INFLOW TO A CRACK IN PLAYA DEPOSITS OF YUCCA LAKE, NEVADA TEST SITE, NYE COUNTY, NEVADA

By Gene C. Doty and F. E. Rush

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4296

Prepared in cooperation with the

U.S. DEPARTMENT OF ENERGY

Denver, Colorado

1985

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Multiply inch-pound units	*By*	*To obtain SI units*
acre-foot (acre-ft)	1233.482	cubic meter
foot (ft)	0.3048	meter
cubic foot (ft^3)	0.02832	cubic meter
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
yard (yd)	0.9144	meter

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ABSTRACT

A crack about 1 mile long opened in 1969 in the dry bed of Yucca Lake, a playa on the Nevada Test Site. Accumulation of water from precipitation on the lakebed drained rapidly into the crack and led to concern whether the water entering the crack was directly recharging the very transmissive Paleozoic carbonate rocks comprising the aquifer for the regional flow system. If so, runoff from nearby areas used for past surface testing of nuclear devices possibly could contribute residual radioactive contaminants directly to the regional flow system by draining into this and similar cracks. An effort was made to determine the quantity of water entering the crack by installing 10 Parshall flumes in a berm surrounding the crack and by monitoring inflow for about 3 years. Flow records from the flumes indicate that an estimated 5 million cubic feet of water flowed into the crack during the period of measurements. Results of one sample of water analyzed for chemical constituents and of several samples analyzed for radioactivity indicate that the water that entered the crack constituted no human-health hazard. In the event another crack opens in the lakebed, and if additional study is undertaken, an improved method of monitoring inflow would result in better records and improved understanding of of these cracks.

INTRODUCTION

In 1969, the most recent of several vertical cracks opened in playa deposits of Yucca Lake in the Nevada Test Site. Within a few hours, a large volume of rain water that had accumulated on the playa drained into the almost 1-mi-long crack. This drainage led to speculation concerning the origin of the crack, the possibility that the drained water was directly recharging the regional ground-water flow system, and the possibility that the drained water might be transporting radioactive surface contaminants from nuclear-weapons tests directly into the regional flow system. This report presents the results of an investigation to describe the crack, to measure the volume of water inflow, and to determine the chemical constituents of the inflow water. The information presented also may contribute to a resolution of the other initial speculations. The investigation was conducted by the U.S. Geological Survey for the U.S. Department of Energy under Interagency Agreement DE-AI08-76DP00474.

The Yucca Flat area was sparsely populated by miners and ranchers for many years. In 1950, the area was included in the Nevada Test Site, which was formed from land used by the Air Force during World War II as a bombing and gunnery range. Since 1950, several paved roads and building complexes associated with nuclear-weapons testing have been constructed near Yucca Lake. Two wells, C and C1, drilled 100 ft apart in 1961 (C) and 1962 (C1), are at the south end of Yucca Lake; these wells supply water for these facilities and well-drilling operations. An unpaved airstrip was built along the western side of the lake; parts of the playa have been disturbed by various testing operations.

GEOHYDROLOGIC SETTING

Yucca Lake is in Yucca Flat, a topographically closed desert valley of 305 mi^2 in the Basin and Range province, southern Nye County, Nevada (Rush, 1968, p. 22), 80 mi northwest of Las Vegas, Nevada (fig. 1). Alluvium and tuff with minimal permeability overlie Paleozoic carbonate rocks comprising the aquifer for a regional ground-water flow system and impede downward flow of precipitation and runoff. A long travel time is required for water to infiltrate and reach principal discharge points at Ash Meadows. Cracks in and near Yucca Lake playa deposits may allow water from the land surface to move directly to a deep, very permeable aquifer.

Average annual precipitation for the valley ranges from about 6 in. on the playa to 12 in. or more on the surrounding mountains. Runoff occurs in response to infrequent, relatively intense precipitation. Runoff in the valley flows in poorly defined drainage channels, culminating at Yucca Lake. Altitude of the potentiometric surface beneath Yucca Lake playa is about 2,400 ft above sea level in a Paleozoic carbonate aquifer. Because the playa is at an altitude of 3,919 ft, the unsaturated zone of alluvial valley fill, volcanic tuffs, and limestone is about 1,500 ft thick beneath the playa (Winograd and Thordarson, 1975, pl. 2).

According to Rush (1970, p. 12), ground-water recharge for the valley is from precipitation and averages about 700 acre-ft per year. Ground-water discharge is by subsurface outflow through the very permeable carbonate strata of Paleozoic age to Frenchman Flat, which is south of Yucca Flat. These two valleys are part of the much larger Ash Meadows ground-water basin, as defined by Winograd and Thordarson (1975). Water that recharges in the valley, after flowing south to Frenchman Flat, then flows southwestward toward the Amargosa Desert, where it mostly discharges as spring flow at Ash Meadows near the Nevada-California State line (fig. 1).

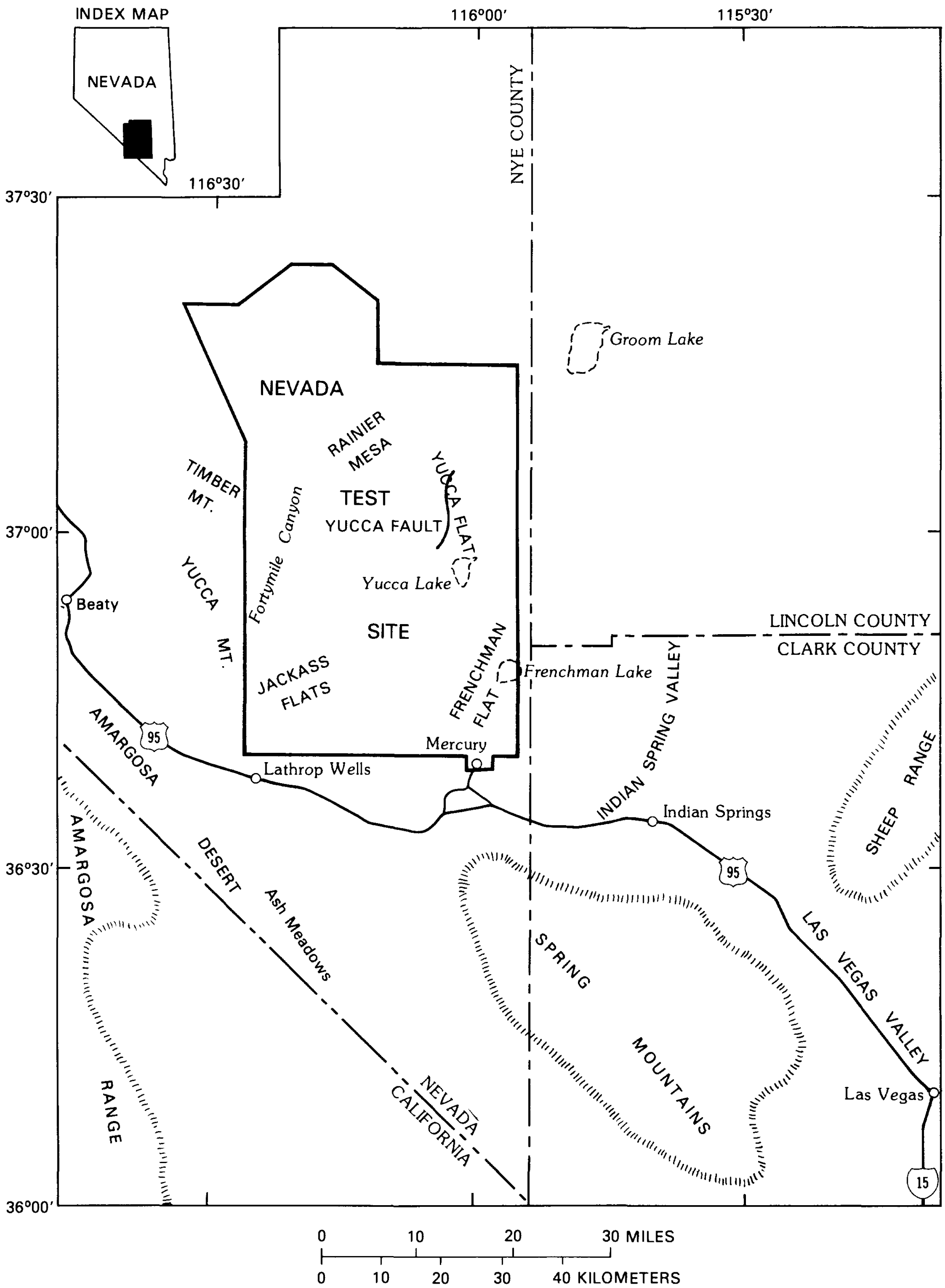

Figure 1.--Location of Yucca Lake and other features in southern Nevada.

The Yucca Flat area is structurally complex. Paleozoic rocks were faulted before, during, and after being covered by a varying thickness of younger volcanic rocks, mostly tuff. More than 2,000 ft of alluvium covers older rocks beneath parts of the valley. The material penetrated by well C, at the south end of the playa (fig. 2), is summarized as follows (Garber and Thordarson, 1962):

Geology	Depth (feet)
Valley fill:	
Playa deposits	0-25
Alluvium	25-215
Oak Spring Formation (now obsolete; rocks assigned to Miocene Tuff units)	
Tuff, welded or partly welded	215-455
Tuff, zeolitized and clayey	455-1,355
Limestone of Paleozoic age	1,355-1,701

The playa deposits and zeolitized and clayey tuff are almost impermeable.

Two features of Yucca Flat are not typical of most other valleys of the Basin and Range province: (1) In most topographically closed valleys, the playa generally is located centrally; the playa in Yucca Flat is at the extreme southern end of the valley, as shown in figure 1. (2) In most valleys, major faults commonly are mapped in abundance only along the mountain fronts and faults seldom are identified in the central part of valleys; however, in Yucca Flat, a fault has been mapped near the north trending axis of the valley, extending from along the west side of the playa to the north end of the valley. This normal fault, Yucca fault, is downthrown on the east. The fault, in part, may be a hydrologic boundary (Winograd and Thordarson, 1975, pl. 3). Both of these two atypical features may be the products of relatively recent structural activity in the area. Additional details of playa-deposit structure and stratigraphy are given by Zohdy and Bisdorf (1979). Thickness of surficial deposits and tuff beneath the valley has been detailed by Fernald (1979).

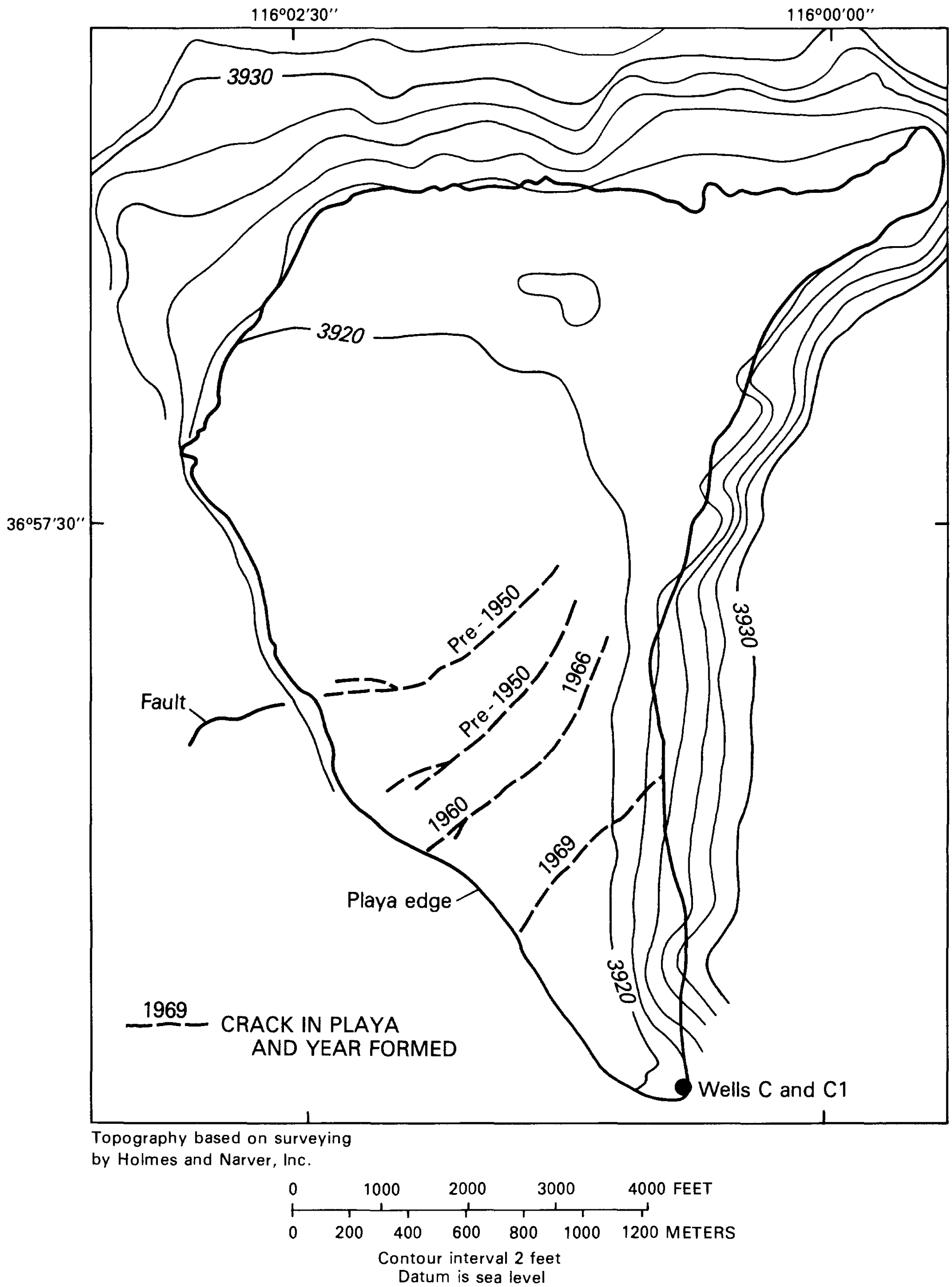

Figure 2.--Cracks and detailed topography of Yucca Lake playa.

ORIGIN OF CRACKS

Vertical cracks in playa deposits of the Basin and Range province are not uncommon. Cracks generally have been attributed to natural desiccation of fine-grained materials or to removal of ground water by nearby pumping (Poland and others, 1975). Cracks resulting from natural desiccation usually have a polygonal or modified polygonal pattern; cracks resulting from ground-water removal are straight or slightly curved. Cracks at Yucca Lake are slightly curved; however, older, slightly curved cracks at Yucca Lake predate pumping of nearby wells C and C1. The relation of cracks at Yucca Lake to known and inferred faulting indicates that a combination of fault movement and natural desiccation of playa deposits probably is responsible for crack opening (Zohdy and Bisdorf, 1979). Colton (1965) concluded that cracks at Frenchman Lake (in Frenchman Flat) and Groom Lake (25 mi northeast of Yucca Lake) resulted from desiccation, not faulting. Carr (1974) presented an argument for tectonic origin of the cracks at Yucca Lake. The relation of the cracks to local structure is discussed in a Nevada Test Site guidebook (U.S. Geological Survey, 1976, p. 42).

The 1969 crack at Yucca Lake was a tensional and erosional opening with no visible lateral or vertical offset, as determined from monitoring a network of steel pins installed along the northern end of the crack. Freshly opened cracks in Antelope Playa deposits (60 mi northwest of Yucca Lake) were observed on September 10, 1976, where lips of the crack were slightly higher than the surrounding playa; this condition may have been caused by wetting and swelling of fine-grained deposits along opposing faces of the crack.

Observation indicates that playa cracks, whether of tectonic or desiccation origin, have a predictable sequence of events. When first opened, a crack ranges from hairline to a small part of 1 inch in width. Erosion from inflowing water quickly erodes the crack to as much as several feet in width; the erosional opening, not the initial crack, usually is the feature first noticed by man. As intermittent inflow continues, water-transported sediment fills or blocks vertical and lateral drainage paths; the crack fills with sediment and eventually fills to the land surface. This process may be accentuated by lateral subsurface erosion (piping) along the crack at depth and subsequent collapse of the roof to the surface. The sequence of events for the 1969 crack at Yucca Lake was interrupted and possibly extended by construction of a runoff-controlling berm around it and channeling of inflow water through flumes.

DESCRIPTION OF YUCCA LAKE CRACKS

Aerial photographs and physical features of traces of four subparallel cracks in the southern part of the Yucca Lake playa (fig. 2) indicate that cracks are continuing natural features that predate use of the area for nuclear-weapons testing. Aerial photographs show traces of two cracks that formed prior to 1950; the northernmost crack is probably the older. South of these cracks is the trace of a crack that opened in 1960 and lengthened northeastward in 1966. The crack that is the subject of this report opened in 1969 and lengthened northwestward twice, about 150 yd in the spring of 1978 (prior to May 2) and about 390 yd in the spring of 1980 (prior to April 3). Aerial photographs of the 1960 and 1969 cracks are shown in figure 3. Oblique aerial photographs taken in May 1982 as part of this study (figs. 4 through 8) show general features of the 1969 crack, progressive erosion since 1973 (fig. 6), and extension of the crack in 1978.

INFLOW MEASUREMENTS

Flume Installation

A berm of playa deposits was constructed in 1970 around the 1969 crack to channel runoff to the crack through Parshall flumes. The berm was made by a road grader piling earth toward the crack, so that the excavation was a collection channel between flumes; the playa was undisturbed elsewhere. Flumes were installed along natural drainageways to the crack to measure water flow. Locations of the berm, flumes, and the eroded crack are shown in figure 9, based on an aerial photograph taken in 1973.

Flume sizes and elevations are given in table 1. A continuous-stage recorder was installed in a well-defined channel, approximately 4 ft deep and 6 ft wide, about 20 yd downstream (north) from flume 1, to monitor water-level stage, so that flume records could be corrected for submergence. All flumes were equipped with digital stage recorders recording data at 1-hour intervals.

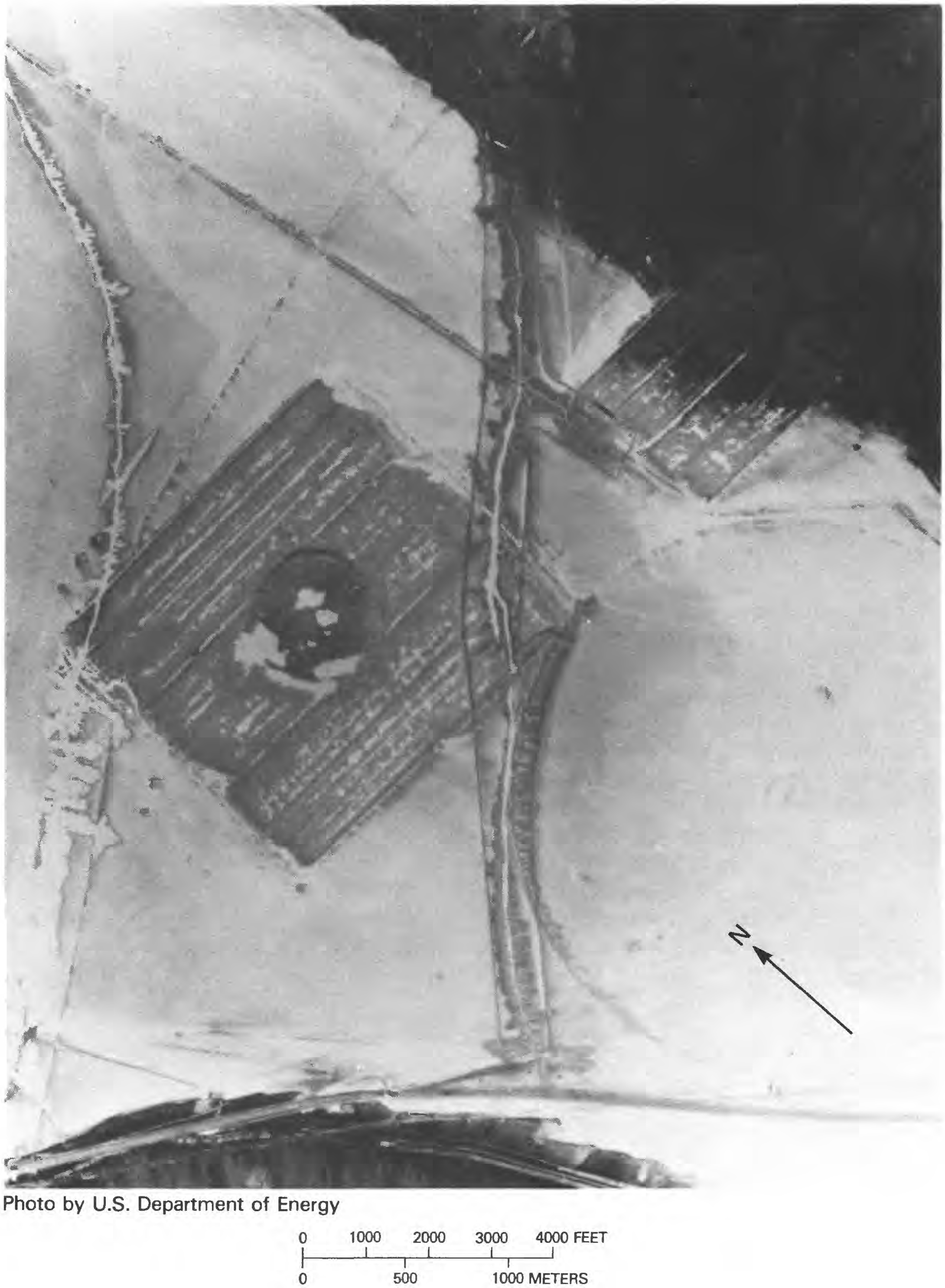

Photo by U.S. Department of Energy

Figure 3.--Vertical aerial photograph (1973) of the southern part of Yucca Lake playa showing the cracks that opened in 1960 (left) and in 1969 (center). (Circular pattern at right and rectangular areas are remnants of testing operations; various straight lines are buried pipes, fences, or cables.)

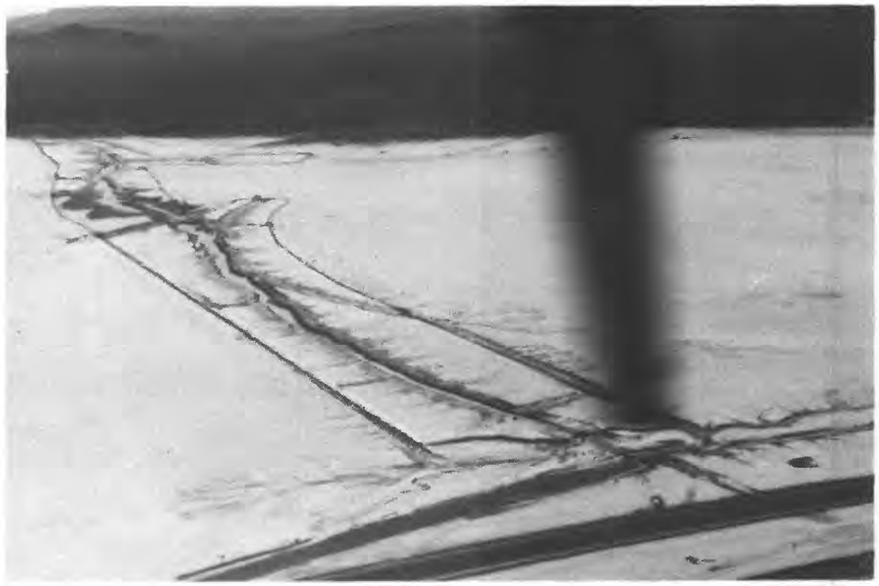

Figure 4.--Northeasterly view of the 1969 crack showing erosion of drainageways along the berm and into the crack, May 1982. (Dark shadow at right side of view is blade of helicopter rotor; paved road is in lower right of photograph; crack is partly filled with water.)

Figure 5.--Northerly view of the 1969 crack showing erosion along the circular test-pattern perimeter inside of the berm. [Deepest erosion (more than 16 feet) occurred near flume 2, right center of photograph; note trace of 1960 crack in upper left of photograph.]

Figure 6.--Northwesterly view of the 1969 crack showing erosion along the buried water line from well C inside of the berm.

Figure 7.--Northerly view of the 1969 crack showing the 1978 extension (center above berm). (Although the 1978 extension and older part of the crack appear parallel, they are slightly divergent.)

Figure 8.--Oblique aerial photograph looking northwestward along the northeastern end of the 1969 crack showing collapse sinks inside of the berm (right center). (Trace of the 1978 extension is along the top of the photograph. Sink at right collapsed first and is about 9 feet deep; sink to left is about 6 feet deep.)

From the first attempts in 1972 to install the flumes, erosion and washout were a problem. Before initial installation was completed in 1972, runoff washed out the flumes; installation was completed in 1974. The playa deposits consist of incohesive clay and silt that erode with a very slow water-flow velocity. Once disturbed, the material is even less cohesive; maintaining the berm and flumes in place was difficult. Because of the length of the berm, intensive compaction was impractical; some compaction was accomplished by driving earth-moving equipment repeatedly along the berm crown. This method worked fairly well; however, erosion from waves, penetration of the berm by rodents, and undetected weak spots resulted in repeated failure. Also, failure of the flumes resulted from insufficient compaction of earth around them, and from upstream gulleying from the crack, despite the use of plywood wing-walls, headwalls, toeplates, and canvas-toeplate curtains. Inability to maintain the berm and flume integrity ultimately resulted in termination of the project. Abandonment occurred shortly before the crack collapsed from piping along the north end, which greatly decreased the quantity of water flowing into the crack.

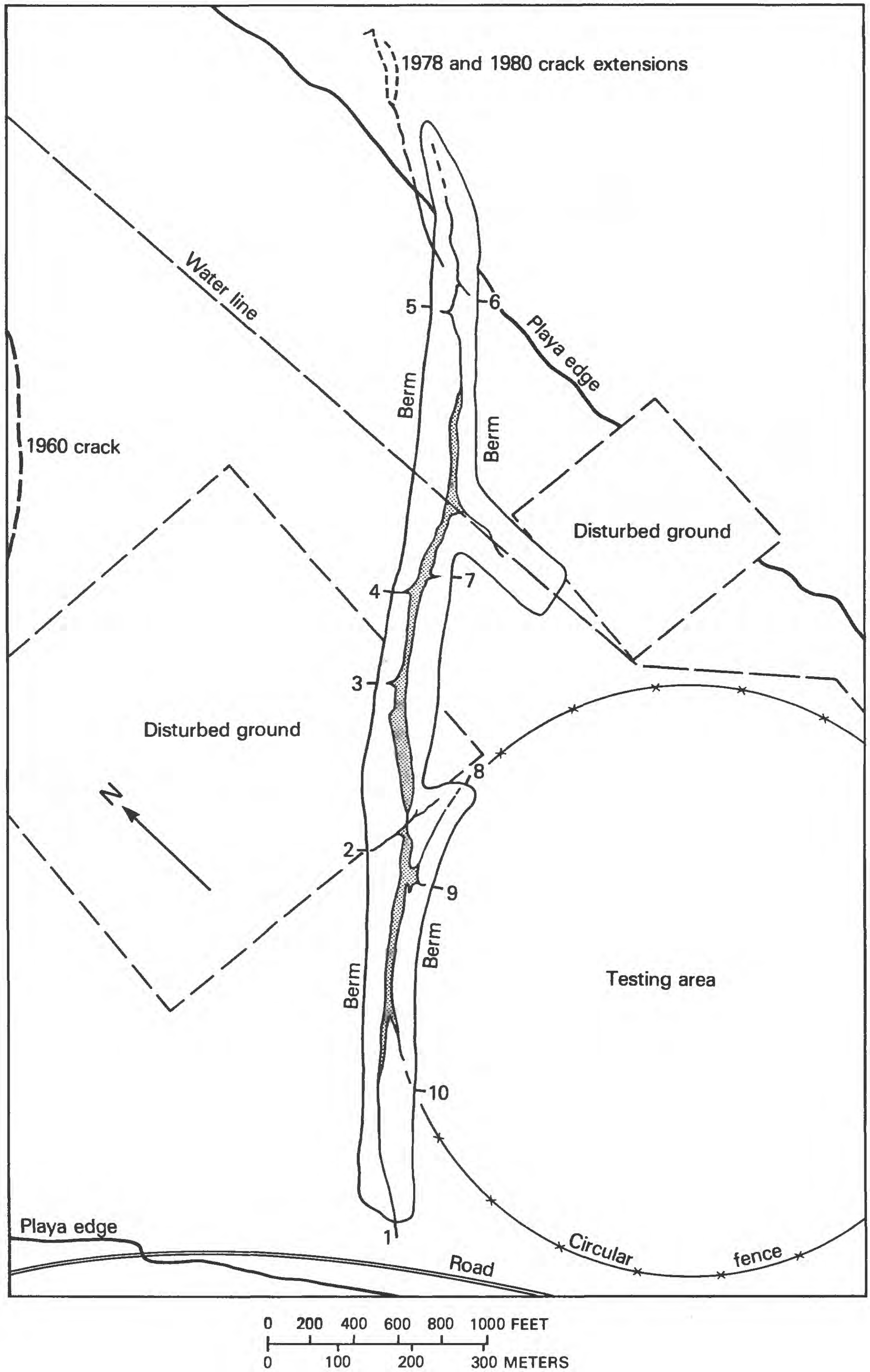

Figure 9.--Sketch of eroded 1969 crack showing 1978 and 1980 extensions, berm, and location of flumes. (Numbers along berm refer to flumes listed in table 1.)

Table 1.--*Standard Parshall flumes installed on Yucca Lake playa*

[Elevations from Holmes and Narver, Inc. (written commun., 1976)]

Flume number in figure 9	Throat width of flume (inches)	Elevation of throat floor of flume (feet)	
		Reference to nearby stake (100.00)	Reference to flume 1
1	30	99.496	0.00
2	24	99.698	+.20
3	6	99.679	+.18
4	18	99.624	+.13
5	30	99.589	+.09
6	9	99.691	+.20
7	12	99.648	+.14
8	12	99.760	+.26
9	9	99.652	+.16
10	9	99.615	+.12

All stage-recording equipment was float-actuated. The onset of runoff to the crack frequently was instantaneous, resulting in float lines disengaging from the actuating sheaves. Wind-driven water piled up on the windward side of the berm, and slack water on the lee side resulted in floats being buried in silt. On one occasion, water was blown through flumes from the windward side. Floats stuck tightly as mud dried after flow, and stilling wells had to be cleared out after each flow to free the floats; if a second flow occurred before cleaning could be accomplished, record was lost from inoperative floats. Freezing weather also immobilized floats. Although a vigorous schedule of battery changing and recorder maintenance was implemented, some record was lost from mechanical and clock malfunction.

Results

A hydrograph for several flows is shown in figure 10. As evident from the hydrograph, flow increase was rapid and the flow periods were short. The hydrograph was constructed from hourly measurements; therefore, the volume of flow computed probably is less than actual flow because of data loss during peak-flow periods. Therefore, the computed flow is a conservative estimate of the volume of water entering the crack. For runoff in which flow persisted at gradually decreasing volume for several hours, error in volume is small.

Data collected for flows are presented in table 2. Data from early flows were computed from hand-plotted hydrographs; data from later flows were computed using an automatic data-processing computer program.

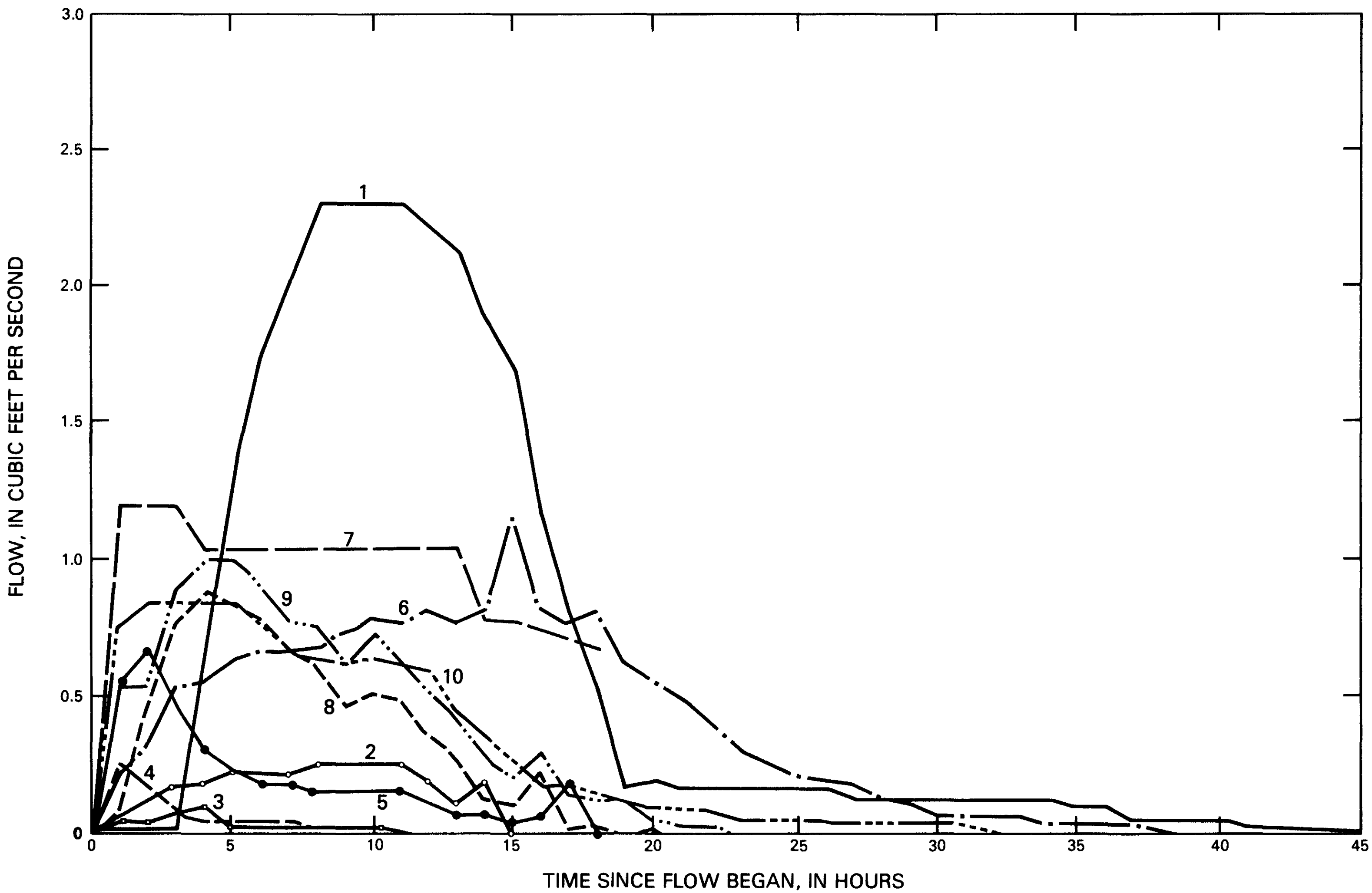

Figure 10.--Composite hydrograph of a typical flow May 8-11, 1977.

Table 2.--*Measured inflow to the crack*

[Only flumes having measured flow are listed]

Flume number	Duration of flow (hours)	Maximum stage (feet)	Total flow (cubic feet)	Remarks for inflow period
			October 20 to November 1, 1974	
1	17	0.10	8,500	Measured precipitation was 0.72 inch.
2	9	.01	3,020	
3	7	.13	611	
6	22	.20	9,620	
7	40	.36	61,000	
8	31	.17	8,820	
9	25	.17	7,670	
10	13	.12	2,940	
Calculated inflow for period (rounded)			102,000	
			December 4 to 14, 1974	
1	194	0.50	314,000	Measured precipitation was 1.26 inches; runoff total was adjusted for loss due to freezing problems. Calculated inflow may be greater than actual inflow.
2	98	.29	112,000	
3	85	.19	11,300	
4	136	.19	12,000	
5	104	.10	11,300	
6	51	.29	31,600	
7	71	.44	77,000	
8	154	.37	86,600	
9	160	.47	80,300	
10	177	.42	78,600	
Calculated inflow for period (rounded)			815,000	
			May 20 to 22, 1975	
1	7	0.05	1,280	Data for flume 4 were estimated. Measured precipitation on May 20 was 0.4 inch. No flow was recorded in flumes other than 1, 3, 4, and 5, because of wind effects.
3	49	.48	17,200	
4	33	.30	28,600	
5	34	.25	38,900	
Calculated inflow for period (rounded)			86,000	

Table 2.--*Measured inflow to the crack*--Continued

Flume number	Duration of flow (hours)	Maximum stage (feet)	Total flow (cubic feet)	Remarks for inflow period
			February 5 to 10, 1976	
				This storm washed out flume 9 and water was observed flowing in and out of flumes during the period of inflow; no estimate of inflow was made. Flume 9 was repaired in June 1976. Measured precipitation for period totaled 3.32 inches.
			May 14 to 16, 1976	
7	42	0.20	21,600	Measured precipitation from May 5 to 7 was 0.45 inch.
Calculated inflow for period (rounded)			21,600	
			July 26 to 28, 1976	
1	41	0.54	164,000	Measured precipitation from July 24 to 27 totaled 1.20 inches. Total inflow should have been greater than calculated inflow.
3	6	.72	5,620	
4	15	.28	9,830	
5	12	.19	8,460	
8	21	.47	62,500	
Calculated inflow for period (rounded)			250,000	

Table 2.--*Measured inflow to the crack*--Continued

Flume number	Duration of flow (hours)	Maximum stage (feet)	Total flow (cubic feet)	Remarks for inflow period
		September 10 to 16, 1976		
1	134	0.41	186,000	Measured precipitation for September 10 and 11 totaled 1.19 inches; flume 7 was silted in and record was lost. Total inflow probably was less than calculated inflow.
2	24	.30	76,500	
3	10	.35	3,490	
4	7	.32	5,800	
5	13	.20	9,860	
6	27	1.03	241,000	
8	28	.65	87,600	
9	43	.70	99,300	
10	42	.55	92,900	
Calculated inflow for period (rounded)			802,000	
		October 2 to 4, 1976		
1	39	0.41	188,000	Measured precipitation for October 1 and 2 totaled 1.68 inches; record was lost for flume 9 because of recorder malfunction.
2	29	.31	61,600	
3	23	.22	7,700	
4	23	.30	27,000	
5	31	.23	36,900	
6	47	.39	75,800	
7	51	.42	113,000	
8	25	.30	30,300	
10	34	.38	46,900	
Calculated inflow for period (rounded)			587,000	

Table 2.--*Measured inflow to the crack*--Continued

Flume number	Duration of flow (hours)	Maximum stage (feet)	Total flow (cubic feet)	Remarks for inflow period
			January 2 to 4, 1977	
1	40	0.40	119,000	Measured precipitation for January 2 and 3 totaled 0.85 inch. Record was lost for flumes 2 and 6 because of recorder malfunctions; flume 7 was silted in. Freezing at night may have affected records.
3	18	.27	3,060	
4	13	.03	324	
5	14	.14	6,840	
8	22	.51	44,100	
9	32	.59	58,000	
10	18	.44	32,200	
Calculated inflow for period (rounded)			264,000	
			May 8 to 11, 1977	
1	57	0.39	102,000	Measured precipitation for May 8 and 9 totaled 0.82 inch. Record was lost for flume 7 because of recorder malfunction.
2	14	.11	10,100	
3	11	.15	1,440	
4	10	.12	2,950	
5	22	.18	14,100	
6	47	.53	66,800	
8	18	.37	27,500	
9	28	.48	38,700	
10	31	.37	32,500	
Calculated inflow for period (rounded)			296,000	

Table 2.--*Measured inflow to the crack*--Continued

Flume number	Duration of flow (hours)	Maximum stage (feet)	Total flow (cubic feet)	Remarks for inflow period
			May 24 to 26, 1977	
1	47	0.27	45,400	Measured precipitation for May 23 and 24 totaled 0.41 inch. Record was lost for flumes 4 and 5.
2	5	.03	396	
3	3	.08	252	
6	45	.45	44,100	
7	31	.41	49,300	
8	10	.22	5,800	
9	18	.33	13,000	
10	26	.22	11,200	
Calculated inflow for period (rounded)			169,000	
			June 8 and 9, 1977	
3	2	0.05	108	Measured precipitation from June 6 to 9 totaled 0.05 inch.
5	10	.05	144	
6	22	.13	3,560	
7	7	.04	468	
8	2	.03	144	
9	6	.07	540	
Calculated inflow for period (rounded)			4,960	
			August 17 to 19, 1977	
1	25	0.91	1,200,000	Measured precipitation totaled 2.18 inches. Flume 1 and berm were washed out during this storm; record is not valid. Crack had insufficient capacity to contain all the flow.
2	23	.16	22,700	
4	37	.30	47,500	
5	58	.25	88,500	
8	28	.49	76,800	
9	36	.61	92,700	
Calculated flow for period (rounded)			1,530,000	

Precipitation records at Yucca Weather Station, about 2.5 mi from Yucca crack, are included in table 2. Lack of correlation between volume of inflow to the crack and measured precipitation results from the prevalence of intense localized thundershowers and the large drainage area of Yucca Flat. Loss of record from several flumes during some flows and the effects of wind also contribute to the lack of correlation. Therefore, estimation of inflow volume from the precipitation record is not possible. Maximum stage at each flume is listed to provide additional information.

A summary of flow is given in table 3. These data include only the volume of water computed from usable records, unless the record is listed as estimated flow. The table shows that about 5 million cubic feet of inflow was measured or estimated between October 1974 and August 1977. For the reasons previously discussed, this record is a conservative estimate of inflow volume for the period of study.

Table 3.--*Summary of inflow to the crack*

Inflow (month)	Measured precipitation (inches)	Inflow (cubic feet)
1974		
October-November	0.72	102,000
December	1.26	815,000
1975		
May	.41	86,000
1976		
February	3.32	([1])
May	.45	21,600
July	1.20	250,000
September	1.19	802,000
October	1.68	587,000
1977		
January	.85	264,000
May 8-11	.82	296,000
May 24-26	.41	169,000
June	.05	4,960
August	2.18	1,530,000
	TOTAL (rounded)	4,930,000

[1]No estimate of inflow made.

An estimate of the crack volume can be made from the inflow data, and the dimensions of the crack can be evaluated from the volume. The data collected during this study indicate that the crack may have had a volume of about 1 million cubic feet. This is based on: (1) Two inflows to the crack of about 800,000 ft^3 in 1974 and 1976; (2) insufficient capacity of the crack for containing 1.5 million cubic feet of runoff in 1977; and (3) no consideration being given to significant evaporation and infiltration from the crack to alluvium and rock during the inflow periods.

Of the three dimensions of the crack, only one was known with any degree of certainty--the lateral extent of the crack. As shown in figure 9, the crack was about 5,800 ft long at land surface. For purposes of calculation, the length at depth is assumed to be the same. The width and depth can only be speculated. If the crack averaged 1 in. in width, the computed average depth would have been about 2,000 ft. If the crack had a narrower average width and the length estimate remained unchanged, then the computed average depth would be proportionally larger. According to information presented by Winograd and Thordarson (1975, pl. 2), the depth to bedrock (base of alluvial valley fill) probably is less than 1,500 ft beneath the area of the crack. Therefore, it is possible that the crack could extend to that contact.

An extensive program of sampling for chemical and radiochemical analysis of the water entering the crack was not undertaken as part of this study. Undoubtedly, quality of the water varies with time and distance of transport over different terrain, and changes with time of residence on the playa deposits. An adequate program of sampling to evaluate these changes was physically and practically impossible under the circumstances in which precipitation falls. The general chemical character of water entering the crack probably is represented by the analysis in table 4, but great variations are possible. Gross-radioactivity assays of the water accumulating in the crack have been made for several years by Reynolds Electrical and Engineering Company radiation-monitoring personnel and have shown no unusual or injurious levels of activity (Earl Sorrom, U.S. Geological Survey, oral commun., 1978).

SUGGESTIONS FOR FURTHER STUDY

If a new, major crack opens in the bottom of Yucca Lake, the following items are needed for inclusion in any study of inflow to the crack:

1. Immediate construction of a berm completely around the crack to prevent inflow until inflow-measuring equipment can be installed. Such a berm needs to be massive, high, regularly shaped, and surrounded on its perimeter by a ditch to channel inflow to the lowest point along the berm. The berm needs to be several tens of feet laterally away from any evidence of the crack.

Table 4.--*Results of chemical analysis of a representative water sample from Yucca Lake*

[Sample collected January 19, 1978. All units in milligrams per liter unless otherwise indicated]

Chemical property or constituents	Value	Chemical property or constituents	Value
Alkalinity	58	Hardness (Ca, Mg)	28
Alpha, dissolved (micrograms per liter)[1]	<2.1	Iron (Fe)	710
Alpha, suspended (micrograms per liter)[1]	1,200	Lithium (Li)	10
Beta, dissolved (picocuries per liter)[2]	21	Magnesium (Mg)	1.1
Beta, suspended (picocuries per liter)[2]	680	pH, laboratory (units)	7.4
Beta, dissolved (picocuries per liter)[3]	18	Potassium (K)	12
Bicarbonate (HCO_3)	71	Residue, filtrable	130
Calcium (Ca)	9.2	Residue, nonfiltrable	14,000
Carbon dioxide (CO_2)	4.0	Silica (SiO_2)	8.5
Carbonate (CO_3)	0	Sodium (Na)	13
Chloride (Cl)	3.6	Specific conductance (microsiemens)[4]	140
Cyanide (CN)	0.00	Strontium (Sr) (micrograms per liter)	10
Dissolved solids (sum)	90	Sulfate (SO_4)	6.5
Dissolved solids (residue)	109	Temperature (degrees Celsius)	4
Fluoride (F)	.2		

[1]Gross as uranium.
[2]Gross as cesium 137.
[3]Gross as strontium 90/yttrium 90.
[4]Equivalent to micromhos per centimeter at 25° Celsius.

2. Inflow needs to be restricted to a single ditch or channel fitted with headgates to regulate inflow. The inflow-measuring structure could be open-channel or pipes with totalizing flow meters; the structure would allow inflow to be adjusted to the quantity the crack would accept and would provide information on any change in rate of acceptance that might occur. Monitoring and maintenance costs would be minimal, and better records of total volume would be obtained by eliminating short-period peak flows by means of controlled-inflow rates.
3. Soil-moisture monitoring (neutron) wells need to be installed within the berm area as quickly as possible to monitor moisture infiltration near the crack, both from land surface and from the crack.
4. Samples of water for sediment load, chemical, and radiochemical analysis need to be collected for each flow period and at intervals within a period.
5. Seismic surveys need to be made and angle holes need to be drilled as soon as possible to attempt to determine depth of the crack. Resistivity methods have proven ineffective in determining depth to which the 1969 crack was opened (Zohdy and Bisdorf, 1979).
6. Post-type rain gages need to be installed to determine precipitation variation in the immediate area of the crack.

SUMMARY AND CONCLUSIONS

The quantity of water entering the crack during the 3-year monitoring period was estimated to be at least 5 million cubic feet (15 acre-ft) or a rate of about 5 acre-ft per year. This potential recharge is less than 1 percent of the estimated average annual recharge to Yucca Flat. This is a conservative estimate; the actual inflow during the period could have been as much as 20 acre-ft. In the early years of inflow to the crack, the volume of water accepted possibly was much larger than during the time inflow was monitored; thus, for a short period, annual percentage of inflow to the regional aquifer flow could have been larger. If the water entering crack is indeed recharging the regional ground-water flow system in the Paleozoic carbonate aquifer, a contaminated water slug would have a 1:100 dilution factor and a potentially short travel time to nearby wells C and C1. Available precipitation records from Yucca Weather Station cannot be used to estimate inflow to the crack, because of uneven distribution of rainfall and runoff. Past history of crack formation at Yucca Lake playa indicates that new cracks are likely to open and to be lengthened.

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