n	02	Ace	6/11/1964	3 kt	4,353	864	1,026	37.148555	116.076866
U-2p	02	Par	10/9/1964	38 kt	4,368	1,331	591	37.151302	116.077863
U-2q	02	Crepe	12/5/1964	20 to 200 kt	4,195	1,325	308	37.114375	116.054312
U-2r	02	Plaid II	2/3/1966	Less than 20 kt	4,260	881	909	37.126269	116.070341
U-2t	04	Dumont	5/19/1966	20 to 200 kt	4,195	2,201	-606	37.111103	116.058798
U-2u	02	Packard	1/15/1969	10 kt	4,315	810	1,075	37.147869	116.066529
U-2v	02	Agile	2/23/1967	20 to 200 kt	4,256	2,406	-623	37.126802	116.067249
U-2x	02	Lanpher	10/18/1967	20 to 200 kt	4,206	2,346	-711	37.115539	116.058507
U-2y	02	Hupmobile	1/18/1968	7.4 kt	4,310	810	1,069	37.145533	116.066549
U3aa	03	Boomer	10/1/1961	Low	4,027	330	1,293	37.048294	116.035380
U-3ab	03	Ermine	3/6/1962	Low	4,028	240	1,383	37.048350	116.034527
U-3ac	03	Shrew	9/16/1961	Low	4,027	322	1,300	37.048408	116.033671
U-3ad	03	Platypus	2/24/1962	Low	4,026	190	1,431	37.048289	116.032771
U-3ae	03	Mink	10/29/1961	Low	4,028	630	993	37.048519	116.031966
U-3af	03	Coypu	4/10/1963	Low	4,027	245	1,378	37.048764	116.031182
U-3ag	03	Chinchilla	2/19/1962	1.9 kt	4,030	492	1,133	37.049006	116.030399
U-3ah	03	Fisher	12/3/1961	13.4 kt	4,020	1,193	421	37.045811	116.028543
U-3ai	03	Hognose	3/15/1962	Low	4,019	789	826	37.043914	116.031904
U-3ajS	03	Raccoon	6/1/1962	Low	4,021	539	1,077	37.045567	116.035330
U-3ak	03	Ringtail	12/17/1961	Low	4,014	1,191	417	37.043114	116.026182
U-3aL	03	Pampas	3/1/1962	9.5 kt	4,012	1,191	416	37.041217	116.029549
U-3amS	03	Aardvark	5/12/1962	40 kt	4,071	1,424	227	37.065144	116.031246
U-3an	03	Wagtail	3/3/1965	20 to 200 kt	4,060	2,459	-845	37.064464	116.038049
U-3ao	03	Agouti	1/18/1962	6.4 kt	4,027	856	766	37.047200	116.035233
U-3ap	03	Stoat	1/9/1962	5.1 kt	4,021	992	624	37.044592	116.035933
U-3aq	03	Dormouse	1/30/1962	Low	4,026	1,191	427	37.046800	116.040352
U-3ar	03	Armadillo	2/9/1962	7.1 kt	4,019	786	827	37.043530	116.039827
U-3as	03	Chinchilla II	3/31/1962	Low	4,026	448	1,172	37.046861	116.037769
U-3at	03	Jerboa	3/1/1963	Low	4,015	988	622	37.044464	116.027363
U-3auS	03	Haymaker	6/27/1962	67 kt	4,013	1,340	270	37.041550	116.036113
U-3av	03	Wolverine	10/12/1962	Low	4,027	241	1,381	37.048733	116.033427
U-3aw	03	Packrat	6/6/1962	Low	4,022	860	755	37.045669	116.040155

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-3ax	03	Paca	5/7/1962	Low	4,021	848	766	37.046519	116.025876
U-3ay	03	Chipmunk	2/15/1963	Low	4,028	195	1,428	37.048967	116.032619
U-3az	03	Dormouse Prime	4/5/1962	10.6 kt	4,016	856	753	37.044458	116.024401
U-3ba	03	Tendrac	12/7/1962	Low	4,033	993	635	37.051697	116.030177
U-3bb	03	Peba	9/20/1962	Low	4,043	792	846	37.054994	116.030152
U-3bc	03	Hutia	6/6/1963	Low	4,019	442	1,172	37.044236	116.037230
U-3bd	03	Merrimac	7/13/1962	Intermediate	4,041	1,356	277	37.055017	116.034263
U-3be	03	Daman I	6/21/1962	Low	4,016	854	757	37.043017	116.031124
U-3bf	03	Ferret	2/8/1963	Low	4,052	1,069	577	37.058292	116.030133
U-3bg	03	Acushi	2/8/1963	Low	4,022	856	759	37.046086	116.021965
U-3bh	03	Hyrax	9/14/1962	Low	4,017	711	899	37.043889	116.021982
U-3bj	03	Bandicoot	10/19/1962	12.5 kt	4,008	792	811	37.039492	116.022015
U-3bk	03	Mataco	6/14/1963	Low	4,026	642	976	37.046072	116.019218
U-3bL	03	Bobac	8/24/1962	Low	4,021	676	938	37.046097	116.024707
U-3bm	03	Gundi	11/15/1962	Low	4,010	792	813	37.041706	116.024740
U-3bn	03	Cassowary	12/16/1964	Less than 20 kt	4,005	493	1,107	37.039511	116.024763
U-3bo	03	Sturgeon	4/15/1964	Less than 20 kt	4,019	491	1,121	37.043872	116.019237
U-3bp	03	Gerbil	3/29/1963	Low	4,012	917	688	37.041675	116.019265
U-3bq	03	Anchovy	11/14/1963	Low	4,007	854	747	37.039478	116.019282
U-3br	03	Belen	2/4/1970	20 to 200 kt	4,045	1,381	248	37.054972	116.039711
U-3bs	03	Puce	6/10/1966	Less than 20 kt	4,053	1,593	23	37.059366	116.039683
U-3bt	03	Bonefish	2/18/1964	Less than 20 kt	4,050	987	647	37.059339	116.034191
U-3bu	03	Numbat	12/12/1962	Low	4,030	761	861	37.046058	116.016476
U-3bv	03	Harkee	5/17/1963	Low	4,021	792	822	37.043861	116.016501
U-3bw	03	Pekan	8/12/1963	Low	4,015	992	616	37.041661	116.016518
U-3bx	03	Barbel	10/16/1964	Less than 20 kt	4,007	849	751	37.039464	116.016540
U-3by	03	Ferret Prime	4/5/1963	Low	4,002	792	805	37.037311	116.024782
U-3bz	03	Grunion	10/11/1963	Low	4,002	857	740	37.037294	116.022040
U-3cb	03	Carp	9/27/1963	Low	4,002	1,081	514	37.037267	116.016562
U-3cd	03	Dovekie	1/21/1966	Less than 20 kt	3,991	1,093	491	37.031769	116.016604
U-3cf	03	Hoopoe	12/16/1964	Less than 20 kt	4,025	231	1,390	37.048378	116.034096
U-3cg	03	Tejon	5/17/1963	Low	4,026	245	1,376	37.048292	116.033224
U-3ch	03	Sardine	12/4/1963	Low	4,007	860	743	37.039536	116.030249
U-3cj	03	Sienna	1/18/1966	Less than 20 kt	4,003	902	695	37.037278	116.019304
U-3cn	03	Bilby	9/13/1963	249 kt	4,074	2,344	-674	37.060372	116.022529
U-3co	03	Pipefish	4/29/1964	Less than 20 kt	4,006	859	743	37.039519	116.027504
U-3cp	03	Canvasback	8/22/1964	Less than 20 kt	4,113	1,469	219	37.065281	116.016318
U-3cr	03	Barracuda	12/4/1963	Low	4,031	864	759	37.043839	116.013076

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-3ct	03	Merlin	2/16/1965	10.1 kt	4,037	972	659	37.051594	116.024665
U-3cu	03	Bitterling	6/12/1964	Less than 20 kt	4,013	632	999	37.038897	116.013120
U-3cv	03	Minnow	5/15/1964	Less than 20 kt	4,021	792	822	37.041639	116.013095
U-3cx	03	Cyclamen	5/5/1966	12 kt	4,036	1,001	627	37.050572	116.038719
U-3cy	03	Pike	3/13/1964	Less than 20 kt	4,060	376	1,269	37.050422	116.012331
U-3cz	03	Solendon	2/12/1964	Less than 20 kt	4,046	493	1,148	37.056564	116.030110
U-3d	03	Pascal-B	8/27/1957	Slight	4,028	500	1,123	37.049011	116.034827
U-3daS	03	Scaup	5/14/1965	Less than 20 kt	4,098	1,401	261	37.058797	116.011409
U-3db	03	Gundi Prime	5/9/1963	Low	4,043	892	742	37.049350	116.016454
U-3dd	03	Kestrel	4/5/1965	Less than 20 kt	3,985	1,466	113	37.025767	116.023512
U-3de	03	Tuna	12/20/1963	Low	4,035	1,359	270	37.052744	116.034246
U-3df	03	Cormorant	7/17/1964	Less than 20 kt	3,975	891	677	37.017564	116.030426
U-3dg	03	Screamer	9/1/1965	Less than 20 kt	3,975	990	578	37.022944	116.009828
U-3dh	07	Buff	12/16/1965	20 to 200 kt	4,102	1,642	47	37.072497	116.029969
U-3di	03	Guanay	9/4/1964	Less than 20 kt	3,975	856	711	37.017528	116.023573
U-3dj	03	Trogon	7/24/1964	Less than 20 kt	4,039	633	997	37.046036	116.013054
U-3dk	03	Parrot	12/16/1964	1.3 kt	4,001	592	1,001	37.034775	116.013151
U-3dL	03	Haddock	8/28/1964	Less than 20 kt	4,097	1,193	497	37.066969	116.023154
U-3dm	03	Cinnamon	3/7/1966	Less than 20 kt	4,000	393	1,204	37.034600	116.031660
U-3dn	03	Persimmon	2/23/1967	Less than 20 kt	3,972	981	582	37.017492	116.016726
U-3do	07	Courser	9/25/1964	Zero	4,148	1,178	537	37.072422	116.016257
U-3dp	03	Mauve	8/6/1965	Less than 20 kt	3,978	1,053	520	37.017616	116.040705
U-3dr	03	Bordeaux	8/18/1967	Less than 20 kt	3,970	1,089	475	37.012108	116.037327
U-3ds	03	Purple	3/18/1966	Less than 20 kt	3,959	1,092	448	37.009208	116.009950
U-3dt	03	Turnstone	10/16/1964	Less than 20 kt	3,996	412	1,179	37.033469	116.025671
U-3du	03	Finfoot	3/7/1966	Less than 20 kt	4,003	642	959	37.037339	116.030263
U-3dw	03	Tern	1/29/1965	Less than 20 kt	4,032	691	933	37.044944	116.014095
U-3dx	03	Muscovy	4/23/1965	Less than 20 kt	3,991	592	990	37.017373	115.996175
U-3dy	03	Petrel	6/11/1965	1.3 kt	4,016	593	1,016	37.042764	116.017884
U-3dz	03	Knife B	11/15/1968	Less than 20 kt	3,987	1,191	390	37.026100	116.034129
U-3e	03	Pascal-C	12/6/1957	Slight	4,031	250	1,376	37.049894	116.031735
U-3eb	03	Tangerine	8/12/1966	Less than 20 kt	4,021	288	1,327	37.046264	116.030188
U-3ec	03	Ochre	4/29/1966	Less than 20 kt	4,013	414	1,192	37.043619	116.023357
U-3ed	03	Moa	9/1/1965	Less than 20 kt	4,005	635	963	37.037256	116.014845
U-3ee	03	Pommard	3/14/1968	1.5 kt	4,053	686	957	37.047678	116.011676
U-3ef	03	Mushroom	3/3/1967	Less than 20 kt	4,019	589	1,022	37.039433	116.011062
U-3eh	03	Futtock	6/18/1975	Less than 20 kt	4,094	610	1,075	37.065592	116.022829
U-3ei	07	Morrones	5/21/1970	20 to 200 kt	4,148	1,584	115	37.070761	116.013874

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-3ej	03	Vise	1/30/1969	20 to 200 kt	4,038	1,490	143	37.053269	116.030129
U-3ek	03	Tomato	4/7/1966	Less than 20 kt	4,010	742	861	37.017361	115.993091
U-3eL	03	Planer	11/21/1969	Less than 20 kt	3,971	1,240	322	37.014781	116.023601
U-3em	03	Umber	6/29/1967	10 kt	3,988	1,018	564	37.028519	116.023487
U-3en	03	Sepia	11/12/1965	Less than 20 kt	4,033	791	835	37.049936	116.022963
U-3eo	03	Fawn	4/7/1967	Less than 20 kt	4,047	889	751	37.054328	116.023096
U-3ep	03	Absinthe	5/26/1967	Less than 20 kt	4,022	389	1,225	37.044975	116.019918
U-3eq	03	Brush	1/24/1968	Less than 20 kt	4,021	388	1,225	37.042747	116.014798
U-3er	03	Knife C	10/3/1968	Less than 20 kt	4,030	989	635	37.025875	115.993703
U-3es	03	Chocolate	4/21/1967	Less than 20 kt	3,979	789	785	37.019255	116.038296
U-3et	03	Khaki	10/15/1966	Less than 20 kt	4,031	763	860	37.047028	116.017846
U-3eu	03	Cerise	11/18/1966	Less than 20 kt	4,031	693	929	37.042728	116.011201
U-3ev-2S Zero Station	03	Snubber	4/21/1970	12.7 kt	4,199	1,127	680	37.054842	115.988992
U-3ew	03	Gibson	8/4/1967	Less than 20 kt	3,980	790	781	37.024339	116.013239
U-3ex	03	Gilroy	9/15/1967	Less than 20 kt	3,998	789	803	37.034822	116.021715
U-3ey	03	Wembley	6/5/1968	Less than 20 kt	3,998	781	810	37.034794	116.016923
U-3ez	03	Sidecar	12/13/1966	Less than 20 kt	4,010	788	817	37.034742	116.007667
U-3fa	03	Sazerac	10/25/1967	Less than 20 kt	3,995	989	601	37.031558	116.027224
U-3fb	03	Knife A	9/12/1968	Less than 20 kt	3,994	1,089	497	37.031750	116.012498
U-3fc	03	Piccalilli	11/21/1969	20 to 200 kt	4,010	1,292	312	37.031147	116.002909
U-3fd	03	Laguna	6/23/1971	20 to 200 kt	3,981	1,493	81	37.021919	116.023540
U-3fe	03	Lovage	12/17/1969	Less than 20 kt	3,963	1,240	310	37.006542	116.023673
U-3ff	03	Plomo	5/1/1974	Less than 20 kt	4,114	490	1,224	37.031056	115.986466
U-3fh	03	Stilt	12/15/1967	Less than 20 kt	4,038	1,091	539	37.036642	116.002859
U-3fj	03	Torch	2/21/1968	Less than 20 kt	4,059	789	855	37.041583	116.002820
U-3fk	03	Sevilla	6/25/1968	Less than 20 kt	4,111	1,177	516	37.041531	115.993219
U-3fm	03	Cognac	10/25/1967	Less than 20 kt	4,034	789	836	37.049750	116.040444
U-3fn	03	Beebalm	5/1/1970	Less than 20 kt	4,054	1,280	369	37.059169	116.029052
U-3fq	07	Canjilon	12/16/1970	Less than 20 kt	4,116	991	720	37.072475	116.025860
U-3fr	03	Fizz	3/10/1967	Less than 20 kt	4,022	386	1,230	37.047314	116.030635
U-3fs	03	Welder	10/3/1968	Less than 20 kt	4,022	386	1,230	37.046478	116.030607
U-3fu	03	Bevel	4/4/1968	Less than 20 kt	4,043	790	845	37.052264	116.021743
U-3fv	03	Mallet	1/31/1968	Less than 20 kt	3,951	788	738	37.000975	116.010017
U-3fw	03	Adze	5/28/1968	Less than 20 kt	3,987	788	772	37.008586	115.996255
U-3fx	03	Auger	11/15/1968	Less than 20 kt	4,097	789	873	37.047617	116.000706
U-3fy	06	Spud	7/17/1968	Less than 20 kt	3,956	788	733	37.000911	115.999744
U-3fz	03	Hatchet	5/3/1968	Less than 20 kt	3,987	789	792	37.028500	116.020743
U-3ga	03	Funnel	6/25/1968	Less than 20 kt	4,023	389	1,229	37.046303	116.031077

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-3gb	03	File	10/31/1968	Less than 20 kt	3,977	751	820	37.017047	116.036599
U-3gc	03	Barsac	3/20/1969	Less than 20 kt	3,982	998	577	37.021961	116.031076
U-3gd Mining	03	Ajo	1/30/1970	Less than 20 kt	3,998	998	596	37.030778	116.035632
U-3ge	03	Sapello	4/12/1974	Less than 20 kt	3,989	593	990	37.014894	116.045008
U-3gf	03	Winch	2/4/1969	Less than 20 kt	3,977	789	783	37.009391	116.043169
U-3gg	03	Tortugas	3/1/1984	20 to 150 kt	4,079	2,100	-541	37.065719	116.047164
U-3gh	03	Scissors	12/12/1968	Less than 20 kt	3,965	789	770	37.003880	116.040135
U-3gi	03	Tuloso	12/12/1972	Less than 20 kt	3,991	889	696	37.031253	116.022096
U-3gj	03	Aliment	5/15/1969	Less than 20 kt	4,049	789	860	37.011825	115.985944
U-3gk	03	Shave	1/22/1969	Less than 20 kt	3,996	790	795	37.015445	115.995164
U-3gL	03	Nipper	2/4/1969	Less than 20 kt	3,953	790	738	37.002619	116.010003
U-3gm	06	Horehound	8/27/1969	Less than 20 kt	3,942	1,089	421	36.992656	115.996397
U-3gn	03	Pliers	8/27/1969	Less than 20 kt	3,984	784	795	37.021455	116.038960
U-3go	03	Tapper	6/12/1969	Less than 20 kt	3,965	994	563	37.008778	116.031185
U-3gq	03	Bay Leaf	12/12/1968	Less than 20 kt	4,023	427	1,191	37.046989	116.031068
U-3gr	03	Manzanas	5/21/1970	Less than 20 kt	4,008	790	801	37.012139	115.992814
U-3gs	03	Apodaca	7/21/1971	Less than 20 kt	4,009	792	807	37.014334	115.992794
U-3gt	03	Bit-A	10/31/1968	Less than 20 kt	4,022	487	1,129	37.046983	116.030332
U-3gt	03	Bit-B	10/31/1968	Less than 20 kt	4,022	387	1,229	37.046983	116.030332
U-3gu	03	Mescalero	1/5/1972	Less than 20 kt	4,020	394	1,220	37.045608	116.030413
U-3gv	03	Bonarda	9/25/1980	20 to 150 kt	4,057	1,250	359	37.056116	116.048956
U-3gx	03	Abeytas	11/5/1970	20 to 200 kt	3,987	1,291	287	37.029417	116.012684
U-3gz	03	Cumarin	2/25/1970	20 to 200 kt	4,045	1,340	295	37.036628	116.000461
U-3ha	03	Corazon	12/3/1970	Less than 20 kt	3,961	791	763	37.001953	116.038777
U-3hb	03	Jib	5/8/1974	Less than 20 kt	3,951	590	927	37.000933	116.002489
U-3hc	03	Sprit	11/10/1976	Less than 20 kt	4,000	600	992	37.035903	116.018282
U-3hd	03	Embudo	6/16/1971	Less than 20 kt	3,996	994	594	37.033133	116.014537
U-3he	03	Barranca	8/4/1971	Less than 20 kt	3,984	888	689	37.026025	116.020423
U-3hf	03	Frijoles-Guaje	9/22/1971	Less than 20 kt	3,980	843	729	37.024353	116.016154
U-3hg	03	Pedernal	9/29/1971	Less than 20 kt	3,961	1,242	300	37.010989	116.008220
U-3hh	06	Jal	3/19/1970	Less than 20 kt	3,955	989	549	37.001047	116.023715
U-3hi-a	03	Culantro-A	12/10/1969	Less than 20 kt	3,964	440	1,109	37.014672	116.003733
U-3hi-b	03	Culantro-B	12/10/1969	Less than 20 kt	3,967	490	1,062	37.014864	116.002019
U-3hj	03	Scupper	8/19/1977	Less than 20 kt	3,976	1,475	94	37.017575	116.032482
U-3hk-a	03	Ipecac-A	5/27/1969	Less than 20 kt	3,965	407	1,143	37.014942	116.003044
U-3hk-b	03	Ipecac-B	5/27/1969	Less than 20 kt	3,968	408	1,145	37.014792	116.000994
U-3hk-c	03	Seaweed-E	10/1/1969	Less than 20 kt	3,974	408	1,148	37.013686	115.999464
U-3hk-d	03	Seaweed B	10/16/1969	Less than 20 kt	3,976	389	1,167	37.012531	115.999131

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-3hk-e	03	Seaweed-C	10/1/1969	Less than 20 kt	3,975	389	1,163	37.011378	115.999486
U-3hk-f	03	Seaweed-D	10/1/1969	Less than 20 kt	3,971	389	1,159	37.010461	116.000436
U-3hL	03	Penasco	11/19/1970	Less than 20 kt	3,969	889	670	37.014744	116.016751
U-3hm	03	Truchas-Rodarte	10/28/1970	Less than 20 kt	3,970	874	687	37.014761	116.020176
U-3hn	03	Truchas-Chacon	10/28/1970	Less than 20 kt	3,968	389	1,169	37.013969	116.018812
U-3ho	03	Truchas-Chamisal	10/28/1970	Less than 20 kt	3,968	388	1,170	37.013967	116.018126
U-3hp	03	Jara	6/6/1974	Less than 20 kt	3,960	1,240	305	37.003797	116.024379
U-3hq	03	Pratt	9/25/1974	Less than 20 kt	3,970	1,028	532	37.012075	116.031160
U-3hr	03	Carrizozo	12/3/1970	Less than 20 kt	3,970	916	648	37.006083	116.040799
U-3hs	03	Dexter	6/23/1971	Less than 20 kt	3,968	394	1,163	37.013167	116.017284
U-3ht	03	Atarque	7/25/1972	Less than 20 kt	3,967	966	588	37.012444	116.015917
U-3hu	03	Keel	12/16/1974	Less than 20 kt	3,966	1,001	553	37.011253	116.018495
U-3hv	03	Colmor	4/26/1973	Less than 20 kt	3,968	806	751	37.012100	116.020834
U-3hx	03	Cowles	2/3/1972	Less than 20 kt	3,955	990	546	37.001028	116.020293
U-3hy	03	Elida	12/19/1973	Less than 20 kt	3,955	1,250	294	37.001094	116.032276
U-3hz	03	Frijoles-Petaca	9/22/1971	Less than 20 kt	3,980	752	832	NA	NA
U-3j	03	Pascal-A	7/26/1957	Slight	4,033	500	1,127	37.051722	116.034288
U-3ja	03	Estaca	10/17/1974	Less than 20 kt	3,959	1,051	488	37.006356	116.015723
U-3jb	03	Bobstay	10/26/1977	Less than 20 kt	3,961	1,250	294	37.007553	116.017573
U-3jc	03	Cebolla	8/9/1972	Less than 20 kt	3,962	941	606	37.007142	116.019898
U-3jd	03	Mesita	5/9/1973	Less than 20 kt	3,960	490	1,053	37.006222	116.016942
U-3je	03	Hospah	12/14/1971	Less than 20 kt	3,987	991	590	37.025803	116.030015
U-3jf	03	Shallows	2/26/1976	Less than 20 kt	3,987	800	776	37.028475	116.016634
U-3jg	03	Angus	4/25/1973	Less than 20 kt	3,962	1,486	65	37.004786	116.029334
U-3jh	06	Backgammon	11/29/1979	Less than 20 kt	3,945	750	779	36.993911	116.024976
U-3ji	06	Pajara	12/12/1973	Less than 20 kt	3,945	912	612	36.991442	116.024995
U-3jj	06	Capitan	6/28/1972	Less than 20 kt	3,946	441	1,083	36.992556	116.023018
U-3jk	06	Velarde	4/25/1973	Less than 20 kt	3,947	908	618	36.993608	116.021912
U-3jL	03	Puye	8/14/1974	Less than 20 kt	3,987	1,411	171	37.023366	116.037229
U-3jm	03	Jicarilla	4/19/1972	Less than 20 kt	3,960	486	1,057	37.006567	116.017473
U-3jn	03	Algodones	8/18/1971	20 to 200 kt	4,046	1,731	-102	37.057142	116.037199
U-3jp	03	Ocate	3/30/1972	Less than 20 kt	3,958	689	849	37.004444	116.015739
U-3jq	03	Monero	5/19/1972	Less than 20 kt	4,175	1,763	-50	37.064656	116.002614
U-3jr	03	Spar	12/19/1973	Less than 20 kt	3,960	490	1,057	37.005722	116.019762
U-3js	03	Onaja	3/30/1972	Less than 20 kt	3,960	915	629	37.005428	116.020940
U-3jt	03	Cuchillo	8/9/1972	Less than 20 kt	3,957	651	888	37.003706	116.019923
U-3ju	03	Frijoles-Espuela	9/22/1971	Less than 20 kt	3,979	490	1,081	37.022656	116.017195
U-3jv	03	Rib	12/14/1977	Less than 20 kt	3,973	700	866	37.017503	116.018779

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-3jw	03	Frijoles-Deming	9/22/1971	Less than 20 kt	3,977	492	1,077	NA	NA
U-3jx	03	Solano	8/9/1972	Less than 20 kt	3,957	439	1,097	37.003153	116.017567
U-3jy	03	Bernal	11/28/1973	Less than 20 kt	3,969	930	624	37.010944	116.025346
U-3k	03	Colfax	10/5/1958	5.5 tons	4,029	350	1,274	37.048794	116.035041
U-3kb	03	Marsh	9/6/1975	Less than 20 kt	3,983	1,400	174	37.023603	116.029179
U-3kc	03	Bilge	2/19/1975	Less than 20 kt	3,956	1,047	498	37.002156	116.025429
U-3kd	03	Deck	11/18/1975	Less than 20 kt	3,978	1,070	480	37.020264	116.021498
U-3kf	03	Forefoot	6/2/1977	Less than 20 kt	4,047	635	1,006	37.054894	116.025832
U-3kg	03	Puddle	11/26/1974	Less than 20 kt	3,925	600	973	37.000983	116.012073
U-3ki	03	Cove	2/16/1977	Less than 20 kt	3,963	1,100	456	37.006589	116.032235
U-3kj	03	Jackpots	6/1/1978	Less than 20 kt	3,979	1,000	574	37.020597	116.032813
U-3kk	03	Cernada	9/24/1981	Less than 20 kt	3,964	699	854	37.008472	116.024668
U-3km	03	Oarlock	2/16/1977	Less than 20 kt	3,970	1,050	520	37.013439	116.029435
U-3kn	03	Concentration	12/1/1978	Less than 20 kt	3,991	800	774	37.029619	116.024999
U-3kp	03	Seamount	11/17/1977	Less than 20 kt	3,979	1,220	357	37.020556	116.025943
U-3kq	03	Memory	3/14/1979	Less than 20 kt	3,995	1,200	393	37.027780	116.040621
U-3kr	03	Clairette	2/5/1981	Less than 20 kt	3,968	1,160	400	37.010847	116.033049
U-3ks	03	Offshore	8/8/1979	20 to 150 kt	3,966	1,300	249	37.014700	116.008873
U-3kt	03	Ebbtide	9/15/1977	Less than 20 kt	4,005	1,250	353	37.032744	116.044005
U-3ku	03	Verdello	7/31/1980	Less than 20 kt	3,969	1,200	361	37.012994	116.023615
U-3kv	03	Victoria	6/19/1992	Less than 20 kt	3,956	800	733	37.005372	116.011009
U-3kw	06	Freezeout	5/11/1979	Less than 20 kt	3,951	1,100	429	36.998136	116.018603
U-3kx	03	Canfield	5/2/1980	Less than 20 kt	4,060	1,150	502	37.055961	116.019826
U-3ky	03	Huron King	6/24/1980	Less than 20 kt	3,985	1,050	529	37.023247	116.035004
U-3kz	03	Aleman	9/11/1986	Less than 20 kt	4,085	1,650	-92	37.069033	116.050561
U-3La	03	Bouschet	5/7/1982	20 to 150 kt	4,083	1,850	-278	37.069014	116.046331
U-3Lb	03	Navata	9/29/1983	Less than 20 kt	4,048	600	1,040	37.053361	116.021221
U-3Lc	06	Sabado	8/11/1983	Less than 20 kt	3,946	1,050	462	36.997639	116.003536
U-3Ld	06	Villita	11/10/1984	Less than 20 kt	3,952	1,225	310	37.000056	116.018245
U-3Lf	03	Cerro	9/2/1982	Less than 20 kt	3,975	750	817	37.019686	116.016537
U-3Lg	03	Flora	5/22/1980	Less than 20 kt	3,958	1,100	449	37.003017	116.032263
U-3Lh	03	Tenaja	4/17/1982	Less than 20 kt	3,952	1,171	373	37.016769	116.010734
U-3Li	03	Mogollon	4/20/1986	Less than 20 kt	3,985	850	726	37.011608	116.046919
U-3Lj	03	Trebbiano	9/4/1981	Less than 20 kt	4,061	1,000	593	37.058039	116.048944
U-3Lk	06	Monahans-A	11/9/1988	Less than 20 kt	3,945	950	570	36.991144	116.021948
U-3LL	03	Tornero	2/11/1987	Less than 20 kt	3,981	979	596	37.010639	116.045555
U-3Lm	03	Seyval	11/12/1982	Less than 20 kt	3,984	1,200	377	37.023619	116.032946
U-3Lo	03	Coalora	2/11/1983	Less than 20 kt	4,058	899	714	37.056103	116.046214

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-3Lp	03	Whiteface-A	12/20/1989	Less than 20 kt	3,985	647	933	37.025814	116.032071
U-3Lp	03	Whiteface-B	12/20/1989	Less than 20 kt	3,985	600	980	37.025814	116.032071
U-3Lr	03	Vaughn	3/15/1985	20 to 150 kt	4,062	1,400	207	37.058025	116.046197
U-3Ls	03	Muggins	12/9/1983	Less than 20 kt	3,987	801	780	37.012705	116.046566
U-3Lt	03	Minero	12/20/1984	Less than 20 kt	3,985	800	776	37.011897	116.045574
U-3Lu	06	Waco	12/1/1987	Less than 20 kt	3,946	600	911	36.996361	116.005331
U-3Lv	06	Duoro	6/20/1984	20 to 150 kt	3,961	1,250	306	37.000330	116.043927
U-3Lw	03	Correo	8/2/1984	Less than 20 kt	3,966	1,100	461	37.016758	116.008511
U-3Lz	03	Chamita	8/17/1985	Less than 20 kt	3,964	1,100	471	37.002253	116.043913
U-3m	03	Luna	9/21/1958	1.5 tons	4,028	484	1,139	37.049194	116.034571
U-3mc	03	Abo	10/30/1985	Less than 20 kt	4,032	650	981	37.050561	116.037005
U-3me	03	Kinibito	12/5/1985	20 to 150 kt	4,052	1,900	-275	37.053219	116.046236
U-3mf	03	Tahoka	8/13/1987	20 to 150 kt	4,067	2,100	-497	37.060911	116.046175
U-3mg	06	Panchuela	6/30/1987	Less than 20 kt	3,957	1,050	505	36.998544	116.043941
U-3mh	03	Laredo	5/21/1988	Less than 150 kt	4,092	1,150	536	37.032436	115.988169
U-3mk	03	Bowie	4/6/1990	Less than 20 kt	4,257	700	1,162	37.067623	115.992992
U-3mL	03	Divider	9/23/1992	Less than 20 kt	4,055	1,115	534	37.020634	115.988778
U-3mn	03	Abilene	4/7/1988	Less than 20 kt	3,985	800	775	37.013111	116.045194
U-3mt	03	Lubbock	10/18/1991	20 to 150 kt	4,067	1,500	37	37.063383	116.046158
U-3n	03	Bernalillo	9/17/1958	0.015 kt	4,028	459	1,167	37.049511	116.034010
U-3p	03	San Juan	10/20/1958	Zero	4,029	234	1,390	37.049733	116.033385
U-3q	03	Otero	9/12/1958	0.038 kt	4,031	480	1,147	37.049847	116.032716
U-3r	03	Valencia	9/26/1958	2 tons	4,029	484	1,140	37.049539	116.030696
U-4a	04	Strait	3/17/1976	200 to 500 kt	4,168	2,560	-978	37.107239	116.053345
U-4aa	04	Trumbull	9/26/1974	Less than 20 kt	4,251	862	449	37.093158	116.095630
U-4ab	04	Temescal	11/2/1974	Less than 20 kt	4,234	862	599	37.093144	116.092544
U-4ac	04	Bellow	5/16/1984	Less than 20 kt	4,241	680	692	37.092463	116.094091
U-4af	04	Carnelian	7/28/1977	Less than 20 kt	4,238	682	931	37.097533	116.091824
U-4ah	04	Karab	3/16/1978	Less than 20 kt	4,182	1,086	636	37.085124	116.082491
U-4ai	04	Burzet	8/3/1979	20 to 150 kt	4,142	1,476	169	37.083902	116.070757
U-4aj	04	Monterey	7/29/1982	20 to 150 kt	4,200	1,312	311	37.102261	116.075843
U-4ak	04	Tilci	11/11/1981	20 to 150 kt	4,131	1,460	155	37.076272	116.069359
U-4aL	04	Manteca	12/10/1982	20 to 150 kt	4,144	1,355	308	37.080136	116.072760
U-4am	04	Ville	6/12/1985	Less than 20 kt	4,189	962	752	37.088266	116.084808
U-4an	04	Coso-Bronze	3/8/1991	Less than 20 kt	4,203	1,093	546	37.104316	116.074902
U-4an	04	Coso-Gray	3/8/1991	Less than 20 kt	4,204	1,450	189	37.104316	116.074902
U-4an	04	Coso-Silver	3/8/1991	Less than 20 kt	4,204	1,558	80	37.104316	116.074902
U-4ar	04	Breton	9/13/1984	20 to 150 kt	4,149	1,585	65	37.086638	116.072046

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-4as	04	Roquefort	10/16/1985	20 to 150 kt	4,488	1,362	303	37.109899	116.122254
U-4at	04	Palisade-1	5/15/1989	Less than 20 kt	4,479	1,100	508	37.107563	116.121756
U-4at	04	Palisade-2	5/15/1989	Less than 20 kt	4,479	1,280	328	37.107563	116.121756
U-4at	04	Palisade-3	5/15/1989	Less than 20 kt	4,479	1,325	284	37.107563	116.121756
U-4au	04	Bullfrog	8/30/1988	Less than 150 kt	4,145	1,605	37	37.085883	116.069387
U-4av	04	Bristol	11/26/1991	Less than 20 kt	4,178	1,500	82	37.096438	116.070482
U-4b	04	Mackerel	2/18/1964	Less than 20 kt	4,145	1,095	493	37.095580	116.051592
U-4c	04	Zaza	9/27/1967	20 to 200 kt	4,158	2,188	-587	37.098719	116.054095
U-4d	04	Latir	2/27/1974	20 to 200 kt	4,167	2,103	-507	37.104211	116.053709
U-4e	04	Topgallant	2/28/1975	20 to 200 kt	4,173	2,340	-754	37.106153	116.057123
U-4f	04	Transom	5/10/1978	Zero	4,129	2,100	-550	37.087728	116.053498
U-4g	04	Iceberg	3/23/1978	20 to 150 kt	4,152	2,100	-509	37.101730	116.052017
U-4h	04	Scantling	8/19/1977	20 to 150 kt	4,175	2,300	-720	37.109986	116.055379
U-4i	04	Glencoe	3/22/1986	29 kt	4,136	2,000	-383	37.082958	116.066909
U-4j	04	Jornada	1/28/1982	139 kt	4,134	2,100	-530	37.091294	116.052103
U-4L	04	Quinella	2/8/1979	20 to 150 kt	4,159	1,900	-313	37.102436	116.055712
U-4n	04	Hearts	9/6/1979	140 kt	4,130	2,100	-549	37.088064	116.053653
U-4o	04	Techado	9/22/1983	Less than 150 kt	4,159	1,750	-131	37.105564	116.050270
U-4p	04	Rousanne	11/12/1981	20 to 150 kt	4,166	1,700	-61	37.108105	116.049848
U-4q	04	Caprock	5/31/1984	20 to 150 kt	4,146	1,969	-352	37.103086	116.048917
U-4r	04	Vermejo	10/2/1984	Less than 20 kt	4,119	1,150	383	37.085180	116.053673
U-4s	04	Tulia	5/26/1989	Less than 20 kt	4,125	1,300	239	37.085819	116.056001
U-4t	07	Gascon	11/14/1986	20 to 150 kt	4,144	1,946	-338	37.100380	116.048939
U-4u	07	Dalhart	10/13/1988	Less than 150 kt	4,120	2,100	-533	37.088950	116.050134
U-6a Shaft	06	Russet	3/5/1968	Less than 20 kt	3,929	393	1,114	36.969997	116.056680
U-6d	06	Presidio	4/22/1987	Less than 20 kt	3,932	1,050	453	36.983092	116.005447
U-6e	06	Austin	6/21/1990	Less than 20 kt	3,942	1,150	354	36.992789	116.005364
U-6g	06	Harlingen-A	8/23/1988	Less than 20 kt	3,945	950	569	36.991133	116.018873
U-6h	06	Harlingen-B	8/23/1988	Less than 20 kt	3,943	950	566	36.988661	116.018889
U-6i	06	Monahans-B	11/9/1988	Less than 20 kt	3,942	950	566	36.988678	116.021970
U-7a	07	Forest	10/31/1964	Less than 20 kt	4,255	1,269	574	37.107161	116.033111
U-7aa	03	Tajique	6/28/1972	Less than 20 kt	4,267	1,090	783	37.069545	115.992975
U-7ab	07	Redmud	12/8/1976	Less than 20 kt	4,251	1,400	350	37.079217	116.002487
U-7ac	07	Escabosa	7/10/1974	20 to 200 kt	4,102	2,100	-411	37.074983	116.032691
U-7ad	07	Miera	3/8/1973	20 to 200 kt	4,286	1,866	14	37.103544	116.027599
U-7ae	07	Strake	8/4/1977	20 to 150 kt	4,266	1,700	94	37.086523	116.007737
U-7af	07	Potrillo	6/21/1973	20 to 200 kt	4,207	1,865	-63	37.091989	116.028091
U-7ag	07	Obar	4/30/1975	20 to 200 kt	4,286	1,867	13	37.108806	116.029666

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-7ah	07	Mizzen	6/3/1975	20 to 200 kt	4,180	2,090	-331	37.094783	116.036978
U-7ai	03	Keelson	2/4/1976	20 to 200 kt	4,084	2,100	-430	37.069208	116.031027
U-7ajS	07	Rudder	12/28/1976	20 to 150 kt	4,205	2,100	-310	37.100447	116.037331
U-7ak	07	Esrom	2/4/1976	20 to 200 kt	4,216	2,150	-352	37.106547	116.038294
U-7aL	07	Draughts	9/27/1978	20 to 150 kt	4,139	1,450	277	37.073819	116.020702
U-7am	07	Bulkhead	4/27/1977	20 to 150 kt	4,219	1,950	-141	37.094739	116.028752
U-7an	07	Billet	7/27/1976	20 to 150 kt	4,099	2,085	-491	37.075322	116.044686
U-7ao	07	Pineau	7/16/1981	Less than 20 kt	4,220	670	1,131	37.088650	116.020238
U-7ap	07	Crewline	5/25/1977	20 to 150 kt	4,148	1,850	-218	37.094280	116.045731
U-7aq	07	Sandreef	11/9/1977	20 to 150 kt	4,094	2,300	-729	37.072058	116.050881
U-7at	07	Chess	6/20/1979	Less than 20 kt	4,384	1,100	882	37.107581	116.015957
U-7au	07	Rummy	9/27/1978	20 to 150 kt	4,111	2,100	-496	37.079755	116.052192
U-7av	07	Lowball	7/12/1978	20 to 150 kt	4,109	1,850	-245	37.078619	116.044656
U-7ax	07	Baccarat	1/24/1979	Less than 20 kt	4,389	1,070	917	37.105364	116.012546
U-7ay	07	Topmast	3/23/1978	Less than 20 kt	4,296	1,500	387	37.098814	116.020491
U-7b	07	Auk	10/2/1964	Less than 20 kt	4,203	1,484	250	37.077878	116.009357
U-7ba	07	Baseball	1/15/1981	20 to 150 kt	4,129	1,850	-346	37.087041	116.045619
U-7bd	07	Paliza	10/1/1981	20 to 150 kt	4,224	1,550	201	37.081572	116.009621
U-7be	07	Pyramid	4/16/1980	20 to 150 kt	4,241	1,900	-72	37.101072	116.031400
U-7bg	07	Aligote	5/29/1981	Less than 20 kt	4,388	1,050	937	37.101806	116.004932
U-7bh	07	Fahada	5/26/1983	Less than 20 kt	4,392	1,260	728	37.102859	116.006568
U-7bi	07	Dolcetto	8/30/1984	Less than 20 kt	4,324	1,200	667	37.089748	116.000234
U-7bk	07	Muleshoe	11/15/1989	Less than 20 kt	4,391	800	1,187	37.106469	116.014246
U-7bL	07	Tajo	6/5/1986	20 to 150 kt	4,317	1,700	208	37.098242	116.016379
U-7bm	07	Dutchess	10/24/1980	Less than 20 kt	4,238	1,401	351	37.074528	116.000131
U-7bo	07	Mundo	5/1/1984	20 to 150 kt	4,328	1,860	67	37.106175	116.023249
U-7bp	07	Atrisco	8/5/1982	138 kt	4,248	2,100	-334	37.084159	116.007415
U-7br	07	Borrego	9/29/1982	Less than 150 kt	4,137	1,850	-230	37.091255	116.045756
U-7bs	07	Hermosa	4/2/1985	20 to 150 kt	4,192	2,100	-318	37.094764	116.033211
U-7bu	07	Turquoise	4/14/1983	Less than 150 kt	4,088	1,749	-174	37.072789	116.046825
U-7bv	07	Ponil	9/27/1985	Less than 20 kt	4,300	1,200	628	37.089761	116.002634
U-7by	07	Midland	7/16/1987	20 to 150 kt	4,300	1,600	297	37.103506	116.024222
U-7ca	07	Texarkana	2/10/1989	20 to 150 kt	4,244	1,650	49	37.076736	116.001481
U-7cb	07	Floydada	8/15/1991	Less than 20 kt	4,287	1,650	137	37.087286	116.002656
U-7e	07	Piranha	5/13/1966	20 to 200 kt	4,146	1,800	-73	37.086803	116.034311
U-7f	07	Bronze	7/23/1965	20 to 200 kt	4,213	1,742	55	37.097786	116.033872
U-7g	07	Charcoal	9/10/1965	20 to 200 kt	4,172	1,494	254	37.077919	116.017582
U-7h	07	Cabresto	5/24/1973	Less than 20 kt	4,118	649	1,053	37.078000	116.031638

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-7i	07	Lampblack	1/18/1966	20 to 200 kt	4,246	1,842	-5	37.091656	116.019549
U-7j	07	Lime	4/1/1966	Less than 20 kt	4,325	1,842	77	37.102658	116.020805
U-7k	03	Tan	6/3/1966	20 to 200 kt	4,070	1,840	-204	37.068411	116.036174
U-7m	07	Mickey	5/10/1967	20 to 200 kt	4,280	1,639	242	37.077803	115.996159
U-7n	07	Bourbon	1/20/1967	20 to 200 kt	4,374	1,836	135	37.099825	116.004707
U-7o	07	Daiquiri	9/23/1966	Less than 20 kt	4,223	1,841	-36	37.103300	116.036569
U-7p	07	Blenton	4/30/1969	20 to 200 kt	4,205	1,830	-72	37.081475	116.014810
U-7r	07	Shaper	3/23/1970	20 to 200 kt	4,195	1,839	-52	37.086186	116.021966
U-7s	07	Grape A	12/17/1969	20 to 200 kt	4,268	1,807	-39	37.083334	116.002451
U-7t	07	Thistle	4/30/1969	20 to 200 kt	4,291	1,839	-16	37.090220	116.006509
U-7u	07	Cobbler	11/8/1967	Less than 20 kt	4,165	2,189	-446	37.091761	116.036669
U-7v	07	Grape B	2/4/1970	20 to 200 kt	4,253	1,818	27	37.098028	116.027355
U-7w	07	Torrido	5/27/1969	20 to 200 kt	4,256	1,689	169	37.075056	115.996181
U-7x	07	Artesia	12/16/1970	20 to 200 kt	4,360	1,591	361	37.100123	116.008824
U-7y	07	Tijeras	10/14/1970	20 to 200 kt	4,187	1,839	-122	37.070609	116.005993
U-7z	07	Oscuro	9/21/1972	20 to 200 kt	4,108	1,838	-154	37.082011	116.037436
U-8a	08	Discus Thrower	5/27/1966	22 kt	4,615	1,106	1,062	37.178341	116.098631
U-8b	08	Cyathus	3/6/1970	8.7 kt	4,526	964	1,039	37.173071	116.092625
U-8c	08	Norbo	3/8/1980	Less than 20 kt	4,515	889	1,207	37.179897	116.083992
U-8d	08	Baneberry	12/18/1970	10 kt	4,573	912	1,216	37.173083	116.099734
U-8e	08	Cremino	9/27/1978	Less than 20 kt	4,488	689	1,240	37.170963	116.088036
U-8e	08	Cremino-Caerphilly	9/27/1978	Less than 20 kt	4,488	1,378	551	37.170963	116.088036
U-8j	08	Cottage	3/23/1985	20 to 150 kt	4,556	1,690	366	37.179927	116.089828
U-8k	08	Vide	4/30/1981	Less than 20 kt	4,506	1,060	1,021	37.177286	116.085633
U-8L	08	Seco	2/25/1981	Less than 20 kt	4,538	656	1,463	37.181849	116.085119
U-8m	08	Frisco	9/23/1982	20 to 150 kt	4,507	1,480	432	37.174702	116.088667
U-8n	08	Kawich A-Blue	12/9/1988	Less than 20 kt	4,542	1,260	512	37.175271	116.092609
U-8n	08	Kawich A-White	12/9/1988	Less than 20 kt	4,542	1,211	562	37.175271	116.092609
U-9 ITS AA-25	09	Piton-C	5/28/1970	Less than 20 kt	4,284	330	1,550	37.138422	116.030786
U-9 ITS S-25	09	Baltic	8/6/1971	Less than 20 kt	4,222	1,350	443	37.138483	116.041767
U-9 ITS T-28	09	Avens-Andorre	12/16/1970	Less than 20 kt	4,236	1,245	577	37.141769	116.040367
U-9 ITS U-24	09	Avens-Alkermes	12/16/1970	Less than 20 kt	4,227	1,004	814	37.137372	116.039031
U-9 I V-24	09	Fob-Red	1/23/1970	Less than 20 kt	4,232	872	953	37.137364	116.037664
U-9 ITS V-26	09	Arabis-Red	3/6/1970	Less than 20 kt	4,238	820	1,012	37.139531	116.032156
U-9 I V-27	09	Fob-Green	1/23/1970	Less than 20 kt	4,242	802	1,034	37.140658	116.037636
U-9 ITS W-21	09	Avens-Asamlte	12/16/1970	Less than 20 kt	4,234	1,005	818	37.134061	116.036320
U-9 ITS W-22	09	Haplopappus	6/28/1972	Less than 20 kt	4,237	605	1,226	37.135156	116.036134
U-9 ITS X-20	09	Hod-B (Red)	5/1/1970	Less than 20 kt	4,242	870	967	37.132953	116.034947

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-9 ITS X-23	09	Hod-A (Green)	5/1/1970	Less than 20 kt	4,248	790	1,054	37.136250	116.034925
U-9 ITS X-24	09	Scree-Acajou	10/13/1970	Less than 20 kt	4,252	820	1,030	37.137403	116.034914
U-9 ITS X-27	09	Piton-B	5/28/1970	Less than 20 kt	4,255	750	1,098	37.140639	116.034881
U-9 ITS X-28	09	Arabis-Green	3/6/1970	Less than 20 kt	4,256	849	1,004	37.141742	116.034878
U-9 ITS X-29	09	Avens-Cream	12/16/1970	Less than 20 kt	4,260	965	896	37.142836	116.034867
U-9 ITS XY-31	09	Nama-Amarylis	8/5/1971	Less than 20 kt	4,266	895	968	37.145033	116.034164
U-9 I Y-27	09	Fob-Blue	1/23/1970	Less than 20 kt	4,264	330	1,531	37.140633	116.033511
U-9 ITS Y-30	09	Piton-A	5/28/1970	Less than 20 kt	4,268	775	1,088	37.143931	116.033489
U-9 ITS Z-21	09	Scree-Alhambra	10/13/1970	Less than 20 kt	4,265	630	1,231	37.134039	116.032197
U-9 ITS Z-24	09	Scree-Chamois	10/13/1970	Less than 20 kt	4,271	330	1,538	37.137303	116.032172
U-9 I Z-25	09	Hod-C (Blue)	5/1/1970	Less than 20 kt	4,273	330	1,540	37.138431	116.032161
U-9 ITS Z-26	09	Arabis-Blue	3/6/1970	Less than 20 kt	4,275	330	1,542	37.139558	116.037645
U-9 ITS Z-27	09	Nama-Mephisto	8/5/1971	Less than 20 kt	4,275	800	1,072	37.140628	116.032144
U-9a	09	Mad	12/13/1961	0.500 kt	4,204	596	1,167	37.126555	116.049629
U-9aa	09	Taunton	12/4/1962	Low	4,209	745	1,018	37.128036	116.050876
U-9ab	09	Kaweah	2/21/1963	3 kt	4,187	745	1,007	37.120269	116.046581
U-9ac	09	Toyah	3/15/1963	Low	4,196	428	1,337	37.125783	116.045645
U-9ad	09	Mississippi	10/5/1962	115 kt	4,234	1,620	168	37.139355	116.051195
U-9ae	07	Stones	5/22/1963	Intermediate	4,213	1,290	504	37.111003	116.039936
U-9af	09	Manatee	12/14/1962	Low	4,202	196	1,587	37.124194	116.040828
U-9ah	09	Pleasant	5/29/1963	Low	4,198	692	1,079	37.128028	116.044289
U-9ai	09	Apshapa	6/6/1963	Low	4,203	292	1,493	37.124605	116.040853
U-9aj	09	Garden	10/23/1964	Less than 20 kt	4,269	491	1,372	37.116986	116.032019
U-9ak	09	Kohocton	8/23/1963	Low	4,267	836	1,022	37.124914	116.036256
U-9ak #1 Zero Station	09	Natches	8/23/1963	Low	4,227	194	1,624	37.124914	116.036119
U-9aL	09	Ajax	11/11/1966	Less than 20 kt	4,202	787	981	37.134408	116.050723
U-9ao	09	Fore	1/16/1964	20 to 200 kt	4,231	1,611	177	37.142233	116.049976
U-9ap	09	Rack	8/15/1968	Less than 20 kt	4,201	655	1,104	37.123686	116.049092
U-9aq	09	Tornillo	10/11/1963	380 tons	4,244	491	1,343	37.118692	116.034731
U-9ar	09	Driver	5/7/1964	Less than 20 kt	4,200	492	1,295	37.120214	116.041167
U-9at	09	Mustang	11/15/1963	Low	4,212	544	1,234	37.132247	116.047756
U-9au	09	Bogey	4/17/1964	Less than 20 kt	4,238	391	1,438	37.119436	116.034761
U-9av	09	Eagle	12/12/1963	5.3 kt	4,203	541	1,233	37.130972	116.044748
U-9aw	09	Backswing	5/14/1964	Less than 20 kt	4,213	527	1,260	37.117306	116.039814
U-9ax	09	Greys	11/22/1963	Intermediate	4,182	988	762	37.119275	116.046042
U-9ay	09	Oconto	1/23/1964	10.5 kt	4,221	869	942	37.126372	116.037164
U-9az	09	Tinderbox	11/22/1968	Less than 20 kt	4,225	1,450	353	37.139864	116.043128
U-9b	09	White	5/25/1962	Low	4,200	632	1,120	37.124811	116.052859

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-9ba	09	Handicap	3/12/1964	Less than 20 kt	4,225	471	1,345	37.129889	116.037209
U-9bb	09	Bunker	2/13/1964	Less than 20 kt	4,254	745	1,108	37.131967	116.033211
U-9bc	09	Hook	4/14/1964	Less than 20 kt	4,274	670	1,202	37.128878	116.030697
U-9bd	09	Spoon	9/11/1964	Less than 20 kt	4,316	590	1,322	37.113675	116.026366
U-9be	09	Fade	6/25/1964	Less than 20 kt	4,287	673	1,209	37.111086	116.029647
U-9bf	09	Links	7/23/1964	Less than 20 kt	4,265	395	1,461	37.113711	116.032883
U-9bg	09	Chenille	4/22/1965	Less than 20 kt	4,276	462	1,406	37.111375	116.031358
U-9bh	09	Wool	1/14/1965	Less than 20 kt	4,310	709	1,200	37.118975	116.025638
U-9bi #1 Zero Station	09	Terrine-White	12/18/1969	20 to 200 kt	4,235	1,500	325	37.120431	116.035642
U-9bi #2 Zero Station	09	Terrine-Yellow	12/18/1969	20 to 200 kt	4,278	1,370	506	37.120639	116.029478
U-9bj	09	Ticking	8/21/1965	Less than 20 kt	4,314	684	1,220	37.112583	116.026891
U-9bk	09	Suede	3/20/1965	Less than 20 kt	4,307	470	1,435	37.115378	116.027364
U-9bm	09	Seersucker	2/19/1965	Less than 20 kt	4,269	473	1,390	37.117231	116.031855
U-9bn	09	Tweed	5/21/1965	Less than 20 kt	4,292	933	957	37.118497	116.028555
U-9bo	09	Organdy	6/11/1965	Less than 20 kt	4,332	554	1,360	37.115728	116.024122
U-9bp	09	Izzer	7/16/1965	Less than 20 kt	4,264	537	1,318	37.114950	116.033044
U-9br	09	Maxwell	1/13/1966	Less than 20 kt	4,298	600	1,295	37.116164	116.028403
U-9bs	07	Elkhart	9/17/1965	Less than 20 kt	4,245	723	1,109	37.110981	116.035478
U-9bt	09	Templar	3/24/1966	370 tons	4,271	492	1,370	37.113292	116.032219
U-9bu	09	Hula	10/29/1968	Less than 20 kt	4,202	658	1,131	37.113211	116.041803
U-9bv	09	Switch	6/22/1967	3.1 kt	4,277	991	885	37.125508	116.029525
U-9bx	09	Noggin	9/6/1968	20 to 200 kt	4,220	1,910	-126	37.136019	116.048029
U-9by	09	Valise	3/18/1969	Less than 20 kt	4,225	300	1,497	37.139091	116.041714
U-9bz	09	Biggin	1/30/1969	Less than 20 kt	4,212	800	993	37.133258	116.041125
U-9c	09	Stillwater	2/8/1962	3.07 kt	4,220	595	1,167	37.127203	116.053523
U-9cb	09	Cup	3/26/1965	20 to 200 kt	4,245	1,768	44	37.147553	116.043762
U-9cc	09	Player	8/27/1964	Less than 20 kt	4,201	296	1,486	37.117311	116.041531
U-9ce	09	Clymer	3/12/1966	Less than 20 kt	4,242	1,306	488	37.143628	116.053390
U-9cf	09	Vat	10/10/1968	Less than 20 kt	4,208	630	1,141	37.133264	116.043184
U-9cg	09	Gruyere	8/16/1977	Less than 20 kt	4,232	679	1,107	37.145116	116.049948
U-9cg	09	Gruyere-Gradino	8/16/1977	Less than 20 kt	4,232	1,050	737	37.145116	116.049948
U-9ch	09	Cathay	10/8/1971	Less than 20 kt	4,226	1,240	570	37.113742	116.038197
U-9ci	09	Arsenate	11/9/1972	Less than 20 kt	4,249	821	1,023	37.121397	116.033194
U-9cj	09	Alumroot	2/14/1973	Less than 20 kt	4,237	600	1,191	37.147044	116.050962
U-9ck	09	Silene	6/28/1973	Less than 20 kt	4,202	650	1,132	37.114861	116.041789
U-9cL	09	Teleme	2/6/1975	Less than 20 kt	4,354	1,000	949	37.114067	116.021905
U-9cm	09	Leyden	11/26/1975	Less than 20 kt	4,363	1,070	889	37.117214	116.019752
U-9cn	09	Kesti	6/16/1982	Less than 20 kt	4,391	948	1,043	37.114181	116.017449

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-9cp	09	Campos	2/13/1978	Less than 20 kt	4,253	1,050	801	37.126069	116.032608
U-9cq	09	Dauphin	11/14/1980	Less than 20 kt	4,372	1,050	919	37.111444	116.019527
U-9cr	09	Niza	7/10/1981	Less than 20 kt	4,242	1,119	717	37.128556	116.034644
U-9cs	09	Armada	4/22/1983	Less than 20 kt	4,339	869	1,067	37.111464	116.023299
U-9cv	09	Galena-Green	6/23/1992	Less than 20 kt	4,251	1,316	536	37.123872	116.032111
U-9cv	09	Galena-Orange	6/23/1992	Less than 20 kt	4,251	1,250	601	37.123872	116.032111
U-9cv	09	Galena-Yellow	6/23/1992	Less than 20 kt	4,251	951	897	37.123872	116.032111
U-9cw	09	Cebrero	8/14/1985	Less than 20 kt	4,405	600	1,404	37.111033	116.015246
U-9d	09	Brazos	3/8/1962	8.4 kt	4,201	841	905	37.122116	116.049751
U-9e	09	Hatchie	2/8/1963	Low	4,208	200	1,592	37.125911	116.039517
U-9f	09	Tioga	10/18/1962	Low	4,203	195	1,587	37.128503	116.041114
U-9g	09	Codsaw	2/19/1962	Low	4,217	696	1,108	37.127406	116.037989
U-9h	09	Cimarron	2/23/1962	11.90 kt	4,208	1,000	770	37.128808	116.049179
U-9i	09	Anacostia	11/27/1962	5.2 kt	4,268	744	1,119	37.122761	116.029889
U-9j	09	Hoosic	3/28/1962	3.40 kt	4,235	613	1,214	37.124272	116.034747
U-9k	09	Dead	4/21/1962	Low	4,261	635	1,221	37.118958	116.032392
U-9L	09	Passaic	4/6/1962	Low	4,183	766	993	37.117628	116.044881
U-9m	09	Eel	5/19/1962	4.5 kt	4,200	714	1,046	37.122589	116.048078
U-9n	09	Hudson	4/12/1962	Low	4,200	495	1,273	37.127130	116.045737
U-9p	09	Black	4/27/1962	Low	4,217	714	1,088	37.118411	116.038639
U-9q	09	Roanoke	10/12/1962	Low	4,198	580	1,230	37.122689	116.051681
U-9r	09	Arikaree	5/10/1962	Low	4,204	546	1,219	37.127539	116.049168
U-9u	09	Raritan	9/6/1962	Low	4,204	516	1,260	37.130264	116.045606
U-9v	09	Sacramento	6/30/1962	Low	4,177	489	1,240	37.117366	116.048287
U-9w	09	Kootanai	4/24/1963	Low	4,225	597	1,215	37.120550	116.037147
U-9w #1	09	Paisano	4/24/1963	Low	4,225	187	1,623	37.120481	116.037044
U-9 ITS W-24.5	09	Solanum	12/14/1972	Less than 20 kt	4,246	660	1,242	37.138036	116.035595
U-9x	09	Allegheny	9/29/1962	Low	4,258	692	1,157	37.116631	116.033647
U-9y	09	Wichita	7/27/1962	Low	4,239	493	1,301	37.129666	116.057354
U-9 ITS yz-26	09	Canna-Limoges	11/17/1972	Less than 20 kt	4,265	700	1,162	37.139536	116.033233
U-9 ITS yz-26	09	Canna-Umbrinus	11/17/1972	Less than 20 kt	4,265	600	1,262	37.139536	116.033233
U-9z	09	York	8/24/1962	Low	4,208	743	1,047	37.118589	116.040353
U-10a	10	Dub	6/30/1964	11.7 kt	4,293	850	1,037	37.174380	116.057266
U-10aa	10	Rivet I	1/18/1967	Less than 20 kt	4,273	498	1,361	37.165072	116.047418
U-10ab	10	Vito	7/14/1967	Less than 20 kt	4,280	317	1,557	37.165200	116.045801
U-10ad	10	Vigil	11/22/1966	Less than 20 kt	4,281	300	1,569	37.169336	116.049184
U-10af	10	Yard	9/7/1967	20 to 200 kt	4,257	1,710	113	37.153111	116.053654
U-10ag	10	Worth	10/25/1967	Less than 20 kt	4,251	615	1,152	37.156291	116.049465

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-10ah	10	Staccato	1/19/1968	20 to 200 kt	4,261	1,455	379	37.156339	116.054751
U-10ai	10	Polka	12/6/1967	Less than 20 kt	4,263	625	1,191	37.159219	116.053821
U-10aj A	10	Tub-F	6/6/1968	Less than 20 kt	4,294	620	1,268	37.166925	116.042920
U-10aj B	10	Tub-B	6/6/1968	Less than 20 kt	4,285	620	1,261	37.165358	116.044309
U-10aj C	10	Tub-A	6/6/1968	Less than 20 kt	4,294	620	1,268	37.167433	116.043359
U-10aj D	10	Tub-D	6/6/1968	Less than 20 kt	4,282	896	981	37.166936	116.045676
U-10aj F	10	Tub-C	6/6/1968	Less than 20 kt	4,298	620	1,272	37.165347	116.041551
U-10ak	10	Crock	5/8/1968	Less than 20 kt	4,317	596	1,317	37.157275	116.035787
U-10am #1 Zero Station	08	Tun-A	12/10/1969	Less than 20 kt	4,429	655	1,351	37.167655	116.080144
U-10am #2 Zero Station	08	Tun-B	12/10/1969	Less than 20 kt	4,434	636	1,376	37.169441	116.080130
U-10am #3 Zero Station	08	Tun-C	12/10/1969	Less than 20 kt	4,415	636	1,359	37.167641	116.077914
U-10am #4 Zero Station	08	Tun-D	12/10/1969	Less than 20 kt	4,420	841	1,159	37.169427	116.077891
U-10an	10	Labis	2/5/1970	25 kt	4,308	1,450	452	37.163914	116.039701
U-10ap #1	10	Cornice-Yellow	5/15/1970	20 to 200 kt	4,329	1,280	636	37.165881	116.036359
U-10ap #3	10	Cornice-Green	5/15/1970	20 to 200 kt	4,306	1,455	447	37.161872	116.039723
U-10aq	10	Bracken	7/9/1971	Less than 20 kt	4,342	1,000	920	37.164403	116.033603
U-10ar	10	Lagoon	10/14/1971	Less than 20 kt	4,307	1,000	887	37.179733	116.053960
U-10as	10	Pinedrops-Bayou	1/10/1974	Less than 20 kt	4,298	1,125	764	37.174078	116.051668
U-10as	10	Pinedrops-Sloat	1/10/1974	Less than 20 kt	4,298	700	1,189	37.174078	116.051668
U-10as	10	Pinedrops-Tawny	1/10/1974	Less than 20 kt	4,298	925	964	37.174078	116.051668
U-10at	10	Dianthus	2/17/1972	Less than 20 kt	4,285	1,000	877	37.165655	116.057110
U-10av	10	Kashan	5/24/1973	Less than 20 kt	4,278	870	989	37.162183	116.056846
U-10aw	10	Natoma	4/5/1973	Less than 20 kt	4,297	800	1,082	37.177828	116.054765
U-10ax	10	Akbar	11/9/1972	Less than 20 kt	4,337	875	1,053	37.161994	116.034023
U-10ay	10	Chevre	11/23/1976	Less than 20 kt	4,281	1,040	836	37.171658	116.053543
U-10b	08	Handcar	11/5/1964	12 kt	4,375	1,323	641	37.174324	116.067902
U-10ba	10	Dofino	3/8/1977	Less than 20 kt	4,296	600	1,285	37.176147	116.053826
U-10ba	10	Dofino-Lawton	3/8/1977	Less than 20 kt	4,296	925	959	37.176147	116.053826
U-10bb	10	Portola	2/6/1975	Less than 20 kt	4,305	650	1,236	37.178361	116.052424
U-10bb	10	Portola-Larkin	2/6/1975	Less than 20 kt	4,305	900	986	37.178361	116.052424
U-10bc	10	Asco	4/25/1978	Less than 20 kt	4,305	600	1,301	37.154517	116.035631
U-10bd	10	Pera	9/8/1979	Less than 20 kt	4,289	656	1,229	37.154947	116.039059
U-10be	08	Orkney	5/2/1984	Less than 20 kt	4,522	689	1,299	37.198428	116.054835
U-10bf	10	Queso	8/11/1982	Less than 20 kt	4,387	709	1,163	37.189744	116.048554
U-10bg	10	Havarti	8/5/1981	Less than 20 kt	4,298	656	1,239	37.153694	116.035945
U-10bh	10	Hazebrook-Apricot (Orange)	2/3/1987	Less than 20 kt	4,322	860	1,012	37.181094	116.049313
U-10bh	10	Hazebrook-Checker-berry (Red)	2/3/1987	Less than 20 kt	4,322	741	1,132	37.181094	116.049313

Appendix 2. Characteristics of underground nuclear detonations in Yucca Flat and vicinity, Nevada Test Site, 1951–1992—Continued

Land-surface altitude: Altitude in feet above sea level.

Shot distance above water table: Distance in feet. Negative values indicate distance below water table.

[NTS, Nevada Test Site; kt, kiloton; NAD83, North American Datum of 1983; NA, not available. Source of data: U.S. Department of Energy (2000)]

NTS hole name	NTS area no.	Test name	Test date	Test yield	Land-surface altitude	Burial depth (feet)	Shot distance above water table	Decimal Latitude (NAD83)	Decimal Longitude (NAD83)
U-10bh	10	Hazebrook-Emerald (Green)	2/3/1987	Less than 20 kt	4,322	610	1,262	37.181094	116.049313
U-10c	09	Turf	4/24/1964	20 to 200 kt	4,260	1,661	216	37.149544	116.056259
U-10ca	10	Jarlsberg	8/27/1983	Less than 20 kt	4,411	656	412	37.192892	116.034909
U-10cb	10	Normanna	7/12/1984	Less than 20 kt	4,404	656	491	37.191936	116.035248
U-10cc	15	Brie	6/18/1987	Less than 20 kt	4,413	666	405	37.193506	116.035884
U-10dS	10	Duffer	6/18/1964	Less than 20 kt	4,312	1,466	438	37.165947	116.039284
U-10dS #1	10	Marvel	9/21/1967	2.2 kt	4,312	577	1,327	37.165769	116.039212
U-10e	09	Klickitat	2/20/1964	70 kt	4,266	1,616	249	37.150839	116.040984
U-10f	09	Santee	10/27/1962	Low	4,253	1,045	760	37.149261	116.054376
U-10g	09	Casselman	2/8/1963	Low	4,247	994	806	37.148825	116.052746
U-10h	10	Sedan	7/6/1962	104 kt	4,317	635	1,212	37.176961	116.046257
U-10i	10	Bye	7/16/1964	20 to 200 kt	4,335	1,282	574	37.182161	116.046218
U-10k	10	Corduroy	12/3/1965	20 to 200 kt	4,273	2,227	-363	37.164691	116.053221
U-10m	10	Reo	1/22/1966	Less than 20 kt	4,296	683	1,209	37.157158	116.039559
U-10n	08	Mudpack	12/16/1964	2.7 kt	4,386	499	1,478	37.177758	116.067880
U-10p	10	Kankakee	6/15/1966	20 to 200 kt	4,292	1,492	393	37.171486	116.049743
U-10q	09	Stanley	7/27/1967	20 to 200 kt	4,237	1,587	209	37.148686	116.049404
U-10r	10	Washer	8/10/1967	Less than 20 kt	4,257	1,530	279	37.156644	116.048143
U-10s	10	Rovena	8/10/1966	Less than 20 kt	4,280	640	1,242	37.168619	116.048634
U-10t	10	Shuffle	4/18/1968	20 to 200 kt	4,285	1,618	264	37.152467	116.037881
U-10u	10	Newark	9/29/1966	Less than 20 kt	4,285	752	1,130	37.168611	116.046918
U-10w	10	Simms	11/5/1966	2.3 kt	4,286	652	1,228	37.169908	116.048082
U-10x	10	Ward	2/8/1967	Less than 20 kt	4,277	853	1,021	37.167475	116.048001
U-10y	10	Rivet III	3/2/1967	Less than 20 kt	4,270	898	963	37.165822	116.049571
U-10z	10	Rivet II	1/26/1967	Less than 20 kt	4,267	648	1,198	37.164750	116.048932
U-15a	15	Hard Hat	2/15/1962	5.7 kt	5,114	942	-215	37.226214	116.060186
U-15.01 Drift	15	Pile Driver	6/2/1966	62 kt	5,090	1,518	-910	37.227022	116.056413
U-15e Tunnel	15	Tiny Tot	6/17/1965	Less than 20 kt	5,022	364	384	37.223366	116.057838
Uncle Crater	10	Uncle	11/29/1951	1.2 kt	4,290	NA	1,855	37.169675	116.043370

Fenelon—ANALYSIS OF GROUND-WATER LEVELS AND ASSOCIATED TRENDS IN YUCCA FLAT, NEVADA TEST SITE, NYE COUNTY, NEVADA, 1951–2003—USGS SIR 2005–5175

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