FY-92 Report on the Isotope Hydrology Characterization of the Faultless Test Site, Nye County, Nevada

by

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ABSTRACT

Recent sampling and isotopic analysis of groundwater by LLNL at the Faultless test site in Hot Creek Valley, Nevada, and close examination of previous hydrochemistry measurements by the USGS show that the similar Na-HCO_3 groundwater chemistry between monitoring wells UC-1-P-2SR and HTH-1 differs from the Ca-HCO_3 groundwater of HTH-2. The $^{87}Sr/^{86}Sr$ ratios (0.7059 to 0.7101) suggest that the shallow groundwater (~300m) from HTH-2 resides in a radiogenic-rich host alluvium that dominates the chemical and strontium isotopic signatures of this shallow well, and contrasts with the lower strontium signatures of groundwater from the deeper monitoring well of HTH-1. The less radiogenic $^{87}Sr/^{86}Sr$ ratios and high pH values of water sampled from UC-1-P-2SR may reflect the host geologic material, but may also be influenced by the cement used in the well construction.

The apparent ^{14}C ages of groundwater range approximately between 2300 and 35,000 years. Carbon-13 corrected ages give a maximum age of ~21,900 years for the groundwater from HTH-1. The ^{13}C corrected age for HTH-2 groundwater is unusually lower and a simple correction formula may not apply in this case. The calculated ages for the groundwater samples from UC-1-P-2SR may also be influenced by the cement used in the well's construction, although their younger ages do support post-shot downward infiltration of younger shallow groundwater into the chimney/cavity region of the test site.

Arrival of high tritium levels (~35,000-1×10^9 pCi/L) near the bottom of UC-1-P-2SR from 1973 and 1977, noted by Thordarson (1984), grossly corresponds to the onset of log-normal water level recovery and filling of the explosion cavity/chimney region with groundwater below a perched water table.

The new radioisotope measurements by LLNL of UC-1-P-2SR shows: 1) ^3H concentrations are between 14 and 22,000 pCi/ml with the highest occurring in the deepest level (789 mbs), 2) ^{85}Kr is detected at all levels and ranges between 400 and

28,000 pCi/L with the highest in the deepest level, 3) $^{36}Cl/Cl$ ratios occur above environmental levels (10^{-12}) between 10^{-11} and 10^{-8} in the deeper two sampling intervals, 4) ^{39}Ar is detectable at the lowest sampling interval at 434 pCi/L. Uncertainties in defining the hydrological source-term activity is high at this time, due to mixing effects in the drill hole during sampling. In general, the high activity groundwaters are probably not advecting out from the cavity/chimney region, and most likely are being diluted by infilling fresh groundwater.

INTRODUCTION

In January of 1968 the Faultless test shot (Fig. 1) at 975m below the surface had an estimated magnitude range between 200kt to 1Mt (Thordarson, 1984). The detonation resulted in a surface crater estimated at 1km in diameter accompanied by a > 3m collapse escarpment at the surface. Careful monitoring of outlying observation wells before, during and after the shot has provided valuable data on the hydrodynamic response of the groundwater (Table 1a and 1b; Thordarson, 1984). Thorough water level and tritium monitoring in the drillback hole UC-1-P-2SR has contributed significantly to the understanding of post-shot groundwater effects (Thordarson, 1987).

This report of FY92 investigations at Faultless by the Nuclear Chemistry Division at LLNL serves to outline new and previous isotopic data of natural and shot-related nuclides measured in the drillback hole (UC-1-P-2SR) and the two closest satellite wells (HTH-1 and HTH-2). The goals of this study are: 1) to investigate and characterize the geochemical and isotopic variabilities of groundwater, as a function of groundwater source and age, in the drillback hole and the satellite wells, 2) to determine concentrations of event-related nuclide activity and investigate any possible migration of the hydrologic source term. A more comprehensive source and age characterization from isotopic and geochemical variations of natural groundwater in the Hot Creek Valley would require a regional scale investigation.

For previous work in hydrogeologic and geologic investigations associated with Faultless and Hot Creek Valley, the reader is directed to the bibliography found in Thordarson (1984) and Thordarson (1987). Other results in which this study originally stems is presented in Buddemeier and Isherwood (1984).

HYDROGEOLOGIC SETTING

Hot Creek Valley is located in central Nevada approximately 160km northeast of Tonopah, Nevada. Hot Creek Valley is a typical basin and range graben that is filled with over 700m of alluvium. The Faultless site is located at the northern end of the valley at 1850m above sea level, and is flanked by Tertiary volcanic lithology that overlies Paleozoic sedimentary rocks at depth (>2000m) within the valley. UC-1-P-2SR and HTH-1 penetrate ~730m of (Table 1b) predominantly clay to boulder size volcanic alluvial sediments that overlie welded and more commonly non-welded tuffaceous sediments (Thordarson, 1984). UC-1-P-2SR is shot perforated continuously from approximately 350-850m below the surface, and HTH-1 is perforated in ten discreet intervals between 200 and 1100 mbs. HTH-2 is drilled into the alluvium to 306 mbs (Table 1b) and is perforated between 200 to 300m.

Pre-Shot Conditions - Pre-shot groundwater levels in HTH-1 and HTH-2 averaged approximately 170m below the surface, but levels over the entire monitoring well network around Faultless are not available at this time. Pre-shot water table gradients probably reflected the topographic gradients and groundwater most likely flowed regionally toward the south.

Groundwater chemistry in some of the wells shows a Na-HCO_3 to Ca-HCO_3 character (Fig 2). Wells UC-1-P-2SR and HTH- 1 have a very similar Na-HCO_3 chemistry with UC-1-P-2SR being more dilute. UCe-18 (~6km down gradient and over 500 meters deeper) also has a similar Na-HCO_3 chemistry, but TDS values are a factor of

5 to 10 higher and are probably related to the higher temperatures at depth. HTH-2, on the other hand, is a Ca-HCO_3 groundwater that defines a unique cationic field in Figure 2.

Post-Shot - Post-shot static water level measurements in UC-1-P-2SR (Table 1a) since 1968 are of great value to the interpretation of the post-shot cavity hydrologic response. The static water table record (Fig. 3) through time is segmented into two phases: 1) an early phase (1968-1973) where water level has a minor initial rise probably due to post drilling fluid injection (Thordarson et al, 1984), followed by a steady 50m decline that flattens out at 695 mbs, 2) a second phase from 1974 to the present that represents an abrupt change to near, log-normal-type water level recovery.

Water pressure data collected during the event that characterized the groundwater response (Table 1a) shows that HTH-1 had the largest excess head of 65m above the pre-shot level. Although HTH-2 has a closer surface distance to UC-1-P-2SR, the well bottom of HTH-1 is actually closer to the detonation point, and has probably recorded the groundwater displacement over a greater depth range.

RESULTS AND DISCUSSION

Field Measurements and Sampling - Field sampling for isotopic analysis in wells UC-1-P-2SR, HTH-1, and HTH-2 at the Faultless site was conducted by LLNL during July 1992. Downhole sampling was completed using an evacuated stainless steel 4.4 liter bailer lowered to the sampling levels by a wire line mechanism that remotely opened and closed a valve on the wireline tool on top of the bailer. The groundwater was immediately sampled at the surface for the field measurements by draining groundwater from the bailers at a bottom needle valve. Untreated samples were drained from the bailer for gamma spectra, ^{3}H, ^{99}Tc, and ^{36}Cl, where samples for strontium isotope analyses were filtered (0.45μ) and acidified (pH~2) into polyethylene I-Chem bottles.

Carbon-14 samples were drained into glass bottles under a nitrogen atmosphere and preserved with $HgCl_2$. The groundwater sample for ^{14}C from HTH-2 was collected by DRI and the sample integrity was unknown. At first it was not certain as to whether this sample was contaminated, but the ^{14}C value was reproduced from samples collected by DRI in FY 93 using LLNL standard sampling procedures for ^{14}C, and subsequently, a high confidence level is associated with the value in Table 3.. Krypton-85 samples were left inside of a sealed, half bailer (2.2 liter) and shipped to LLNL for gas extraction under vacuum conditions. Groundwater from UC-1-P-2SR, HTH-1, and HTH-2 were measured in the field for pH, conductivity, and temperature (Table 3), and UC-1-P-2SR was measured for dissolved oxygen.

Radionuclide data is reported as activities in pCi per measured volume, where the ^{36}Cl is reported as an atom ratio to total dissolved chloride in the water sample. The Sr isotope analyses are reported as atom ratios. The ^{14}C is reported as a percent of modern carbon relative to a pre-nuclear fallout (1950's) standard (NBS-Oxalic Acid-1).

Tritium - Figure 4 is a time series of tritium concentrations vs. depth in UC-1-P-2SR from quarterly measurements between 1972 to 1982 after Thordarson (1984). The first significant rise in tritium activity (> one order of magnitude) showed up in the lower part of the well in the spring of 1973, approximately 5.5 years after the detonation. The tritium activity subsided in the fall of 1974, but then returned at a much higher concentration by February 1976. Again, the activity subsided by the Fall 1977 and began gradually climbing in late 1979.

Tritium levels measured by LLNL in 1992 are elevated between 14 and 22,000 pCi/ml from the upper to lower sampling intervals of UC-1-P-2SR (Table 3). These levels are approximately the same as those reported by Buddemeier and Isherwood (1984). Tritium levels in HTH-1 and HTH-2 are between 0.02 and 0.06 pCi/ml (Table 3) and are less than a factor of 4 below drinking water standards (20 pCi/L).

Noble Gas - Krypton-85 is a fission product formed during detonation and by short-lived decay of bromine, selenium, and germanium fission products (Bryant, 1992). The ^{85}Kr is predominantly dissolved in the groundwater where high concentrations are expected to occur simultaneous to high tritium levels. The ^{85}Kr concentrations are above detection limits in all groundwater samples from UC-1-P-2SR and range from 443 to 27,093 pCi/L from the upper to lower sampling intervals, respectively (Table 3). Although the ^{85}Kr and ^{3}H concentrations both increase with depth, their activity ratios vary over an order of magnitude and are independent of depth, a phenomenon not understood at this time.

The ^{39}Ar present in the groundwater from the cavity zone is a proton decay product from ^{39}K formed from neutron flux during the test. The ^{39}Ar release will probably be controlled by devitrification of fused glass surrounding the cavity and its build up should be slower than the ^{85}Kr. The only detectable ^{39}Ar occurring in the groundwater was found in the lowest level of UC-1-P-2SR and was 434 pCi/L.

Chlorine-36- Background values for ^{36}Cl/Cl ratios in groundwater at the Faultless site range between 1.1×10^{-12} to 4.3×10^{-13} (Table 3) and are similar to NTS groundwaters (Davisson et al., 1993). The ^{36}Cl/Cl ratios above background levels found in the groundwater from UC-1-P-2SR are formed by neutron capture of stable ^{35}Cl already in the water and surrounding rock material during the detonation. The two lower sampling levels in UC-1-P-2SR show abnormal ^{36}Cl/Cl ratios of 7.2×10^{-11}, and 1×10^{-8} in the lowest sampling level, and is consistent with the highest tritium concentrations.

Gamma Activity and Technetium-99 - No gamma activity above analytical background (see Table 3) from ^{60}Co, ^{125}Sb, and ^{137}Cs were detected, nor was ^{99}Tc detected (detection limit = 1.6×10^{4} pCi/L) in any of the groundwater samples from the Faultless test site and will not be discussed further in this report.

Carbon-14 - Natural ^{14}C abundances in the groundwater at the Faultless site range between 1 and 76% modern carbon (Table 3). HTH-2 has the youngest apparent ^{14}C age of approximately 2000 years. HTH-1 has the oldest apparent age of approximately 35,000 years, where the two upper sampling intervals of UC-1-P-2SR have apparent ages between 9300 and 9800 years old. The ^{14}C content for the tritiated waters in the deeper levels of UC-1-P-2SR have not been measured at this time.

Carbon-13 analyses of the Faultless groundwaters show a considerable variation (Table 3). These variations are comparable to those seen in groundwaters at the Nevada Test site (Spencer, 1990). The $\delta^{13}C$ value of vadose zone groundwater at the NTS is assumed to be approximately -12‰ (Spencer, 1990). The ^{13}C content of a groundwater will increase with dissolution of the "dead" carbonate lithology into the fluid. This dissolution will also give rise to an increase in the apparent ^{14}C age of the groundwater. A simple ^{13}C correction formula (Grove et al., 1968) can be used to modify the measured ^{14}C abundances and correct for any dissolution of "dead" carbonate, such that:

$$^{14}C_{correct} = \left(\frac{\delta^{13}C_{soil} - \delta^{13}C_{carbonate}}{\delta^{13}C_{measured} - \delta^{13}C_{carbonate}} \right) {}^{14}C_{measured}$$

where $\delta^{13}C = (R_{sa}/R_{st} - 1)1000$, R is the $^{13}C/^{12}C$ ratio of the sample and a standard respectively, and $\delta^{13}C_{soil} = -12‰$.

The modified ^{14}C ages are listed in Table 3 and shown in Figure 5. HTH-2 being the shallowest well appears to be the youngest, but its ^{13}C correction results in a negative age. Given that the ^{14}C value for HTH-2 has been reproduced, the carbon isotope systematics between HTH-2 and HTH-1 may not necessarily be comparable by simplified means such as the above equation. The real age difference of waters between the wells has a high uncertainty at this time. The maximum possible age difference, though, is represented by the apparent ^{14}C ages which have a higher confidence level. The modified ^{14}C ages for the remaining samples show a systematic increase with depth and have reasonable ages that are comparable to ^{14}C groundwater ages measured at the NTS (Grove et al, 1968; Davisson et al., 1993)

HTH-1 has approximately the same aged groundwater in the upper and lower sampling intervals. This suggests that the water that flows into the well bore is predominantly from one zone, and given the old ^{14}C age of the groundwater, this suggests that the inflow may be from the lower levels.

The ^{14}C ages for the upper levels of UC-1-P-2SR suggest that the groundwater age increases with depth, but is much younger than the groundwater from HTH-1. This suggests that the upper levels of UC-1-P-2SR may be a mixture of young shallow groundwater and the deeper groundwater characteristic of HTH-1. This would be consistent with the evidence for the post-shot water table disturbance and infilling from a perched aquifer above the cavity (Thordarson, 1987). Possible well construction affects on the ^{14}C ages are discussed below.

^{87}Sr/^{86}Sr - The ^{87}Sr/^{86}Sr ratios of groundwater not affected by the nuclear detonation can provide a good indicator of a groundwater source as a function of host lithology. Values presented in Table 3 for the Faultless site show that they correspond to the typical range of ^{87}Sr/^{86}Sr ratios found at the Nevada Test Site (0.706-0.714; Peterman et al., 1992). Groundwater from HTH-2 has a significantly higher ratio than UC-1-P-2SR and HTH-1, where the latter two wells have very similar ^{87}Sr/^{86}Sr ratios, with HTH-1 being slightly more radiogenic. The ionic abundance of groundwater from UC-1-P-2SR is very similar to HTH-1. The only apparent difference between the wells is that the trace element abundance (Thordarson, 1984) is slightly higher in HTH-1, and may be related to its higher TDS and older apparent age. HTH-2 has a higher proportion of Ca and Mg and a lower TDS than UC-1-P-2SR and HTH-1, but has the same anionic proportions. The

more radiogenic $^{87}Sr/^{86}Sr$ ratio in HTH-2 reflects a host lithology distinctly more radiogenic than the host lithology in the other two wells. The higher Ca and Mg concentrations of the groundwater from HTH-2 (Thordarson, 1984) possibly reflects a more carbonate-rich host alluvium in this part of the alluvial aquifer. Thordarson (1984) reported in lithological drill logs that Paleozoic sediments comprised 1-5% of the alluvium above 549m, and <1% below 549m. The high $^{87}Sr/^{86}Sr$ in HTH-2 is not consistent with lower $^{87}Sr/^{86}Sr$ ratios of Ca-dominated groundwaters observed by Peterman et al. (1992) at the NTS. On the other hand, recent work on groundwaters at the NTS has shown that groundwater residing in the Paleozoic carbonates has similar $^{87}Sr/^{86}Sr$ ratios to HTH-2, (Davisson et al., 1993). Peterman et al. (1992) also indicated that the $^{87}Sr/^{86}Sr$ ratios of volcanic tuffs at the NTS can be locally heterogeneous and vary over the entire measured range. It is possible that local heterogeneity in the $^{87}Sr/^{86}Sr$ ratio exists in the Paleozoic carbonates, and direct measurements of the rock material is needed to resolve the origin of the $^{87}Sr/^{86}Sr$ ratios of the groundwaters.

The unique geochemical character of groundwater from HTH-2 does not necessarily mean that the well penetrates an isolated aquifer. The geochemistry of the groundwater from HTH-2 may reflect its shallower perforations levels and shallow completion depth relative to UC-1-P-2SR and HTH-1. A larger proportion of the groundwater in the latter two wells may be from greater depths, and the groundwater has an older age and a more geochemically evolved signature.

Possible Well Construction Effects - If groundwater from the upper levels in UC-1-P-2SR is a mixture of waters characteristic of HTH-2 and HTH-1, then the $^{87}Sr/^{86}Sr$ ratio of the UC-1-P-2SR waters should be intermediate between the other two well waters. Instead, the groundwater from UC-1-P-2SR has a $^{87}Sr/^{86}Sr$ ratio lower than the other two wells. This may suggest that a separate mechanism is controlling the $^{87}Sr/^{86}Sr$ ratio in UC-1-P-2SR. The pH is much higher in UC-1-P-2SR than the other two wells and it is speculated that perhaps minor dissolution of the cement plugs outside the casing may influence the pH and the strontium isotopic signature of the groundwater in the well bore. Further speculation would suggest that even the ^{14}C values may be suspect in this well, given that cement is a carbon-rich material.

Implications for Groundwater Flow - Given that large hydraulic gradients existed between UC-1-P-2SR and the two HTH wells, the water table measurements following the detonation most likely record infilling of the groundwater void space of the cavity/chimney area created by the event. The detonation displaced a considerable amount of groundwater as indicated by upward displacement of groundwater in outlying monitoring wells up to 6 km away (Table 1b). The detonation probably left a large groundwater void within the cavity/chimney region. Subsequent groundwater infilling of the cavity/chimney region probably occurred by a combination of radial inflow at depth and downward flow from the water table surface through an enhanced fracture permeability of the chimney (Fig. 5; Borg et al., 1976). Flow velocities are controlled by the high hydraulic gradients around UC-1-P-2SR (Table 1a and 1b) and transmissivities of the altered rock rimming the cavity. Fracture permeability decreases radially away from the detonation point (Borg et al., 1976) and most likely groundwater flow rates would decrease proportionally. The consistent depth of the water table in UC-1-P-2SR prior to 1974 probably represents a steady-state condition between the rate groundwater laterally flows toward the cavity and downward flow from above the cavity (Fig. 5). Given this conceptual model of the data, the onset of the log-normal recovery of the water table in UC-1-P-2SR probably began when the groundwater void space is full. It should also be noted that possible thermal effects on groundwater flow have been neglected, although thermal gradients are high around the cavity, groundwater flow is still gravity driven.

As shown in Figure 4, the tritium concentrations in the lower part of UC-1-P-2SR dramatically increase in two pulses between 5.5 and 8 years after the detonation, and during this time the water table began its log-normal recovery. As the cavity is recharged after the detonation, tritium enriched groundwater probably moves upward, following flow paths defined by the hydraulic gradient (Fig. 5). Associated with the tritiated groundwater will be the elevated ^{85}Kr and ^{36}Cl levels, as these constituents will be mobile aqueous species (Bryant, 1992). Since the groundwater table is today still depressed above the cavity/chimney, the advective flow of the radionuclide-rich groundwater is probably confined within the cavity/chimney area.

The current concentrations of and ^{3}H and ^{85}Kr in UC-1-P-2SR are 3 to 4 orders of magnitude lower than concentrations measured in chimney regions after similar tests (Bryant, 1992). The lower concentrations are probably due to simple dilution and decay of these nuclides over the course of 24 years since their formation.

SUMMARY

Groundwater chemistry of UC-1-P-2SR and HTH-1 have a similar Na-HCO_3 character that have approximately the same ^{87}Sr/^{86}Sr ratios. These two wells penetrate similar depths and lithologies and probably share the same groundwater reservoir. The pH is unusually high (>9.0) in UC-1-P-2SR, though, and its ^{87}Sr/^{86}Sr ratio is much lower than expected for a mixture of young shallow water and the deeper groundwater as suggested by ^{14}C analysis. It is speculated that the cement plugs used in the well construction may be influencing the strontium isotope signature. Further work is needed to resolve this question.

HTH-2 has a Ca-HCO_3 groundwater with an ^{87}Sr/^{86}Sr ratio typical of a more radiogenic rock source that probably dominates this zone of the alluvial fill. The different chemical and isotopic signature of HTH-2 may be an artifact of the well's small perforation thickness (~100m), and the groundwater from HTH-2 may not necessarily be isolated from the deeper groundwater. Further isotopic investigations of groundwater in the Hot Creek Valley region would help better resolve these geochemical differences.

The new isotopic analyses of UC-1-P-2SR show proportionally elevated concentrations of ^{3}H, ^{85}Kr, ^{36}Cl, and a lesser amount of ^{39}Ar in the deeper sampling intervals, where the ^{3}H levels are similar to those measured in 1983. At the current time, the high activity groundwater is probably isolated in a water table depression surrounding the post-shot cavity and is being diluted by infilling fresh groundwater.

Uncertainties cannot be assigned to the hydrologic source-term at this time, since many of the radiochemical samples were collected after multiple drops of the bailer, which most likely disturbed the concentration in the water column of the drill hole. Sampling strategies are currently being developed in order to quantify the mixing effects caused by multiple sampling with a wireline and bailer.

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FIGURE CAPTIONS

Figure 1. Regional location map of Hot Creek Valley showing Faultless detonation site, the drillback hole UC-1-P-2SR, and monitoring wells HTH-1, HTH-2, and UCe-18.

Figure 2. Piper plot of groundwaters from UC-1-P-2SR, UCe-18, and the two HTH wells. The TDS levels are represented as circles on the plot in mg/L. Note that although HTH-2 forms a unique cationic field, anionic proportions are identical. UCe-18 has much higher TDS levels due probably to its elevated down-hole temperatures.

Figure 3. Water level data of UC-1-P-2SR beginning 3 months after the shot. Note the first 80 months are characterized by little groundwater level rise, but abruptly begins log-normal recovery in 1974. This recovery is attributed to the completion of groundwater filling of the post shot cavity/chimney region.

Figure 4. Tritium time series in UC-1-P-2SR between 1971 and 1982. Note that high tritium pulses arrive around the same time as the assumed length of time for cavity infilling with groundwater.

Figure 5. Conceptualized cartoon for post-shot groundwater flow surrounding the cavity area prior to 1974. A perched water table condition exists above the chimney/cavity area, groundwater is positively displaced in the HTH wells, and groundwater flow is gravity driven radially toward the cavity/chimney region and is controlled by the high hydraulic gradients. The ^{13}C-corrected ^{14}C ages of the groundwater sampled in FY92 are noted at their respective depths. The ^{3}H-rich groundwater today is probably confined to the cavity/chimney region and is currently being diluted by surrounding groundwater.

TABLE FOOTNOTES

* Data from Thordarson (1984).

£ The symbol (nd) stands for non-detectable.

§ These represent analytical limits for the gamma analyses

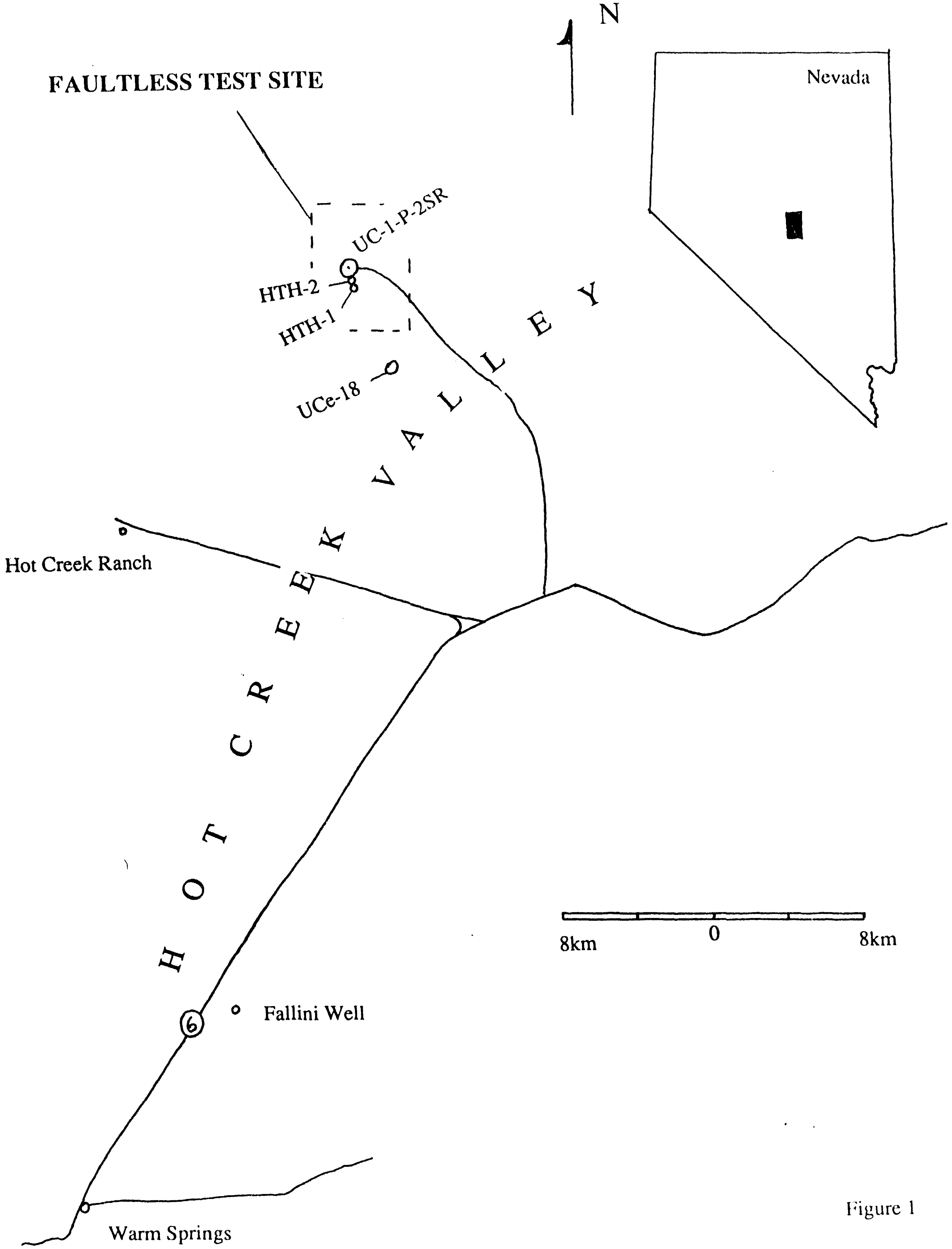
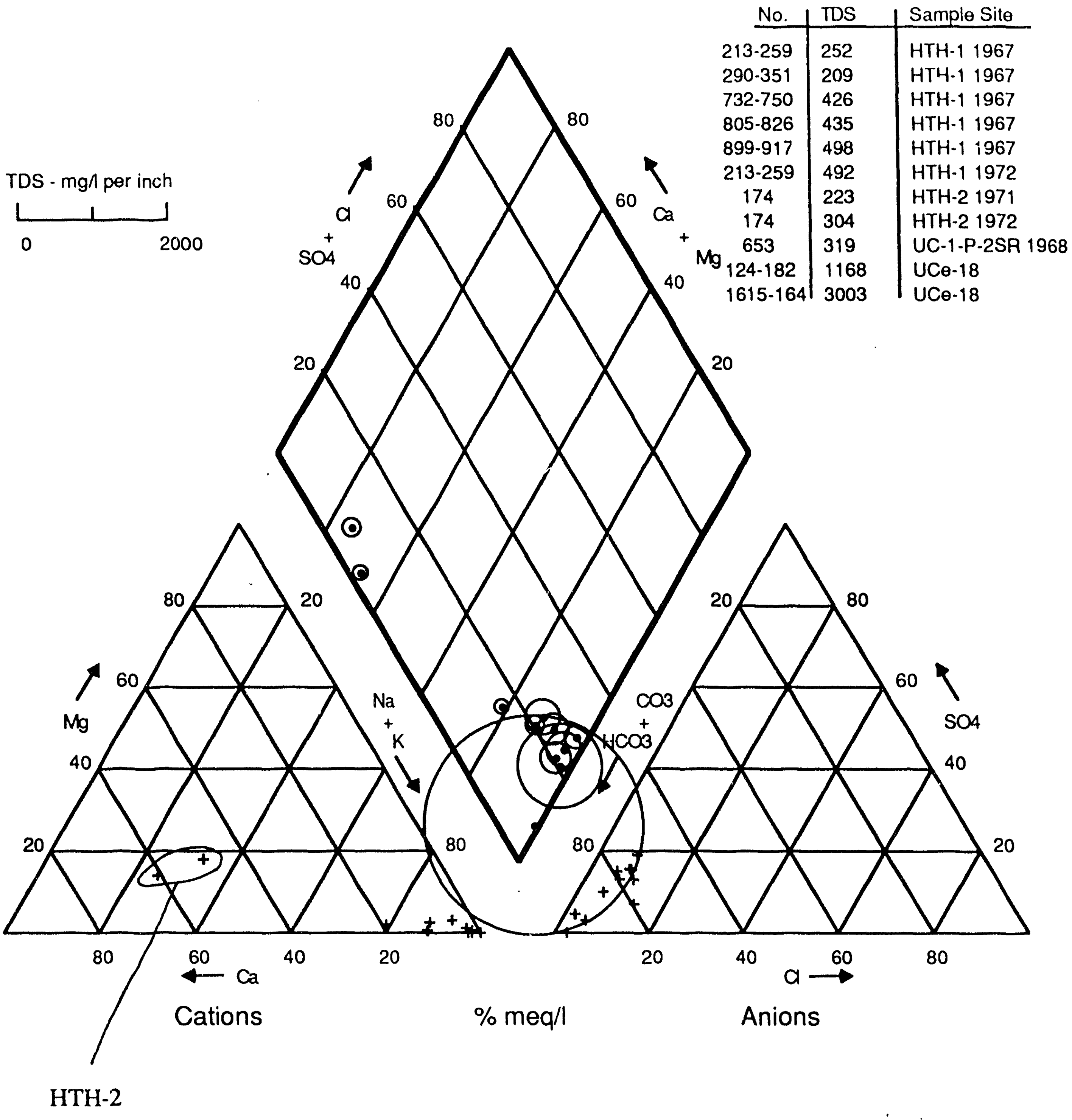

N
FAULTLESS TEST SITE
Nevada
UC-1-P-2SR
HTH-2
HTH-1
UCe-18
HOT CREEK VALLEY
Hot Creek Ranch
8km
0
8km
6
Fallini Well
Warm Springs

Figure 1



No.	TDS	Sample Site
213-259	252	HTH-1 1967
290-351	209	HTH-1 1967
732-750	426	HTH-1 1967
805-826	435	HTH-1 1967
899-917	498	HTH-1 1967
213-259	492	HTH-1 1972
174	223	HTH-2 1971
174	304	HTH-2 1972
653	319	UC-1-P-2SR 1968
124-182	1168	UCe-18
1615-164	3003	UCe-18

Figure 2

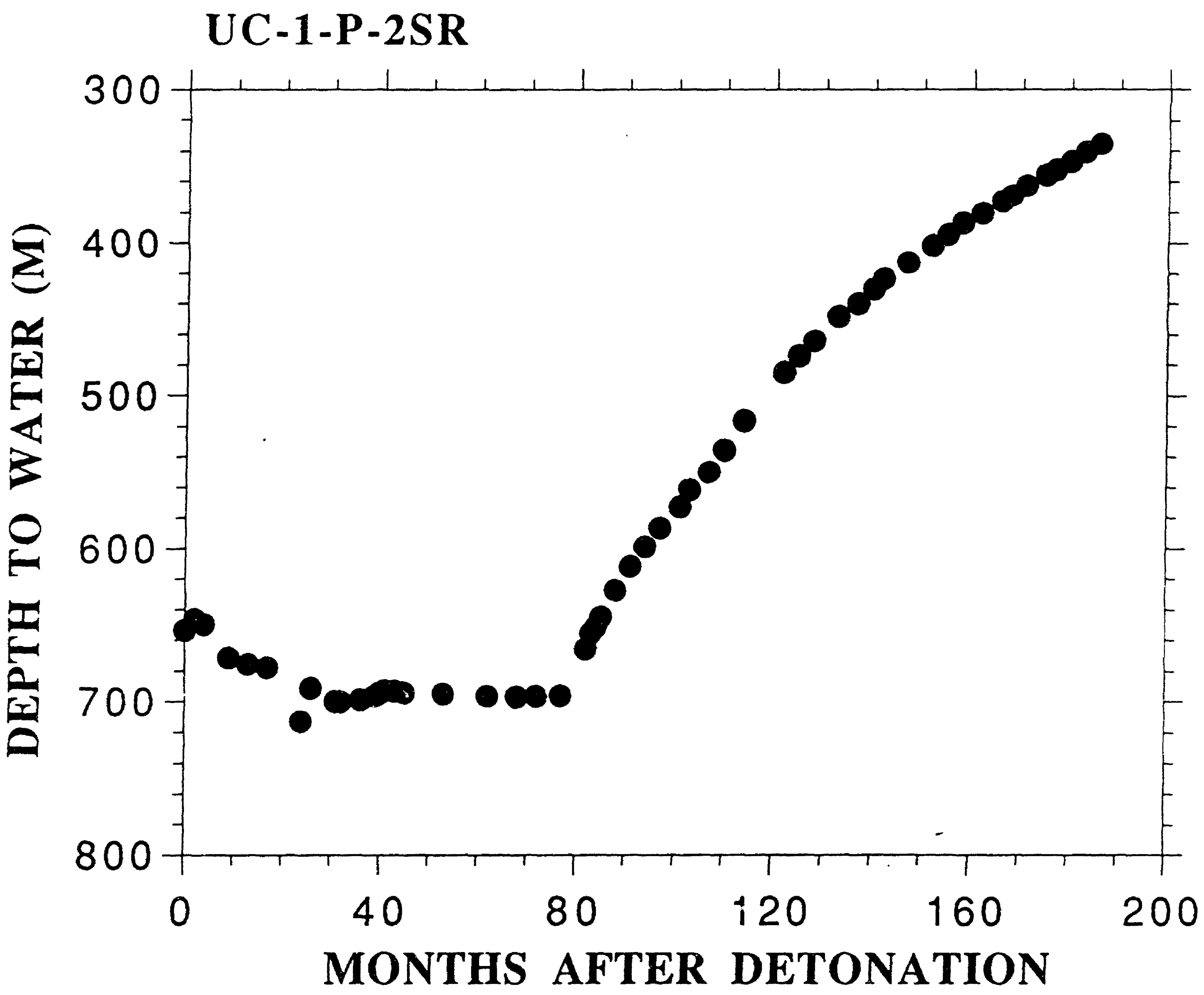
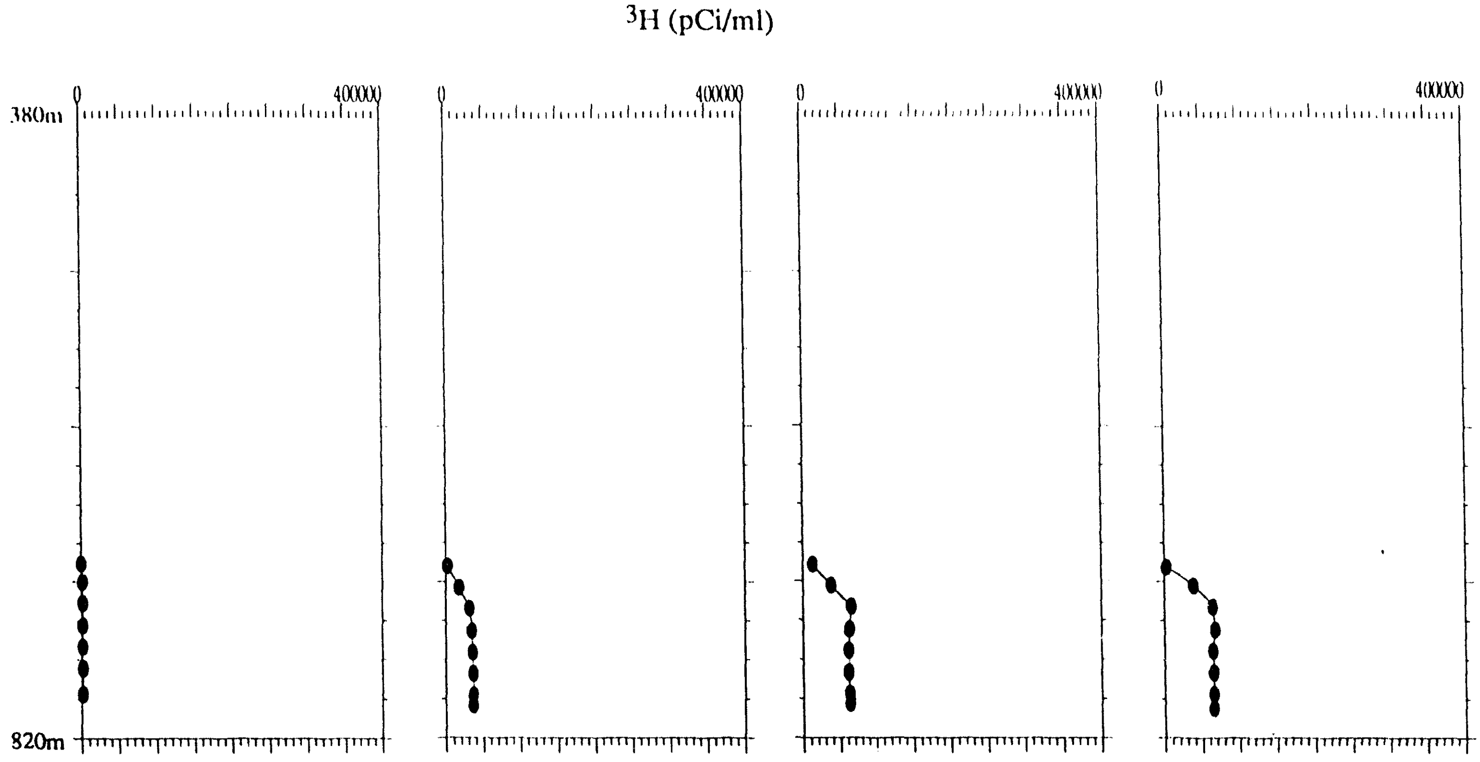
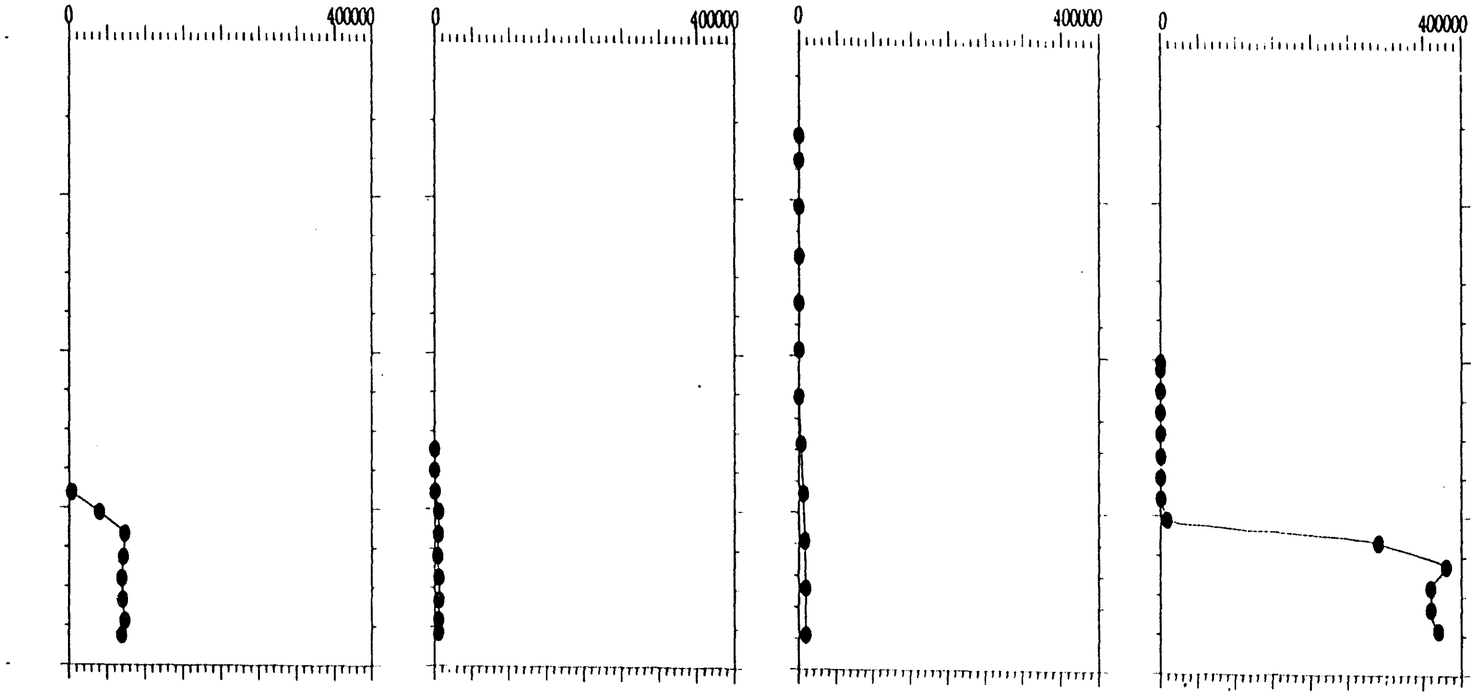

UC-1-P-2SR
DEPTH TO WATER (M)
300
400
500
600
700
800
0
40
80
120
160
200
MONTHS AFTER DETONATION

Figure 3



DEC-1972 JUNE-1973 DEC-1973 APRIL1974



SEPT-1974 FEB-1975 AUGUST-1975 FEB-1976

Figure 4

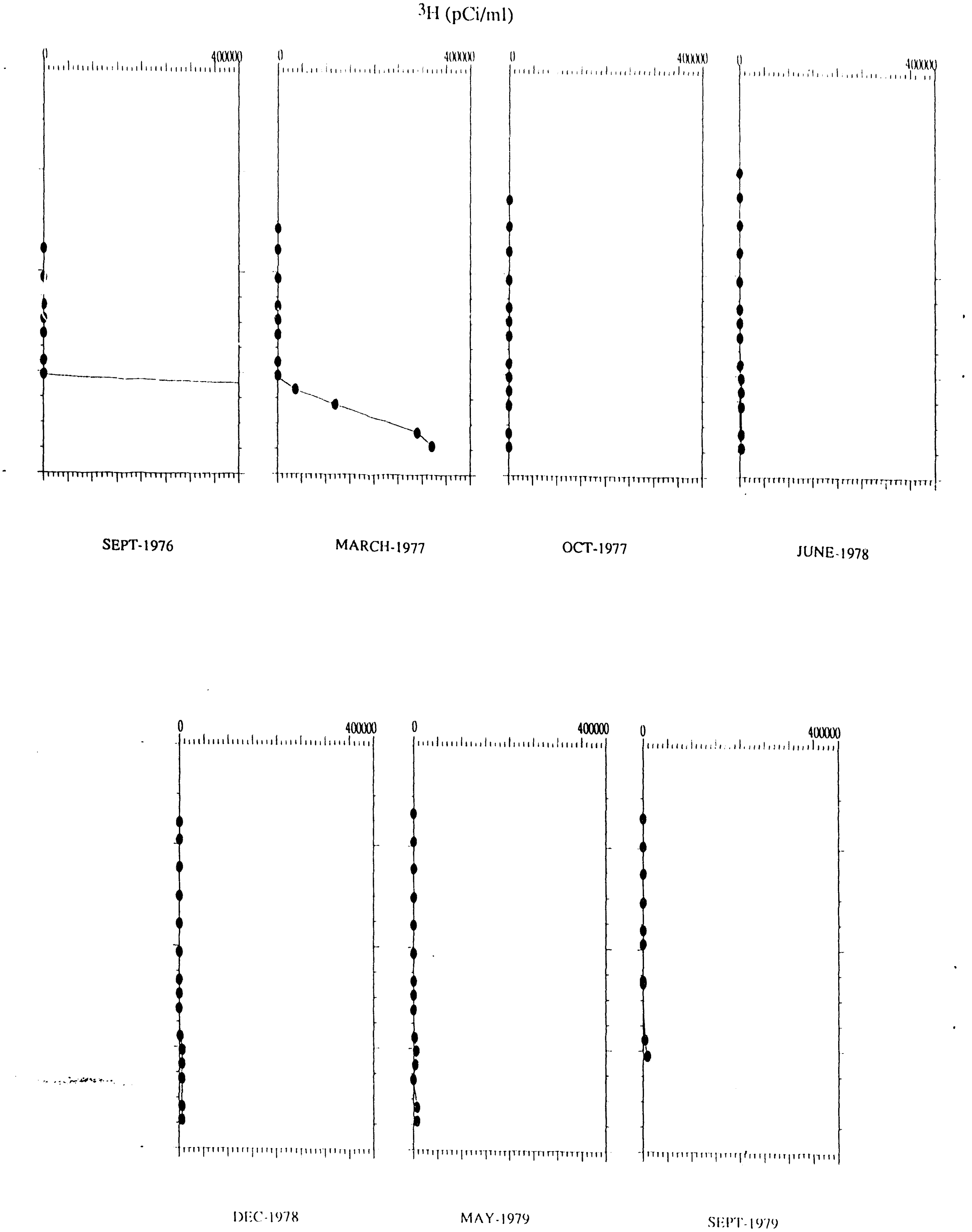
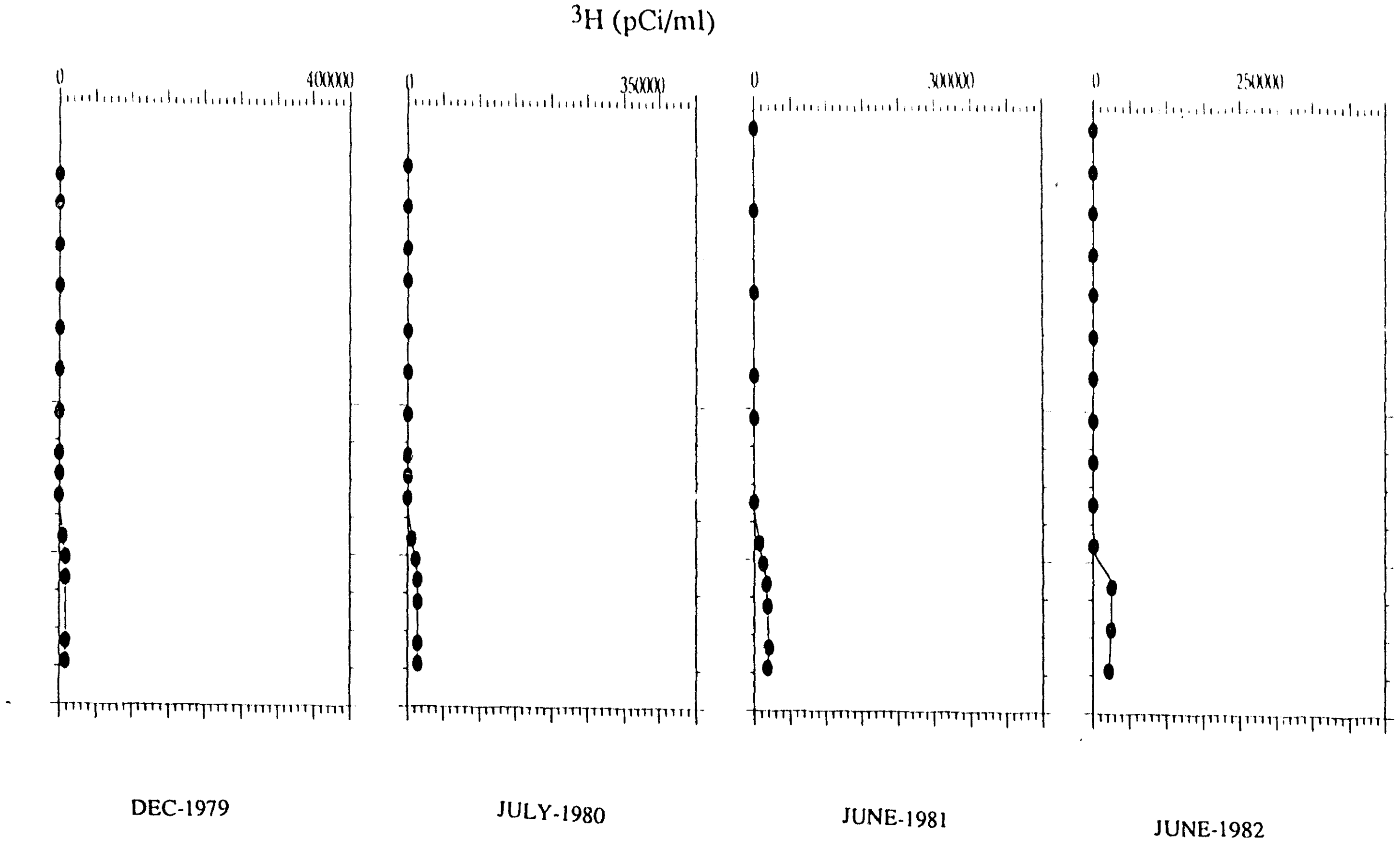

^3H (pCi/ml)
0
400000
SEPT-1976
MARCH-1977
OCT-1977
JUNE-1978
DEC-1978
MAY-1979
SEPT-1979

Figure 4



^3H (pCi/ml)
0
400000
0
350000
0
300000
0
250000
DEC-1979
JULY-1980
JUNE-1981
JUNE-1982

Figure 4

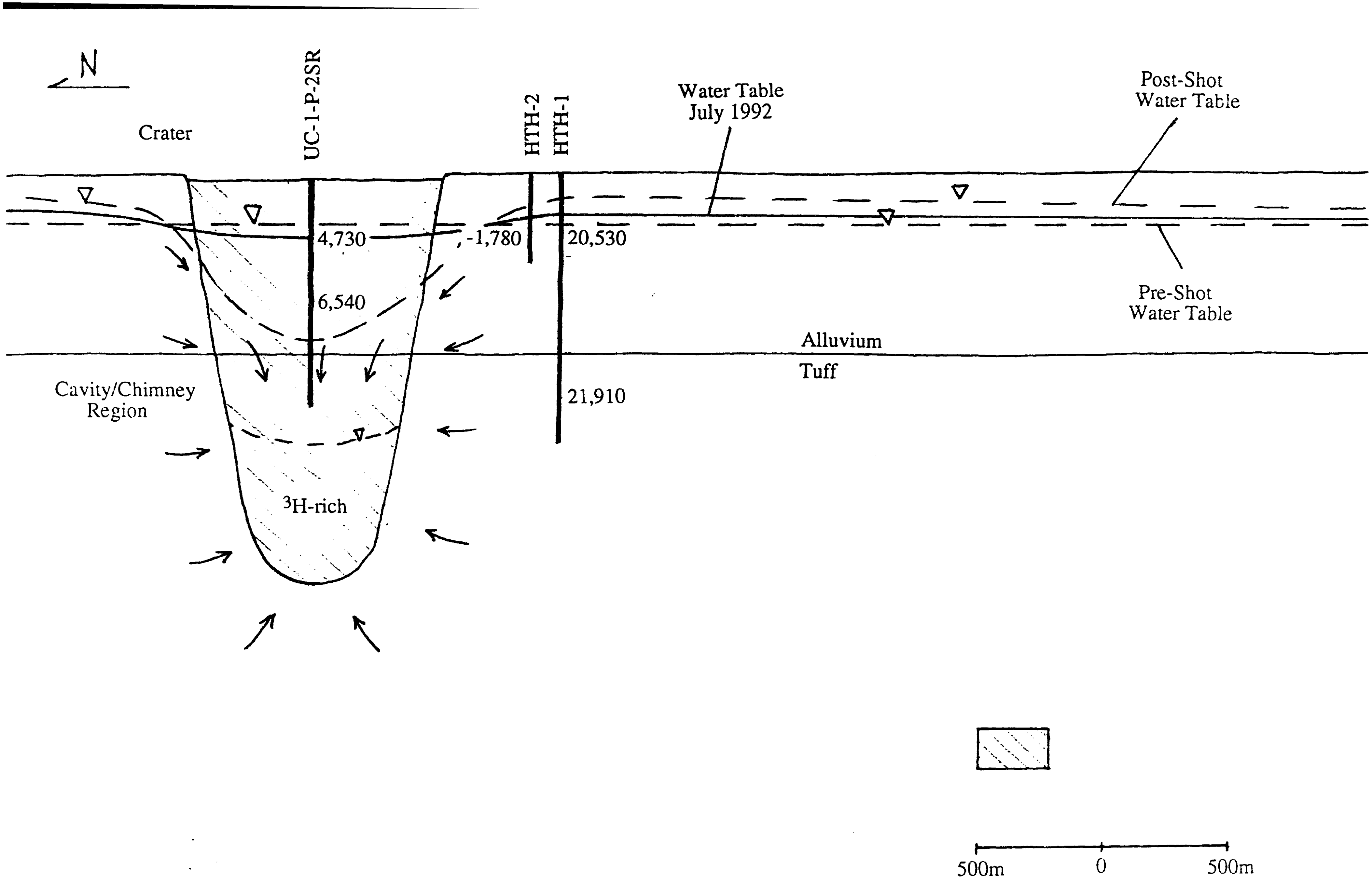

N
Crater
UC-1-P-2SR
HTH-2
HTH-1
Water Table
July 1992
Post-Shot
Water Table
4,730
-1,780
20,530
6,540
Pre-Shot
Water Table
Alluvium
Tuff
Cavity/Chimney
Region
21,910
³H-rich
500m
0
500m

Figure 5

*Table 1a

Months	UC-1-P-2SR Depth (m)	HTH-1 Depth (m)
3	653.5	
4		131.7
5	646.2	
6		142.3
7	649.8	
9		144.5
12	671.5	148.4
16	675.4	150.9
20	677.6	154.2
27	712.9	
29	691.3	157
34	699.8	157.6
35	699.8	
39	698.6	157.9
42	696.2	
43	694.0	
44	692.5	
46	693.1	
48	694.0	159.7
56	694.9	160.3
65	696.2	
71	696.8	
75	696.5	
80	695.9	
83		161.8
85	665.4	
86	655.3	161.2
87	651.4	
88	645.0	
91	627.3	161.8
94	611.7	
97	598.9	161.5
100	586.7	161.5
104	572.7	
106	561.7	
110	549.9	
113	535.5	
117	516.3	
125	484.6	
128	473.7	
131	464.2	
136	448.1	
140	439.8	
143	430.1	
145	423.4	
150	412.4	
155	401.4	
158	394.4	
161	386.8	
165	380.4	
169	372.4	
171	368.7	
174	362.2	
178	355.2	
180	352.1	
183	346.7	
186	340.3	
189	335.1	

*Table 1b

Well	Distance to UC-1-P-2SR (m)	Total Depth (m)	Perforation Depths (m)	Excess Head (m)	Time
HTH-2	762	306	~200-305	14	0
				-14	0
				410	50 mins
				50	4 hrs
				38.6	1 day
				2.6	30 days
				2	110 days
HTH-1	916	1128	~200-1130	60	0
			intermittent	-16	0
			shot perforated	12	3 sec
				61	30 sec
				46	4 hrs
				51	1 day
				65	3 days
				52	30 days
				37	110 days
UCe-18	5738	1985	~100-200	>30	1.8 sec
			~1200-1400	18	1 day

* Table 2

Month/Year	Depth below surface (m)	Tritium (pCi/ml)	Month/Year	Depth below surface (m)	Tritium (pCi/ml)	Month/Year	Depth below surface (m)	Tritium (pCi/ml)
Mar-71	702	330	Dec-73	698	13,000	Feb-75	668	120
	711	580		713	38,000		683	120
	725	810		728	65,000		698	340
	740	1,500		744	62,000		712	5,400
	756	1,700		759	61,000		728	4,900
	771	1,600		774	61,000		743	3,900
	786	1,300		789	62,000		758	5,800
	801	1,400		796	63,000		774	5,700
							788	5,200
Jul-71	704	330	Apr-74	700	2,600		797	5,300
	722	700		713	38,000			
	741	1,800		728	64,000	Aug-75	629	93
	759	500		744	67,000		637	96
	777	470		759	64,000		652	120
	796	470		774	65,000		668	170
				789	65,000		683	170
Sep-72	697	170		799	65,000		698	170
	710	1,700					713	200
	725	1,900	Sep-74	699	3,000		728	3,000
	741	1,900		713	40,000		744	6,000
	756	1,500		728	73,000		759	7,900
	771	2,000		744	71,000		774	9,300
	789	1,900		759	69,000		789	9,600
				774	70,000			
Jun-73	699	2,500		789	73,000			
	714	17,000		799	69,000			
	729	31,000						
	745	34,000						
	760	35,000						
	775	36,000						
	790	36,000						
	797	36,000						

* Table 2

Month/Year	Depth below surface (m)	Tritium (pCi/ml)	Month/Year	Depth below surface (m)	Tritium (pCi/ml)	Month/Year	Depth below surface (m)	Tritium (pCi/ml)
Feb-76	602	18	Mar-77	553	0.5	Jun-78	488	0.6
	607	81		576	0.5		515	0.36
	622	70		607	51		546	0.6
	637	81		637	55		576	0.41
	652	230		652	110		576	0.48
	668	390		668	190		607	38
	683	390		698	190		637	43
	698	380		713	190		652	89
	713	8,600		728	37,000		668	150
	728	290,000		744	120,000		698	750
	744	380,000		774	290,000		713	2,900
	759	360,000		789	320,000		728	2,800
	774	360,000					744	2,800
	789	370,000	Oct-77	520	0.3		774	2,800
				549	0.3		789	2,900
Sep-76	576	2.2		576	0.3			
	607	79		607	45	Dec-78	466	1.6
	637	85		637	49		485	1.3
	652	180		652	100		515	1.2
	668	320		668	230		546	1.2
	698	320		698	230		576	1.3
	713	640		713	240		607	36
	728	640,000		728	240		637	41
	744	760,000		744	240		652	77
	774	760,000		774	230		668	130
	789	920,000		789	230		698	2,100
							713	6,100
							728	5,600
							744	5,600
							774	5,900
							789	5,500

* Table 2

Month/Year	Depth below surface (m)	Tritium (pCi/ml)	Month/Year	Depth below surface (m)	Tritium (pCi/ml)	Month/Year	Depth below surface (m)	Tritium (pCi/ml)
May-79	454	48	Dec-79	433	1.3	Jun-81	393	1.1
	485	3.3		454	1.1		454	0.97
	515	2.7		485	1.2		515	0.99
	546	1.8		515	1.1		576	1.1
	576	1.3		546	1.1		607	26
	607	19		576	1.1		668	67
	637	21		607	33		698	6,800
	652	39		637	36		713	12,000
	668	74		652	52		728	17,000
	698	2,300		668	90		744	18,000
	713	5,500		698	4,900		774	20,000
	728	3,600		713	8,700		789	18,000
	744	17		728	8,800			
	774	7,300		744		Jul-82	375	1.3
	789	7,200		774	8,800		393	1.5
				789	8,000		424	1.4
Sep-79	457	0.73					454	1.5
	488	0.58	Jul-80	424	1.1		485	1.3
	518	0.49		454	0.88		515	1.4
	549	0.52		485	0.92		546	1.6
	579	0.34		509	1.1		576	1.6
	594	9.7		546	0.76		607	23
	634	35		576	0.97		637	25
	637	39		607	31		668	63
	698	4,000		637	32		698	600
	716	8,800		652	43		728	25,000
				668	74		759	24,000
				698	5,700		789	21,000
				713	11,000			
				728	14,000			
				744	14,000			
				774	14,000			
				789	14,000			

£ Table 3

Well	UC-1-P-2SR	UC-1-P-2SR	UC-1-P-2SR	UC-1-P-2SR	HTH-1	HTH-1	HTH-2
Sample Depth (m)	238	485	668	786	236	815	229
D.O. (ppm)	-	4.5	1.5	-	-	-	-
pH	9.42	9.42	9.18	-	8.25	8.15	7.83
Temp °C	29.4	28.3	30.9	-	21.5	26.5	19.5
Cond. µS	308	302	365	379	486	528	266
Tritium (pCi/ml)	14.32	58.7	94.6	21100	0.024	0.0564	0.0385
Kr-85 (pCi/L)	443	279	6981	27093	(nd)	(nd)	(nd)
Ar-39 (pCi/L)	(nd)	(nd)	(nd)	434	(nd)	(nd)	(nd)
Tc-99	(nd)	(nd)	(nd)	(nd)	(nd)	(nd)	(nd)
§ Co-60 (pCi/L)	≤0.59	≤0.59	≤0.59	≤0.59	≤0.59	≤0.59	≤0.59
§ Sb-125 (pCi/L)	≤1.28	≤1.28	≤1.28	≤1.28	≤1.28	≤1.28	≤1.28
§ Cs-137 (pCi/L)	≤0.43	≤0.43	≤0.43	≤0.43	≤0.43	≤0.43	≤0.43
Cl-36/Cl	-	3.37E-12	7.20E-11	1.00E-08	4.27E-13	2.38E-13	1.12E-12
C-14 (pmc)	30.4	32.3	-	-	1.7	1.4	75.5
C-14 age (yrs)	9,850	9,340	-	-	32,730	35,110	2,320
C-13 (per mil)	-6.5	-8.6	-	-	-2.4	-2.4	-7.3
Corr. C-14 age	4,730	6,540	-	-	20,530	21,910	-1,780
Sr-87/86	0.70586	0.70606	-	-	0.70667	0.70735	0.7101