Hydro

WATER LEVELS IN PERIODICALLY MEASURED WELLS IN THE YUCCA MOUNTAIN AREA, NEVADA, 1988

U.S. GEOLOGICAL SURVEY

Open-File Report 90-113

Prepared in cooperation with the
NEVADA OPERATIONS OFFICE,
U.S. DEPARTMENT OF ENERGY, under
Interagency Agreement DE-A108-78ET44802

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By James M. Gemmell

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Denver, Colorado
1990

DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

Multiply	*By*	*To obtain*
foot (ft)	0.3048	meter (m)
inch (in.)	25.40	millimeter (mm)
kilogram (kg)	2.205	pound (lb)
kilogram per meter (kg/m)	0.6720	pound per foot (lb/ft)
kilometer (km)	0.6214	mile (mi)
liter (L)	0.2642	gallon (gal)
liter per second (L/s)	15.85	gallon per minute (gal/min)
meter (m)	3.281	foot (ft)
meter per meter (m/m)	1	foot per foot (ft/ft)
meter per (meter·degree Celsius)	0.5556	foot per (foot·degree Fahrenheit)
meter per (meter·kilogram)	0.4535	foot per (foot·pound)
millimeter (mm)	0.03937	inch (in.)
square kilometer (km^2)	0.3861	square mile (mi^2)

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

$$°F = [9/5°C + 32°].$$

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

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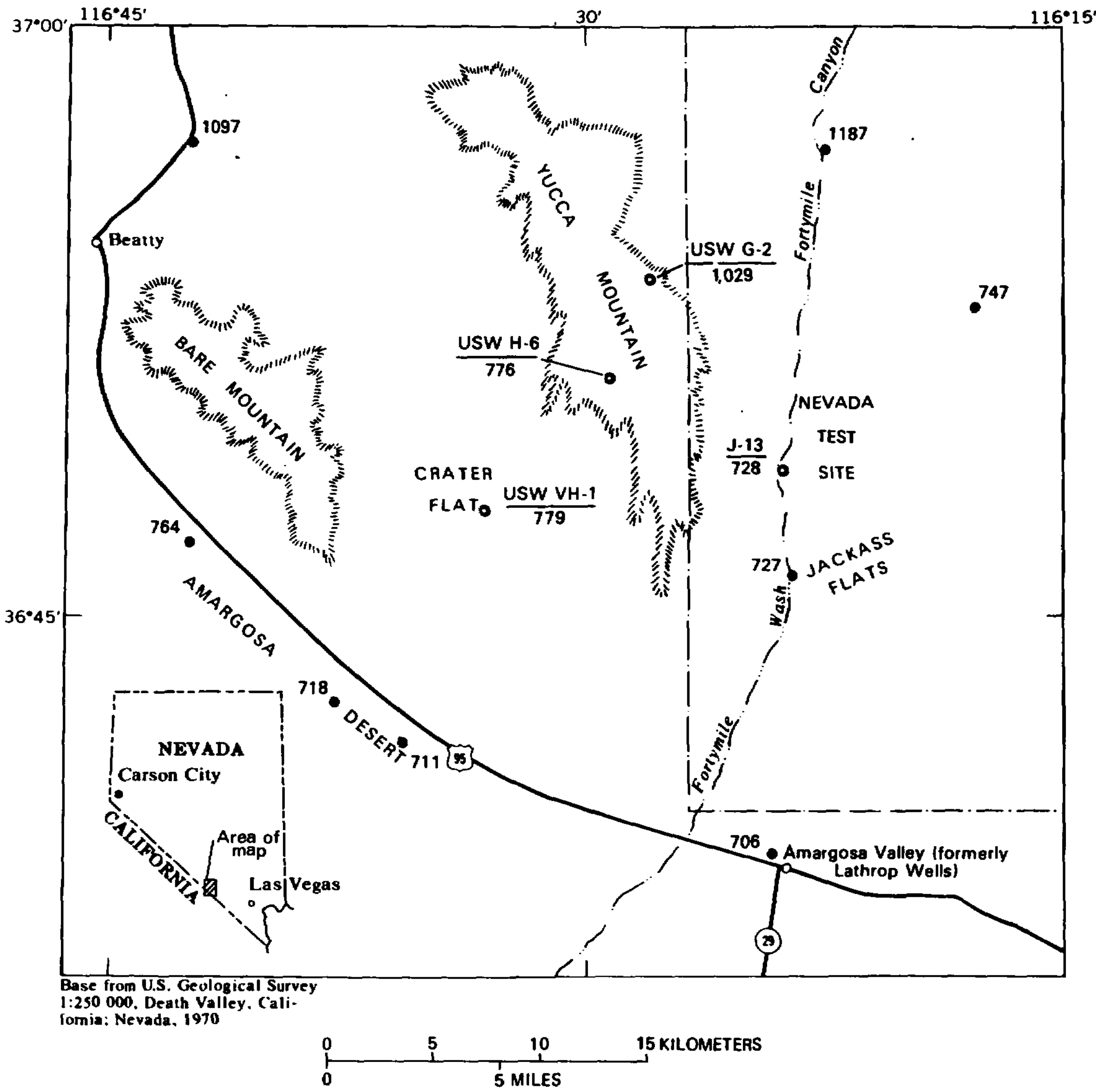
ABSTRACT

This report presents water-level data for 10 wells that were periodically measured in 1988 in the Yucca Mountain area, Nevada. Water levels measured during 1987 are included in the report for reference. The report includes discussions of the methods used and corrections applied to obtain water-level depths and altitudes from onsite measurements. Water levels for each well are presented in tabular and graphical (hydrograph) form. The altitude of the water level in the upper part of the saturated zone is about 775 meters above sea level to the west of and along part of the crest of Yucca Mountain; along the eastern edge and southern end of Yucca Mountain, the water level is 728 to 730 meters above sea level. The water-level data were obtained to help evaluate the suitability of the area for storing high-level nuclear waste.

INTRODUCTION

The Yucca Mountain area is being evaluated by the U.S. Department of Energy for suitability to store high-level nuclear waste in a mined, underground repository (U.S. Department of Energy, 1988). A 150-km^2 area located about 150 km northwest of Las Vegas in southern Nevada is being studied extensively (fig. 1). In the Yucca Mountain area, the water table is in air-fall and ash-flow tuff of Tertiary age, which is underlain at depth by carbonate rocks of Paleozoic age (Robison, 1984). Water levels in wells have been periodically measured since 1981 (Robison and others, 1988) as part of the studies to gain a better understanding of the hydrologic system in the area.

This report describes the methods used to collect and adjust measurements of water levels and lists water-level altitudes for 10 wells for the 1987 and 1988 calendar years. Historically, water-level measurements have been made at the Nevada Test Site (NTS) using steel tapes, single-conductor cables (Iron Horses), and hoist units that use multiconductor cables. Corrections have been made to the water-level measurements for thermal expansion and mechanical stretch of the steel tapes and borehole deviation from vertical. Water-level altitudes are computed by subtracting the water-level measurement from the altitude of a reference point. The water-level altitudes are presented in a data table for each well, accompanied by a hydrograph. Water levels and hydrographs for the 1987 calendar year have been included in this report for the convenience of the reader. As the equipment and techniques for measuring water levels in deep wells are refined, data become more reliable. A trend may be developing toward a more consistent water-level record that may be a result of improved equipment and techniques. An examination of the previously published hydrographs (Robison and others, 1988) seems to support this contention. Values of maximum and minimum water-level altitudes and



EXPLANATION

USW VH-1 / 779 ○ WELL--Upper number is well number; lower number is approximate altitude of water level, in meters above sea level

764 ● WELL--Number is altitude of water level reported in Waddell (1982), in meters above sea level

Figure 1.--Location of Yucca Mountain area and selected water-level altitudes (from Robison and others, 1988).

average annual water-level altitudes are included in this report for reference. The sections, presented with data for each well, entitled "History of instrumentation and water-level measurements, and comments," will aid in resolving any apparent anomalies in the water-level data that might have resulted from outside influences, such as recording errors or effects from pumping. Water-level data in this report have been collected under quality-assurance procedures required for study of Yucca Mountain as a candidate site for storage of nuclear waste. The water-level data were obtained as part of the Yucca Mountain Project. This study is being made by the U.S. Geological Survey in cooperation with the U.S. Department of Energy under Interagency Agreement DE-AI08-78ET44802.

WELL DESIGNATIONS

Each well used in the study of the Yucca Mountain area has a unique designation. Wells within the NTS use the NTS designation, whereas wells outside of the NTS use a slightly different designation. Wells within the NTS begin with UE (U for underground and E for exploratory), followed by the NTS area number (always 25 in this report). This designation--UE-25--commonly is followed by one or more letters signifying the purpose of the well or simply a sequential letter, followed by a sequence number. The only well not designated using this system that is referred to in this report is well J-13. Well J-13 was completed in 1963 and predates the current system of well designation. Wells outside of the NTS begin with the letters USW (U for underground, S for southern Nevada, and W for waste). The designation--USW--is followed by one or more letters signifying the purpose of the well, followed by a sequence number. The letters signifying purpose that most commonly are used in this report are H (drilled primarily to collect hydrologic data), V (drilled primarily to collect data on volcanism), and WT (drilled primarily to determine the water table).

Nevada State Coordinates are used to identify the location of wells cited in this report. These coordinates are for the central zone of Nevada and are based on a Transverse Mercator projection. The origin of this projection for the central zone of Nevada is latitude 34° 45' N., and the central meridian is at longitude 116° 40' W. The Nevada State Coordinates given in the section on well data are in feet north of the baseline and in feet plus 500,000 east of the central meridian. The Nevada State Coordinates for the wells were determined by Holmes & Narver, Inc.,[1] contractor to the U.S. Department of Energy for surveying at the NTS and Yucca Mountain area. Latitude and longitude values of the wells were calculated from the Nevada State Coordinates as described by Snyder (1982).

The Site ID number is used for unique identification of the well in the U.S. Geological Survey's computer files. The Site ID is generated by combining the original values of the latitude and longitude of the well with a two-digit sequence number. The Site ID is for convenience of identification only and can not be used to geographically locate a well because the original values of latitude and longitude might be inaccurate. Even if original values

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[1]Use of firm, brand, and trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

of the latitude and longitude were revised later, the Site ID for the site would not be changed. If more than one well exists within the 1-second rectangle of latitude and longitude, the two-digit sequence number is used to ensure uniqueness of the Site ID.

GENERAL DESCRIPTION OF WATER-LEVEL SURFACE

The water-level altitude in the Yucca Mountain area ranges from about 700 m to about 1,200 m above sea level (fig. 1). Water-level altitudes beneath Yucca Mountain are shown in greater detail in figure 2; water-level altitudes are highest to the north at wells USW G-2 and UE-25 WT #6, at about 1,030 m above sea level. In wells USW H-6, USW WT-7, and USW WT-10, west of the crest of Yucca Mountain, and in well USW H-5 on the crest, the water-level altitudes all are about 775 m above sea level. Water-level altitudes are as much as 45 m lower at wells USW G-3 and USW H-3, about 1 km east of well USW WT-7. From the eastern edge and southern end of Yucca Mountain to western Jackass Flats, the water level decreases from about 730 to 728 m above sea level (fig. 2) and decreases further to 706 m at Amargosa Valley (fig. 1).

WATER-LEVEL MONITORING NETWORK

History and Development

Well drilling to collect hydrologic and geologic data for preliminary evaluation of the suitability of the Yucca Mountain site to store high-level nuclear waste began in 1980; the first wells were completed in 1981. Water levels were measured as each well was completed and tested. After these initial water-level measurements, the U.S. Geological Survey began to measure the water levels in these wells periodically in order to determine the stability of the original measurements and to determine if any cycles or trends in the water levels occur that might provide insight about the local hydrologic system. In addition, the nearly horizontal water-level surface beneath part of the area (Robison, 1984) indicated that periodic measurements for calculating long-term average water levels would be needed to determine hydraulic gradients with adequate precision. As more water levels were measured, it became apparent that periodic measurements might not be sufficient for calculating average water levels, nor for determining short-term changes that could help evaluate conceptual models and mechanisms of ground-water flow beneath Yucca Mountain. In late 1983, continuous water-level monitoring was attempted at well UE-25b #1. Methods for continuous water-level monitoring were developed for use at well USW H-1 in 1983 and for use at well USW H-4 in 1984. By early 1985, methods were sufficiently developed to obtain usable data. By 1986, the present water-level monitoring network of continuously monitored and periodically measured wells had evolved.

Present Water-Level Monitoring Network

The water-level monitoring network has evolved into one that, by the end of 1988, consists of 10 wells that are periodically measured and 14 wells that are continuously monitored (table 1). Measurements in four wells included in

Table 1.--*Summary of wells monitored for water levels*

[p, periodic measurements; c, continuous monitoring; d, discontinued]

Well number	Drilled depth (meters)	Date completed	Water level: Approximate depth[1] (meters)	Water level: Approximate altitude[1] (meters)	Frequency monitored at end of 1988
USW WT-1	515	5-83	471	730	p
USW WT-2	628	7-83	571	730	c
UE-25 WT #3	348	5-83	300	730	c
UE-25 WT #4	482	6-83	438	731	p
UE-25 WT #6	383	6-83	279	1,034	c
USW WT-7	491	7-83	421	776	p
USW WT-10	431	8-83	347	776	p
USW WT-11	441	8-83	363	731	c
UE-25 WT #12	399	8-83	346	729	p
UE-25 WT #13	354	7-83	303	729	c
UE-25 WT #14	399	9-83	346	730	p
UE-25 WT #15	415	11-83	354	729	p
UE-25 WT #16	521	11-83	473	738	c
UE-25 WT #17	443	10-83	394	730	p
UE-25a #1	762	9-78	469	731	d
UE-25b #1	1,220	9-81	471	730	c
UE-25c #1	914	10-83	401	730	d
UE-25p #1	1,805	5-83	362	752	c
USW G-2	1,831	10-81	525	1,029	d
USW G-3	1,533	3-82	750	730	c
USW G-4	915	1-83	539	731	d
USW H-1	1,829	1-81	573	730	c
USW H-3	1,219	3-82	752	731	c
USW H-4	1,219	6-82	518	730	c
USW H-5	1,219	8-82	704	775	c
USW H-6	1,220	10-82	526	776	c
USW VH-1	762	2-81	185	779	p
J-13	1,063	1-63	283	728	p

[1]Composite water level of saturated interval, or level of shallowest interval monitored. See section on "Well Data, Water Levels, and Hydrographs."

the previous network have been discontinued (Robison and others, 1988); not all wells that have had reported water levels in previous reports are necessarily part of the present water-level monitoring network. The depth drilled, date completed, and water-level data for the 24 wells in the present water-level monitoring network as well as for the 4 wells removed from the network are summarized in table 1; the location of the wells are shown in figures 1 and 2.

The maximum variation in measured water-level altitudes for the periodically measured wells was measured in well J-13 (1962-88). The total variation in measured water-level altitudes at well J-13 was 0.90 m for the period of record. Because well J-13 is used for water supply, it is routinely subject to the effects of pumping; therefore, the measured water levels might not be representative of the static water level. The maximum variation in the measured water-level altitudes for the remainder of the periodically measured wells was measured in well UE-25 WT #14 (1983-88). The maximum variation in measured water-level altitudes was 0.69 m for the period of record at this well, and probably can be considered to represent the actual observed change in static water-level altitude. The minimum variation in the measured water-level altitudes for the periodically measured wells was measured in well USW VH-1 (1984-88). The total variation in measured water-level altitudes for the period of record at well USW VH-1 was 0.28 m.

HISTORY OF MEASUREMENT TECHNIQUES USED AT YUCCA MOUNTAIN

Most water-level measurements made in 1981 and the early part of 1982 were made with a single-conductor cable. Most measurements from September 10, 1982, through January 21, 1983, were made with a multiconductor cable. Most measurements from February 1, 1983, through April 29, 1985, were made with a multiconductor cable.

Most measurements from May 1985 until January 8, 1986, were made with a 2,800-ft steel tape. Measurements made after January 8, 1986, were made with a 2,600-ft steel tape. The 2,600-ft steel tape was calibrated in January 1986, in January 1988, and in January 1989. Some measurements during 1988 were made with a multiconductor cable (van I-133970). This unit was calibrated in January 1989.

The method used to make the water-level measurements in 1987 and 1988 is shown in the water-level tables for individual wells in the section "Well data, water levels, and hydrographs." The method used to make water-level measurements prior to 1987 is documented by Robison and others (1988). In 1988, the steel tape was the prefered method for making water-level measurements because of its higher accuracy. The multiconductor-cable unit was used when it was impractical to use the steel tape (for example, when condensation in the access tube prevented the steel tape from being lowered to the water surface).

PERIODIC MEASUREMENTS

Periodic water-level measurements at wells require onsite visits by trained personnel, who perform specific operations and record the results. Frequency of periodic measurements necessarily is a compromise between availability of personnel and cost of operation. The maximum frequency is continuous monitoring. Operational plans during 1988 resulted in measurements about once per month at each periodically measured well. Measurement frequency,

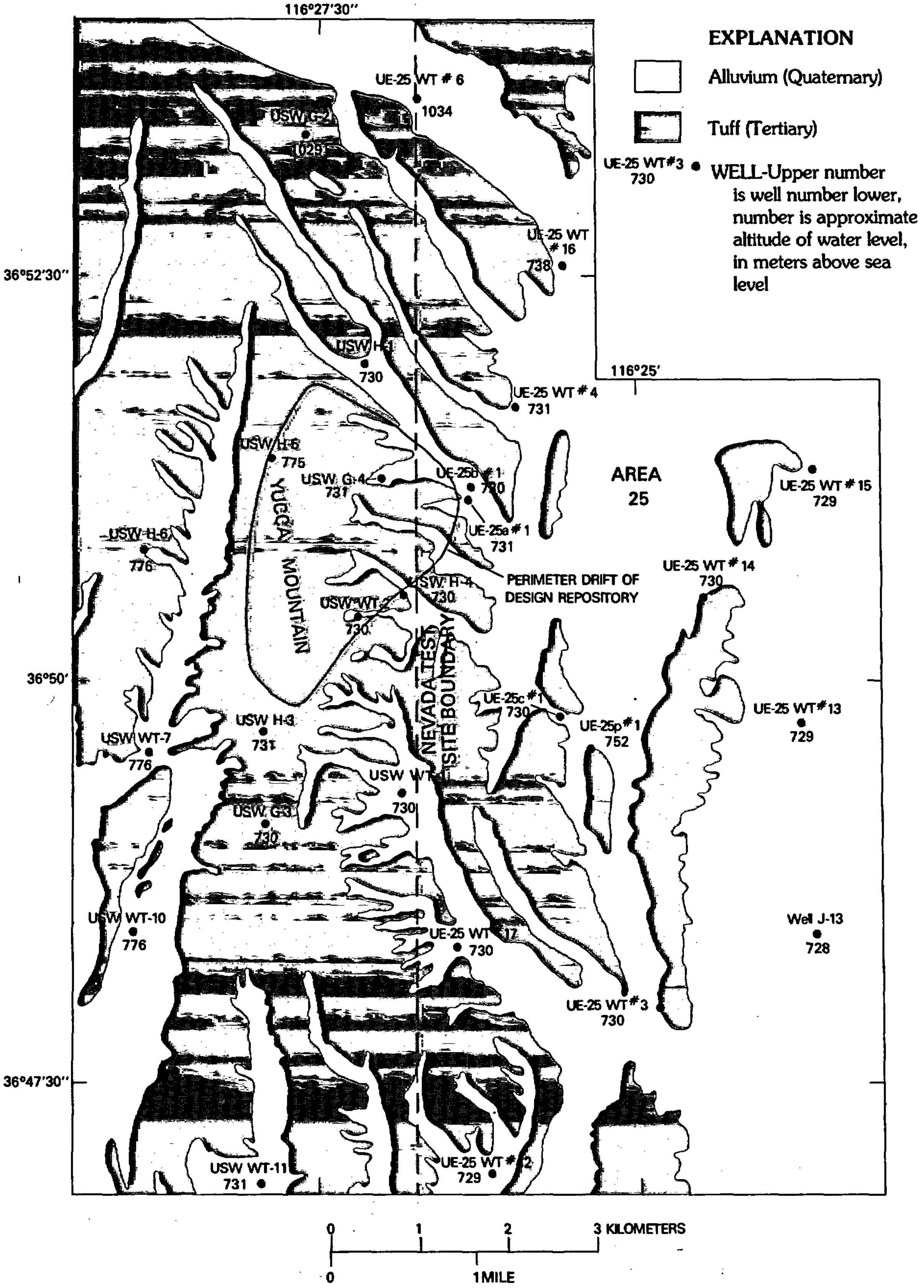


Figure 2.--Location of wells and water-level altitudes in the vicinity of Yucca Mountain (from Robison and others, 1988).

however, did vary; some wells were measured less frequently because of such factors as temporary shortage of trained personnel, breakdown of equipment, or well-site inaccessibility due to road washouts.

Periodic measurements during 1988 were made using the reference steel tape, the reeled steel tape, and the multiconductor cable. The equipment and measuring techniques varied and depended on a number of factors, such as availability of equipment, well construction that limits some equipment or techniques, length of time, or number of personnel needed for a technique.

Reference Steel Tape

The reference steel tape is a steel surveyor's chain. From January 8, 1986, through 1987, a steel tape 6.4 mm wide and 853 m long has been considered the reference. The steel tape is marked in feet rather than meters; therefore it is identified as the 2,800-ft reference steel tape. This tape is marked at 1-ft intervals, except for the lower part, which is marked in hundredths of a foot. The reference tape is one to which other tapes or measuring equipment are calibrated. Because it is a standard, the reference tape is not routinely used for measurements to prevent undue wear or stretch. When water levels are measured using the reference steel tape or other tapes that have been calibrated against this tape, the end of the tape is lowered to slightly below the estimated water level in the well, until a convenient foot value on the tape is reached; this point on the tape is held against a measuring point (MP) of known altitude, such as the top of the well casing. The level of the water is indicated on the tape by the limit of wetted chalk, color-change paste, or salt previously applied to the lower part of the tape. The tape is removed from the well and the distance between the foot value held at the MP and the top of the wetted interval is calculated immediately. This distance is the apparent depth to water below the MP; the distance between the MP and the land surface is either subtracted or added to obtain the apparent depth to water below land surface. Because depths to water beneath Yucca Mountain are as great as 750 m, it may take as long as 2 hours to obtain a single water-level measurement. A small plumb bob, weighing about 0.45 kg, is attached to the end of the tape to keep it hanging straight. Mechanical-stretch coefficients (because of weight of the plumb bob and the weight of the tape), thermal-expansion coefficients, and other tape specifications are used to make corrections to obtain the actual depth to water below the land surface (table 2).

The correction for mechanical stretch of the tape is given by:

$$C = \frac{L^2\,WS}{2} + PLS - KLS\ , \qquad (1)$$

where C is the correction, in meters;
L is the apparent length of tape, in meters;
W is the unit weight of the tape, 2.08×10^{-2} kilograms per meter;
S is the stretch coefficient, 2.48×10^{-5} meters per (meter·kilogram);
P is the weight of the plumb bob, in kilograms; and
K is reference tension during manufacture, 9.07 kilograms.

The value for the stretch coefficient "S" in equation 1 was incorrectly stated in Robison and others (1988). The corrected value is 2.48×10^{-5} meters per (meter·kilogram). The correct value of "S" for the 2,000-ft tape of Robison and others (1988) is 3.86×10^{-5} meters per (meter·kilogram). The quality of the published data in that report was not affected by this inconsistency because the table of correction factors used to reduce the data was generated using equation 1 with the proper value for "S". Therefore, no further corrections are required.

Table 2.--*Corrections applicable to steel tapes used for measuring water levels in the vicinity of Yucca Mountain*

Well number	Approximate depth to water (meters)	Average air temperature in well (degrees Celsius)	Correction for 2,800-foot reference tape (meters)			Correction for reeled (2,600-foot) tape (meters)			Correction for borehole deviation from vertical (meters)
			Thermal expansion	Mechanical stretch	Total[1]	Thermal expansion	Mechanical stretch	Total[1]	
USW WT-1	470.9	25.0	.027	-.043	-.016	.027	-.054	-.027	-.33
UE-25 WT #4	438.9	25.0	.025	-.044	-.019	.025	-.054	-.028	-.46
USW WT-7	420.6	27.8	.038	-.044	-.006	.038	-.053	-.015	-.03
USW WT-10	347.5	29.4	.038	-.043	-.005	.038	-.049	-.011	-.03
UE-25 WT #12	345.9	27.2	.029	-.043	-.014	.029	-.049	-.020	-.20
UE-25 WT #14	345.9	24.4	.018	-.043	-.025	.018	-.049	-.031	-.09
UE-25 WT #15	353.6	23.9	.016	-.043	-.027	.016	-.050	-.034	-.19
UE-25 WT #17	394.7	25.0	.023	-.044	-.021	.023	-.052	-.029	-.48
USW VH-1	184.4	[2]23.9	.008	-.031	-.022	.008	-.033	-.024	-.05
J-13	283.5	25.0	.016	-.040	-.023	.016	-.044	-.028	([3])

[1]Total correction may not equal sum of thermal expansion and mechanical stretch due to rounding.
[2]The average air temperature for well USW VH-1 is estimated from the water temperature and the air temperature in nearby wells.
[3]Gryoscopic survey not available for well J-13; therefore, no correction was made for borehole deviation.

Correction for thermal expansion of the tape is given by:

$$E = (D - R)\,TL\ , \qquad (2)$$

where E is the correction, in meters;
D is the average air temperature in the well, in degrees Celsius;
R is the reference temperature during manufacture, 20 degrees Celsius;
T is the thermal expansion coefficient, 1.16×10^{-5} meters per (meter·degree); and
L is the apparent length of the tape, in meters.

Reeled Steel Tape

The reeled steel tape, referred to in this report as the 2,600-ft tape, also is a steel surveyor's chain, 6.4 mm wide and 792 m long, that is similar to the 2,800-ft reference steel tape. The measurement technique with the 2,600-ft tape is similar to that with the reference steel tape. The reeled steel tape and associated equipment were custom manufactured in 1985 for the U.S. Geological Survey's use at Yucca Mountain, and are used for many routine periodic measurements. The reeled steel tape is calibrated directly to the reference steel tape and measurements have similar accuracy and precision. For this tape the unit weight "W" is 1.70×10^{-2} kg/m, the stretch coefficient "S" is 2.50×10^{-5} meters per (meter·kilogram), and the reference tension "K" is 9.07 kg. The unit weight and coefficient of mechanical stretch was determined by U.S. Geological Survey personnel, and the reference tension was provided by the manufacturer. The coefficient of mechanical stretch was verified by comparing concurrent water-level measurements of the reference steel tape and this tape. The correction for mechanical stretch of the tape is given by

$$C = 2.12 \times 10^{-7} L^2 + 2.50 \times 10^{-5} PL - 2.27 \times 10^{-4} L , \qquad (3)$$

where the variables are the same as for equation 1.

The correction for thermal expansion for the 2,600-ft tape is given by

$$E = (D - 20.0) \times 1.16 \times 10^{-5} L , \qquad (4)$$

where the variables are the same as for equation 2. The thermal-expansion coefficient, 1.16×10^{-5} meter per (meter·degree), was provided by the tape manufacturer.

On January 10-13, 1989, concurrent water-level measurements with the reeled steel tape and the reference tape were made in three wells that spanned the range in water levels that are normally measured around Yucca Mountain. Depth to water in the three wells ranged from 216 to 752 m. At least two measurements were made in each well with each tape. After all previously described corrections were applied, the difference between the two sets of measurements ranged from zero for 450 m to water to 0.03 m for 752 m to water.

In some wells with small-diameter access tubes, water condensation in the tube, or possibly pipe-joint compound, causes excess friction between the flat steel tape and the tube, inhibiting insertion of the tape even with the standard plumb bob attached to the end of the tape. When this happens, the water--level measurements are made with the multiconductor-cable unit.

Multiconductor Cable

A four-conductor, armored cable, about 1,000 m long, mounted on a powered reel and housed in a truck or mobile van, uses one of several different possible sensing devices on the end to indicate contact with the water. The cable passes over a sheave that indicates depth in feet. The water-level sensing device may be a float switch or similar device, used to indicate electrical contact with water, or a pressure transducer, used to indicate initial submergence.

The probe or "tool" that contains the sensing device also functions as the weight to keep the cable taut as it is lowered down the well. The length of this probe can vary depending on the weight deemed necessary for a particular well. The variation in probe lengths used at the NTS ranges from about 0.5 to 2.4 m. Check measurements made with the different length probes indicate that the calibration of the cable unit is not significantly affected by this small variation in weight. The top of the probe, as it is suspended at the top of the well and level with the MP, is used as the reference to zero on the depth indicator on the cable unit. This requires that a careful measurement of the distance from the top of the probe to the actual sensor location within the probe be made so that the indicated depth to water on the depth counter can be corrected for the probe length. A measurement is made by initially setting the depth indicator to zero when the top of the probe containing the sensing device is level with the MP and then lowering the probe until the sensing device reaches the water surface to obtain an IN reading. The IN reading is the indicated footage of cable displayed by the depth indicator when the sensing device is at the water surface. The cable is then withdrawn and an OUT reading is obtained when the top of the probe is again level with the MP. The difference between the IN and OUT reading is equivalent to measuring the actual length of cable withdrawn from the well. Frequently, as the probe containing the sensing device is withdrawn to the MP to obtain an OUT reading, the depth indicator returns to slightly past zero; when this occurs, the value indicated by the depth indicator is recorded in the field log books as a number slightly less than 100, reflecting the final four digits displayed on the depth indicator. For example, a recorded OUT reading of 99.70 ft is actually -0.30 ft, and -0.30 is the value used in the calculation.

The multiconductor-cable unit in use during 1988 was purchased in mid-1985 and was housed in van I-133970. Although this unit is similar to other units used previously, the calibration for each unit is unique and care needs to be used to not confuse the different units when calculating water-level altitudes. The multiconductor-cable unit was calibrated during January 10-11, 1989, at the NTS. Water-level measurements were made in three wells, with depths to water ranging from 216 to 752 m, using the 2,800-ft steel reference tape and the multiconductor-cable unit. At least two measurements were made with both the 2,800 ft steel reference tape and the multiconductor-cable unit in each of the three wells. The reference steel tape measurements were corrected for mechanical stretch and thermal expansion and then compared with those made with the multiconductor-cable unit in order to define the difference between the two sets of measurements. An average correction factor, based on the calculated differences of the water-level measurements for the three wells, was computed for the multiconductor-cable unit. The average correction factor for the multiconductor-cable unit was determined to be +0.00162 m/m. No previous calibrations had been made for this multiconductor-cable unit, although concurrent measurements in one well were made using this unit and the 2,600-ft tape in November 1987 and January 1988. The November 1987 measurement indicated a correction factor similar to the one determined during calibration, but the January 1988 measurement did not. However, no tool-length correction was recorded for the January 1988 measurement, making the measurement difficult to evaluate. Based on the January 1989 calibration and the November 1987 measurement, a correction factor of +0.00162 m/m was used to correct all measurements in this report that were made using the multiconductor-cable unit (van I-133970).

The correction factor is applied directly to the apparent length of cable measured before any other corrections are applied in arriving at the true water-level altitude. For example, if the apparent length of the cable was 436.34 m in May 1988, the corrected depth to water would have been

$$\begin{aligned}\text{Corrected length of cable} &= 436.34 \text{ m} + [436.34 \text{ m} \times 0.00162 \text{ m/m}] \\ &= 436.34 \text{ m} + 0.71 \text{ m} \\ &= 437.05 \text{ m}.\end{aligned}$$

Corrections and Adjustments

Various factors affect the accuracy of periodic water-level measurements and need to be considered in the process of determining the apparent depth below land surface, the true depth below land surface, and the water-level altitude. All the measurements in this report have been corrected as previously described to reflect the true water-level altitude. The correction factors applied to steel-tape measurements for each well are summarized in table 2.

Apparent Depth

Mechanical stretch is associated with the weight of the steel tape and plumb bob or multiconductor cable, and probe (Garber and Koopman, 1968). For the steel tapes used during 1988, the calculated adjustment, based on stretch coefficients given previously and an approximate weight of 0.45 kg for the plumb bob on the end of the tape, ranges from -0.015 to -0.055 m for water levels measured in wells at and near Yucca Mountain. This mechanical stretch may be several tenths of a meter or more for the multiconductor cable; however, no additional correction was necessary because the cable had been calibrated to the reference steel tape.

Thermal expansion of a steel tape or a multiconductor cable occurs because of downhole increase or decrease in temperature. For steel tapes, the calculated correction for thermal expansion is based on manufacturers' specifications for thermal-expansion coefficients and on temperature profiles of wells at Yucca Mountain (Sass and Lachenbruch, 1982). The correction ranges from +0.008 to +0.053 m and usually is not made separately from other corrections. No correction for thermal expansion is made for the multiconductor cable. Based on the range in temperature and depths to water at Yucca Mountain, a correction of up to 0.05 m may be required. Some temperature correction may be accounted for in the cable correction factor because the cable is calibrated in the temperature range in which it is used.

Sheave slippage occurs because of change of diameter of the sheave or operator error. Slippage can vary with hoist design, but errors can be minimized by comparing the IN and OUT readings of water levels. The sheaves used for depth indicators can wear, eventually causing errors in measurements. Annual calibration of the multiconductor-cable unit decreases the error and, along with a visual inspection of the sheave, indicates when the sheave needs to be replaced. This factor is not applicable to steel tapes that have permanently marked depths.

True Depth

Factors that affect determination of the true depth to water below land surface include the apparent-depth factors, above, plus corrections for boreholes that are not plumb or not straight. High-precision gyroscopic surveys were made in all the periodically measured wells except well J-13. Corrections for most wells are -0.2 m or less, but they range from -0.03 to -0.48 m (table 2). Corrections generally increase with increasing well depth.

Altitude

Factors that affect determination of water-level altitude include the apparent-depth and true-depth factors. Water-level altitude is calculated by subtracting the true depth to water from the altitude of the land surface or the reference point, or from the altitude of the measuring-point datum, adjusted to land surface or the reference point. Water-level altitudes in this report are based on a survey of the water-level monitoring network in late 1984 by the U.S. Geological Survey.

Example Calculations

Two measurements for well UE-25 WT #4 are presented to illustrate the calculations that are made to derive the true altitude of the water level. The true altitude is the value reported in the section on "Well data, water levels, and hydrographs." Measurements made in January and December 1988 were chosen as the examples.

Water-level measurements at well UE-25 WT #4 are made from the top of a 62-mm-inside-diameter steel tube, which is the MP at this well. The measurements are corrected to the reference point, which at this well is the top of a metal tag welded to the casing. Because the precise altitude of the reference point is known, it is used as a basis for determining the true altitude of the water level in the well. The difference in altitude between the MP and the reference point can be measured with a pocket tape; at well UE-25 WT #4 the MP is 0.31 m or 1.02 ft above the reference point. The water-level measurements, which are recorded to the nearest 0.01 ft, later are converted to meters. Most intermediate calculations are made to three decimal places; the final values for water levels are rounded to two decimal places.

At least two measurements of the water level are made and averaged during each visit to the well. In most instances, additional measurements are made if the values differ by more than 0.05 ft. In some of the more difficult wells to measure, some discretion is required in applying this criterion. Even in the worst instance, the difference between measurements is limited to 0.10 ft. After averaging, the appropriate corrections are applied.

Example A

Water-level measurements on January 27, 1988, were made with a reeled steel tape (2,600-ft tape). The HELD is the indicated footage on the tape when it is held at the MP during a measurement, and CUT is the footage of tape that is wetted during its submersion in the water. The difference between HELD and CUT is the apparent depth to water below the MP.

The readings for January 27, 1988, were:

Reading	Measurement 1	Measurement 2
HELD (ft)	1,442.00	1,443.00
CUT (ft)	-1.10	-2.09
Apparent depth below measuring point (ft)	1,440.90	1,440.91

The following calculations were made:

Determination of apparent depth below reference point:	
Average of two apparent depths below MP (ft)	1,440.90
MP height above reference point (ft)	-1.02
Apparent depth below reference point (ft)	1,439.88
Determination of true depth below reference point:	
Apparent depth below reference point (1,439.88 x 0.3048) (m)	438.875
Tape correction, from table 2 (m)	-0.028
Correction for borehole deviation from vertical from table 2 (m)	-0.460
True depth below reference point (m)	438.387
Determination of water-level altitude:	
Altitude of reference point (m)	1,169.210
True depth below reference point (m)	-438.387
Altitude of water level (m)	730.82

Example B

Water-level measurements on December 20, 1988, were made with a multi-conductor cable (housed in van I-133970). The IN reading is the indicated footage of cable displayed by the depth indicator when the sensing device is at the water surface, and the OUT reading is the indicated footage when the sensing device has been withdrawn to the MP. The length of the probe containing the sensing device also was considered in the measurement, because it is not accounted for in the depth-indicator reading. This length was measured using a pocket tape, and care was taken to ensure the measurement was from the top of the probe to the actual sensing point (not necessarily the bottom of the probe).

The readings for December 20, 1988, were:

Reading	Measurement 1	Measurement 2
IN reading (ft)	1,436.26	1,436.23
Recorded OUT reading (ft)	99.63	99.58
Actual OUT reading (ft)	-0.37	-0.42
Apparent depth below measuring point--IN reading minus OUT reading (ft)	1,436.63	1,436.65

The following calculations were made:

Determination of apparent depth below reference point:	
Average of two apparent depths below MP (ft)	1,436.64
Cable correction (1,436.64 x 0.00162) (ft)	+2.33
Apparent depth below measuring point (ft)	1,438.97
MP height above reference point (ft)	-1.02
Apparent depth below reference point (ft)	1,437.95
Determination of true depth below reference point:	
Apparent depth below reference point (1,437.95 x 0.3048) (m)	438.287
Correction for length of probe (m)	+0.57
Correction for borehole deviation from vertical from table 2 (m)	-0.46
True depth below reference point (m)	438.397
Determination of water-level altitude:	
Altitude of reference point (m)	1,169.21
True depth (m)	438.40
Altitude of water level (m)	730.81

Quality Assurance

Data in this report may be used in characterizing the Yucca Mountain site to evaluate its suitability for a nuclear-waste repository. Adequate confidence in the reliability of collection, processing, and reporting of the water-level data is necessary so that the data can be used in assessing the expected performance of a proposed repository. Quality assurance includes all the actions and records of those actions supporting the reliability of the data. Water-level measurements are obtained by methods described in formal technical procedures. The technical procedures include tests and adjustments performed during the measuring operation that ensure that the equipment is operating properly and that expected precision and accuracy will be attained. For example, the procedure for multiconductor-cable measurements includes:

1. That at least two measurements be made.
2. How the measurements are to be made.
3. That the accuracy of the measurements be at least 0.1 percent of the depth to water.
4. How the data are to be recorded on forms or in logbooks.
5. That the multiconductor-cable unit be calibrated annually.

Data are recorded at the well site in bound logbooks. Data recorded in the logbook are: Designation of the well name; time and date of the measurement; names of the personnel making the measurement; identification of procedures and specific measuring equipment used; adjustments from the MP to the land surface or reference point; and the actual measurement.

In addition to recording the above detailed information in a logbook, the entry might include comments about anything that seems relevant to the data, such as discussion of problems with equipment, or temporary inaccessability of the well site to obtain measurements. Air temperature and barometric pressure are commonly recorded in the logbook; these indicate conditions under which the measurement is made.

After completion of the water-level measurements, the measurement information is reviewed for completeness and accuracy by the supervisor responsible for onsite operations. The original logbooks and records are maintained at the onsite operations headquarters, near Mercury, Nevada. Photocopies are made periodically and transmitted to the project office located in Denver, Colorado. The transmitted records are reviewed, and any needed adjustments or corrections are made that were not made during onsite operations. It is at this stage that true water-level altitude is calculated. After this review and calculation, the data are ready for publication by the U.S. Geological Survey. The water-level data also are available for transfer to a computer data base, such as the Ground Water Site Inventory system used by the U.S. Geological Survey.

WELL DATA, WATER LEVELS, AND HYDROGRAPHS

Sources of information, well specifications, the equipment used to make water-level measurements, the maximum and minimum measured water-level altitudes for the period of record, a table of average annual water levels for the period of record, and water-level altitudes measured in 1987 and 1988 are given for individual wells. The sources of information, published or unpublished, are indicated for each well; the published sources also are listed in "References cited" at the back of the report. The well specifications include the location, the land-surface altitude, the start and completion dates of drilling, the drilling method, description of access tubes for measuring water levels, description and altitude of the reference point, and the depth correction for borehole deviation. Water-level altitudes are given in tabular form and in a hydrograph. The average annual water-level altitudes for well J-13 are not presented because the limited data available makes averaging impractical. The section on "History of measurement techniques used at Yucca Mountain" may be relevant and important to the understanding or analysis of the data from each well.

Well USW WT-1

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Fenix & Scisson, Inc (1986a, 1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 753,941; E 563,739.
      Latitude and longitude: 36°49'16" N.; 116°26'56" W.
      Site ID: 364916116265601.
   b. Land-surface altitude: 1,201.4 m (Robison, 1986; based on survey by U.S. Geological Survey in 1984).
   c. Date drilling started: April 28, 1983.
   d. Date drilling completed: May 18, 1983.
   e. Drilling method: Rotary, using rock bits and air, water, and soap circulating medium; bottom-hole core obtained.
   f. Total drilled depth: 515 m (1,689 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.).
   h. Casing extending below water level: None [surface casing only, to a depth of 10 m (32 ft)].
   i. Description of access for measuring water levels, including tubes or piezometers: 62-mm (2.4-in.) inside-diameter tubing that has a 3.6-m- (12-ft-) long well screen on the bottom; tubing and attached screen extend from land surface to a depth of 507 m (1,665 ft); saturated interval of borehole within tuffaceous beds of Calico Hills to Bullfrog Member of Crater Flat Tuff.
   j. Description and altitude of reference point: Top of metal tag on well casing, 1,201.11 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.33 m, based on approximate depth to water of 471 m (1,541 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor-cable unit (logging van I-127410) from June 29, 1983, through April 11, 1985. Measurements were made using the 2,800-ft steel tape from June 13, 1985, through Dececember 27, 1985, and for one measurement made March 21, 1988. The 2,600-ft steel tape was used from January 27, 1986, through December 20, 1988.

4. Extremes:

   a. June 1983 through 1987: Maximum measured water-level altitude, 730.50 m, November 20, 1985, and December 27, 1985; minimum measured water-level altitude, 729.91 m, November 26, 1984.

b. 1988: Maximum measured water-level altitude, 730.44 m, May 23; minimum measured water-level altitude, 730.37 m, March 21, and September 14.

5. Average annual water-level altitudes:

Calendar year	Average water-level altitude (meters)
1983 (June-December)	730.19
1984	730.09
1985	730.19
1986	730.32
1987	730.35
1988	730.40

6. Periodic measurements of water-level altitude in well USW WT-1:

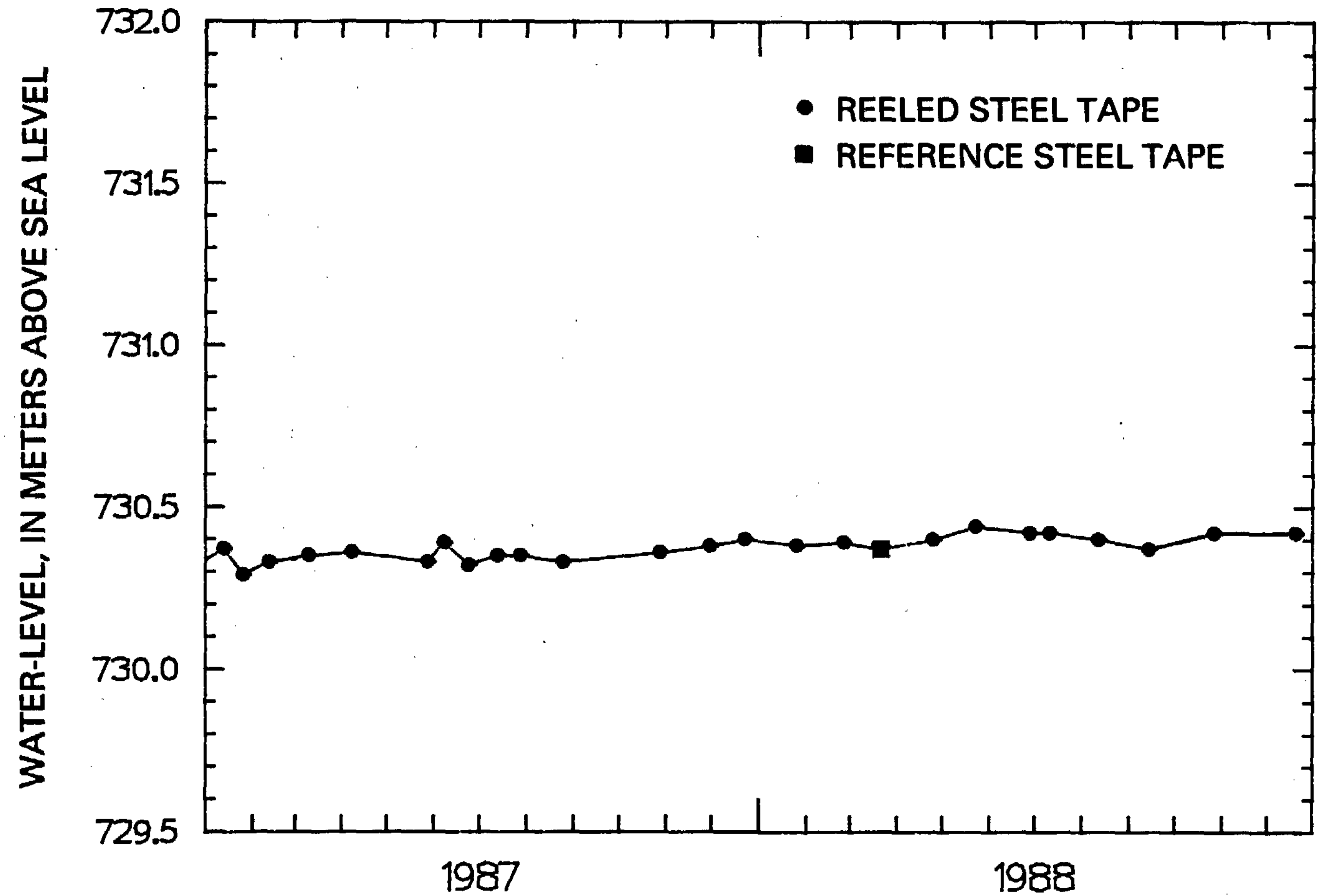
[S, 2,600-ft tape; R, 2,800-ft tape]

Site ID: 364916116265601
Depth interval: 471-515 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-13-87	730.37	S	12-23-87	730.40	S
01-26-87	730.29	S	01-26-88	730.38	S
02-12-87	730.33	S	02-26-88	730.39	S
03-10-87	730.35	S	03-21-88	730.37	R
04-08-87	730.36	S	04-25-88	730.40	S
05-28-87	730.33	S	05-23-88	730.44	S
06-08-87	730.39	S	06-28-88	730.42	S
06-24-87	730.32	S	07-11-88	730.42	S
07-13-87	730.35	S	08-12-88	730.40	S
07-28-87	730.35	S	09-14-88	730.37	S
08-25-87	730.33	S	10-27-88	730.42	S
10-28-87	730.36	S	12-20-88	730.42	S
11-30-87	730.38	S			

USW WT-1

Site ID: 364916116265601



7. Hydrograph of water-level altitude (plotted from data in section 6):

Well UE-25 WT #4

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Fenix & Scisson, Inc. (1986a, 1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 768,512; E 568,040.
      Latitude and longitude: 36°51'40" N.; 116°26'03" W.
      Site ID: 365140116260301.
   b. Land-surface altitude: 1,169.2 m (Robison, 1986; based on survey by U.S. Geological Survey, 1984).
   c. Date drilling started: May 28, 1983.
   d. Date drilling completed: June 6, 1983.
   e. Drilling method: Rotary, using rock bits and air-foam circulating medium; bottom-hole core obtained.
   f. Total drilled depth: 482 m (1,580 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.).
   h. Casing extending below water level: None [surface casing only, to a depth of 15 m (50 ft)].
   i. Description of access for measuring water levels, including tubes or piezometers: 62-mm (2.4-in.) inside-diameter tubing that has a 3.6-m- (12-ft-) long well screen on the bottom; tubing and attached screen extend from land surface to a depth of 478 m (1,567 ft); saturated interval of borehole within tuffaceous beds of Calico Hills.
   j. Description and altitude of reference point: Top of metal tag on well casing, 1,169.21 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.46 m, based on approximate depth to water of 439 m (1,440 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor-cable unit (logging van I-127410) from June 8, 1983, through April 29, 1985. Measurements were made using the 2,800-ft steel tape from June 12, 1985, through December 6, 1985, and using the 2,600-ft steel tape from January 29, 1986, through April 11, 1988. The multiconductor-cable unit housed in van I-133970 was used to make the water-level measurements from April 18, 1988, to December 20, 1988.

From April 11 through 18, 1988, personnel from the Desert Research Institute pumped a total volume of about 3,000 L of water from the well for the purpose of obtaining water samples. As a result, subsequent water-level measurements might reflect some residual effects from pumping until the saturated interval had sufficient time to recover.

4. Extremes:

   a. June 1983 through 1987: Maximum measured water-level altitude, 730.85 m, December 23, 1987; minimum measured water-level altitude, 730.28 m, March 20, 1985.

b. 1988: Maximum measured water-level altitude, 730.83 m, April 11; minimum measured water-level altitude, 730.61 m, June 29, and September 22.

5. Average annual water-level altitudes:

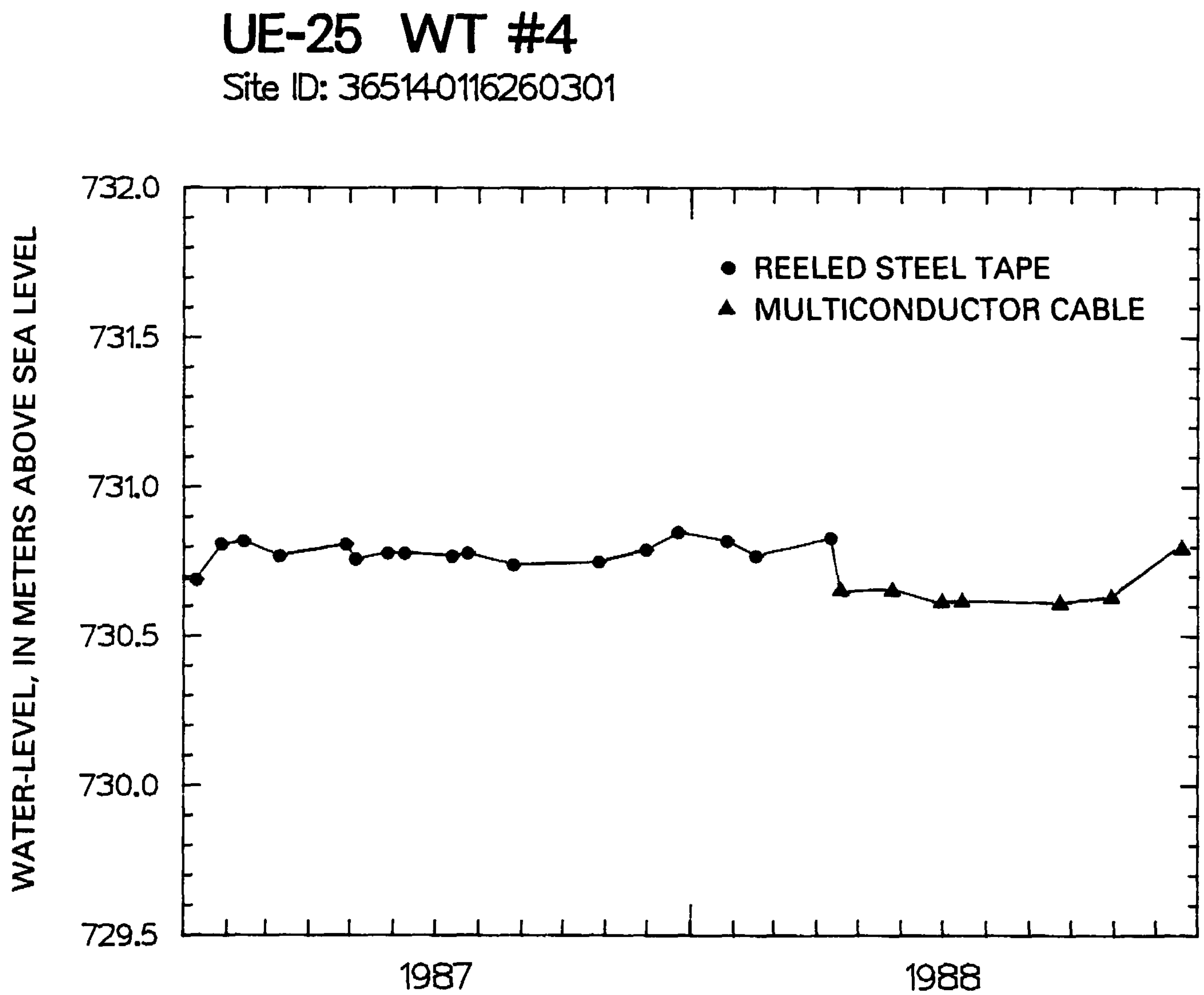
Calendar year	Average water-level altitude (meters)
1983 (June-December)	730.60
1984	730.48
1985	730.55
1986	730.75
1987	730.78
1988	730.70

6. Periodic measurements of water-level altitude in well UE-25 WT #4:

[S, 2,600-ft tape; V, multiconductor cable]

Site ID: 365140116260301
Depth interval: 439-482 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-10-87	730.69	S	12-23-87	730.85	S
01-28-87	730.81	S	01-27-88	730.82	S
02-13-87	730.82	S	02-17-88	730.77	S
03-11-87	730.77	S	04-11-88	730.83	S
04-28-87	730.81	S	04-18-88	730.65	V
05-05-87	730.76	S	04-19-88	730.65	V
05-28-87	730.78	S	05-24-88	730.66	V
06-09-87	730.78	S	06-29-88	730.61	V
07-13-87	730.77	S	07-14-88	730.62	V
07-24-87	730.78	S	09-22-88	730.61	V
08-26-87	730.74	S	10-28-88	730.63	V
10-27-87	730.75	S	12-20-88	730.81	V
11-30-87	730.79	S			



7. Hydrograph of water-level altitude (plotted from data in section 6):

Well USW WT-7

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Fenix & Scisson, Inc. (1986a, 1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 755,570; E 553,891.
      Latitude and longitude: 36°49'33" N.; 116°28'57" W.
      Site ID: 364933116285701.
   b. Land-surface altitude: 1,196.9 m (Robison, 1986; based on survey by U.S. Geological Survey, 1984).
   c. Date drilling started: July 19, 1983.
   d. Date drilling completed: July 26, 1983.
   e. Drilling method: Rotary, using rock bits and air-foam circulating medium; bottom-hole core obtained.
   f. Total drilled depth: 491 m (1,610 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.).
   h. Casing extending below water level: None [surface casing only, to a depth of 16 m (52 ft)].
   i. Description of access for measuring water levels, including tubes or piezometers: 62-mm (2.4-in.) inside-diameter tubing that has a 3.6-m- (12-ft-) long well screen on the bottom; tubing and attached screen extend from land surface to a depth of 481 m (1,579 ft); saturated interval of borehole within Topopah Spring Member of Paintbrush Tuff to Prow Pass Member of Crater Flat Tuff.
   j. Description and altitude of reference point: Top of metal tag on well casing, 1,196.88 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.03 m, based on approximate depth to water of 421 m (1,381 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor cable (logging van I-127410) from August 30, 1983, through April 16, 1985. Measurements were made using the 2,800-ft steel tape from June 21, 1985, through December 28, 1985, and using the 2,600-ft steel tape from January 1, 1986, through May 27, 1987. The multiconductor cable unit, which is housed in van I-133970, was used to make water-level measurements from May 16, 1988, to December 21, 1988.

On June 6, 1988, personnel with the Desert Research Institute pumped about 760 L of water from the well for the purpose of obtaining water samples. As a result, subsequent water-level measurements might reflect some residual effects from pumping until the saturated interval had sufficient time to recover.

4. Extremes:

   a. August 1983 through May 1987: Maximum measured water-level altitude, 775.88 m, January 14, 1987; minimum measured water-level altitude, 775.47 m, March 18, 1985.

b. 1988: Maximum measured water-level altitude, 775.88 m, December 21; minimum measured water-level altitude, 775.57 m, July 8.

5. Average annual water-level altitudes:

Calendar year	Average water-level altitude (meters)
1983 (August-December)	775.74
1984	775.64
1985	775.73
1986	775.78
1987 (January-May)	775.80
1988 (May-December)	775.70

6. Periodic measurements of water-level altitude in well USW WT-7:

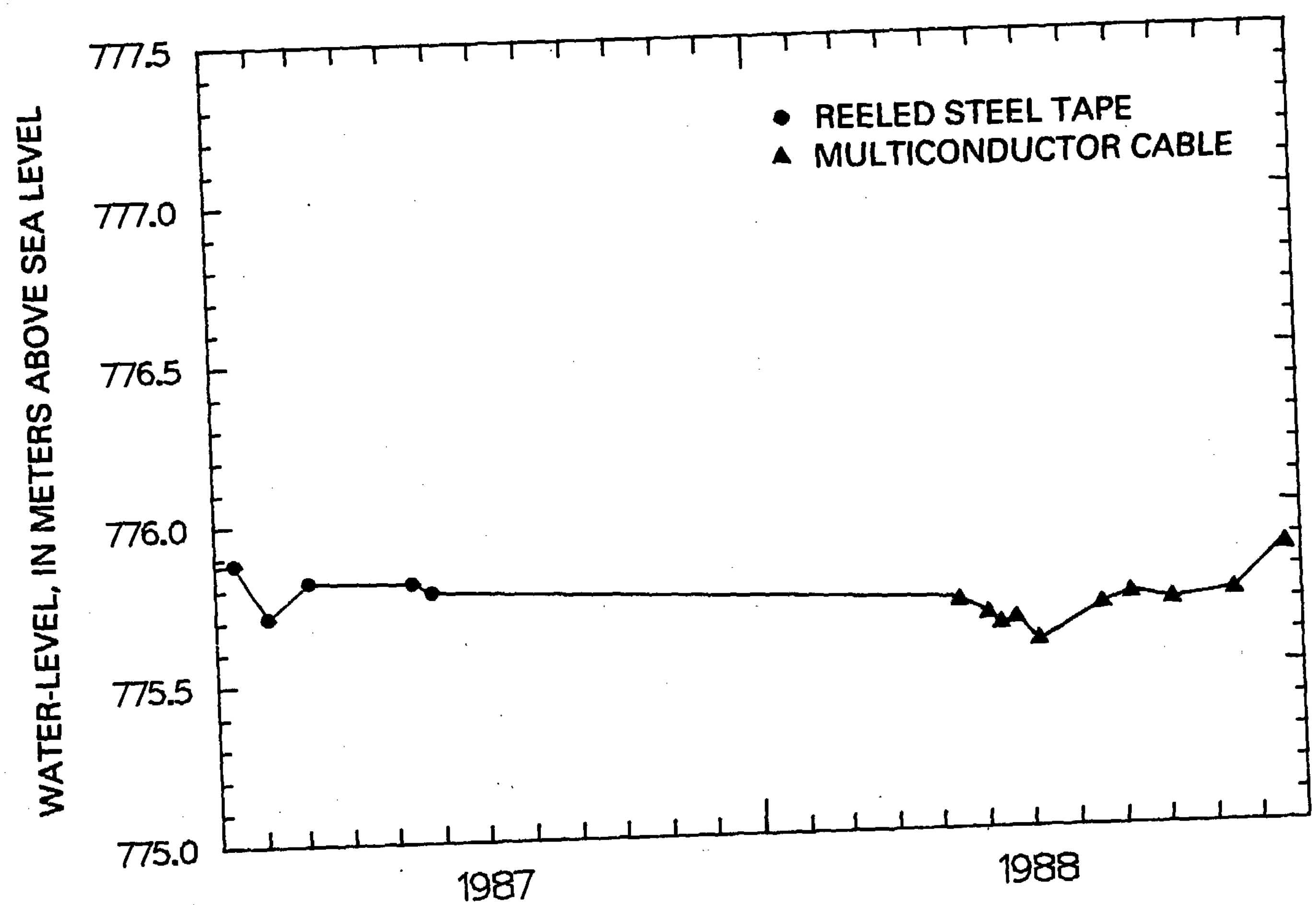
[S, 2,600-ft tape; V, multiconductor cable]

Site ID: 364933116285701
Depth interval: 421-491 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-14-87	775.88	S	06-23-88	775.66	V
02-05-87	775.71	S	07-08-88	775.57	V
03-05-87	775.82	S	08-17-88	775.69	V
05-14-87	775.81	S	09-08-88	775.73	V
05-27-87	775.78	S	10-06-88	775.70	V
05-16-88	775.72	V	11-17-88	775.73	V
06-03-88	775.67	V	12-21-88	775.88	V
06-13-88	775.62	V			

USW WT-7

Site ID: 364933116285701



7. Hydrograph of water-level altitude (plotted from data in section 6):

Well USW WT-10

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Fenix & Scisson, Inc. (1986a, 1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 748,771; E 553,302.
      Latitude and longitude: 36°48'25" N.; 116°29'05" W.
      Site ID: 364825116290501.
   b. Land-surface altitude: 1,123.4 m (Robison, 1986; based on survey by U.S. Geological Survey, 1984).
   c. Date drilling started: July 26, 1983.
   d. Date drilling completed: August 2, 1983.
   e. Drilling method: Rotary, using rock bits and air-foam circulating medium; bottom-hole core obtained.
   f. Total drilled depth: 431 m (1,413 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.).
   h. Casing extending below water level: None [surface casing only, to a depth of 35 m (114 ft)].
   i. Description of access for measuring water levels, including tubes or piezometers: 62-mm (2.4-in.) inside-diameter tubing that has a 3.6-m- (12-ft-) long well screen on the bottom; tubing and attached screen extend from land surface to a depth of 403 m (1,321 ft); saturated interval of borehole within Topopah Spring Member of Paintbrush Tuff.
   j. Description and altitude of reference point: Top of metal tag on well casing, 1,123.40 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.03 m, based on approximate depth to water of 348 m (1,142 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor-cable unit (logging van I-127410) from August 30, 1983, through April 16, 1985. Measurements were made using the 2,800-ft steel tape from June 21, 1985, through December 13, 1985. Measurements thereafter were made using the 2,600-ft steel tape, except that the measurement on December 16, 1987, was made using the 2,800-ft steel tape, and those made August 17, 1988, and September 8, 1988, were made using the multiconductor cable unit housed in van I-133970.

The water-level altitude on May 14, 1987, was about 0.3 m (1 ft) below the general trend. The water-level measurement is reported here in meters, but was actually measured in feet using the 2,600-ft steel tape. Because of the measurement process, unverifiable onsite recording errors, when they occur, are more likely to be in multiples of feet; therefore, users of the data are cautioned that the May 14, 1987, water-level altitude might not be accurate.

From May 9 through 16, 1988, personnel from the Desert Research Institute pumped about 12,000 L of water from the well for the purpose of obtaining water samples. As a result, subsequent water-level measurements might reflect some residual effects from pumping until the saturated interval had sufficient time to recover.

4. Extremes:

   a. August 1983 through 1987: Maximum measured water-level altitude, 776.15 m, December 13, 1985; minimum measured water-level altitude, 775.55 m, February 6, 1985.
   b. 1988: Maximum measured water-level altitude, 776.06 m, November 17; minimum measured water-level altitude, 775.63 m, April 5 and May 9.

5. Average annual water-level altitudes:

Calendar year	Average water-level altitude (meters)
1983 (August-December)	775.90
1984	775.83
1985	775.90
1986	775.93
1987	775.93
1988	775.92

6. Periodic measurements of water-level altitude in well USW WT-10:

[S, 2,600-ft tape; R, 2,800-ft tape; V, multiconductor cable]

Site ID: 364825116290501
Depth interval: 348-431 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-14-87	775.99	S	01-22-88	775.89	S
02-05-87	775.85	S	02-24-88	776.00	S
03-05-87	775.98	S	03-07-88	775.96	S
05-14-87	775.63	S	04-05-88	775.63	S
05-27-87	775.95	S	05-09-88	775.63	S
06-17-87	775.98	S	05-17-88	776.04	S
07-14-87	775.96	S	05-18-88	775.99	S
08-06-87	775.97	S	06-23-88	775.99	S
08-27-87	775.94	S	07-08-88	775.99	S
09-17-87	775.95	S	08-17-88	775.79	V
10-21-87	775.97	S	09-08-88	775.85	V
11-08-87	775.90	S	10-06-88	776.01	S
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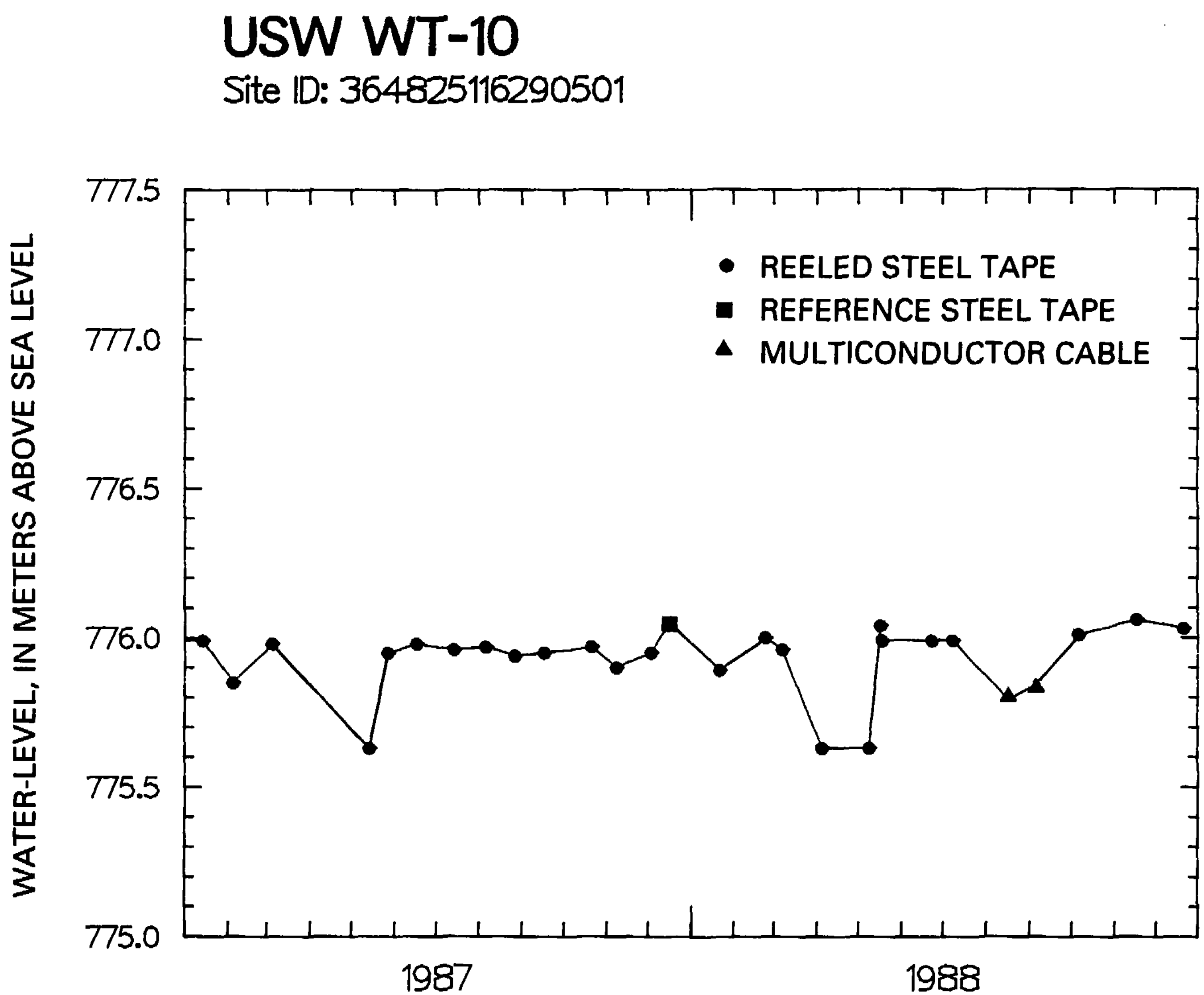
12-16-87	776.05	R	12-21-88	776.03	S



7. **Hydrograph of water-level altitude (plotted from data in section 6):**

Well UE-25 WT #12

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Fenix & Scisson, Inc. (1986a, 1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 739,726; E 567,011.
      Latitude and longitude: 36°46'56" N.; 116°26'16" W.
      Site ID: 364656116261601.
   b. Land-surface altitude: 1,074.7 m (Robison, 1986; based on survey by U.S. Geological Survey, 1984).
   c. Date drilling started: August 11, 1983.
   d. Date drilling completed: August 16, 1983.
   e. Drilling method: Rotary, using rock bits and air-foam circulating medium; bottom-hole core obtained.
   f. Total drilled depth: 399 m (1,308 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.).
   h. Casing extending below water level: None [surface casing only, to a depth of 21 m (70 ft)].
   i. Description of access for measuring water levels, including tubes or piezometers: 62-mm (2.4-in.) inside-diameter tubing that has a 3.6-m- (12-ft-) long well screen on the bottom; tubing and attached screen extend from land surface to a depth of 389 m (1,276 ft); saturated interval of borehole within Topopah Spring Member of Paintbrush Tuff and tuffaceous beds of Calico Hills.
   j. Description and altitude of reference point: Top of metal tag on well casing, 1,074.74 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.20 m, based on approximate depth to water of 345 m (1,132 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor-cable unit (logging van I-127410) from September 1, 1983, through April 10, 1985. Measurements were made using the 2,800-ft steel tape from July 16, 1985, through December 6, 1985, and using the 2,600-ft steel tape from January 29, 1986, through December 23, 1988.

From April 25 to May 2, 1988, personnel from the Desert Research Institute pumped a total volume of about 9,500 L of water from the well for the purpose of obtaining water samples. As a result, subsequent water-level measurements might reflect some residual effects from pumping until the saturated interval had sufficient time to recover.

4. Extremes:

   a. September 1983 through 1987: Maximum measured water-level altitude, 729.61 m, October 13, 1983; minimum measured water-level altitude, 729.11 m, March 5, 1985.

b. Current year 1988: Maximum measured water-level altitude, 729.57 m, August 12; minimum measured water-level altitude, 729.45 m, May 2.

5. Average annual water-level altitudes:

Calendar year	Average water-level altitude (meters)
1983 (September-December)	729.42
1984	729.34
1985	729.33
1986	729.45
1987	729.50
1988	729.52

6. Periodic measurements of water-level altitude in well UE-25 WT #12:

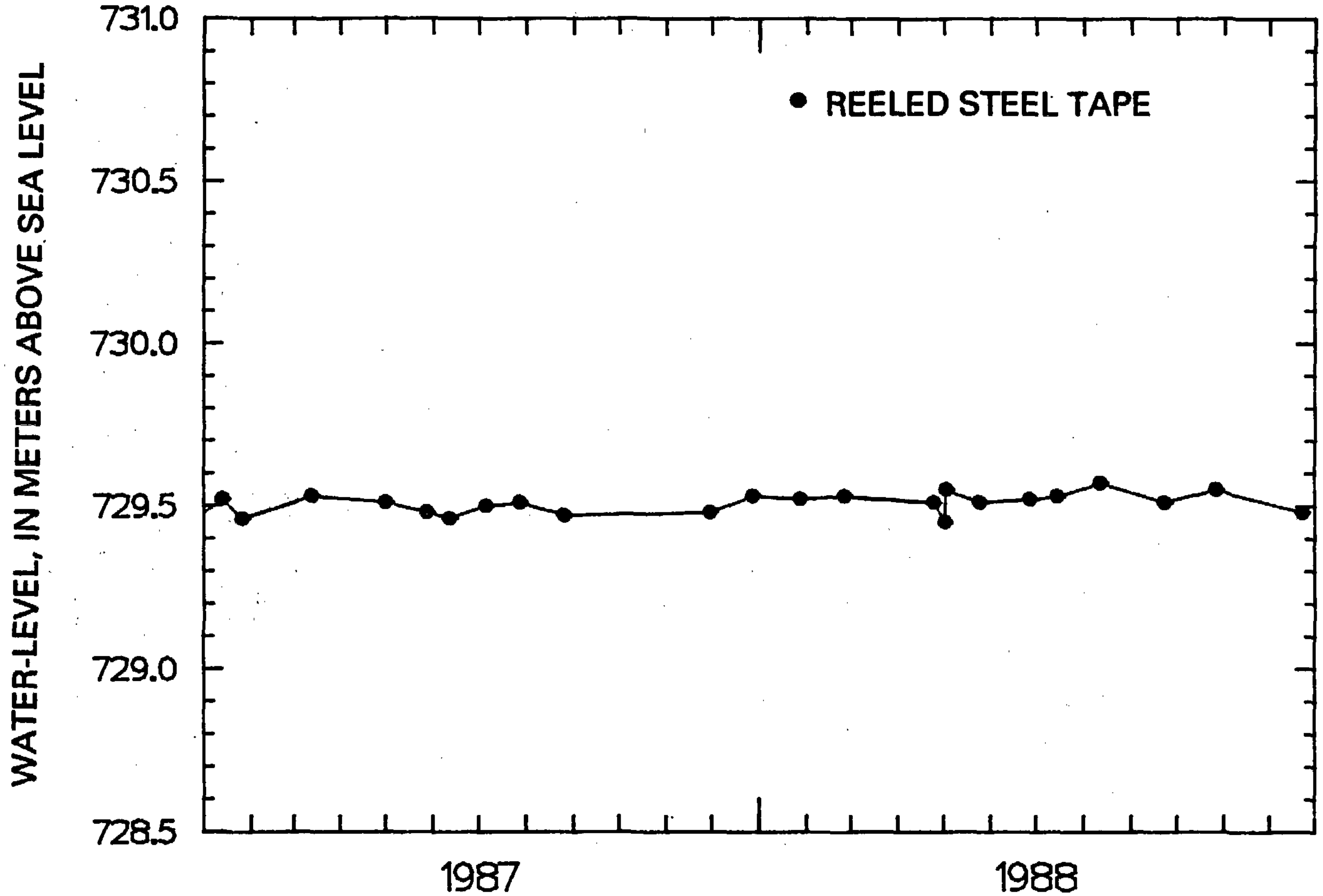
[S, 2,600-ft tape;]

Site ID: 364656116261601
Depth interval: 345-399 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-13-87	729.52	S	02-26-88	729.53	S
01-26-87	729.46	S	04-25-88	729.51	S
03-13-87	729.53	S	05-02-88	729.45	S
05-01-87	729.51	S	05-03-88	729.55	S
05-28-87	729.48	S	05-25-88	729.51	S
06-12-87	729.46	S	06-27-88	729.52	S
07-06-87	729.50	S	07-15-88	729.53	S
07-28-87	729.51	S	08-12-88	729.57	S
08-26-87	729.47	S	09-23-88	729.51	S
11-30-87	729.48	S	10-27-88	729.55	S
12-28-87	729.53	S	12-23-88	729.48	S
01-28-88	729.52	S			

UE-25 WT #12

Site ID: 364656116261601



7. **Hydrograph of water-level altitude (plotted from data in section 6):**

Well UE-25 WT #14

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc., (written commun., 1986); Fenix & Scisson, Inc. (1986a, 1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 761,651; E 575,210.
      Latitude and longitude: 36°50'32" N.; 116°24'35" W.
      Site ID: 365032116243501.
   b. Land-surface altitude: 1,075.9 m (Robison, 1986; based on survey by U.S. Geological Survey, 1984).
   c. Date drilling started: August 17, 1983.
   d. Date drilling completed: September 30, 1983.
   e. Drilling method: Rotary, using rock bits and air-foam circulating medium; bottom-hole core obtained.
   f. Total drilled depth: 399 m (1,310 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.).
   h. Casing extending below water level: None [surface casing only, to a depth of 37 m (120 ft)].
   i. Description of access for measuring water levels, including tubes or piezometers: 62-mm (2.4-in.) inside-diameter tubing that has a 3.6-m- (12-ft-) long well screen on the bottom; tubing and attached screen extend from land surface to a depth of 397 m (1,303 ft); saturated interval of borehole within Topopah Spring Member of Paintbrush Tuff and tuffaceous beds of Calico Hills.
   j. Description and altitude of reference point: Top of metal tag on well casing, 1,076.05 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.09 m, based on approximate depth to water of 346 m (1,135 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor-cable unit (logging van I-127410) from October 21, 1983, through April 29, 1985. Measurements were made using the 2,800-ft steel tape from June 11, 1985, through December 6, 1985, and using the 2,600-ft steel tape from January 28, 1986, through December 20, 1988, except for measurements made March 18 through April 1, 1988, which were made using the 2,800-ft steel tape.

The water-level altitude on May 5, 1987, was about 0.3 m (1 ft) above the general trend. The water level is reported here in meters, but was actually measured in feet using the 2,600-ft tape. Because of the measurement process, unverifiable onsite recording errors, when they occur, are more likely to be in multiples of feet; therefore, users of the data are cautioned the May 5, 1987, water-level altitude might not be accurate.

From March 22 through 26, 1988, personnel from the Desert Research Institute pumped a total volume of about 9,200 L of water from the well for the purpose of obtaining water samples. As a result, subsequent water-level measurements might reflect some residual effects from pumping until the saturated interval had sufficient time to recover.

4. Extremes:

a. October 1983 through 1987: Maximum measured water-level altitude, 729.98 m, May 5, 1987; minimum measured water-level altitude, 729.29 m, March 20, 1985.
b. 1988: Maximum measured water-level altitude, 729.74 m, August 10; minimum measured water-level altitude, 729.67 m, March 18.

5. Average annual water-level altitudes:

Calendar year	Average water-level altitude (meters)
1983 (October-December)	729.61
1984	729.55
1985	729.54
1986	729.68
1987	729.71
1988	729.71

6. Periodic measurements of water-level altitude in well UE-25 WT #14:

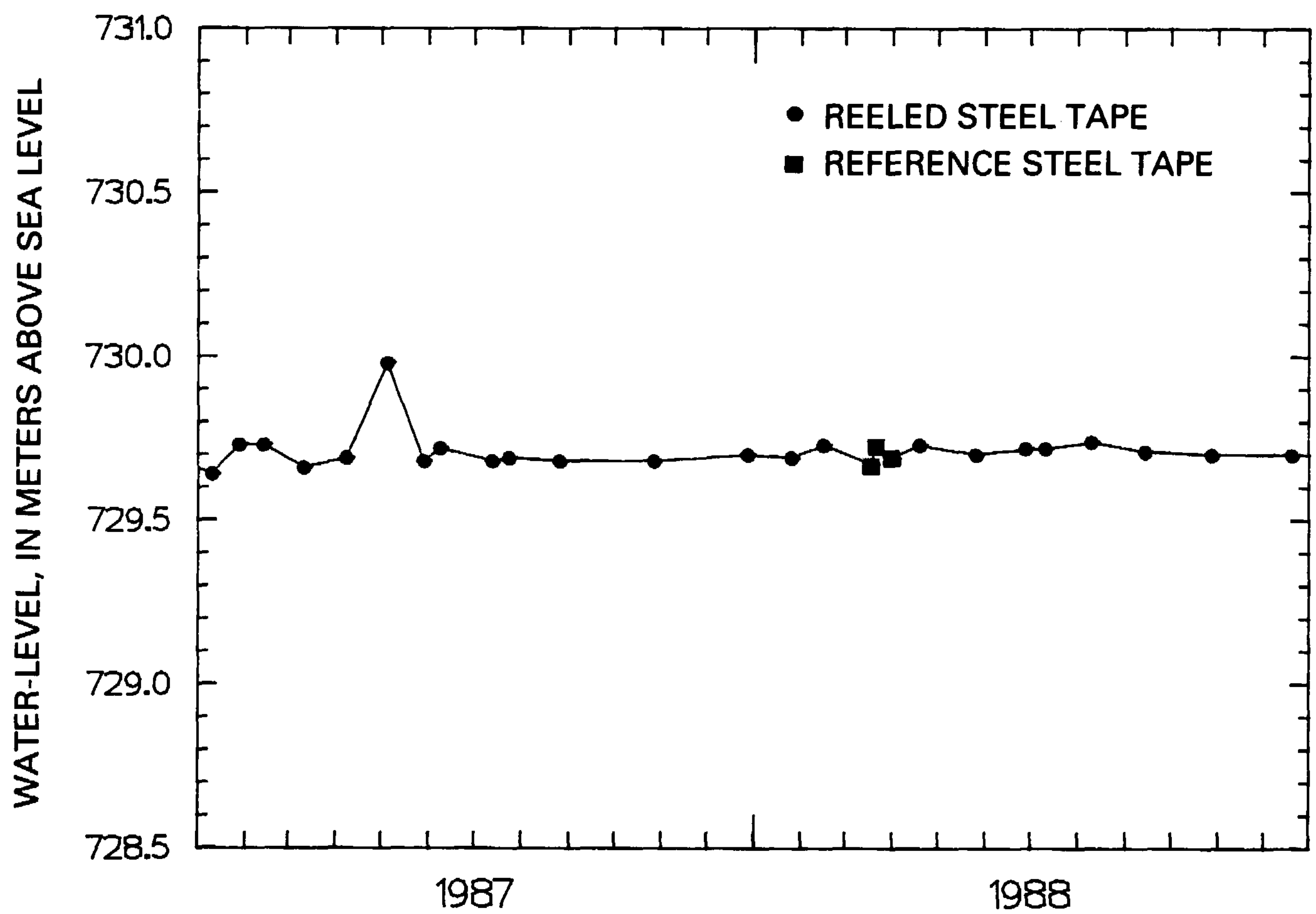
[S, 2,600-ft tape; R, 2,800-ft tape]

Site ID: 365032116243501
Depth interval: 346-399 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-10-87	729.64	S	02-16-88	729.73	S
01-28-87	729.73	S	03-18-88	729.67	R
02-13-87	729.73	S	03-21-88	729.72	R
03-11-87	729.66	S	03-31-88	729.69	R
04-08-87	729.69	S	04-01-88	729.69	R
05-05-87	729.98	S	04-19-88	729.73	S
05-29-87	729.68	S	05-26-88	729.70	S
06-09-87	729.72	S	06-28-88	729.72	S
07-13-87	729.68	S	07-11-88	729.72	S
07-24-87	729.69	S	08-10-88	729.74	S
08-26-87	729.68	S	09-14-88	729.71	S
10-27-87	729.68	S	10-28-88	729.70	S
12-28-87	729.70	S	12-20-88	729.70	S
01-26-88	729.69	S			

UE-25 WT #14

Site ID: 365032116243501



7. Hydrograph of water-level altitude (plotted from data in section 6):

Well UE-25 WT #15

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Fenix & Scisson, Inc. (1986a, 1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 766,117; E 579,806.
      Latitude and longitude: 36°51'16" N.; 116°23'38" W.
      Site ID: 365116116233801.
   b. Land-surface altitude: 1,083.2 m (Robison, 1986; based on survey by U.S. Geological Survey, 1984).
   c. Date drilling started: November 12, 1983.
   d. Date drilling completed: November 22, 1983.
   e. Drilling method: Rotary, using rock bits and air-foam circulating medium; bottom-hole core obtained.
   f. Total drilled depth: 415 m (1,360 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.).
   h. Casing extending below water level: None [surface casing only, to a depth of 39 m (127 ft].
   i. Description of access for measuring water levels, including tubes or piezometers: 62-mm (2.4-in.) inside-diameter tubing that has a 3.6-m- (12-ft-) long well screen on the bottom; tubing and attached screen extend from land surface to a depth of 407 m (1,335 ft); saturated interval of borehole within Topopah Spring Member of Paintbrush Tuff.
   j. Description and altitude of reference point: Top of metal tag on well casing, 1,082.94 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.19 m, based on approximate depth to water of 354 m (1,160 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor-cable unit (logging van I-127410) from November 29, 1983, through April 29, 1985. Measurements were made using the 2,800-ft steel tape from June 11, 1985, through December 30, 1985, and using the 2,600-ft steel tape from January 28, 1986, through December 20, 1988.

From April 18 through 25, 1988, personnel from the Desert Research Institute pumped a total volume of about 11,000 L of water from the well for the purpose of obtaining water samples. As a result, subsequent water-level measurements might reflect some residual effects from pumping until the saturated interval had sufficient time to recover.

4. Extremes:

   a. November 1983 through 1987: Maximum measured water-level altitude, 729.27 m, November 29, 1986; minimum measured water-level altitude, 728.96 m, December 18, 1984.

b. 1988: Maximum measured water-level altitude, 729.28 m, August 19; minimum measured water-level altitude, 729.18 m, April 25.

5. Average annual water-level altitudes:

Calendar year	Average water-level altitude (meters)
1983 (November-December)	729.07
1984	729.07
1985	729.08
1986	729.23
1987	729.22
1988	729.24

6. Periodic measurements of water-level altitude in well UE-25 WT #15:

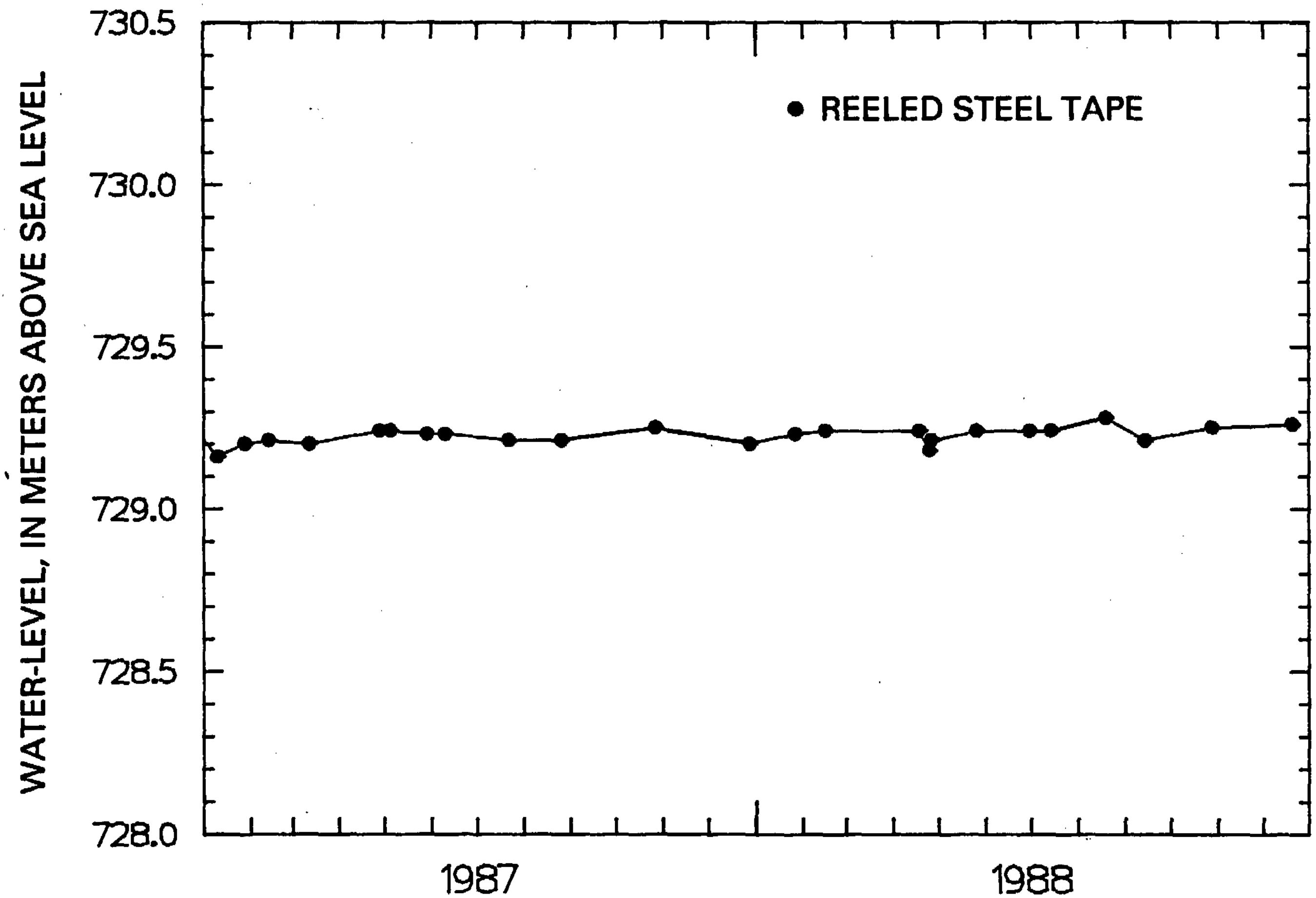
[S, 2,600-ft tape]

Site ID: 365116116233801
Depth interval: 354-415 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-10-87	729.16	S	01-27-88	729.23	S
01-28-87	729.20	S	02-16-88	729.24	S
02-13-87	729.21	S	04-18-88	729.24	S
03-12-87	729.20	S	04-25-88	729.18	S
04-28-87	729.24	S	04-26-88	729.21	S
05-05-87	729.24	S	05-26-88	729.24	S
05-29-87	729.23	S	06-30-88	729.24	S
06-10-87	729.23	S	07-14-88	729.24	S
07-22-87	729.21	S	08-19-88	729.28	S
08-26-87	729.21	S	09-14-88	729.21	S
10-27-87	729.25	S	10-28-88	729.25	S
12-28-87	729.20	S	12-20-88	729.26	S

UE-25 WT #15

Site ID: 365116116233801



7. **Hydrograph of water-level altitude (plotted from data in section 6):**

Well UE-25 WT #17

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Fenix & Scisson, Inc. (1986a, 1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 748,420; E 566,212.
      Latitude and longitude: 36°48'22" N.; 116°26'26" W.
      Site ID: 364822116262601.
   b. Land-surface altitude: 1,124.0 m (Robison, 1986; based on survey by U.S. Geological Survey, 1984).
   c. Date drilling started: October 20, 1983.
   d. Date drilling completed: October 30, 1983.
   e. Drilling method: Rotary, using rock bits and air-foam circulating medium; attempt to obtain bottom-hole core unsuccessful.
   f. Total drilled depth: 443 m (1,453 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.).
   h. Casing extending below water level: None [surface casing only, to a depth of 17 m (55 ft)].
   i. Description of access for measuring water levels, including tubes or piezometers: 62-mm (2.4-in.) inside-diameter tubing that has a 3.6-m- (12-ft-) long well screen on the bottom; tubing and attached screen extend from land surface to a depth of 419 m (1,376 ft); saturated interval of borehole within Prow Pass Member of Crater Flat Tuff.
   j. Description and altitude of reference point: Top of metal tag on well casing, 1,124.06 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.48 m, based on approximate depth to water of 395 m (1,296 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor-cable unit (logging van I-127410) from October 31, 1983, through April 11, 1985. Measurements were made using the 2,800-ft steel tape from June 12, 1985, through November 20, 1985, and using the 2,600-ft steel tape from January 27, 1986, through April 25, 1988. The multiconductor cable unit housed in van I-133970 was used to make water-level measurements from May 24 through December 20, 1988.

4. Extremes:

   a. October 1983 through 1987: Maximum measured water-level altitude, 729.77 m, October 1, 1986; minimum measured water-level altitude, 729.35 m, November 26, 1984.
   b. 1988: Maximum measured water-level altitude, 729.75 m, February 26; minimum measured water-level altitude, 729.54 m, September 22.

5. Average annual water-level altitudes:

Calendar year	Average water-level altitude (meters)
1983 (October-December)	729.58
1984	729.54
1985	729.55
1986	729.71
1987	729.71
1988	729.64

6. Periodic measurements of water-level altitude in well UE-25 WT #17:

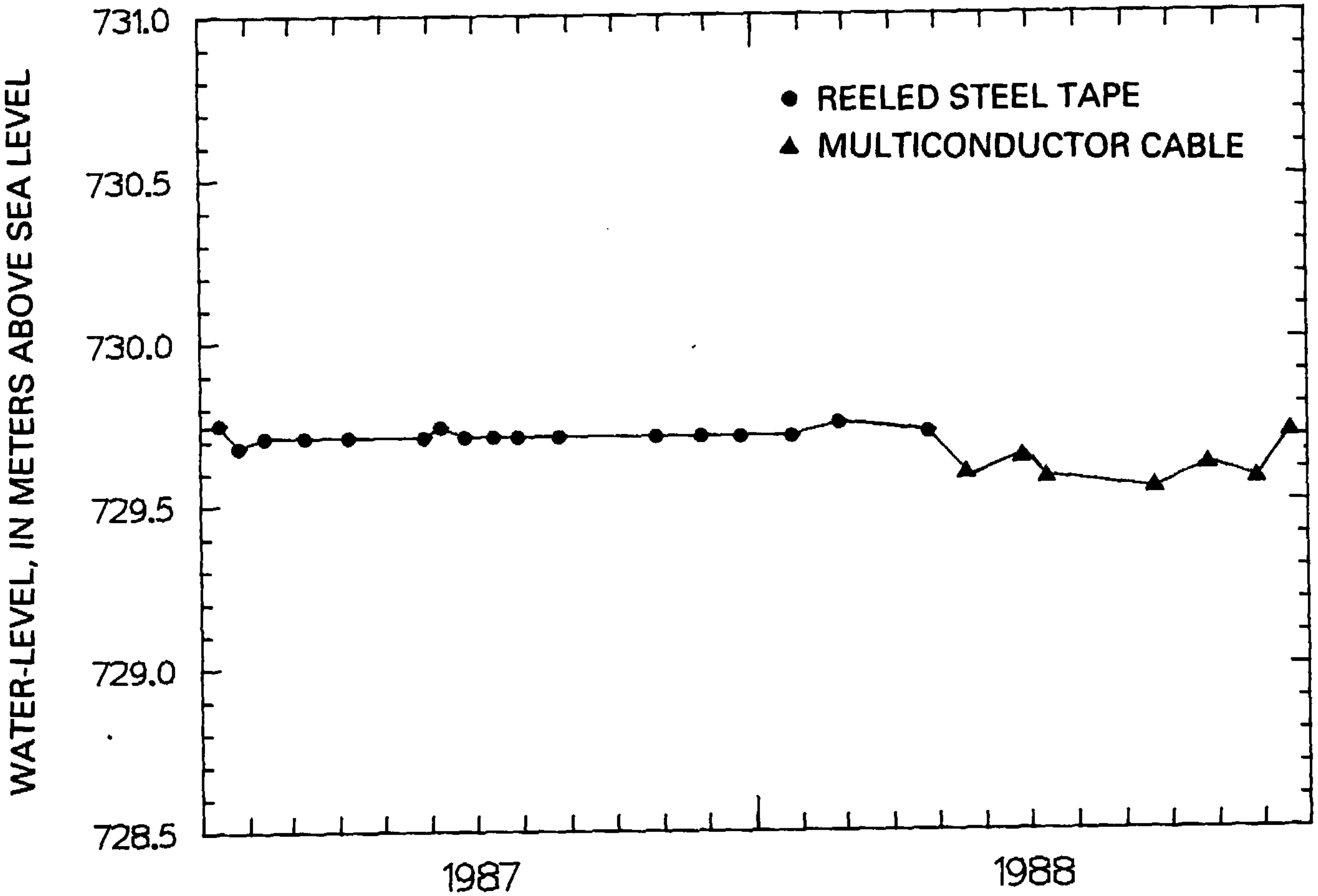
[S, 2,600-ft tape; V, multiconductor cable]

Site ID: 364822116262601
Depth interval: 394-443 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-13-87	729.75	S	11-27-87	729.71	S
01-26-87	729.68	S	12-23-87	729.71	S
02-12-87	729.71	S	01-26-88	729.71	S
03-10-87	729.71	S	02-26-88	729.75	S
04-08-87	729.71	S	04-25-88	729.72	S
05-28-87	729.71	S	05-24-88	729.58	V
06-08-87	729.74	S	06-29-88	729.66	V
06-24-87	729.71	S	07-13-88	729.58	V
07-13-87	729.71	S	09-22-88	729.54	V
07-29-87	729.71	S	10-27-88	729.62	V
08-25-87	729.71	S	11-28-88	729.57	V
10-28-87	729.71	S	12-20-88	729.72	V

UE-25 WT #17

Site ID: 364822116262601



7. Hydrograph of water-level altitude (plotted from data in section 6):

Well USW VH-1

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Fenix & Scisson, Inc. (1986b, 1987); Thordarson and Howells (1987).

2. Well specifications:
   a. Location:
   Nevada State Central Zone Coordinates (ft): N 743,356; E 533,626.
   Latitude and longitude: 36°47'32" N.; 116°33'07" W.
   Site ID: 364732116330701.
   b. Land-surface altitude: 963.5 m (Robison, 1986).
   c. Date drilling started: October 28, 1980.
   d. Date drilling completed: February 18, 1981.
   e. Drilling method: Rotary, using rock bits, and air-foam and polymer circulating medium.
   f. Total drilled depth: 762 m (2,501 ft).
   g. Bit diameter below water level: 222 mm (8.75 in.) to 278 m (912 ft); 159 mm (6.25 in.) from 278 m (912 ft) to total depth.
   h. Casing extending below water level: 177-mm (6.97-in.) inside diameter to 277.5 m (911 ft).
   i. Description of access for measuring water levels, including tubes or piezometers: 48-mm (1.9-in.) inside-diameter tubing, open ended from land surface to 205 m (674 ft); saturated interval of well within Tiva Canyon, Topopah Spring, Prow Pass, and Bullfrog Members of Paintbrush Tuff. A pump was installed in the well on July 8, 1982, at a depth of 212 m (695 ft).
   j. Description and altitude of reference point: Top of casing, 963.23 m (Holmes & Narver, Inc., March 3, 1986).
   k. Depth correction for measured water levels because of borehole deviation from vertical (the correction is subtracted from measured depth to obtain true depth): 0.05 m, based on approximate depth to water of 184 m (604 ft).

3. History of instrumentation and water-level measurements, and comments:

The water-level measurements were made using a multiconductor-cable unit (logging van I-127410) from April 12, 1984, through April 16, 1985; measurements were made using a 2,800-ft steel tape during the remainder of 1985. Measurements were made using a 2,600-ft steel tape from January 22, 1986, through April 5, 1988. Measurements were made using a multiconductor-cable unit housed in van I-133970 from May 17, 1988, through December 21, 1988.

4. Extremes:

   a. April 1984 through 1987: Maximum measured water-level altitude, 779.50 m, December 16, 1987; minimum measured water-level altitude, 779.23 m, October 18, 1984, and December 6, 1984.
   b. 1988: Maximum measured water-level altitude, 779.51 m, May 17, October 6, and December 21; minimum measured water-level altitude, 779.37 m, January 22.

5. Average annual water-level altitudes:

Calendar year	Average water-level altitude (meters)
1984 (April-December)	779.36
1985	779.40
1986	779.43
1987	779.42
1988	779.46

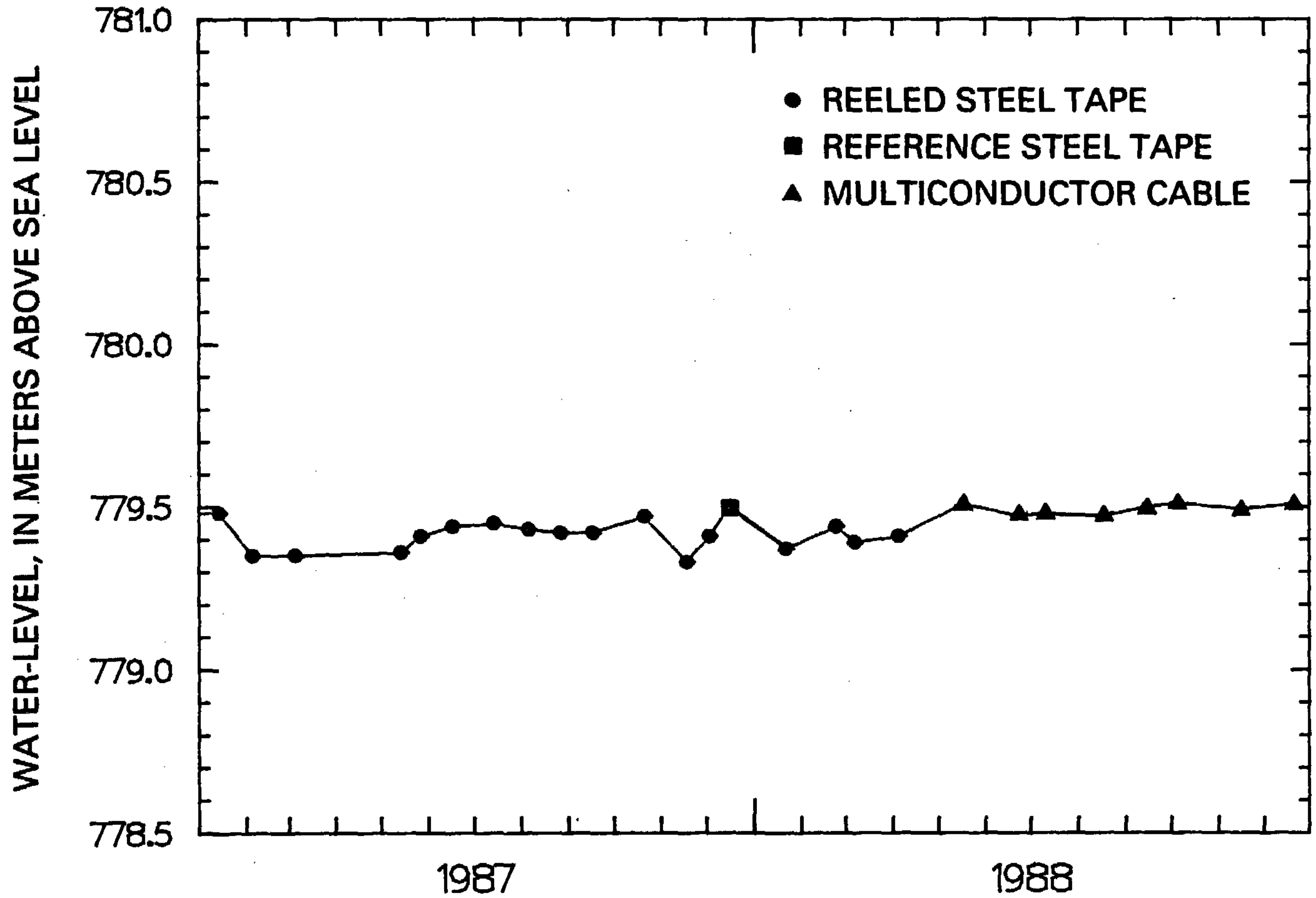
6. Periodic measurements of water-level altitude in well USW VH-1:

[S, 2,600-ft tape; R, 2,800-ft tape; V, multiconductor cable]

Site ID: 364732116330701
Depth interval: 185-762 m (composite)

Date	Water-level altitude (meters)	Method	Date	Water-level altitude (meters)	Method
01-14-87	779.48	S	12-16-87	779.50	R
02-05-87	779.35	S	01-22-88	779.37	S
03-05-87	779.35	S	02-24-88	779.44	S
05-14-87	779.36	S	03-07-88	779.39	S
05-27-87	779.41	S	04-05-88	779.41	S
06-17-87	779.44	S	05-17-88	779.51	V
07-14-87	779.45	S	06-23-88	779.47	V
08-06-87	779.43	S	07-08-88	779.48	V
08-27-87	779.42	S	08-17-88	779.47	V
09-17-87	779.42	S	09-15-88	779.50	V
10-21-87	779.47	S	10-06-88	779.51	V
11-18-87	779.33	S	11-17-88	779.49	V
12-03-87	779.41	S	12-21-88	779.51	V

USW VH-1
Site ID: 364732116330701



7. **Hydrograph of water-level altitude (plotted from data in section 6):**

Well J-13

1. References or information sources: Robison (1984, 1986); Robison and others (1988); Holmes & Narver, Inc. (written commun., 1986); Thordarson (1983); Young (1972); Fenix & Scisson (1987).

2. Well specifications:
   a. Location:
      Nevada State Central Zone Coordinates (ft): N 749,209; E 579,651.
      Latitude and longitude: 36°48'28" N.; 116°23'40" W.
      Site ID: 364828116234001.
   b. Land-surface altitude: 1,011.3 m (Robison, 1986).
   c. Date drilling started: September 12, 1962.
   d. Date drilling completed: January 8, 1963.
   e. Drilling method: Rotary, using air, and aerated mud as circulating medium.
   f. Total drilled depth: 1,063 m (3,488 ft).
   g. Bit diameter below water level: 438 mm (17.25 in.) to 402 m (1,319 ft); 381 mm (15 in.) from 402 m (1,319 ft) to 471 m (1,546 ft); 194 mm (7.62 in.) from 471 m (1,546 ft) to total depth.
   h. Casing extending below water level: 323-mm (12.7-in.) inside diameter, from land surface to 397 m (1,301 ft); 282-mm (11.1-in.) inside diameter from 397 to 471 m (1,301 to 1,546 ft); 126-mm (4.95-in.) inside diameter from 452 to 1,032 m (1,484 to 3,385 ft); casing perforated from 304 to 424 m (996 to 1,390 ft) within Topopah Spring Member of Paintbrush Tuff, and from 820 to 1,010 m (2,690 to 3,312 ft) within Tram Member of Crater Flat Tuff and upper part of Lithic Ridge Tuff.
   i. Description of access for measuring water levels, including tubes or piezometers: Access tube installed in 1986, in order for measuring equipment to safely bypass pump assembly.
   j. Description and altitude of reference point: Chiseled square on concrete well collar, 1,011.47 m (surveyed by U.S. Geological Survey, 1984).
   k. Depth correction for measured water levels because of well deviation from vertical: Not available.

3. History of instrumentation and water-level measurements, and comments:

Well J-13 was completed in 1963 to supply water for activities in the western part of the Nevada Test Site and continues to serve that purpose. In automatic response to needs of the connected water-supply system, well J-13 typically is pumped several times per day. The well has been observed to yield about 50 L/s (800 gal/min).

From December 30, 1962, through August 20, 1980, occasional measurements of the static water level were made at well J-13 and are reported by Thordarson (1983).

An attempt to continuously monitor the water level in this well was begun in September 1986. Two water-level measurements were made in September 1986 during the process of installing and calibrating the continuous monitoring equipment and are published in Robison and others (1988). By the end of

1988 it was apparent that the quantity of usable, continuous water-level data that had been collected was insufficient to support any type of meaningful analysis of the data. The water-level measurements made during the attempt to continuously monitor the water level are included in this report.

4. Extremes:

   a. December 1962 through 1987: Maximum measured water-level altitude, 728.90 m, August 20, 1980; minimum measured water-level altitude, 728.00 m, April 21, 1969.
   b. 1988: Maximum measured water-level altitude, 728.53 m, October 26; minimum measured water-level altitude, 728.41 m, July 7.

5. Periodic measurements of water-level altitude in well J-13:

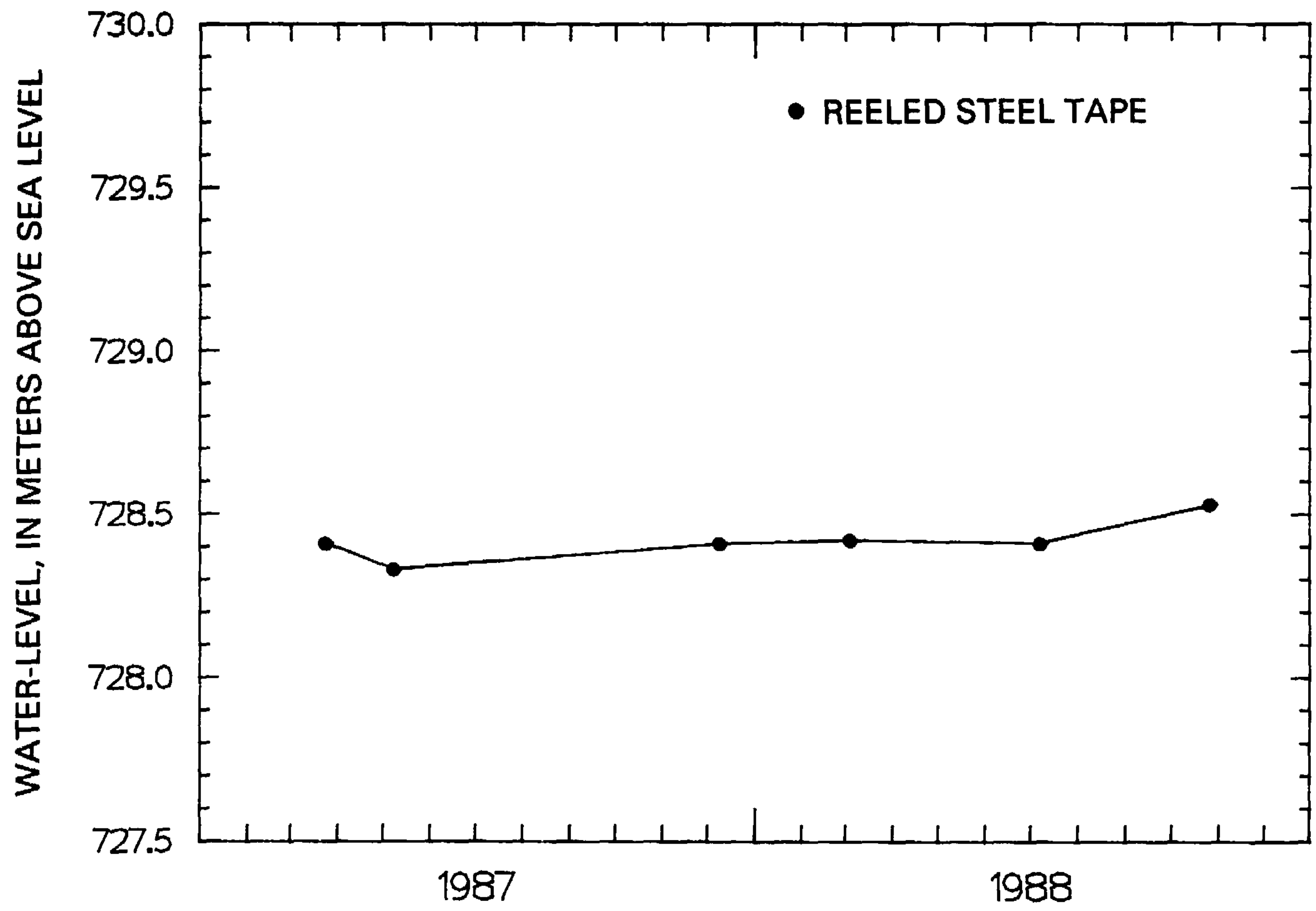
[S, 2,600-ft tape]

Site ID: 364828116234001
Depth interval: 283-1,063 m
(composite)

Date	Water-level altitude (meters)	Method
03-24-87	728.41	S
05-08-87	728.33	S
12-09-87	728.41	S
03-04-88	728.42	S
07-07-88	728.41	S
10-26-88	728.53	S

J-13

Site ID: 364828116234001



6. Hydrograph of water-level altitude (plotted from data in section 5):

REFERENCES CITED

Fenix & Scisson, Inc., 1986a, NNWSI hole histories--UE-25 WT #3, UE-25 WT #4, UE-25 WT #5, UE-25 WT #6, UE-25 WT #12, UE-25 WT #13, UE-25 WT #14, UE-25 WT #15, UE-25 WT #16, UE-25 WT #17, UE-25 WT #18, USW WT-1, USW WT-2, USW WT-7, USW WT-10, USW WT-11: U.S. Department of Energy Report DOE/NV/10322-10, 111 p. (HQS.880517.1199)

_____1986b, NNWSI hole histories--USW VH-1, USW VH-2: U.S. Department of Energy Report DOE/NV/10322-17, 57 p. (NNA.870317.0155)

_____1987, NNWSI drilling and mining summary: U.S. Department of Energy Report DOE/NV/10322-24, 45 p. (NNA.870624.0037)

Garber, M.S., and Koopman, F.C., 1968, Methods of measuring water levels in deep wells: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 8, chapter A-1, 23 p. (NNA.900104.0472)

Robison, J.H., 1984, Ground-water level data and preliminary potentiometric-surface maps, Yucca Mountain and vicinity, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations Report 84-4197, 8 p. (NNA.870519.0096)

Robison, J.H., 1986, Letter from J.H. Robison (U.S. Geological Survey, Lakewood, Colorado) to D.L. Vieth (U.S. Department of Energy/Nevada Operations Office, Las Vegas, Nevada), September 17, 1986; regarding revisions of Yucca Mountain water levels reported in Robison, 1984. (HQS.880517.1935)

Robison, J.H., Stevens, D.M., Luckey, R.R., and Baldwin, D.A., 1988, Water levels in periodically measured wells in the Yucca Mountain area, Nevada, 1981-87: U.S. Geological Survey Open-File Report 88-468, 132 p. (NNA.890306.0113)

Sass, J.H., and Lachenbruch, A.H., 1982, Preliminary interpretation of thermal data from the Nevada Test Site: U.S. Geological Survey Open-File Report 82-973, 30 p. (HQS.880517.1427)

Snyder, J.P., 1982, Map projections used by the U.S. Geological Survey: U.S. Geological Survey Bulletin 1532, 313 p. (NNA.900216.0227)

Thordarson, William, 1983, Geohydrologic data and test results from well J-13, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations Report 83-4171, 57 p. (NNA.870518.0071)

Thordarson, William, and Howells, Lewis, 1987, Hydraulic tests and chemical quality of water at well USW VH-1, Crater Flat, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations Report 86-4359, 20 p. (NNA.890922.0289)

U.S. Department of Energy, 1988, Site characterization plan, Yucca Mountain site, Nevada research and developement area, Nevada: U.S. Department of Energy Report DOE RW/0199, 8 v., various pagination. (HQS.881201.0002)

Waddell, R.K., 1982, Two-dimensional, steady-state model of ground-water flow, Nevada Test Site and vicinity, Nevada-California: U.S. Geological Survey Water-Resources Investigations Report 82-4085, 77 p. (NNA.870518.0055)

Young, R.A., 1972, Water supply for the Nuclear Rocket Developement Station at the U.S. Atomic Energy Commission's Nevada Test Site: U.S. Geological Survey Water-Supply Paper 1938, 19 p. (NNA.870519.0070)