

Tritium in Unsaturated Zone Gases and Air at the
Amargosa Desert Research Site, and in
Spring and River Water, near
Beatty, Nevada, May 1997

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U.S. GEOLOGICAL SURVEY
Open-File Report 97-778



Carson City, Nevada
1998

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Multiply	By	To obtain
millimeter (mm)	0.0394	inch
meter (m)	3.2808	foot
kilometer (km)	0.6215	mile
liter (L)	0.2642	gallon
cubic meter (m ³)	35.31	cubic foot
tritium unit (TU)	3.2	picocurie per liter

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ABSTRACT

Elevated tritium concentrations in the unsaturated zone at the Amargosa Desert Research Site (ADRS), immediately south and west of the low-level radioactive-waste burial site south of Beatty, Nevada, have stimulated research of processes that control the transport of tritium in arid unsaturated zones. In May 1997, 58 samples were collected from 1.5 m (meters) depth within a 250 m by 250 m grid at the ADRS. Measured concentrations ranged from 16 ± 9 to $36,900 \pm 300$ tritium units (TU), decreasing from northeast to southwest, possibly along an ancestral Amargosa River channel.

The 10 air ports at test hole UZB-2 also were sampled, including ports at 57.6, 106.4, and 108.8 m depths that had not been sampled since 1994. Of the remaining seven ports, five were sampled in 1994, 1995, and 1996, and two were sampled in 1994 and 1996. Tritium concentrations at the four ports deeper than 50 m ranged from 791 ± 15 to 1765 ± 29 TU, having increased since they were last sampled. Tritium concentrations at the six ports shallower than 50 m ranged from 367 ± 11 to 1283 ± 20 TU, and appear to have stabilized since 1996.

Tritium concentration in water vapor collected from air within the creosote bush canopy was 75 ± 9 TU near test hole UZB-2 and 9 ± 6 TU near the uncontaminated Fischer test hole, 3.2 km to the south. Elevated tritium concentration in air near test hole UZB-2 was attributed to plant transpiration removing water from the unsaturated zone. Nearby surface water tritium concentrations were 6.3 ± 0.4 TU at Specie Spring, 0.0 ± 0.3 TU at Lower Indian Springs and at Upper Indian Springs, and 0.8 ± 0.6 TU in Amargosa River water.

INTRODUCTION

Elevated tritium concentrations in water vapor collected from the unsaturated zone and plants at the Amargosa Desert Research Site (ADRS), south and west of a commercial burial site for low-level radioactive waste near Beatty, Nevada (Prudic and Striegl, 1995; Striegl and others, 1996; Prudic and others, 1997), have caused speculation regarding the exact mechanisms that control tritium transport in arid unsaturated zones. Measured tritium concentrations in the ADRS unsaturated zone are greater than concentrations predicted by applying current tritium transport models to ranges of geological, hydrological and chemical conditions that encompass *in situ* conditions at the site (Striegl and others, 1996). Understanding of tritium transport at the ADRS is

complicated by several unknown factors, including tritium source strength; form, timing, and location of tritium contamination; complex geology of the unsaturated zone; and the extent of liquid-water/water-vapor interaction that occurs in the unsaturated zone.

During May 15-24, 1997, as part of ongoing research to understand the mechanisms that control the transport of tritium in arid unsaturated zones, water vapor and liquid water samples were collected from several locations at and near the ADRS for tritium analysis. A primary focus of the field investigation was to measure the spatial distribution of tritium in water vapor approximately 1.5 m below land surface, near the middle of a coarse gravel that underlies surficial silt and sand at the site (Fischer, 1992, p. 19; Striegl and others, 1996). Spatial data on the tritium concentration in the gravel can provide insight regarding the direction and extent of tritium movement at the ADRS and may help in locating possible preferential geological pathways for radionuclide movement, such as ancestral Amargosa River channels. The data also can aid in selecting potential sites of new deep test holes for continued study of the physical and chemical processes that control tritium transport at the ADRS.

Tritium also was measured in water vapor collected from 10 air-sampling ports installed in test hole UZB-2, from above-ground air within the creosote bush (*Larrea tridentata*) canopy near test hole UZB-2, and from the shallow unsaturated zone and above-ground air within the creosote bush canopy near the uncontaminated Fischer test hole, 3.2 km to the south. Surface-water samples from nearby Specie Spring, Lower Indian Springs, Upper Indian Springs, and the Amargosa River also were collected and analyzed for tritium content.

Water-vapor samples collected from air ports at UZB-2 since 1994 document the recent history of tritium concentration in the unsaturated zone near the test hole (Prudic and Striegl, 1995; Striegl and others, 1996; Prudic and others, 1997). Samples of water vapor and liquid water from above-ground air, the Fischer test hole, nearby springs, and the Amargosa River provide general information on local tritium concentrations.

The purpose of this report is to present and discuss new data on the spatial distribution of tritium concentration in the shallow unsaturated zone at the ADRS. The report also adds to the information base on tritium concentration at test hole UZB-2 and at nearby uncontaminated sites.

STUDY AREA

Tritium-in-water-vapor samples were collected within a 250 m by 250 m grid at the ADRS, directly south and west of a commercial low-level radioactive-waste burial site, in the Amargosa Valley, approximately 16 km south of Beatty, Nevada. They also were collected near the Fischer test hole, 3.2 km south of the burial site (fig. 1; the Fischer test hole is referred to as "distant test hole" in Prudic and Striegl, 1995; and Striegl and others, 1996). Nodes in the 11 by 11 sampling grid are spaced approximately 25 m apart. Rows 1-11 of the grid are numbered from north to south, having the northernmost row 1 located at the south fence of the waste burial site. Columns A-K are lettered from east to west. Node E1 is the southwest corner of the burial site fence (fig. 2). Test hole UZB-2 is located between nodes D5 and E5.

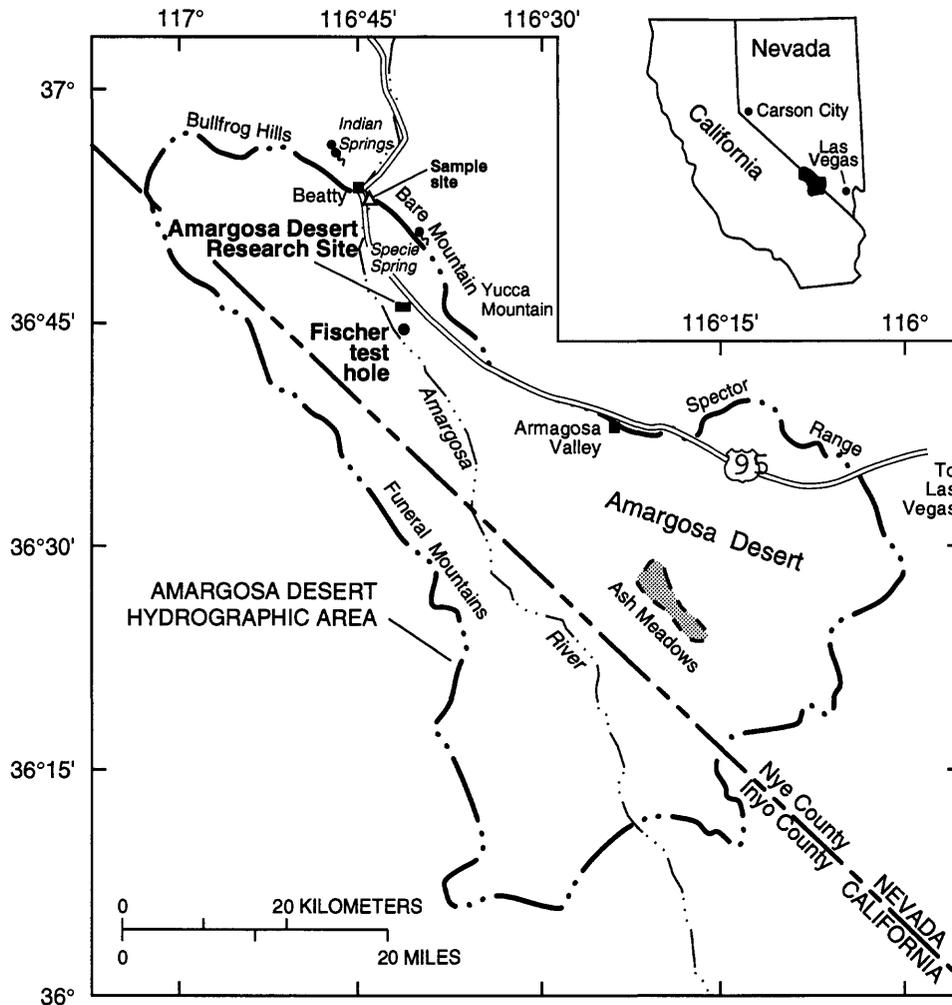
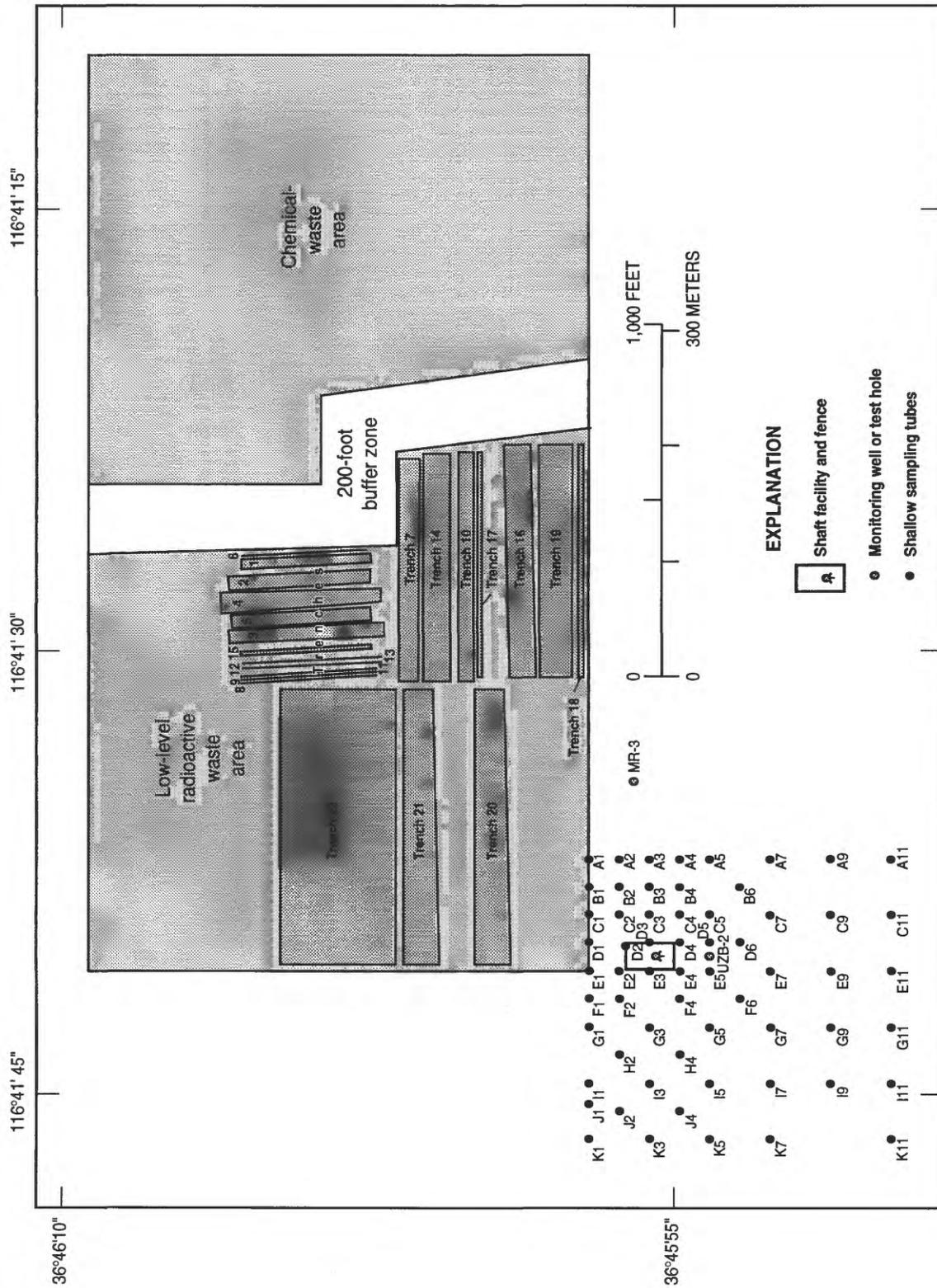


Figure 1. Map showing location of the Amargosa Desert Research Site, Fischer test hole, and surface-water sampling locations within the Amargosa Desert hydrographic area.

Detailed descriptions of test hole UZB-2 and of the local geology are summarized in Prudic and Striegl (1995); Striegl and others (1996); and Prudic and others (1997). Surface-water tritium samples also were obtained within several kilometers of the ADRS at Specie Spring, Upper Indian Springs, Lower Indian Springs, and the Amargosa River (fig. 1).

METHODS

Steel tubes having an outside diameter of 9.5 mm and an inside diameter of 3.2 mm were hand-driven 1.5 m into the unconsolidated deposits at each grid node, or to the point of refusal, if that was slightly shallower. All tubes were hand-driven to at least 1.3 m. Prior to driving, a nail having a narrow shaft and a 9.5 mm head was inserted into the bottom end of each tube to prevent clogging of the tube with sediment as it was driven downward. After driving, the tube was pulled upward about 10 mm to free the nail and to open a space at the bottom of the tube through which air was drawn. Unless otherwise noted, the depth of sampling at the grid nodes is referred to as the "1.5 m depth." Steel tubes also were driven to depths of 0.25, 0.50, 0.75, and 1.0 m at node A-1 and to depths of 0.5, 1.0, and 1.5 m at test hole UZB-2 and the Fischer test hole.



Base modified from US Ecology, Inc., 1989

Figure 2. Map identifying node distribution within the sampling grid at the Amargosa Desert Research Site.

Water vapor was collected by attaching 6 mm inside-diameter Bevaline tubing to the steel tubes or to the nylon tubing connected to the ten UZB-2 air ports, attaching a glass freeze trap to the free end of the tubing, and pulling the unsaturated zone air through the sampling apparatus using a diaphragm air-sampling pump. The freeze traps were chilled in a slurry of dry ice and ethanol or propanol, and water vapor was frozen out of the air stream into the freeze traps (Striegl, 1988). Three to ten milliliters of water were collected at each sample location for tritium analysis at a U.S. Geological Survey isotope laboratory. Sample collection times varied with location from 6 to 24 hours. Pumping rates generally ranged from 1 to 2 liters of air per minute.

Water vapor was freeze-trapped from above-ground air at two locations and analyzed for tritium content. The locations were within the creosote bush canopy, 0.8 m above the ground near test hole UZB-2 between nodes E4 and E5; and 0.9 m above the ground near the Fischer test hole.

TRITIUM CONCENTRATION

Sampling Grid (shallow unsaturated zone)

Tritium concentrations for 58 locations at the 1.5 m depth, within the sampling grid, are listed in table 1. Concentrations ranged from 16 ± 9 TU at K11, in the southwest corner of the grid, to $36,900 \pm 300$ TU at A3, near the northeast corner. Concentration at the Fischer test hole was 11 ± 7 TU at the 1.5 m depth (table 2). Assuming that this value represents natural background levels, all values measured within the sampling grid (with the possible exception of K11) indicate tritium concentrations above expected environmental values. Contours of tritium concentrations within the sampling grid (fig. 3) show a general trend of decreasing concentration from near the northeast corner of the grid to the southwest. A secondary area of high concentration exists in the north-central part of the grid near F1, F2, and G3.

Table 1. Tritium concentration in water vapor collected from the shallow unsaturated zone within the sampling grid at the Amargosa Desert Research Site, May 19-23, 1997

Grid location	Depth below land surface (meters)	Tritium concentration (tritium units)	Counting uncertainty (tritium units)
A1	0.25	3820	± 50
A1	0.50	13,800	± 130
A1	0.75	20,760	± 180
A1	1.0	29,120	± 250
A1	1.5	25,190	± 220
A2	1.5	33,800	± 300
A3	1.5	36,900	± 300
A4	1.5	33,000	± 300
A5	1.5	24,750	± 220
A7	1.5	7000	± 70
A9	1.5	3420	± 40
A11	1.5	116	± 11
B1	1.5	18,990	± 160
B2	1.5	35,000	± 300
B3	1.5	28,240	± 240
B6	1.5	17,030	± 150
C1	1.5	15,920	± 140
C2	1.5	21,010	± 180
C3	1.5	22,200	± 190
C4	1.5	17,670	± 160
C5	1.5	26,180	± 230
C7	1.5	5900	± 70
C9	1.5	476	± 12
C11	1.5	91	± 8
D1	1.5	8580	± 90
D2	1.5	11,180	± 100
D3	1.5	12,670	± 120
D4	1.5	20,490	± 180
D5	1.5	15,390	± 140
D6	1.5	18,260	± 170
E1	1.5	2810	± 40
E2	1.5	5380	± 60
E3	1.5	6940	± 70
E4	1.5	1041	± 20
E5	1.5	11,340	± 110
E7	1.5	2580	± 40
E9	1.5	78	± 8
E11	1.5	59	± 8

Table 1. Tritium concentration in water vapor collected from the shallow unsaturated zone within the sampling grid at the Amargosa Desert Research Site, May 19-23, 1997 -- continued

Grid location	Depth below land surface (meters)	Tritium concentration (tritium units)	Counting uncertainty (tritium units)
F1	1.5	10,750	± 90
F2	1.5	10,630	± 90
F4	1.5	6740	± 60
F6	1.5	2533	± 26
G1	1.5	6340	± 60
G3	1.5	10,330	± 90
G5	1.5	1889	± 25
G7	1.5	331	± 11
G9	1.5	73	± 8
G11	1.5	43	± 8
H2	1.5	5540	± 60
I1	1.5	2764	± 28
I3	1.5	1181	± 15
I5	1.5	177	± 7
I7	1.5	51	± 6
I9	1.5	51	± 7
J1	1.5	2166	± 24
J2	1.5	1013	± 15
J4	1.5	448	± 10
K1	1.5	340	± 10
K3	1.5	290	± 10
K5	1.5	51	± 7
K7	1.5	35	± 7
K11	1.5	16	± 9

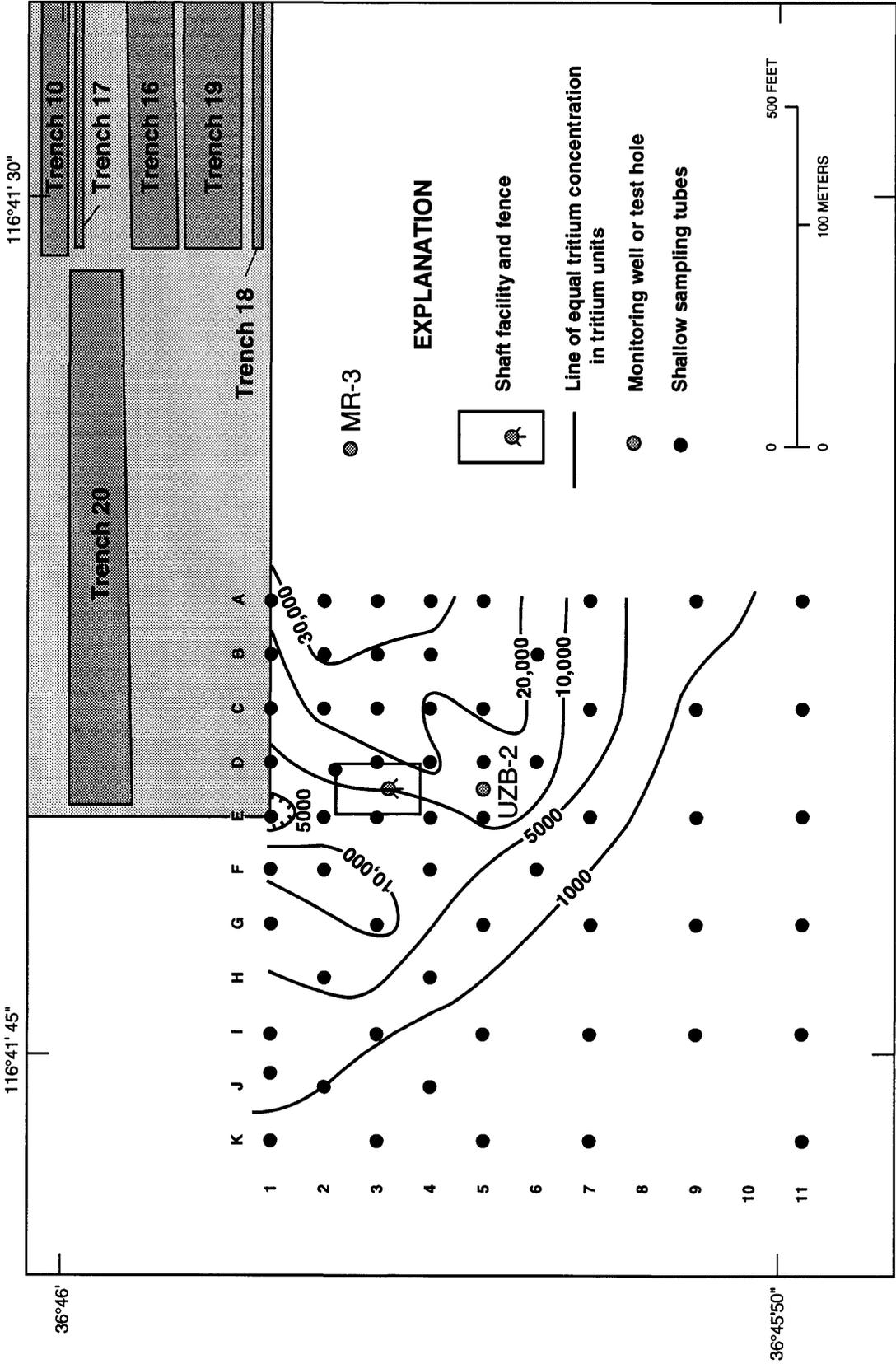


Figure 3. Map showing tritium concentration in water vapor collected at the 1.5 m depth within the sampling grid at the Amargosa Desert Research Site.

The greatest tritium concentration measured at node A1 was $29,120 \pm 250$ TU at depth 1.0 m (table 1). The soil has been reworked by earth moving equipment at sites A1 through E1, which are along the south fence of the burial site. The sampling tube at depth 1.0 m at site A1 penetrates the shallow gravel. Measured tritium concentrations at A1 were nearly 4000 TU greater at the 1.0 m depth than at the 1.5 m depth. The reason for this pattern is not clear. Increasing concentration with depth would be expected if migration were upward from a deeper source. However, because the sampling method requires continuous pumping for several hours, air is pumped from about 2 m^3 of unsaturated zone for each sample. The volumes of unsaturated zone influenced by pumping may therefore overlap for closely spaced samples.

Test Hole UZB-2

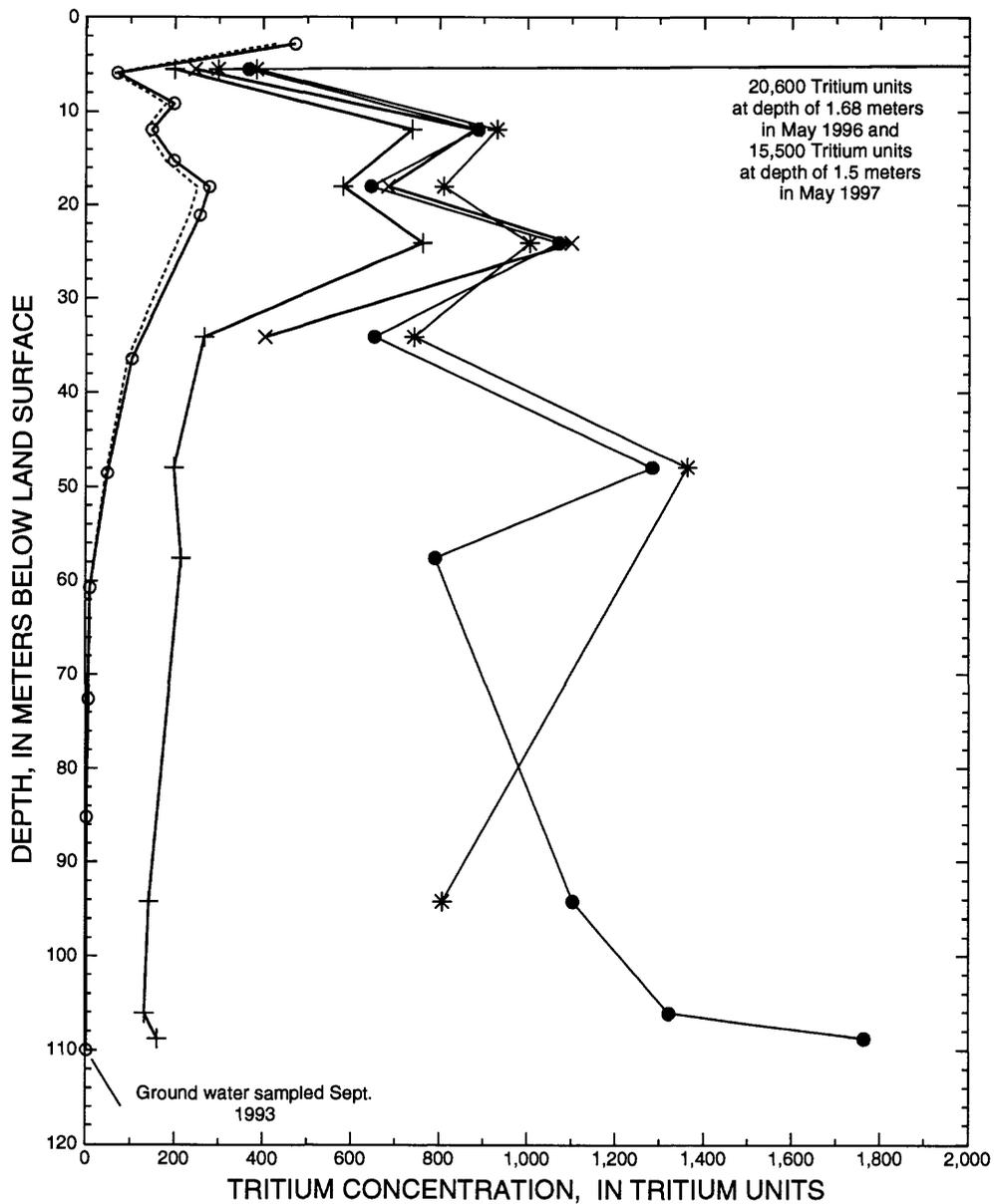
The greatest measured tritium concentration at test hole UZB-2 was $15,510 \pm 140$ TU at depth 1.5 m (table 2). The tritium concentration versus depth profile at UZB-2 has three depths of high concentration: $15,500 \pm 140$ TU in the shallow gravel at 1.5 m, 1283 ± 20 TU at 47.9 m, and 1765 ± 29 at 108.8 m (table 2, fig. 4). Lateral movement of tritium from the burial site in the shallow gravel is the likely explanation for high tritium concentrations at the 1.5 m depth.

The combined lateral and vertical movements of tritium to deeper locations at UZB-2 are not yet understood. Following an initial sharp rise in tritium concentrations from 1994 to 1995, measured concentrations at depths of 5.5, 11.9, 18.0, 24.1, and 34.1 m remained fairly constant or decreased between 1996 and 1997 (table 2; Prudic and Striegl, 1995; Striegl and others, 1996; and Prudic and others, 1997). Tritium concentrations increased substantially since they were last sampled in 1994 at depths 57.6, 106.4, and 108.8 m and in 1996 at depth 94.2 m (fig. 4; Prudic and Striegl, 1995; Striegl and others, 1996; and Prudic and others, 1997).

Table 2. Tritium concentration in water vapor collected from the unsaturated zone at test hole UZB-2 and at the Fischer test hole at the Amargosa Desert Research Site, May 15-18, 1997

Depth below land surface (meters)	Tritium concentration (tritium units)	Sampling uncertainty (tritium units)
Test hole UZB-2		
0.5	12,180	± 110
1.0	12,000	± 120
1.5	15,510	± 140
5.5	367	± 11
11.9	888	± 17
18.0	645	± 14
24.1	1071	± 24
34.1	652	± 14
47.9	1283	± 20
57.6	791	± 15
94.2	1104	± 22
106.4	1322	± 26
108.8	1765	± 29
Fischer test hole		
0.5	22	± 7
1.0	13	± 6
1.5	11	± 7

One hypothesis to explain the time history of tritium concentration at UZB-2 is that air injected during the drilling operation diluted the high-tritium-content subsurface air with low-tritium-content atmospheric air. This could explain the large rise in tritium concentration in the years immediately following drilling and the subsequent stabilization of tritium concentration in recent years, as ambient subsurface air gradually mixed back into the area that was injected with atmospheric air. It is expected that the greatest dilution would have occurred at depths greater than 91 m. Above that depth, ODEX air hammer was used for drilling, whereas below that depth, air rotary, which injects more air into the hole, was used (Prudic and Striegl, 1995). This hypothesis, however, cannot explain the large differences between the high tritium concentrations measured in water vapor in 1996-97 and the low tritium concentrations measured in liquid water extracted from the 1992-93 core samples (fig. 4; Prudic and others, 1997). These differences could possibly be explained by the movement of a tritium pulse over time.



EXPLANATION

- Pore water, Nov. 1992 and Sept. 1993
- Water vapor in equilibrium with pore water, Nov. 1992 and Sept. 1993
- +— Water vapor, Apr. 1994
- ×— Water vapor, July 1995
- *— Water vapor, May 1996
- Water vapor, May 1997

Figure 4. Graph showing tritium concentration in water vapor collected from air ports at UZB-2 during April 1994, July 1995, May 1996, and May 1997, and tritium concentration in water extracted from UZB-1 and UZB-2 core samples.

Tritium contamination was not suspected at the ADRS when test hole UZB-2 was drilled in 1993, so obtaining a continuous tritium profile from the test hole at the time of drilling was not a concern (Prudic and Striegl, 1995). A profile showing tritium concentrations at all depths was constructed in 1996 using water extracted from archived core samples that were collected from UZB-2 during drilling in 1993 and from nearby UZB-1 during drilling in 1992 (fig. 4; Prudic and others, 1997). Below about 50 m, tritium concentrations in the core were close to concentrations expected for uncontaminated soils.

The immediate and long-term effects of the ODEX air-hammer and the air-rotary drilling at UZB-2 are not known, so it cannot be determined whether measured changes in tritium concentration at the test hole since 1994 are attributable to increased tritium transport past the test hole since drilling or to recovery of the test hole from air injection when the hole was drilled. Migration of the tritium down the test hole also is a possibility, although great care was taken during test hole construction to prevent communication of air and water along the test hole annulus (Prudic and Striegl, 1995).

Air and Surface Water

Water vapor in air collected at 0.8 m above land surface, within the canopy of a creosote bush located between nodes E4 and E5, had a concentration of 75 ± 9 TU (table 3). This elevated concentration is attributed to creosote bush transpiration that removes water from the shallow unsaturated zone, mixing it with water vapor in atmospheric air. Striegl and others (1996) reported concentrations from 2960 ± 50 to 9800 ± 90 TU in transpiration water from creosote bushes within the area bounded by grid nodes A1, A5, E1, and E5. Water vapor in air within the creosote bush canopy at the Fischer test hole had a concentration of 9 ± 6 TU.

Table 3. Tritium concentration in air and surface water at and near the Amargosa Desert Research Site, May 15-24, 1997

Location	Height above land surface (meters)	Tritium concentration (tritium units)	Counting uncertainty (tritium units)
Air in creosote bush canopy			
Between nodes E4 and E5	0.8	75	± 9
Fischer test hole	0.9	9	± 6
Surface water			
Specie Spring		6.3	± 0.4
Lower Indian Springs		0.0	± 0.3
Upper Indian Springs		0.0	± 0.3
Amargosa River		0.8	± 0.6

Tritium concentrations measured in the unsaturated zone at the Fischer test hole suggest decreasing tritium concentration with depth (22 ± 7 TU at 0.5 m, 13 ± 6 TU at 1.0 m, and 11 ± 7 TU at 1.5 m, table 3). However, all three of these values are statistically similar if the counting errors are considered, so the measured apparent gradient may not be real.

Four local surface-water sources, Specie Spring, Lower Indian Springs, Upper Indian Springs, and the Amargosa River also were sampled (table 3). The tritium concentration measured at Specie Spring of 6.3 TU is probably close to tritium concentrations in precipitation at the present time. The spring is located at an elevated site on Bare Mountain (fig. 1), and flow paths from the source area must be short. Samples collected at the other surface-water sites have concentrations indicative of waters that were deposited prior to the advent of nuclear testing. These waters can be presumed to originate in ground waters that have long flow paths from the point of recharge to the discharge area.

REFERENCES CITED

- Fischer, J.M., 1992, Sediment properties and water movement through shallow unsaturated alluvium at an arid site for disposal of low-level radioactive waste near Beatty, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations Report 92-4032, 48 p.
- Prudic, D.E., Stonestrom, D.A., and Striegl, R.G., 1997, Tritium, deuterium, and oxygen-18 in water collected from unsaturated sediments near a low-level radioactive-waste burial site south of Beatty, Nevada: U.S. Geological Survey Water-Resources Investigations Report 97-4062, 23 p.
- Prudic, D.E., and Striegl, R.G., 1995, Tritium and radioactive carbon (^{14}C) analyses of gas collected from unsaturated sediments next to a low-level radioactive-waste burial site south of Beatty, Nevada, April 1994 and July 1995: U.S. Geological Survey Open-File Report 95-741, 7 p.
- Striegl, R.G., 1988, Distribution of gases in the unsaturated zone at a low-level radioactive-waste disposal site near Sheffield, Illinois: U.S. Geological Survey Water-Resources Investigations Report 88-4025, 69 p.
- Striegl, R.G., Prudic, D.E., Duval, J.S., Healy, R.W., Landa, E.R., Pollock, D.W., Thorstenson, D.C., and Weeks, E.P., 1996, Factors affecting tritium and ^{14}C carbon distributions in the unsaturated zone near the low-level radioactive-waste burial site south of Beatty, Nevada: U.S. Geological Survey Open-File Report 96-110, 16 p.
- US Ecology, Inc., 1989, Site stabilization and closure plan for low-level radioactive waste management facility: Beatty, Nev., Radioactive Materials License State of Nevada No. 13-11-0043-02, attachment 1.