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WATER TABLE AND RELATED MAPS
FOR
NEVADA TEST SITE AND CENTRAL NEVADA TEST AREA

by

Paul R. Fenske
Chalon L. Carnahan

Water Resources Center
Desert Research Institute
University of Nevada System
Reno, Nevada 89507
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ABSTRACT

Water table maps, water table gradient maps, and depth-to-water maps have been constructed for the Nevada Test Site and the Central Nevada Test Area by empirical simulation using a digital computer. Although the digital computer program has been developed specifically for the areas mapped, it is directly applicable to any hydrologic province where ground-water recharge areas occur between the discharge areas such as humid regions and the arid Great Basin of the Western United States. This report presents maps constructed during May 1975, a listing of the water level control points, and a brief description of the empirical mapping technique.

WATER TABLE AND RELATED MAPS

FOR

NEVADA TEST SITE AND CENTRAL NEVADA TEST AREA

INTRODUCTION

In areas where underground nuclear tests are conducted, knowledge of the ground-water resource is required for containment design, emplacement design, assessment of radionuclide transport away from the explosion environment, and water supplied for human consumption and drilling operations. The first and most easily accomplished step in analyzing a ground-water resource is construction of a map showing the probable configuration of the water table.

A method has been developed to construct water-table maps for regions where ground-water recharge areas occur between discharge areas. Such areas include most humid regions as well as the arid Great Basin of the western United States. Computations are made with a series of digital computer programs. The method, rationale, and computer programs are discussed in detail in a report entitled, "An Empirical Method for Simulation of Water Tables by Digital Computers" (Carnahan and Fenske, 1975) and the current program listing and detailed instructions for its implementation in the University of Nevada System CDC 6400 computer is presented in "Water-Table Mapping User's Manual" (Carnahan, 1975). The present report presents water-table maps for the Nevada Test Site and the Central Nevada Test Area constructed during May 1975, along with a listing of the water levels used and a brief description of the mapping process and rationale.

GENERAL PROCEDURE

Fundamentally, the water-table map construction program is a series of computer programs which calculate a probable water level for each intersection of a grid of the region being mapped. Output from the program is a matrix of these water levels that can be contoured and plotted with a contour plotting program.

Water-level elevation data is seldom sufficient, and it is usually poorly distributed throughout the area of interest. Clues other than water levels must therefore be used by hydrologists to extrapolate computed water levels on a probabilistic basis into areas where no known water levels are available. In the empirical water-table mapping program, the clues are turned into rules that the computer follows in calculating water levels for the water-level matrix. These rules follow:

1. As a first approximation the water table can be represented by subdued topography.
2. The water table is never above land surface.
3. There are no sinks (enclosed low areas) in the water table which are not controlled by topography or by known water levels.
4. Significant recharge does not occur below a specified topographic elevation.

In the following sections these rules and implications arising from their use will be discussed.

Water-Table Represented by Subdued Topography

This rule has been generally applied by hydrologists in humid regions. In humid regions, ground-water recharge occurs at all elevations, but discharge, except for isolated instances, occurs only along valley bottoms. Consequently, water recharged at higher elevations moves through the ground-water system to discharge points at lower elevations. Since a gradient is required to move the water, the water table rises away from the discharge areas. The result is the water table appears to have the configuration of the subdued topography of the area. This concept of subdued topography was advanced as early as 1902, by C. S. Slichter, who discussed the configuration of the water table in detail. A generalization of Slichter's concept that follows from the discussion above is that the water table will assume the configuration of subdued topography in any region where ground-water recharge occurs at higher elevations between discharge areas. The requirement then is met for the establishment of a hydraulic gradient toward the discharge areas. The configuration of ground-water flow systems and relationships to topography was implied by Hubbert (1940) and has been investigated in depth by Toth (1962, 1963) and Freeze and Witherspoon (1966, 1967). The application of the concept to the Great Basin was formalized by Maxey (1968) and substantiated by data from the Sand Springs Range. Mifflin (1968) discussed in detail ground-water flow systems in Nevada. An excellent, well-documented example of topographic influence is provided by Trauger (1972) for Grant County, New Mexico.

In using this rule, that the water table is represented at a first approximation by the subdued topography, the assumption is made that the matrix of the hydrologic system is somewhat homogeneous. When data on water levels is available, however, the mapping program accommodates rather severe inhomogeneities.

Water Table Never Above Land Surface

The water table is by definition beneath the surface of the ground. However, it may intersect the ground surface at the edges of surface bodies of water such as lakes, ponds, rivers, or springs, or may be tangent to the land surface in swampy areas.

No Sinks in the Water Table

The presence of a sink in the water table indicates the water is flowing toward that area. Either water is removed from the sink area or the sink fills and disappears. In a hydrologic system in dynamic equilibrium, a sink would not exist unless some mechanism were available to remove water from the sink as rapidly as it flowed toward the sink. Water is removed from sinks in enclosed basins by discharge at the surface and evaporation in swampy areas or lakes or evapotranspiration by phreatophytes. Because of discharge by phreatophytes, a sink may exist with the water table as much as 15 metre beneath ground surface. Alternately, water may be removed from the sink by downward movement into an underlying aquifer of much greater transmissivity. Surface discharge to maintain a sink is common in northern Nevada. Downward movement of water to maintain a sink occurs in southeastern Nevada, for example, at Yucca Flat and Frenchman Flat on the Nevada Test Site.

Significant Recharge

In arid regions, precipitation is higher at higher elevations (Houghton, 1969). Many valleys in the Great Basin have a desert climate with only a few centimetre of precipitation per year, yet the surrounding mountainous areas may receive as much as one metre per year. In addition, evapotranspiration may be lower and much of the precipitation at higher elevations accumulates over the winter months in a snow pack enhancing the opportunity for recharge. Consequently, both precipitation and the fraction of precipitation available for recharge are greater at higher elevations. Below some elevation the amount of recharge becomes insignificant. The amount of recharge is so low relative to the average hydraulic conductivity that the hydraulic gradient established to transport this recharge to the discharge area is vanishingly small. In some areas, such as Yucca Flat, the water table may be so far beneath the land surface that recharge by infiltration probably does not even occur, since the small quantity of water available may not bring the soil moisture zone up to field capacity and will later be completely removed from the soil moisture zone by evapotranspiration. In any region, then, it should be possible to specify an elevation below which significant recharge does not take place and consequently recharge mounds or sources do not exist.

RELIABILITY

The reliability of the water table and associated maps depends upon:

1. the reliability of the water-level measurements
2. the quantity and distribution of water-level measurements
3. the spacing of nodes in the topographic and mapping matrices

Errors that occur in the collection of water-level data are instrumental, recording, and transmission errors and the misinterpretation of the origin of the water level. The water-level measurement that is desired for the construction of water table maps is the measurement of the elevation of the water table or a close approximation to this elevation. In practice, however, a water-level measurement may represent pumping level, perched water table, or composite static water level, instead of water-table elevation. Errors appear in the hand constructed maps as well as and to the same extent as in computer constructed maps and are often difficult to identify. For the current maps any point that appeared anomalous was omitted. From the point of view of basic data the computer constructed maps are as reliable as any other map.

As with any maps based upon areally distributed data, the more evenly the data is distributed, the greater the reliability of the map. Between data points the map is constructed by interpolation. Beyond data points the map is constructed by extrapolation. In both cases, there is ample room for diversity of opinion as to where the contours should be located. The application of topographic control as is done in the computer program and also by some hydrologists lends a greater reliability to the map.

The use of nodes to represent a continuous surface implies an averaging is some cases and a sampling in other cases of the area of the surface represented by the node. In obtaining the original topographic matrix, the topography is sampled on the nodal spacing, and all of the other matrices basically represent averaging of data. Since the topographic matrix is smoothed before being used in the program to provide the first approximation to the water table much of the topographic information is discarded and only the major topographic features are retained. As far as the water-table mapping program is concerned, topographic information could be collected on a spacing two or three times the nodal spacing used to calculate the water-table matrix. Missing rows and columns could be filled in by interpolation. Since obtaining topographic data is tedious and time consuming, this approach will shorten considerably the time required to construct a map of an area. However, other topographic information is required on a closely spaced grid. The depth-to-water map represents a probable depth-to-water only at the nodal point for topographic data sampling. In areas of smooth and moderate or less topographic change, the depth-to-water map has its greatest reliability. In areas of rapid topographic change, the depth-to-water map has its poorest reliability.

MAPS FOR NEVADA TEST SITE AND CENTRAL NEVADA TEST AREA

The method described here has been used to simulate water tables in an area around and including the Nevada Test Site in southern Nevada, and an area including Hot Creek Valley in central Nevada, the Central Nevada Test Site.

The water-table mapping program accommodates the requirement that the water table is a function of relief by smoothing the topographic matrix to obtain the first approximation of the water table. The relationship of recharge to hydraulic gradient and average hydraulic conductivity is approximated by a least-squares fit of the approximate water table (smoothed topography) to the known water level data. After the least-squares fitting procedure, residuals still remain between the actual water levels and the approximated water levels.

Figure 1 is a plot of observed water elevations versus smoothed topographic elevations at control nodes for the Nevada Test Site, computed in program PWTA. Also shown are centroids of elevations for 500-foot intervals of smoothed topographic elevations. The centroids are input for the least-squares linear regression used to adjust smoothed topographic elevations to produce the first approximation fo the water table. The regression line is labelled in Figure 1.

Figure 2 is a plot of observed water elevations versus smoothed topographic elevations at control nodes for the Central Nevada Test Area, computed in program PWTA. Also shown are the centroids of elevations used as input for the least-squares linear regression used to adjust smoothed topographic elevations to produce the first approximation surface.

At the Central Nevada Test Area, the correlation is high and the residuals small indicating the Hot Creek Valley hydrologic system is typical or normal and fits the assumptions made. The correlation at the Nevada Test Site, however, is not as good but still acceptable and the residuals are higher on the average indicating the Nevada Test Site hydrologic system is not normal or typical. Inspection shows that most of the water-level data for the Nevada Test Site comes from anomalous areas. On Pahute Mesa, a topographic high recharge area, more water appears to flow through the mesa from the north than is recharged to the mesa. Beneath Yucca Flat, a topographic low and enclosed basin which should discharge ground water at the surface, a transmissive carbonate horizon

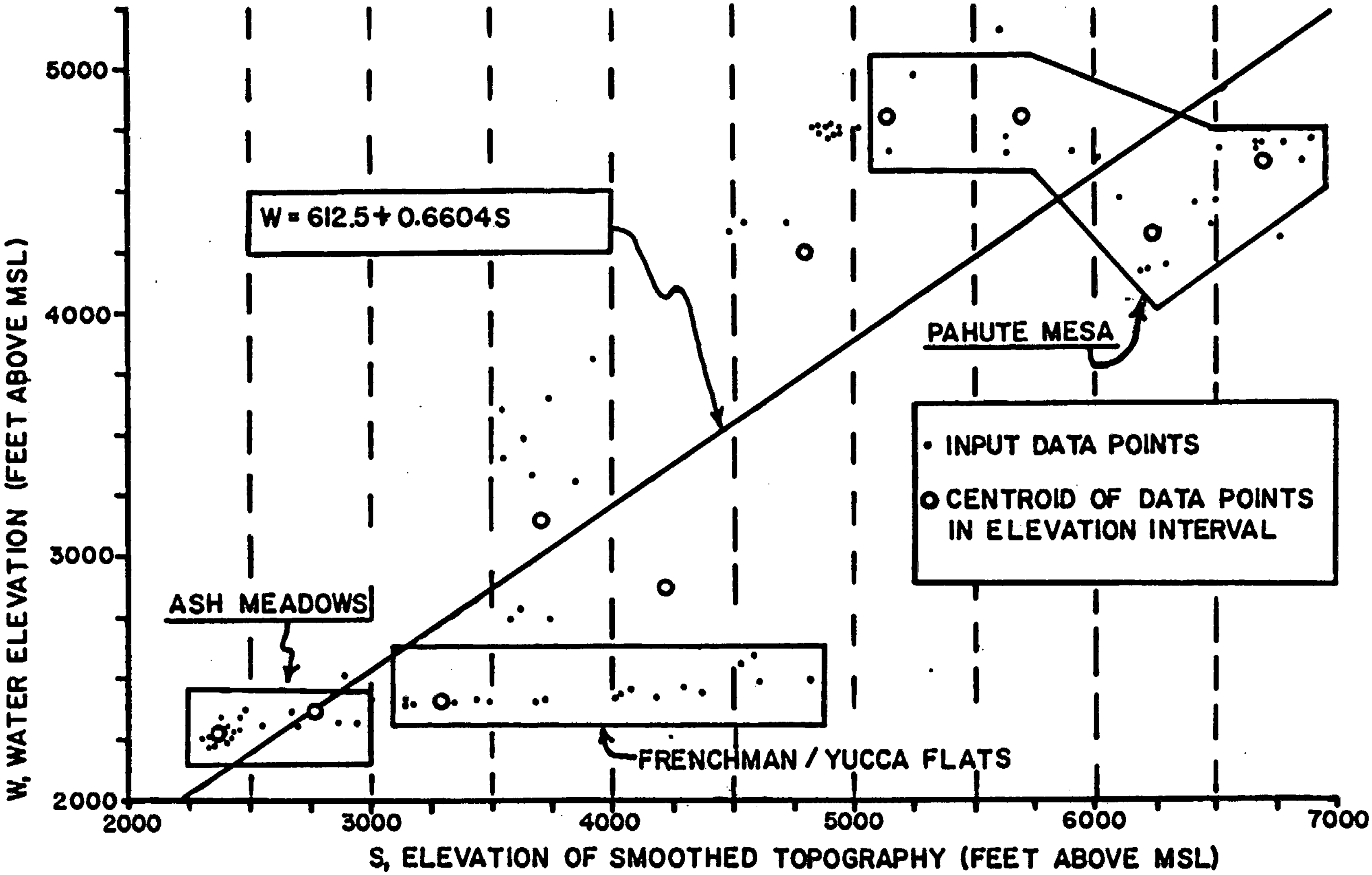

Figure 1. Observed water elevations versus smoothed topographic elevations, Nevada Test Site.

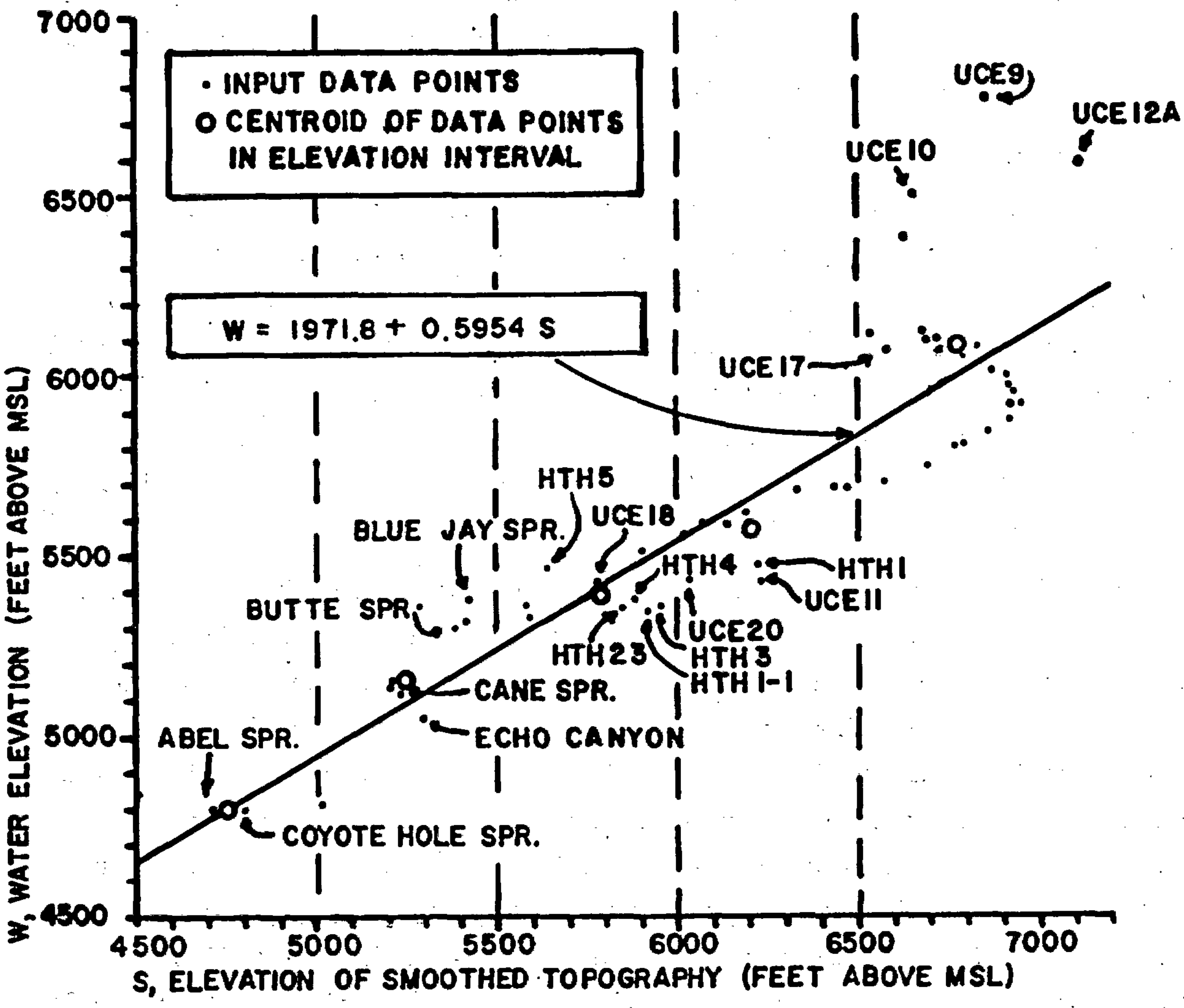

Figure 2. Observed water elevations versus smoothed topographic elevations, Central Nevada Test Area.

below the alluvial and tuff aquifer conducts the water away toward the southwest in the deep subsurface depressing the water table to a depth of 2000 feet below the valley bottom. Although the mapping procedure is flexible and utilizes the water-level data from the anomalous areas to construct a probable water-level map, the map for the Nevada Test Site would be different, particularly in the Yucca Flat area, if the data demonstrating the presence of these anomalous areas were not available.

Nevada Test Site

The elevation grid of the Nevada Test Site area consists of 143 columns running south to north and 227 rows running west to east. The southwest corner of the grid (column 1, row 1) is located at 480,000 feet east, 640,000 feet north in the Nevada coordinate system, central zone. The grid spacing is 2000 feet. The grid was ruled on U.S. Geological Survey topographic maps covering the region of interest and topographic elevations were read at grid-line intersection. 7 1/2-minute quadrangle sheets were used where available; otherwise, 15-minute quadrangle sheets were used.

The water-elevation control data set was obtained from the NV00 hydrologic data bank. Several computed water-table maps of the Nevada Test Site showed anomalies which were traced back to erroneous water-elevation control data, and erroneous control points were eliminated when found. The final set of control data is tabulated in Table 1. The first two columns of Table 1 give the location of the control point in the Nevada coordinate system, central zone. The third column gives the water-table elevation in feet above mean sea level. The fourth column lists the name, if any, associated with the control point. All control points used in this simulation are wells, except for a set of five points representing surface water elevations at Oasis Valley.

Plates 1, 2, and 3 (in pocket) are contour maps of, respectively, the final simulated water table, depth of the water table below land surface, and hydraulic gradients at the water table.

Central Nevada Test Area

The elevation grid of the Hot Creek Valley area consists of 91 columns running south to north, and 164 rows running west to east. The southwest corner of the grid (column 1, row 1) is located at 550,000 feet east, 1,220,000

TABLE 1.

CONTROL DATA USED FOR SIMULATION OF WATER TABLE AT NEVADA TEST SITE

Nevada Coordinates		Water		Grid Coordinates	
E	N	Elevation	Name	X	Y
480,000	792,000	3400	Oasis V.	1.00	77.00
480,715	1,076,860	5162		1.36	219.43
484,000	810,000	3600	Oasis V.	3.00	86.00
484,000	820,000	3640	Oasis V.	3.00	91.00
486,000	802,000	3480	Oasis V.	4.00	82.00
486,000	832,000	3820	Oasis V.	4.00	97.00
490,228	709,754	2355		6.11	35.88
494,305	734,022	2506		8.15	48.01
516,535	975,014	4967		19.27	168.51
522,017	671,335	2278		22.01	16.67
522,020	666,279	2272		22.01	14.14
522,840	661,224	2273		22.42	11.61
525,283	666,282	2273		23.64	14.14
525,287	661,226	2269		23.64	11.61
525,295	653,137	2275		23.65	7.57
527,732	663,251	2273		24.87	12.63
528,665	944,583	4722	PM-2	25.33	153.29
530,179	663,253	2277		26.09	12.63
530,181	661,231	2285		26.09	11.62
532,643	648,088	2265		27.32	5.04
533,439	666,291	2281		27.72	14.15
533,445	661,235	2276		27.72	11.62
535,083	655,170	2273		28.54	8.58
535,097	644,047	2266		28.55	3.02
535,100	642,024	2261		28.55	2.01
535,879	671,350	2285		28.94	16,67
535,892	661,238	2279		28.95	11.62

Table 1 Cont.

Nevada Coordinates E	Nevada Coordinates N	Water Elevation	Name	Grid Coordinates X	Grid Coordinates Y
538,325	67,353	2287		30.16	16.68
538,338	661,241	2278		30.17	11.62
538,350	653,151	2265		30.17	7.58
538,539	928,313	4655	UE20J	30.27	145.16
540,776	668,333	2286		31.39	15.17
540,795	655,177	2274		31.40	8.59
540,802	650,121	2260		31.40	6.06
542,100	942,800	4653	UE20P	32.05	152.40
543,246	653,159	2263		32.62	7.58
543,255	647,091	2260		32.63	4.55
545,693	653,162	2268		33.85	7.58
545,698	650,129	2258		33.85	6.06
545,706	645,073	2256		33.85	3.54
545,711	642,039	2250		33.86	2.02
549,768	656,203	2265		35.88	9.10
549,775	652,158	2260		35.89	7.08
549,787	645,080	2257		35.89	3.54
551,396	658,228	2267		36.70	10.11
551,407	652,161	2264		36.70	7.08
551,970	917,818	4170	UE20F	36.99	139.91
553,847	656,210	2266		37.92	9.10
553,864	647,110	2257		37.93	4.56
553,874	642,054	2253		37.94	2.03
554,331	909,226	4174	UE20D	38.17	135.61
556,302	652,170	2256		39.15	7.08
556,323	642,058	2255		39.16	2.03
556,769	903,163	4157	UE20C	39.38	132.58
557,012	981,036	4663		39.51	171.52
558,761	647,119	2257		40.38	4.56
558,768	644,086	2254		40.38	3.04
559,543	663,300	2284		40.77	12.65
560,824	934,522	4469	UE20E1	41.41	148.26

Table 1 Cont.

Nevada Coordinates		Water		Grid Coordinates	
E	N	Elevation	Name	X	Y
562,019	650,160	2261		42.01	6.08
562,026	647,126	2257		42.01	4.56
563,617	665,531	2292		42.81	13.67
564,453	656,232	2264		43.23	9.12
565,213	680,503	2311		43.61	21.25
567,731	918,054	4446	UE20H	44.87	140.03
568,562	644,108	2256		45.28	3.05
571,476	907,445	4359	U20A2	46.74	134.72
572,602	660,297	2280		47.30	11.15
572,612	656,252	2297		47.31	9.13
572,635	647,152	2245		47.32	4.58
572,643	644,118	2224		47.32	3.06
573,241	728,050	2394		47.62	45.02
575,886	921,109	4445	PM-1	48.94	141.55
579,045	689,639	2314		50.52	25.82
579,119	663,348	2365		50.56	12.67
581,038	733,532	2387	J12	51.52	47.77
585,270	943,892	4672	UE19H	53.63	152.95
587,000	900,900	4433	UE19FS	54.50	131.45
587,895	931,359	4676	UE19GS	54.95	146.68
593,137	910,038	4619	UE19I	57.57	136.02
596,957	927,243	4687	UE19E	59.48	144.62
597,795	687,676	2321		59.90	24.84
597,806	684,642	2316		59.90	23.32
600,074	734,200	2397		61.04	48.10
601,035	917,044	4714	UE19C	61.52	139.52
606,871	933,652	4685	UE19B1	64.44	147.83
609,995	879,457	TW-8		66.00	120.73
611,764	740,919	2404	J11	66.88	51.46
629,513	876,912	4188	TW-1	75.76	119.46
642,017	645,392	2344		82.01	3.70
642,042	640,337	2343		82.02	1.17
666,018	836,957	2907	UE1C	94.01	99.48

Table 1 Cont.

Nevada Coordinates E	N	Water Elevation	Name	Grid Coordinates X	Y
668,700	881,600	2584	UE8E	95.35	121.80
668,755	879,955	2555	TW-2	95.38	120.98
672,605	846,605	2418	TW-D	97.30	104.30
673,300	875,000	2431	UE2AA	97.65	118.50
677,500	814,000	2425	UE6D	99.75	88.00
677,500	833,500	2449	UE1K	99.75	97.75
677,733	817,714	2424	Well 3	99.87	89.86
678,500	891,800	2490	UE10 ITS 5	100.25	126.90
680,700	887,200	2480	UE10 ITS 3	101.35	124.60
684.506	774,979	2784	UE5J	103.25	68.49
693,021	812,456	2422	TW-B	107.51	87.23
696,000	840,000	2455	TW-E	109.00	101.00
704,231	920,448	4371		113.12	141.22
704,289	747,306	2409	Well 5B	113.14	54.65
708,297	777,068	2410	UE11A	115.15	69.53
711,012	772,538	2411	UE5F	116.51	67.27
712,346	778,818	2410	UE11B	117.17	70.41
718,034	932,994	4368		120.02	147.50
733,950	1,064,714	4745		127.97	213.36
733,967	1,062,691	4725		127.98	212.35
735,146	655,722	3313		128.57	8.86
736,370	1,063,723	4738		129.18	212.86
737,130	1,068,787	4718		129.56	215.39
739,015	671,025	2730		130.51	16.51
739,622	1,059,706	4747		130.81	210.85
739,756	1,044,535	4755		130.88	203.27
740,372	1,065,782	4735		131.19	213.89
740,893	915,080	4333		131.45	138.54
742,268	914,991	4339		132.13	138.50

Table 1 Cont.

Nevada Coordinates		Water		Grid Coordinates	
E	N	Elevation	Name	X	Y
744,510	1,052,669	4768		133.25	207.33
745,297	1,054,699	4760		133.65	208.35
747,460	1,082,029	4761		134.73	222.01
750,094	1,057,777	4756		136.07	206.85
750,122	1,054,743	4744		136.06	208.37
750,150	1,051,709	4756		136.05	209.89
751,693	1,058,804	4759		136.85	210.40
755,174	669,851	2742		138.59	15.93
760,619	654,226	3329		141.31	8.11

feet north in the Nevada coordinate system, central zone. The grid spacing is 2000 feet. The grid was ruled on U.S. Geological Survey topographic maps covering the region of interest and topographic elevations were read at grid-line intersection. 7 1/2 minute quadrangle sheets were used where available; otherwise 15-minute quadrangle sheets were used. The water-elevation control data set was obtained from the NV00 hydrologic data bank.

The control data set used for the Hot Creek Valley simulation includes wells, valley-bottom springs, a lake (Little Fish Lake) and a reservoir (Echo Canyon Reservoir). Several anomalous wells were found and were eventually excluded from the simulation. High-altitude springs were excluded because of the possibility they might be manifestations of perched water. It was found necessary to include 27 control points along Hot Creek in order to accurately reproduce the course of the creek in its descent from Little Fish Lake Valley into Hot Creek Valley.

The set of control data used in the final simulation is tabulated in Table 2. The first two columns of Table 2 give the location of the control point in the Nevada coordinate system, central zone. The third column gives the water-table elevation in feet above mean sea level. The fourth column lists the name, if any, associated with the control point. The fifth and sixth columns give the internal grid coordinates of the control point.

Plates 4, 5, and 6 (in pocket) are contour maps of the final simulated water table, depth of the water table below the land surface, and hydraulic gradients at the water table respectively.

TABLE 2
CONTROL DATA USED FOR SIMULATION OF WATER
TABLE AT HOT CREEK VALLEY, NEVADA

Nevada Coordinates E	N	Water Elevation	Name	Grid Coordinates X	Y
556,000	1,408,000	6380	Little Fish Lake	4.00	95.00
556,000	1,410,000	6380	Little Fish Lake	4.00	96.00
558,000	1,378,000	6120	Hot Creek	5.00	80.00
558,295	1,433,560	6499	UCE10	5.15	112.78
560,000	1,378,000	6100	Hot Creek	6.00	80.00
560,000	1,380,000	6110	Hot Creek	6.00	81.00
562,000	1,378,000	6090	Hot Creek	7.00	80.00
562,000	1,380,000	6070	Hot Creek	7.00	81.00
562,341	1,477,976	6771	UCE9	7.17	129.99
564,000	1,378,000	6080	Hot Creek	8.00	80.00
564,000	1,380,000	6060	Hot Creek	8.00	81.00
566,000	1,378,000	6010	Hot Creek	9.00	80.00
568,000	1,378,000	6000	Hot Creek	10.00	80.00
570,000	1,378,000	5970	Hot Creek	11.00	80.00
572,000	1,378,000	5960	Hot Creek	12.00	80.00
574,000	1,376,000	5920	Hot Creek	13.00	79.00
576,000	1,376,000	5880	Hot Creek	14.00	79.00
578,000	1,376,000	5850	Hot Creek	15.00	79.00
580,000	1,374,000	5810	Hot Creek	16.00	78.00
582,000	1,374,000	5750	Hot Creek	17.00	78.00
584,000	1,374,000	5700	Hot Creek	18.00	78.00
584,408	1,319,734	6110		18.20	50.87
586,000	1,372,000	5690	Hot Creek	19.00	77.00
586,000	1,374,000	5690	Hot Creek	19.00	78.00
588,000	1,372,000	5680	Hot Creek	20.00	77.00
590,000	1,370,000	5590	Hot Creek	21.00	76.00
590,000	1,372,000	5620	Hot Creek	21.00	77.00
592,000	1,370,000	5560	Hot Creek	22.00	76.00
592,000	1,372,000	5590	Hot Creek	22.00	77.00
594,000	1,370,000	5510	Hot Creek	23.00	76.00
594,617	1,514,976	6589	UCE12A	23.31	148.49
598,035	1,295,505	5330		25.02	38.75
600,303	1,327,882	5357		26.15	54.94
605,500	1,346,000	5380	Blue Jay Spring	28.75	64.05
610,830	1,285,441	5171		31.42	33.72
616,100	1,333,600	5300	Butte Spring	34.05	57.80
626,475	1,401,351	5429	UCE11	39.24	91.68
627,179	1,367,448	5471	HTH5	39.59	74.72
628,093	1,399,868	5426	UCE20	40.05	90.93
628,172	1,430,622	6070	UCE17	40.09	106.31
628,986	1,322,948	5319		40.49	52.47
629,129	1,293,615	5140		40.56	37.81
629,720	1,411,433	5467	HTH1	40.86	96.72
630,055	1,267,320	5147		41.03	24.66
632,318	1,293,631	5145		42.16	37.82
634,868	1,262,287	5117		43.43	22.14
635,840	1,396,833	5418	UCE18	43.92	89.42
638,200	1,265,300	5130	Cane Spring	45.10	23.65
657,119	1,385,944	5360	HTH3	54.56	83.97
658,000	1,242,000	5050	Echo Canyon Res.	55.00	12.00
668,506	1,397,250	5354	HTH21-1	60.25	89.62
683,276	1,379,469	5380	HTH4	67.64	80.73
684,237	1,368,087	5359	HTH23	68.12	75.04
712,295	1,260,769	4820		82.15	21.38
728,980	1,317,020	4800	Abel Spring	90.49	49.51
729,500	1,325,500	4800	Coyote Hole Spring	90.75	53.75

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