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

Potentiometric Surface, Carbonate-Rock Province, Southern Nevada and Southeastern California, 1998–2000

Open-File Report 01-335

Prepared in cooperation with the
NEVADA DIVISION OF WATER RESOURCES

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U.S. Department of the Interior
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By Jon W. Wilson

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Carson City, Nevada
2001

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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CONTENTS

PLATE

[Plate is in pocket at back of report]

FIGURES

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)] + 32. Degrees Fahrenheit can be converted to degrees Celsius by using the formula °C = 0.556(°F – 32).

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.

Altitude, as used in this report, refers to distance above or below sea level.

Note: English units are used thoughout this report, except in instances where a measurement has no common English-unit equivalent.

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ABSTRACT

The carbonate-rock aquifer that underlies most of southern Nevada occupies part of what is known as the carbonate-rock province, a physiographic region that encompasses the eastern two-thirds of the Great Basin. The potential for development of water resources in this aquifer has prompted Federal, State, and local authorities to seek additional information about the quality and quantity of ground water in the carbonate-rock province.

Investigations of the region's hydrogeology have been ongoing since the early 1900's. U.S. Geological Survey studies dating from 1975 to 1996 used these data to identify temporal changes of water levels in wells, regional potentiometric surfaces, and the direction of regional ground-water flow in southern Nevada. In the current study, the ground-water potentiometric surface in a 20,000-square-mile section of the regional carbonate-rock aquifer in southern Nevada and southeastern California was identified based on interpretation of water-level data collected from 1998 through 2000. Also included are hydrographs that were constructed from water-level data collected from 1985 through 2000. The hydrographs and accompanying map provide a generalized picture of water levels in consolidated rocks of the southern portion of the carbonate-rock province. Interpretation of the potentiometric surface was constrained by the limited number of wells completed in the carbonate-rock aquifer.

INTRODUCTION

The potentiometric surface of water levels measured from 1998 through 2000 in the carbonate-rock province in southern Nevada and southeastern California is shown on plate 1, which was prepared in cooperation with the Nevada Division of Water Resources. The water-level contours displayed are similar to and modeled after work by Winograd and Thordarson (1975), Waddell and others (1984), Thomas and others (1986, 1996), and Laczniak and others (1996). The carbonate-rock province, as defined by Mifflin (1968), Hess and Mifflin (1978), and Harrill and others (1983), encompasses about 100,000 mi^2 of the eastern half of the Great Basin, and includes the eastern half of Nevada, much of western Utah, and part of southeastern Idaho (pl. 1). Plate 1 focuses on about 20,000 mi^2 of the carbonate-rock province in southern Nevada.

Purpose and Scope

The purpose of this report is to provide a current, generalized description of ground-water levels in consolidated rocks of the carbonate-rock province in southern Nevada. These ground-water levels are shown on plate 1 as contour lines that represent the regional potentiometric surface of ground water based on measurements made from 1998 through 2000. Also included in the report are 26 hydrographs that convey general water-level trends in the map area from 1985 through 2000. These hydrographs show water-level measurements in wells completed primarily in carbonate rock (fig. 1); water-level measurements in wells completed in basin-fill deposits (fig. 2); and discharge data from selected springs that issue primarily from

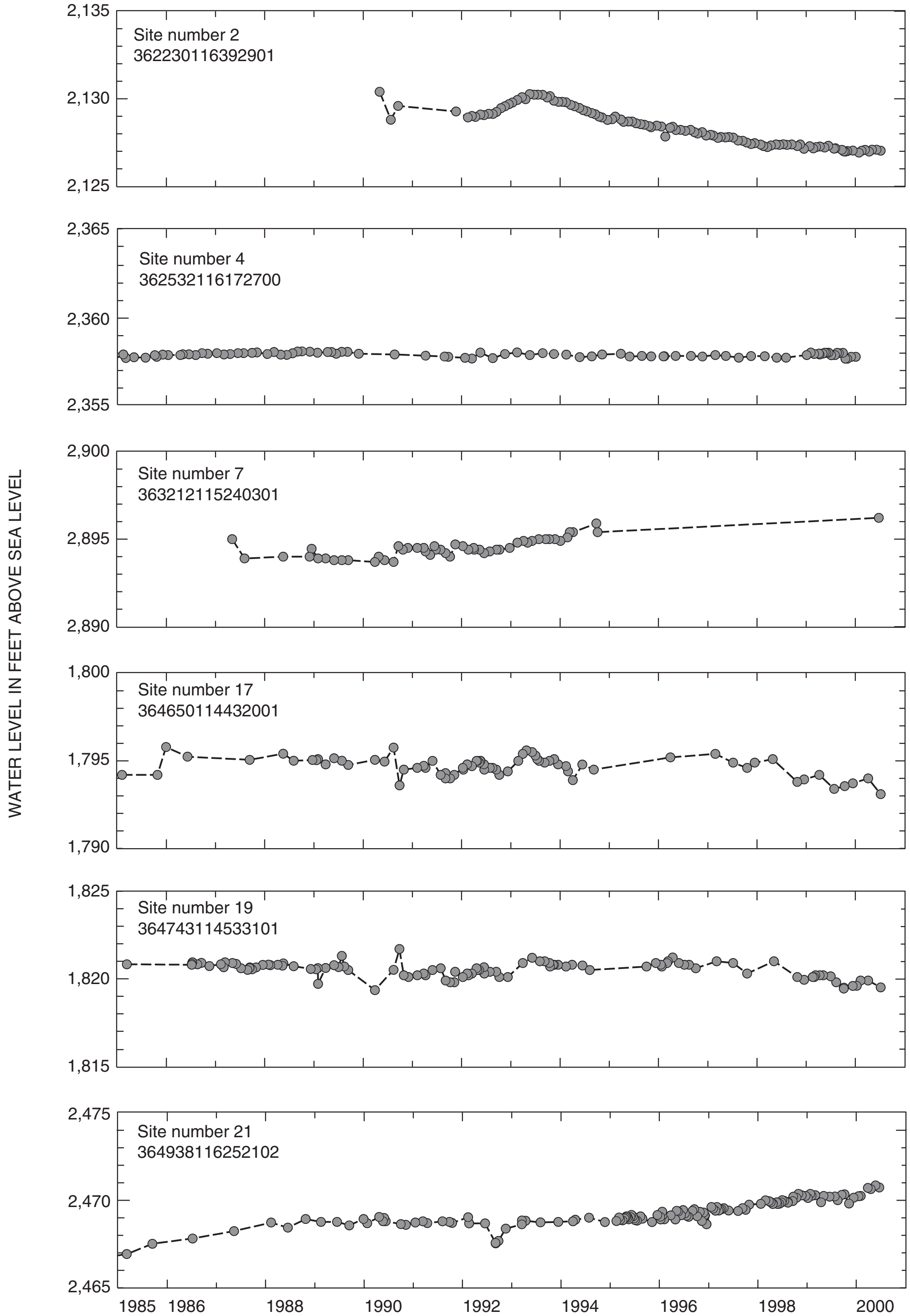

Figure 1. Water levels from selected wells in primarily carbonate rock.

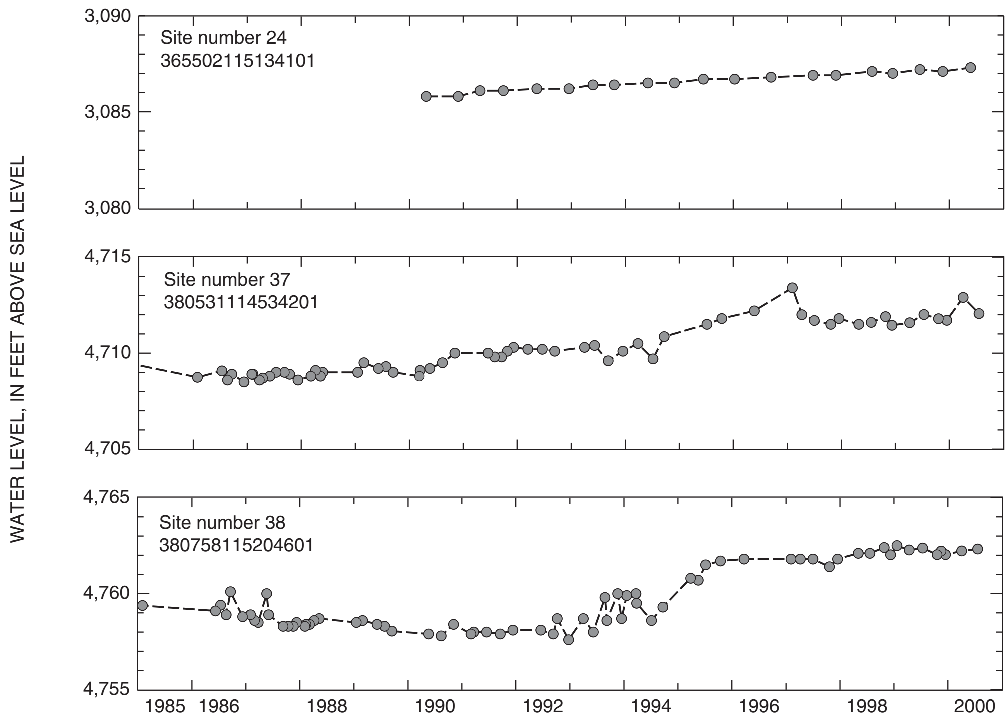

Figure 1. Continued.

carbonate rock (fig. 3). Hydrogeologic and physical data for these wells and springs are listed in tables 1, 2, and 3.

Previous Investigations

Geologic investigations of the carbonate-rock province date from the late 1860's. Since then numerous studies have been completed describing geologic formations, metamorphic core complexes, and geologic structure. Investigations of southern Nevada ground water began in the early 1900's. Mendenhall (1909, p. 13) suggested that many of the desert springs in southern Nevada derive their flow from distant recharge areas rather than from nearby rainfall. U.S. Geological Survey (USGS) studies in the carbonate-rock province began in the 1960's, when a systematic reconnaissance was made of all unstudied basins in Nevada to assess potential ground-water resources. The USGS Regional Aquifer-System Analysis Program was started in 1978 following a congressional mandate to develop quantitative appraisals of the major ground-water systems of the United States. In 1981, the USGS began to evaluate the hydrogeology in the Basin and Range physiographic province for potential use for storage of high-level radioactive waste (Bedinger and others, 1989, 1990). In the early 1990's, the Nevada Carbonate Aquifer Program (in cooperation with the State of Nevada, Las Vegas Valley Water District, City of North Las Vegas, and the Bureau of Reclamation) was developed to monitor and collect hydrologic data from carbonate wells and springs throughout southern Nevada (Dettinger and others, 1995). An evaluation of the geochemistry in the carbonate-rock province was recently completed (Thomas and others, 1996) and water-level investigations and monitoring efforts are ongoing.

GENERALIZED HYDROGEOLOGY

Within the carbonate-rock province, carbonate rocks were deposited from about 280 million to about 570 million years ago along the continental shelf of what was the west coast of North America during the Early Paleozoic Era (Stewart, 1980). These rocks consist of up to 30,000 ft of ancient marine sediment, with less significant interfingering layers of shale, quartzite, chert, and siltstone. These rocks are under-

Table 1. Wells completed primarily in carbonate rock

USGS site ID: The standard site identification is based on the grid system of latitude and longitude. The number consists of 15 digits. The first six denote the degrees, minutes, and seconds of latitude; the next seven denote the degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify the sites within a 1-second grid. For example, site 361736114531601 is at 36°17′36″ N latitude and 114°53′16″ W longitude, and is the first site recorded in that 1-second grid. The assigned number is retained as a permanent identifier even if a more precise latitude and longitude are determined.

Top of open interval: Depth to top part of well that can receive water from lithologic interval. Open interval may indicate a depth deeper than well depth, which may reflect original well depth; U, unknown or no data.

Bottom of open interval: Depth to bottom part of well that can receive water from lithologic interval. Open interval may indicate a depth deeper than well depth, which may reflect original well depth; U, unknown or no data.

Type of open interval: F, fractured rock; P, perforated or slotted casing; S, screen, type unknown; U, unknown or no data; W, walled or shored; X, open hole.

Diameter of open interval: Casing diameter (rounded to nearest 0.1 inch), or hole diameter where no casing is present; U, unknown or no data.

Site number (pl. 1)	USGS Site ID	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water-level measurements			Hole depth (feet below land surface)	Well depth (feet below land surface)	Open interval			
					Water-level date	Depth to water (feet below land surface)	Potentiometric surface (feet above sea level)			Feet below land surface: Top	Feet below land surface: Bottom	Type	Diameter (inches)
1	361736114531601	36°17′36″	114°53′16″	2,388	08/21/00	575.6	1,812	1,241	900	540	900	P	6.6
2	362230116392901	36°22′31″	116°39′32″	2,728	10/08/99	601.4	2,127	970	650	100	970	X	5.0
3	362417116163600	36°24′20″	116°16′37″	2,334	10/07/99	7.3	2,326	818	586	132	467	P	13.5
										468	818	X	14.0
4	362532116172700	36°25′32″	116°17′27″	2,360	08/18/99	1.9	2,358	U	U	U	U	U	U
5	362755116190401	36°27′55″	116°19′04″	2,367	10/07/99	.2	2,367	140	123	0	100	P	13.0
										100	140	X	14.0
6	362846114495501	36°28′46″	114°49′55″	2,070	08/21/00	254.9	1,815	565	565	510	560	S	8.6
7	363212115240301	36°32′12″	115°24′03″	3,475	06/23/00	578.8	2,896	720	720	665	695	S	6.0
8	363213116133800	36°32′13″	116°13′38″	2,402	06/01/99	41.6	2,361	807	678	620	807	X	5.5
9	363255115515801	36°32′55″	115°51′58″	3,799	05/20/99	497.1	3,302	658	627	92	658	X	U
10	363308114553001	36°33′10″	114°55′25″	2,649	08/12/99	831.7	1,817	920	920	45	920	X	6.0
11	363332115244001	36°33′28″	115°24′38″	3,579	05/18/99	815.5	2,763	957	930	870	930	P	6.0
12	363427114472301	36°34′27″	114°47′23″	2,340	08/21/00	526.0	1,814	1,200	U	U	U	U	U
13	363508115391701	36°35′08″	115°39′17″	3,100	08/17/99	40.4	3,060	65	65	35	65	S	2.0
14	363530116021401	36°35′30″	116°02′14″	3,153	09/27/99	785.0	2,368	1,953	1,953	800	1,050	P	10.8
										1,368	1,370	X	9.9
										1,370	1,684	X	9.0
										1,684	1,953	X	6.8
15	363815116175901	36°38′15″	116°17′59″	3,056	10/07/99	677.9	2,378	916	800	735	800	P	6.2
										800	916	X	U
16	364604114471301	36°46′04″	114°47′13″	2,275	10/01/99	461.0	1,814	937	937	325	937	F	9.9
17	364650114432001	36°46′50″	114°43′20″	2,186	10/14/99	392.4	1,793	478	478	95	478	F	U
18	364741114532801	36°47′43″	114°53′28″	2,170	08/13/99	349.8	1,820	628	628	126	628	X	17.5

Site number (pl. 1)	USGS Site ID	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water-level measurements			Hole depth (feet below land surface)	Well depth (feet below land surface)	Open interval			
					Water-level date	Depth to water (feet below land surface)	Potentiometric surface (feet above sea level)			Feet below land surface: Top	Feet below land surface: Bottom	Type	Diameter (inches)
19	364743114533101	36°47′43″	114°53′31″	2,173	10/08/99	353.1	1,819	669	669	50	669	F	7.9
20	364830115512601	36°48′30″	115°51′26″	3,489	04/28/99	1,105.2	2,384	1,853	1,356	1,192	1,516	P	7.0
21	364938116252102	36°49′38″	116°25′21″	3,656	06/17/99	1,185.3	2,470	U	5,923	4,256	4,279	X	9.9
										4,279	4,322	X	6.9
										4,322	5,900	X	6.8
										5,900	5,923	X	6.1
22	365227114554401	36°52′27″	114°56′45″	2,467	08/12/99	609.6	1,857	1,221	1,221	50	840	W	10.0
										860	1,221	X	9.9
23	365500116003901	36°55′07″	116°00′34″	3,921	05/11/98	1,543.9	2,377	1,707	1,707	1,536	1,650	P	16.6
										1,650	1,707	X	18.6
24	365502115134101	36°55′02″	115°13′41″	3,300	06/16/99	212.8	3,087	460	460	13	460	X	6.0
25	365740116043501	36°57′40″	116°04′35″	4,231	09/14/99	1,786.9	2,444	3,430	2,008	1,746	1,898	X	20.0
										1,898	2,006	X	10.7
										2,006	2,008	X	5.5
26	365904115593401	36°59′04″	115°59′34″	3,935	09/13/99	1,546.9	2,388	2,129	2,129	1,819	2,097	X	12.3
										2,097	2,129	X	8.8
27	370005116040301	37°00′05″	116°04′03″	3,995	04/27/99	1,555.9	2,439	3,358	3,228	2,134	2,349	X	12.3
										2,349	3,358	X	8.8
28	370116115561302	37°01′09″	115°56′09″	4,408	09/14/99	2,015.4	2,393	2,807	2,310	2,208	2,310	X	12.3
29	370320116012001	37°03′34″	116°01′21″	4,012	04/26/99	1,620.4	2,392	3,030	2,830	2,832	2,835	X	8.8
										2,835	3,028	X	5.8
										3,028	3,030	X	5.1
30	370337116033002	37°03′37″	116°03′30″	4,082	09/09/99	1,655.8	2,426	2,600	2,600	2,459	2,470	X	12.3
										2,470	2,600	X	6.8
31	370556116000901	37°05′56″	116°00′09″	4,370	04/26/99	1,969.4	2,400	2,205	2,205	1,995	2,199	P	7.0
										2,199	2,205	X	10.6
32	370831116080701	37°08′30″	116°08′07″	4,764	04/27/99	1,446.7	3,318	1,650	1,649	1,384	1,624	P	7.8
										1,624	1,650	X	12.3
33	370958116051512	37°09′58″	116°05′15″	4,470	09/09/99	2,053.1	2,417	3,422	3,422	2,700	2,950	P	6.6
										3,164	3,412	P	6.6
34	371108116045301	37°11′08″	116°04′53″	4,574	09/09/99	2,159.6	2,414	2,380	2,380	55	2,380	X	9.6
35	374058115113501	37°40′57″	115°11′35″	4,057	01/07/99	210.8	3,846	U	479	213	479	U	U
36	375547115244201	37°55′48″	115°21′00″	4,932	08/23/99	127.7	4,804	1,880	1,560	911	1,560	X	8.8
37	380531114534201	38°05′31″	114°53′42″	5,560	10/20/99	848.2	4,712	2,395	2,395	775	935	X	8.9
										935	2,395	X	7.9
38	380758115204601	38°08′16″	115°20′19″	5,560	07/14/99	797.6	4,762	1,837	1,837	118	1,837	X	7.9

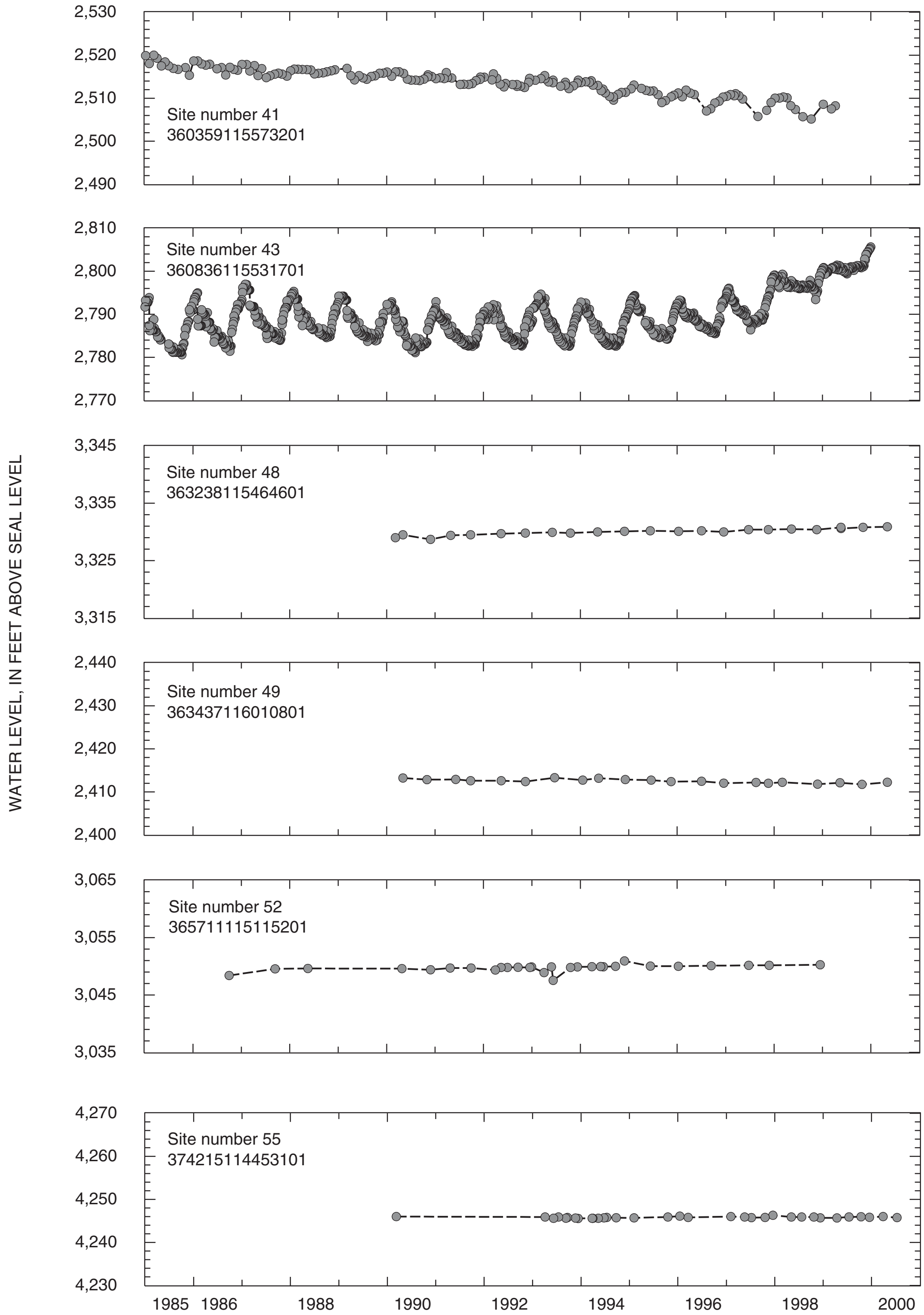

Figure 2. Water levels from selected wells in basin-fill deposits.

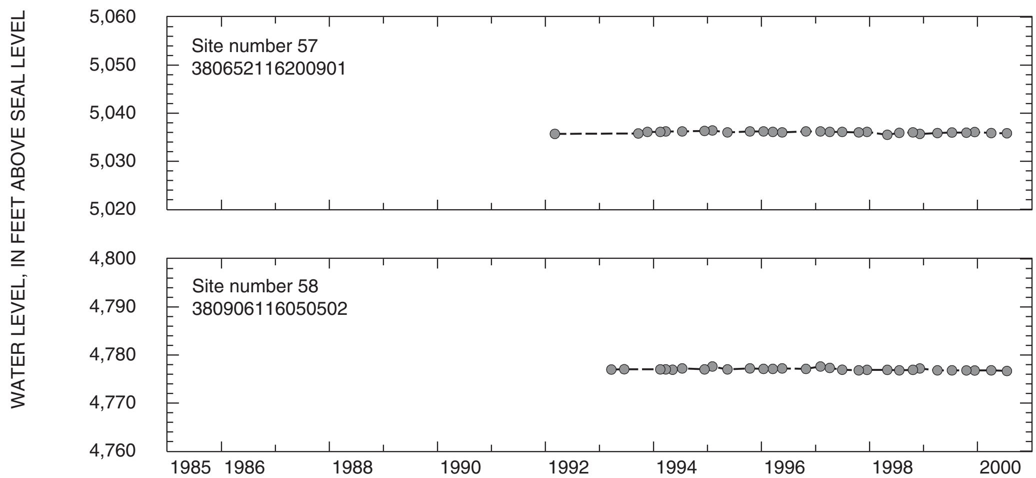

Figure 2. Continued.

lain by Precambrian metamorphic and granitic rocks and by Late Precambrian to Middle Cambrian clastic sedimentary rocks, and are overlain by Late Paleozoic to Mesozoic clastic sedimentary rocks, Cenozoic volcanic rocks, and Cenozoic basin-fill deposits. Intrusions of Late Mesozoic to Cenozoic igneous rocks are also common in the carbonate-rock province.

The physiography of the study area is characterized by generally parallel, north- to northeast-trending mountain ranges separated by broad alluvial desert basins. These ranges typically rise 1,000 to 7,000 ft above the intervening valleys. The elongated ranges and valleys generally are 5 to 15 mi wide and 40 to 80 mi long (Prudic and others, 1995). The Basin and Range topography that typifies the carbonate-rock province consists of extensional (normally) faulted terrains forming complex, heterogeneous geologic settings, each with unique local and regional characteristics. Strike-slip faults from the Early Jurassic to the Late Tertiary associated with compressive and extensional faulting add to the structural complexity of the study area (Stewart, 1980).

The carbonate rocks in the province form complex aquifers whose shapes and sizes are largely unknown. These aquifers are interconnected with aquifers of other rock types. Where deformed and fractured, these saturated ancient sedimentary rocks have the potential to transmit ground water. Within the carbonate-rock province, the carbonate rocks are believed to be the principal water-bearing zones because of their brittleness and capacity to chemically dissolve in flowing water, and because of the fractures and joints that have been widened by solution to varying degrees (Winograd and Thordarson, 1975, p. 19). Although many hydrogeologic properties (including transmissivity, storativity, hydraulic conductivity, and porosity) of the different lithologies probably influence flow, the broadest and simplest hydrogeologic influences in these areas may be variations in the thickness and continuity of carbonate-rock aquifers that are associated with extended terrains (Dettinger and Schaefer, 1995). Dettinger and Schaefer (1996) analyzed gravity and aeromagnetic profiles and indicated identifiable patterns of extension in the eastern Great Basin. These large-scale extensional features correlate with the regional ground-water flow system and can be used to define directions of ground-water flow (Dettinger and Schaefer, 1996). Regionally, in areas of extreme extension, most of the carbonate rocks that would connect and integrate flow in basin-fill and volcanic-rock aquifers have been thinned and removed. Where there has been only slight extension, carbonate rocks form thick layers, resulting in continuous aquifers that exhibit broadly integrated flow. Dettinger (1989) described a thick, laterally continuous corridor of Paleozoic carbonate rock resulting from 25 million years of extension (pl. 1, green-shaded area). Dettinger and Schaefer (1996) noted that the bounds of these terrains commonly mark divides between regionally deep and locally shallow ground-water flow (pl. 1). Furthermore, Dettinger and Schaefer (1996) and Laczniak and others (1996) previously defined the southernmost extent of this terrain where it crosses into southeastern California.

Table 2. Wells completed primarily in basin-fill deposits

USGS site ID: The standard site identification is based on the grid system of latitude and longitude. The number consists of 15 digits. The first six denote the degrees, minutes, and seconds of latitude; the next seven denote the degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify the sites within a 1-second grid. For example, site 355941115490901 is at 34°59′41″ N latitude and 115°49′09″ W longitude, and is the first site recorded in that 1-second grid. The assigned number is retained as a permanent identifier even if a more precise latitude and longitude are determined.

Top of open interval: Depth to top part of well that can receive water from lithologic interval. Open interval may indicate a depth deeper than well depth, which may reflect original well depth; U, unknown or no data.

Bottom of open interval: Depth to bottom part of well that can receive water from lithologic interval. Open interval may indicate a depth deeper than well depth, which may reflect original well depth; U, unknown or no data.

Type of open interval: P, perforated or slotted casing; S, screen, type unknown; U, unknown or no data; X, open hole.

Diameter of open interval: Casing diameter (rounded to nearest 0.1 inch), or hole diameter where no casing is present; U, unknown or no data.

Site number (pl. 1)	USGS site ID	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water-level measurements			Hole depth (feet below land surface)	Well depth (feet below land surface)	Open interval			
					Water-level date	Depth to water (feet below land surface)	Potentiometric surface (feet above sea level)			Feet below land surface		Type	Diameter (inches)
										Top	Bottom		
39	355941115490901	35°59′41″	115°49′09″	2,825.0	07/15/99	20.2	2,805	120	120	U	U	U	2.0
40	360047115171401	36°01′01″	115°17′28″	2,810.0	10/01/99	472.9	2,337	710	710	610	710	P	8.0
41	360359115573201	36°03′59″	115°57′32″	2,580.0	04/08/99	71.8	2,508	325	325	75	325	P	16.0
42	360429115462101	36°04′30″	115°46′19″	3,357.0	02/22/00	372.5	2,984	500	497	330	497	P	8.0
43	360836115531701	36°08′36″	115°53′17″	2,885.0	11/10/98	91.6	2,793	800	472	100	450	P	14.0
44	360913116010901	36°09′13″	116°01′09″	2,549.0	07/15/99	48.7	2,500	71	71	U	U	U	2.0
45	362715116322301	36°27′15″	116°32′23″	2,247.4	09/30/99	33.2	2,214	U	300	U	U	U	14.0
46	362725116305901	36°27′29″	116°30′49″	2,237.2	09/23/99	37.0	2,200	U	393	U	U	U	14.0
47	362830115270501	36°28′30″	115°26′57″	3,180.0	10/01/99	212.6	2,967	300	300	U	U	U	12.0
48	363238115464601	36°32′38″	115°46′46″	3,617.0	05/21/99	286.4	3,331	826	826	310	435	P	10.0
										453	826	X	U
49	363437116010801	36°34′37″	116°01′08″	3,445.0	05/13/99	1,032.9	2,412	1,253	1,253	1,157	1,228	P	9.0
50	364127114553001	36°41′27″	114°55′30″	2,414.3	07/07/00	590.1	1,824	780	756	736	756	S	6.0
51	364601114514301	36°46′01″	114°51′43″	2,158.6	07/07/00	346.1	1,813	765	765	645	765	P	4.0
52	365711115115201	36°57′11″	115°11′52″	3,208.0	12/15/98	157.7	3,050	420	164	U	U	U	U
53	371243115050601	37°12′34″	115°04′37″	3,193.0	12/29/98	22.7	3,170	91	91	U	U	U	U
54	373215115165801	37°32′14″	115°16′58″	4,165.0	08/26/99	366.2	3,799	404	395	U	U	U	4.0

Site number (pl. 1)	USGS site ID	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water-level measurements			Hole depth (feet below land surface)	Well depth (feet below land surface)	Open interval			
					Water-level date	Depth to water (feet below land surface)	Potentiometric surface (feet above sea level)			Feet below land surface: Top	Feet below land surface: Bottom	Type	Diameter (inches)
55	374215114453101	37°42′15″	114°45′31″	4,640.0	03/28/00	394.0	4,246	1,010	1,000	600	620	S	10.3
										650	670	S	10.3
										700	720	S	10.3
										750	770	S	10.3
										800	820	S	10.3
										850	870	S	10.3
										900	920	S	10.3
										950	970	S	10.3
56	380132115333501	38°01′34″	115°33'44″	5,550.0	04/04/00	406.2	5,144	1,065	970	555	575	S	10.8
										600	630	S	10.8
										690	700	S	10.8
										720	730	S	10.8
										755	785	S	10.8
										830	880	S	10.8
										890	950	S	10.8
57	380652116200901	38°06′52″	116°20′09″	5,350.0	04/03/00	314.2	5,036	682	682	398	418	S	10.8
										448	468	S	10.8
										499	519	S	10.8
										559	579	S	10.8
										618	648	S	10.8
58	380906116050502	38°09′06″	116°05′05″	5,010.0	04/03/00	233.2	4,777	492	492	U	U	U	9.9

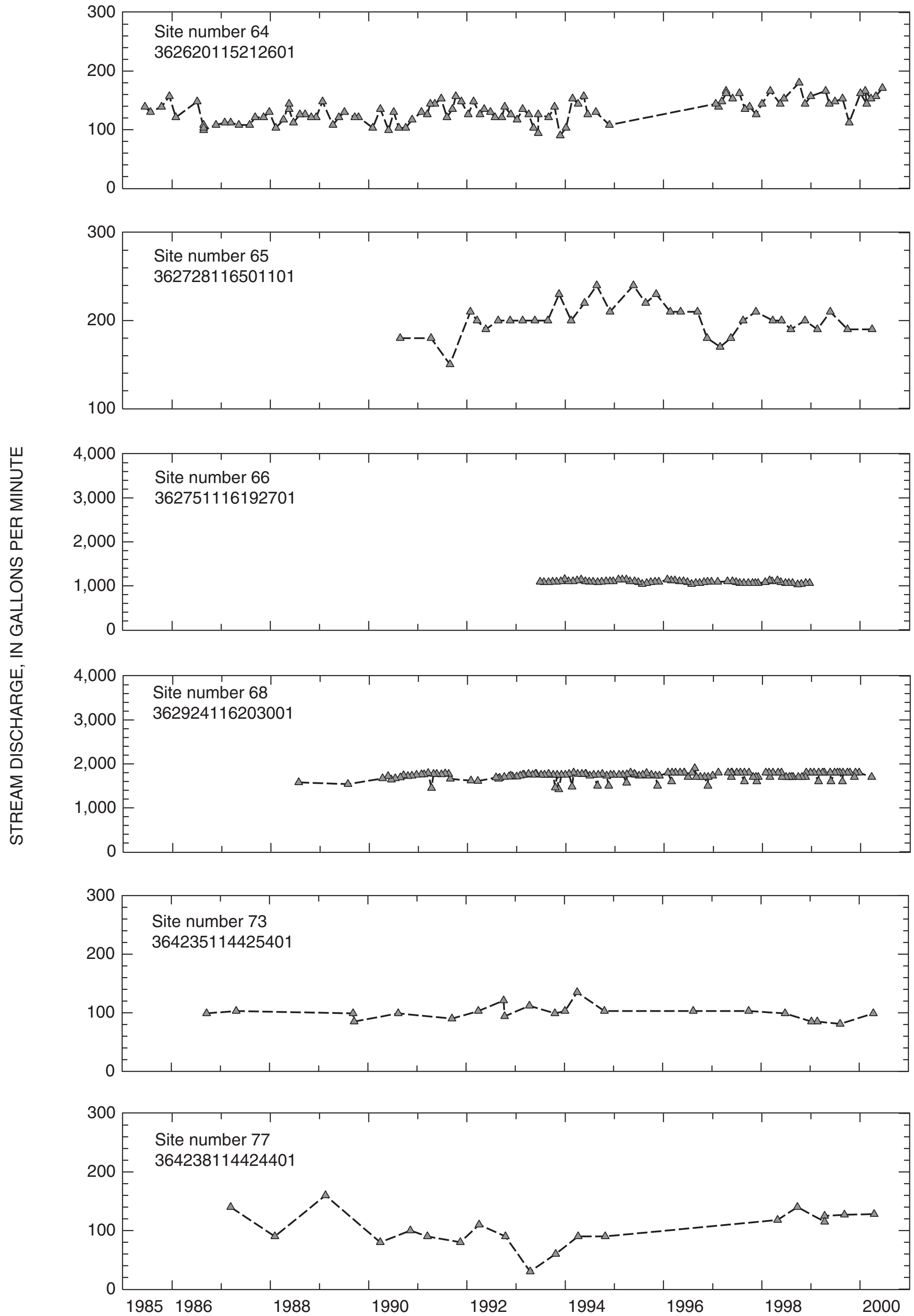

Figure 3. Discharge in gallons per minute from selected springs emanating from carbonate rock (stream discharge scale is variable).

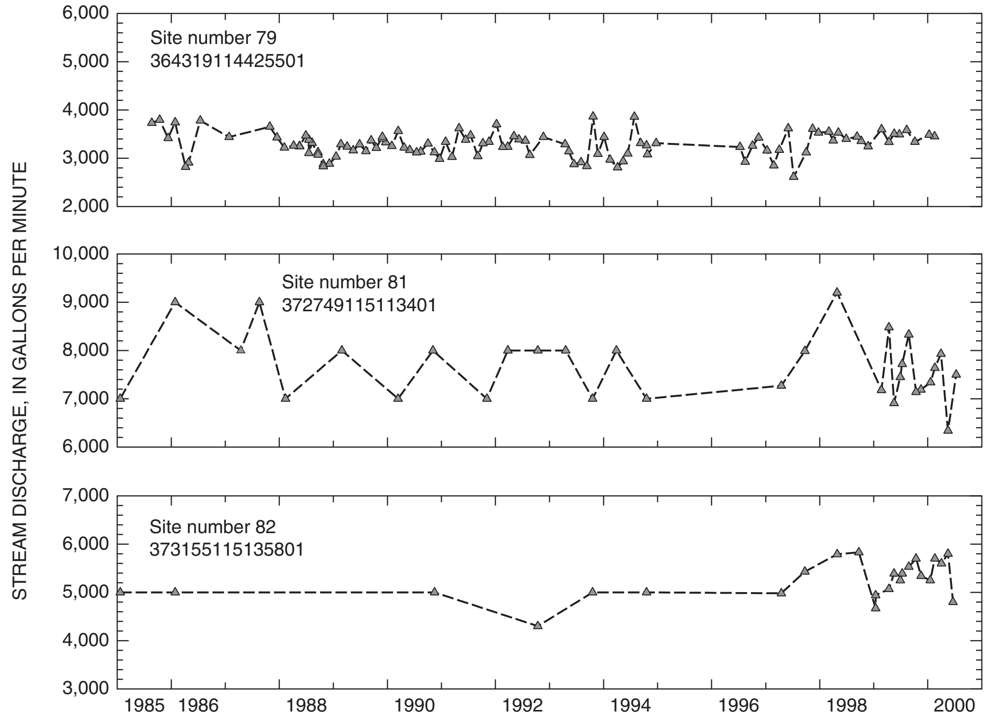

Figure 3. Continued.

This report, however, does not depict the boundary of thick continuous carbonate rock past the Nevada–California border.

Recharge to the carbonate aquifers originates in high mountain ranges where snowpack accumulations release water over a sustained period (Dettinger, 1989, p. 7). Discharge from carbonate aquifers consists of direct evaporation from the soil, transpiration by plants, and the flow of springs.

WATER-LEVEL CONTOURS

Water-level contours shown on plate 1 represent the regional potentiometric surface of ground water in consolidated rocks of the carbonate-rock province. Assumptions made during construction of the contour lines are that: (1) in primarily carbonate rock, water levels represent the water table, (2) water flows nearly horizontally through the aquifer, (3) no hydrologic barriers are between wells and springs, and (4) inferred flow paths are perpendicular to the potentiometric contours. The contour lines were generated initially using ARC/INFO, a comprehensive Geographic Information System software package (Environmental Systems Research Institute, 1994), then were refined according to known hydrogeologic conditions. Although these water-level contours are based on current conditions, uncertainties remain. First, water levels are based on approximate land-surface altitudes derived from topographic maps and global positioning system field measurements. Second, the potentiometric surface may be poorly defined in areas where wells are sparsely distributed.

The full extent of contour lines that can be shown on plate 1 is limited by lack of available data from wells completed primarily in carbonate rock. The dashed parts of the contour lines show areas that are similar to previous representations of regional ground-water levels (Winograd and Thordarson, 1975; Waddell and others, 1984; Thomas and others, 1986, 1996; Laczniak and others, 1996), and are supported only by current water-level measurements in alluvial wells that are thought to have a good hydraulic connection between carbonate rocks and basin fill.

In the study area, basin-fill deposits overlying carbonate rocks are the source of most of the ground water being pumped (Dettinger, 1989). Composed primarily of sand and gravel, basin-fill aquifers facili-

Table 3. Selected springs emanating primarily from carbonate rock

USGS site ID: The standard site identification is based on the grid system of latitude and longitude. The number consists of 15 digits. The first six denote the degrees, minutes, and seconds of latitude; the next seven denote the degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify the sites within a 1-second grid. For example, site 355850116162001 is at 35°58′50″ N latitude and 116°16′20″ W longitude, and is the first site recorded in that 1-second grid. The assigned number is retained as a permanent identifier even if a more precise latitude and longitude are determined.

Altitude of land surface (feet above sea level): Value indicates land surface elevation at spring orifice. Water levels may be at or above reported level.

Abbreviation: USFWS, U.S. Fish & Wildlife Service.

Site number (pl. 1)	USGS site ID	Latitude	Longitude	Name of spring	Altitude of land surface (feet above sea level)
59	355850116162001	35°58′50″	116°16′20″	Shoshone Spring	1,620
60	360920115541001	36°09′20″	115°54′10″	Manse Spring	2,780
61	361820115374001	36°18′20″	115°37′40″	Deer Creek Spring	8,680
62	362410116161002	36°24′05″	116°16′15″	Point of Rocks (King) Spring	2,320
63	362502116192301	36°25′15″	116°19′25″	Crystal Pool	2,195
64	362620115212601	36°26′20″	115°21′25″	Corn Creek Spring	2,931
65	362728116501101	36°27′28″	116°50′11″	Texas Spring	400
66	362751116192701	36°28′05″	116°19′30″	Longstreet Spring	2,310
67	362855116200701	36°28′52″	116°20′04″	Rogers Spring ET1 Well	2,255
68	362924116203001	36°29′26″	116°20′28″	Fairbanks Spring	2,250
69	363045116491601	36°30′45″	116°49′15″	Nevares Spring	955
70	363354115400601	36°33′50″	115°40′10″	Indian Spring	3,183
71	364235114425201	36°42′40″	114°42′50″	M-11 USFWS	1,800
72	364235114425301	36°42′35″	114°42′53″	Muddy River Spring 19	1,800
73	364235114425401	36°42′35″	114°42′54″	M-14 USFWS (Pederson Spring)	1,800
74	364236114425401	36°42′35″	114°42′55″	M-13 USFWS	1,800
75	364237114425401	36°42′35″	114°42′55″	M-12 USFWS	1,800
76	364238114424201	36°42′40″	114°42′40″	M-15	1,780
77	364238114424401	36°42′40″	114°42′45″	M-16	1,780
78	364314114432401	36°43′15″	114°43′25″	M-5	1,800
79	364319114425501	36°43′20″	114°42′55″	M-18	1,770
80	364333114433801	36°43′35″	114°43′40″	M-9	1,780
81	372749115113401	37°27′50″	115°11′30″	Ash Spring	3,615
82	373155115135801	37°31′55″	115°14′00″	Crystal Spring	3,810
83	373554115125201	37°35′55″	115°12′50″	Hiko Spring	3,875

tate ground-water flow into and out of the carbonate rock. Together with carbonate-rock aquifers, these basin-fill aquifers support regional flow systems. Water levels in highly permeable basin-fill aquifers can represent water levels in carbonate aquifers where highly permeable carbonate rocks are overlain by basin-fill deposits. Ertec Western, Inc. (1981) concludes that in many places basin-fill deposits are hydraulically connected with adjacent and underlying carbonate rocks, resulting in one continuous ground-water flow system that is bounded by noncarbonate rocks or structural features. Thomas and others (1986) also notes that basin-fill deposits generally are more permeable than carbonate rocks and are capable of storing and transmitting vast quantities of water. Therefore, in areas in which carbonate and basin-fill aquifers are hydrologically connected, the interpolated water-level gradient between wells completed primarily in carbonate rock, and wells completed in basin-fill deposits may be less steep than contour lines indicate (pl. 1).

Springs are found where fractures in carbonate rock are exposed to the surface below the associated water table. Water-level altitudes at these springs, based upon the land-surface altitude of the spring orifice (table 3), were used to define regional water levels in the carbonate-rock aquifer (pl. 1). These water levels will be slightly lower than the vertically averaged water level because of the lack of bounded rock around the orifice of the spring.

Prudic and others (1995) described geologic barriers that affect regional ground-water flow in the carbonate-rock province. These barriers consist of isolated complexes of possible Mesozoic age, metamorphic rocks; Early Cambrian and Late Precambrian clastic sedimentary rocks; Paleozoic and Precambrian metamorphic core complexes; and Precambrian crystalline basement rocks (Coney, 1980). Isolated, Mesozoic-age metamorphic rocks generally are identified as mobile metamorphic-plutonic basement rocks, overlain by unmetamorphosed rocks that are deformed by low-angle extensional faults (Prudic and others, 1995). The thickness and subsurface distribution of these barriers at depth are not known. The region in which these rocks are known to exist is structurally complex; differing rock types potentially are more extensive at depth than is indicated by outcrops. Surface exposures of these geologic barriers (pl. 1, red-shaded areas) are shown as one unit. Where such barriers exist, geologic or otherwise, contours have been omitted.

Potentiometric contours also have been omitted in areas where measured water levels, between wells, did not provide enough gradient for interpretation. For example, ground water has been described previously to flow through carbonate rocks in a south-southeasterly direction from Coyote Spring Valley to Moapa Valley (pl. 1; Winograd and Thordarson, 1975). Deuterium mass-balance ratios were used (Thomas and others, 1996) to identify the source of water flowing into Moapa Valley. These ratios suggest that 62 percent of the discharge from the Muddy River Springs in Moapa Valley originated in Coyote Spring Valley, and that the remaining 38 percent originated in the Sheep Range (Thomas and others, 1996). Water levels measured in Moapa and Coyote Spring Valleys define a potentiometric surface that is relatively flat throughout Moapa Valley. The potentio-metric contour drawn in Moapa Valley (pl. 1) can be substantiated only by the altitudes of the Muddy River Springs. As noted, water-level altitudes at the Muddy River Springs are based upon land-surface altitudes at the spring orifices. The inherent error associated with these water levels at the Muddy River Springs and relatively similar ground-water altitude in wells surrounding the Moapa Valley are factors that make interpretation of the potentiometric surface difficult.

Geologic structural features may further inhibit ground-water flow in Moapa Valley. Winograd and Thordarson (1975) described the Las Vegas Valley shear zone (pl. 1) as a barrier to flow. Plume (1996) identified the combined effects of the crystalline basement and thin clastic sedimentary rocks in the valley as factors that inhibit ground-water flow and force water to the surface as spring discharge. Furthermore, the Sevier Thrust Belt, which is composed of Mesozoic-age compressional features, could be a barrier to ground-water flow and support a mechanism for its discharge at the Muddy River Springs. In addition, the carbonate rocks from Coyote Spring Valley to Moapa Valley appear to be more transmissive than surrounding carbonate rocks (pl. 1). This interpretation is supported by the finding that ground-water gradients are less than 1 ft/mi near wells 18 and 16, compared to gradients of more than 10 ft/mi upgradient of well 18 and downgradient of the Muddy River Springs. Transmissivity of the Paleozoic carbonate rocks from Coyote Spring Valley to Moapa Valley probably has been enhanced by secondary permeability from Late Tertiary extensional fracturing and faulting (Schmidt and Dixon, 1995).

HYDROGRAPHS

Figures 1, 2, and 3 indicate the general trend of regional water levels from 1985 through 2000. Although these graphs are relatively incomplete, there is some indication of fluctuation in water levels that is probably caused by seasonal changes and by variations in recharge. However, these data show relatively little change within the period of record (1985–2000). The influence of earth tides and barometric pressure on ground-water levels was not considered when these graphs were compiled. These global and atmospheric influences do not significantly affect long-term (10 years and greater) trends in water levels (Fenelon, 2000). Bright and others (2001) noted that water-level measurement errors at Desert Rock station at the Nevada Test Site near Mercury were greater than the rate of long-term changes in barometric pressure, therein concealing any barometric-pressure influences. Evaluation and explanation of trends in water levels and spring discharge as shown in these graphs are beyond the scope of this report. However, analysis of water-level trends within the central Great Basin-(Dettinger and Schaefer, 1995) suggests that upward trends in water levels may be the result of long-ter variations in regional precipitation.

SOURCES OF DATA

Current (1998–2000) water-level values were obtained from the USGS National Water Information System (NWIS). Additional ground-water levels and spring altitudes were obtained from the Bureau of Land Management and the Southern Nevada Water Authority, and through field checking and updating of data from existing wells and springs. Water levels and spring discharges shown in figures 1, 2, and 3 are based on quarterly ground-water measurements and periodic spring measurements by the USGS and on periodic and continuing ground-water measurements by the Nevada Division of Water Resources. Two criteria were used in choosing these hydrographs—that they provide: (1) a distribution of wells and springs that convey a good regional representation of water-level trends, and (2) a selection of wells and springs with the most complete period of record from 1985 through 2000. Well parameters were taken from drillers' logs, the USGS NWIS database, and an International Technology Corporation (1996) data documentation package .

SUMMARY

The plate that accompanies this report describes the potentiometric surface of water levels measured from 1998 through 2000 in the carbonate-rock province in southern Nevada and southeastern California. Additionally, a current, generalized description of the carbonate-rock province is provided. The graphs presented in the report offer additional data that indicate the general trend in water levels in the carbonate rocks from 1985 through 2000. Challenges associated with this study stem from the complex hydrogeology of the region and the lack of available water-level data from wells completed primarily in carbonate rock.

REFERENCES CITED

Bedinger, M.S., Sargent, K.A., and Langer, W.H., 1989, Studies of geology and hydrology in the Basin and Range province, southwestern United States, for isolation of high-level radioactive waste—Characterization of the Death Valley region, Nevada and California: U.S. Geological Survey Professional Paper 1370-F, 49 p.

———, 1990, Studies of geology and hydrology in the Basin and Range province, southwestern United States, for isolation of high-level radioactive waste—Characterization of Bonneville region, Utah and Nevada: U.S. Geological Survey Professional Paper 1370-G, 38 p.

Bright, D.J., Watkins, S.A., and Lisle, B.A., 2001, Analysis of water levels in the Frenchman Flat Area, Nevada Test Site: U.S. Geological Survey, Water-Resources Investigations Report 00-4272, 43 p.

Coney, P.J., 1980, Cordilleran metamorphic core complexes—An overview, *in* Crittenden, M.D., Jr., Coney, P.J., and Davis, G.K., eds., Cordilleran metamorphic core complexes: Geological Society of America Memoir 153, p. 7–31.

Dettinger, M.D., 1989, Distribution of carbonate-rock aquifers in southern Nevada and the potential for their development—Summary of findings, 1985–88: Carson City, Nev., Program for the Study and Testing of Carbonate-Rock Aquifers in Eastern and Southern Nevada, Summary Report No. 1, 37 p.

Dettinger, M.D., Harrill, J.R., and Schmidt, D.L., 1995, Distribution of carbonate-rock aquifers and the potential for their development, southern Nevada and adjacent parts of California, Arizona, and Utah: U.S. Geological Survey Water-Resources Investigations Report 91-4146, 100 p.

Dettinger, M.D., and Schaefer, D.H., 1995, Decade-scale hydroclimatic forcing of ground-water levels in the Central Great Basin, Eastern Nevada, *in* American Water Resources Association Annual Summer Symposium, Honolulu, Hawaii, June 1995, Proceedings, Water Resources and Environmental Hazards: Emphasis on Hydrologic and Cultural Insight in the Pacific Rim, p. 195–204.

———, 1996, Hydrogeology of structurally extended terrain in the eastern Great Basin of Nevada, Utah, and adjacent states, from geologic and geophysical models: U.S. Geological Survey Hydrologic Investigations Atlas HA-694-D, 1 sheet.

Environmental Systems Research Institute, Inc., 1994, ARC/INFO—Users guide: Environmental Systems Research Institute, Redlands, Calif., 7 volumes.

Ertec Western, Inc., 1981, MX siting investigation, water resources program, technical summary report: Long Beach, Calif., Report E-TR-52, 611 p.

Fenelon, J.M., 2000, Quality assurance and analysis of water levels in wells on Pahute Mesa and vicinity, Nevada Test Site, Ney County, Nevada: U.S. Geological Survey, Water-Resources Investigations Report 00-4014, 68 p.

Harrill, J R., and Prudic, D.E., 1998, Aquifer systems in the Great Basin region of Nevada, Utah, and adjacent states; summary report: U.S. Geological Survey Professional Paper 1409-A, 66 p.

Harrill, J.R., Welch, A.H., Prudic, D.E., Thomas, J.M., Carman, R.L., Plume, R.W., Gates, J.S., and Mason, J.L., 1983, Aquifer systems in the Great Basin region of Nevada, Utah, and adjacent states—A study plan: U.S. Geological Survey Open-File Report 82-445, 49 p.

Harrill, J R., and Prudic, D.E., 1998, Aquifer systems in the Great Basin region of Nevada, Utah, and adjacent states; summary report: U.S. Geological Survey Professional Paper 1409-A, 66 p.

Hess, J.W., and Mifflin, M.D., 1978, A feasibility study of water production from deep carbonate aquifers in Nevada: University of Nevada, Desert Research Institute Publication 41054, 125 p.

International Technology Corporation (IT), 1996, Underground Test Area Subproject Phase 1 Data Analysis Task: IT/HIS Geotrans, data documentation package, v. 1–8, 1 CD.

Laczniak, R.J., Cole, J.C., Sawyer, D.A., and Trudeau, D.A., 1996, Summary of hydrogeologic controls on ground-water flow at the Nevada Test Site, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations Report 96-4109, 59 p.

Mendenhall, W.C., 1909, Some desert watering places in southeastern California and southwestern Nevada: U.S. Geological Survey Water-Supply Paper 224, 86 p.

Mifflin, M.D., 1968, Delineation of ground-water flow systems in Nevada: University of Nevada, Desert Research Institute Technical Report H-W 4, 89 p.

Plume, R.W., 1996, Hydrogeologic Framework of the Great Basin Region of Nevada, Utah, and Adjacent States: U.S. Geological Survey Professional Paper 1409-B, 64 p.

Prudic, D.E., Harrill, J.R., and Burbey, T.J., 1995, Conceptual evaluation of regional ground-water flow in the carbonate-rock province of the Great Basin, Nevada, Utah and adjacent states: U.S. Geological Survey Professional Paper 1409-D, 102 p.

Schmidt, D.L., and Dixon, G.L., 1995, Geology and aquifer system of the Coyote Spring Valley area, Southeastern Nevada: U.S. Geological Survey Open-File Report 95-579, 47 p.

Stewart, J.H., 1980, Geology of Nevada—A discussion to accompany the geologic map of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Thomas, J.M., Mason, J.L., and Crabtree, J.D., 1986, Ground-water levels in the Great Basin region of Nevada, Utah, and adjacent states: U.S. Geological Survey Hydrologic Investigations Atlas HA-694-B, 2 sheets, scale 1:1,000,000.

Thomas, J.M., Welch, A.H., and Dettinger, M.D., 1996, Geochemistry and isotope hydrology of representative aquifers in the Great Basin Region of Nevada, Utah, and adjacent states: U.S. Geological Survey Professional Paper 1409-C, 100 p.

Waddell, R.K., Robinson, J.H., and Blankennagel, R.K., 1984, Hydrology of Yucca Mountain and vicinity, Nevada–California—Investigative results through mid-1983: U.S. Geological Survey Water-Resources Investigations Report 84-4267, 72 p.

Winograd, I.J., and Thordarson, W., 1975, Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada–California, with special reference to the Nevada Test Site: U.S. Geological Survey Professional Paper 712-C, 126 p.