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Laboratory and Field Studies Related to Radionuclide Migration at the Nevada Test Site

October 1, 1998–September 30, 1999

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CONTENTS

EXECUTIVE SUMMARY

This report describes the work done at Los Alamos National Laboratory in FY 1999 to study the movement of radionuclides in groundwater in the vicinity of nuclear test cavities at the Nevada Test Site (NTS). The Defense Programs and Environmental Restoration Divisions of the US Department of Energy/Nevada Operations Office support this work. Our activities are carried out in cooperation with the Lawrence Livermore National Laboratory, the Desert Research Institute, the US Geological Survey, and the contractors International Technology and Bechtel Nevada. We seek to understand the physical and chemical parameters that control the mobilization and transport of contaminant radionuclides at the NTS. This information is essential for responsible management of the land and water resources there, and for modeling future risks. The present report is the latest in a series of annual reports begun in 1977.

We acquired equipment this year that will allow us to make down-hole measurements of water temperature, pH, specific conductance, dissolved oxygen and oxidation-reduction potential. These parameters are significant in determining the speciation of radionuclides in groundwater, so gaining the ability to make *in situ* measurements is an important advance for us. Also, we purchased four more Bennett pumps that we expect to deploy to the field for use in tandem in holes otherwise inaccessible for pumping. Finally, we have upgraded our particle measuring spectrometer so that a wider range of colloid sizes and concentrations may be determined in groundwater samples.

At the Camembert site, we analyzed groundwater pumped from the chimney region several hundred meters above the cavity. We measured ^{3}H, ^{85}Kr, and a very low concentration of ^{137}Cs. These data indicate that only volatile materials (^{137}Cs has volatile precursors) have penetrated the chimney region. We measured no plutonium in our samples.

No new samples were collected from the Cheshire site in FY 1999, although this hole was sampled soon after the end of the fiscal year. We did complete some analyses from previous collections and made several interesting observations. We confirm our previous measurements that show that while tritium diminished in concentration in cavity water by a factor of two between 1984 and 1998, the concentrations of gamma-emitting fission products remained the same or increased slightly. A possible explanation is that dissolution of melt glass in the cavity is occurring even as the groundwater is circulating away from the cavity. Another observation, resulting from examination of a water sample archived since 1984, was that the colloids present in Cheshire cavity fluids were remarkably stable and neither coagulated nor plated out on the container walls during this extended storage.

At the Cambric site, our sample collection was terminated unexpectedly, but we were able to observe some changes in the concentration of tritium and of colloids during the initial stages of pumping. As noted in previous years, at this site the tritium concentration increases during the early hours of pumping and eventually reaches a steady state value equal to that at previous extended

pumping campaigns. That is to say, there appears to be no natural groundwater movement away from RNM-2S sufficient to cause the tritium concentration to decrease over periods of a few years. Analyses of the colloid concentrations during the early stages of pumping show that the concentrations of particles of all size decrease and finally reach relatively low values.

At UE-5n, a hole near the Cambric effluent ditch, we detected ^{3}H and ^{85}Kr in pumped water samples. More sampling from this location during the next few years is in order if we are to learn whether the radionuclides are moving by diffusion from the ditch or have some other origin. We also need more samples to evaluate whether the trace of ^{137}Cs detected is from cross-contamination during sample collection or processing, or is really present in the groundwater.

The Almendro site is unusual because.water in the cavity region has remained quite hot over many years. Water samples collected in 1999 contained lower concentrations of ^{3}H and ^{85}Kr than previous samples, perhaps because the sampling depth was somewhat less. The temperature at this site remains too high to sample from the bottom of the cavity.

Los Alamos personnel contributed to programmatic advances by reviewing a number of documents generated within collaborating organizations. We also made presentations at several international meetings to publicize the work done at the NTS.

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ABSTRACT

In this report we describe our research in FY 1999 at the Nevada Test Site regarding the movement of radionuclides in groundwater. This work is funded by the US Department of Energy/Nevada Operations Office through their Defense Programs and Environmental Restorations divisions. Significant accomplishments include upgrading a spectrometer used to characterize groundwater colloids, acquisition of a probe to allow *in situ* measurement of groundwater parameters, and purchase of pumps for use in small-diameter access tubing. We collected water samples from a number of nuclear test sites during the past year. Samples from the chimney horizon at the Camembert site show that only volatile radionuclides are present there, as expected. Groundwater from the cavity region at the Cheshire site shows evidence of fission product leaching or desorption from melt glass or rock surfaces. Colloids present in this water were found to be remarkably stable during storage for many years. The colloid content of groundwater at the Cambric site and at UE–5n was found to be low relative to that in groundwater on Pahute Mesa. This, coupled with the apparent lack of groundwater flow in the alluvial rock at the Cambric site, suggests that radionuclide movement underground in this area is relatively minimal. We continued our yearly monitoring of the thermally hot cavity fluids at the Almendro site. We conclude this report by listing documents reviewed and presentations and publications generated by our program.

I. INTRODUCTION

Since 1973, personnel from the Los Alamos National Laboratory (LANL) have been studying the behavior of radionuclides inserted into the underground environment of the Nevada Test Site (NTS) by the testing of nuclear devices. This is a collaborative effort which also involves the Lawrence Livermore National Laboratory (LLNL), the Desert Research Institute (DRI), the US Geological Survey (USGS) and NTS contractors Bechtel Nevada (BN) and International Technology (IT). Our work is supported by the Defense Programs and Environmental Restoration Divisions of the Department of Energy, Nevada Operations Office (DOE/NV) at the NTS, specifically through the Hydrologic Resources Management Program (HRMP) and the Underground Test Area (UGTA) program. We contribute to DOE/NV commitments to stockpile stewardship, maintenance of test readiness, monitoring of radioactivity in groundwater, and modeling of radionuclide transport on and off the NTS. Our work over the past 26 years illustrates the long-term efforts of DOE/NV to carefully manage the land and water resources of the NTS.

This report describes the work done at LANL during FY 1999 to document the movement of radionuclides in groundwater at the NTS. It is the latest in a series of annual reports,[1-22] topical reports,[23-29] and journal articles.[30-41]

II. EQUIPMENT ACQUISITIONS/UPGRADES

During the past year we have significantly increased our measurement capabilities through the acquisition and upgrading of equipment. We purchased an instrument for down-hole measurement of temperature, pH, specific conductance, dissolved oxygen and oxidation-reduction potential. The "MiniSonde 4a" unit manufactured by Hydrolab Corporation has a 4.4-cm OD probe that can be used to 225 m below the water surface. Data are stored in the probe and later downloaded directly into a personal computer. We have checked its performance against standards and expect to deploy it into the field soon. Last year[22] we reported success in using Bennett pumps in tandem to purge water from small diameter piezometer tubes. These results were encouraging, so we purchased four more Bennett pumps and will put them in use as soon as we have the necessary coupling hoses. Finally, our Particle Measuring System S-50 spectrometer has been upgraded so that colloids in the diameter range of 50- to 1000-nm and in concentrations above 1E4 particles/ml may be measured. This instrument operates on the principle that light scattered by water-borne particles resident in a laser beam is directly proportional to their sizes and so particles of the same size transiting the laser beam produce the same amplitude pulses. Photodiode detectors sense the pulses of radiant energy, which are amplified and stored with a pulse analyzer into different channels according to the size of the colloidal particles. A 30-mwatt polarized 780-nm laser is employed in this system.

III. WATER SAMPLES FROM NUCLEAR TEST SITES

A. Camembert (U-19q)

The Camembert test was fired 26 June 1975 at a depth of 1.31E3 m, well below the water table at 6.68E2 m. In September and October 1998, the drill back hole was found to be open to about 1.12E3 m slant depth. A Centrilift pump on 6.0-cm Hydril tubing was inserted to a slant depth of 9.16E2 m, and water was pumped out at approximately 3.8E-2 m^3/min (10 gpm) for more than a week. In collaboration with IT personnel, we collected water samples in 208-L drums and in 2-L pressure tubes, as well as taking grab samples for colloid and for tritium analyses. The measurements reported below were done on samples collected on 20 October (4.86E1 m^3 pumped) and on 21 October (5.20E1 m^3 pumped). The two samples collected for colloid analysis were shipped immediately to Los Alamos, where they were analyzed using a spectrometer that detects particles in the size range 50–200 nm (and >200 nm). The results of our analyses are displayed graphically in Figures 1 and 2. The two samples were collected within 5 minutes of one another on October 21 and received similar treatment during handling and analysis. The size distributions of the colloids are very similar but the concentrations in these two samples are somewhat different. Additionally, we note that there are more large diameter particles than we have seen at other locations (e.g., at Tybo ER-20-5 as shown in Figure 1). All this suggests that the purging of drilling materials from U-19q may not have been complete by the time we collected water samples.

We measured tritium by liquid scintillation counting of water aliquots in the grab samples, the pressure tubes, and the drums. We measured ^{85}Kr in the 2-L water samples collected in the pressure tubes and determined the gamma-emitting radionuclides present in the 208-L drum samples after evaporating them to dryness. No gamma-emitters other than naturally occurring radionuclides and ^{137}Cs were detected. Our results are shown in Table I.

Table I. Radionuclides in water collected from U-19q. All values are referenced to the test time for Camembert (t_o = 26 Jun 1975).

Sample ID	Sample Type	Collection Date	^{3}H Bq/L (pCi/L)	^{85}Kr Bq/L (pCi/L)	^{137}Cs Bq/L (pCi/L)
840-98-210	Pressure tube	20 Oct 98	1.6E6 (4.3E7)	9.7E3 (2.6E5)	
840-98-220	Pressure tube	20 Oct 98	1.6E6 (4.3E7)	8.6E3 (2.3E5)	
840-98-150	Grab – colloid	21 Oct 98			
840-98-160	Grab – colloid	21 Oct 98			
840-98-190	Grab – tritium	21 Oct 98	3.3E6 (8.8E7)		
840-98-180	208 L	21 Oct 98	2.3E6 (6.3E7)		5.0E-1 (1.4E1)
840-98-230	Pressure tube	21 Oct 98	2.6E6 (6.9E7)	9E3 (2.4E5)	

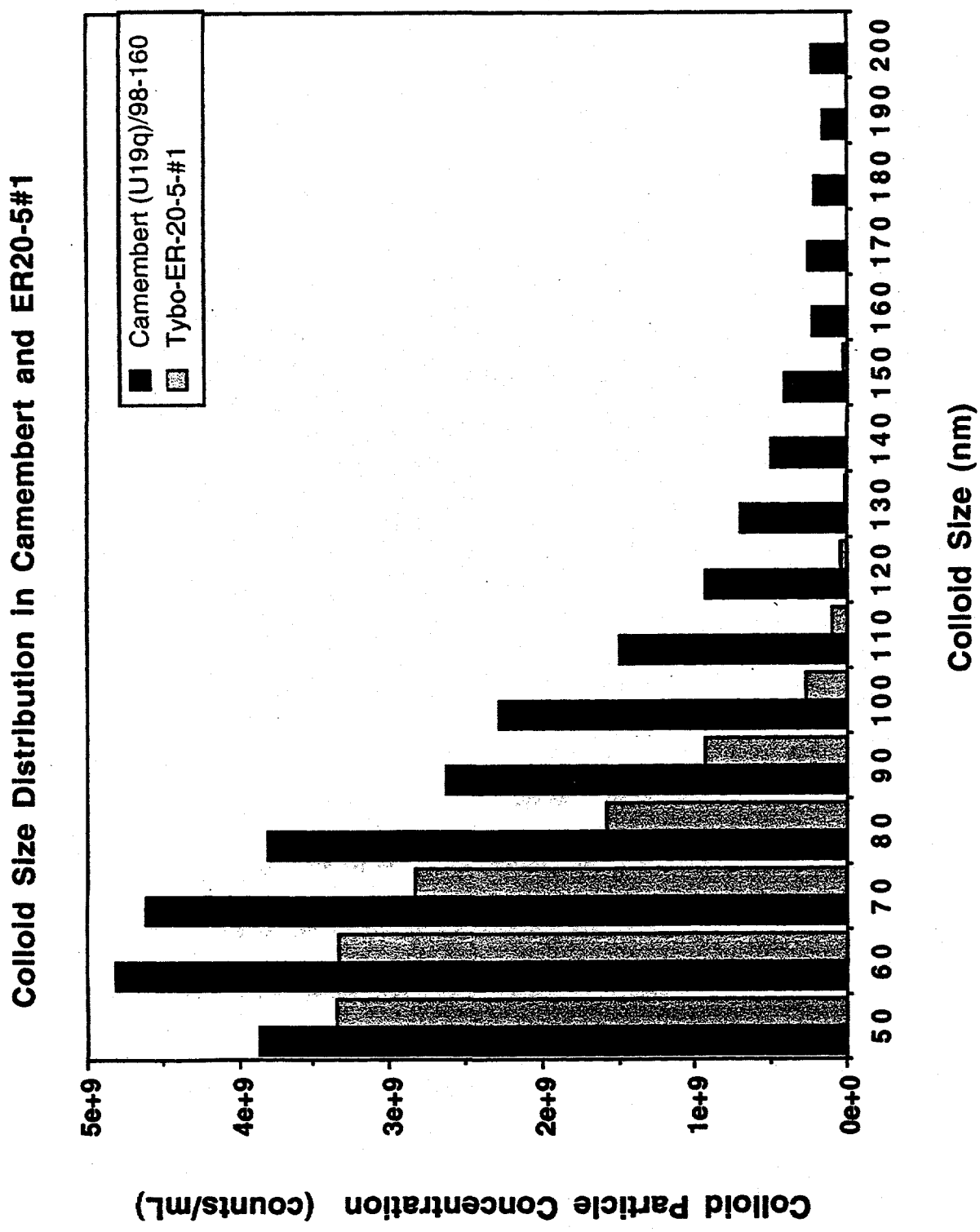

Figure 1. Colloid size distribution in Camembert and Tybo.

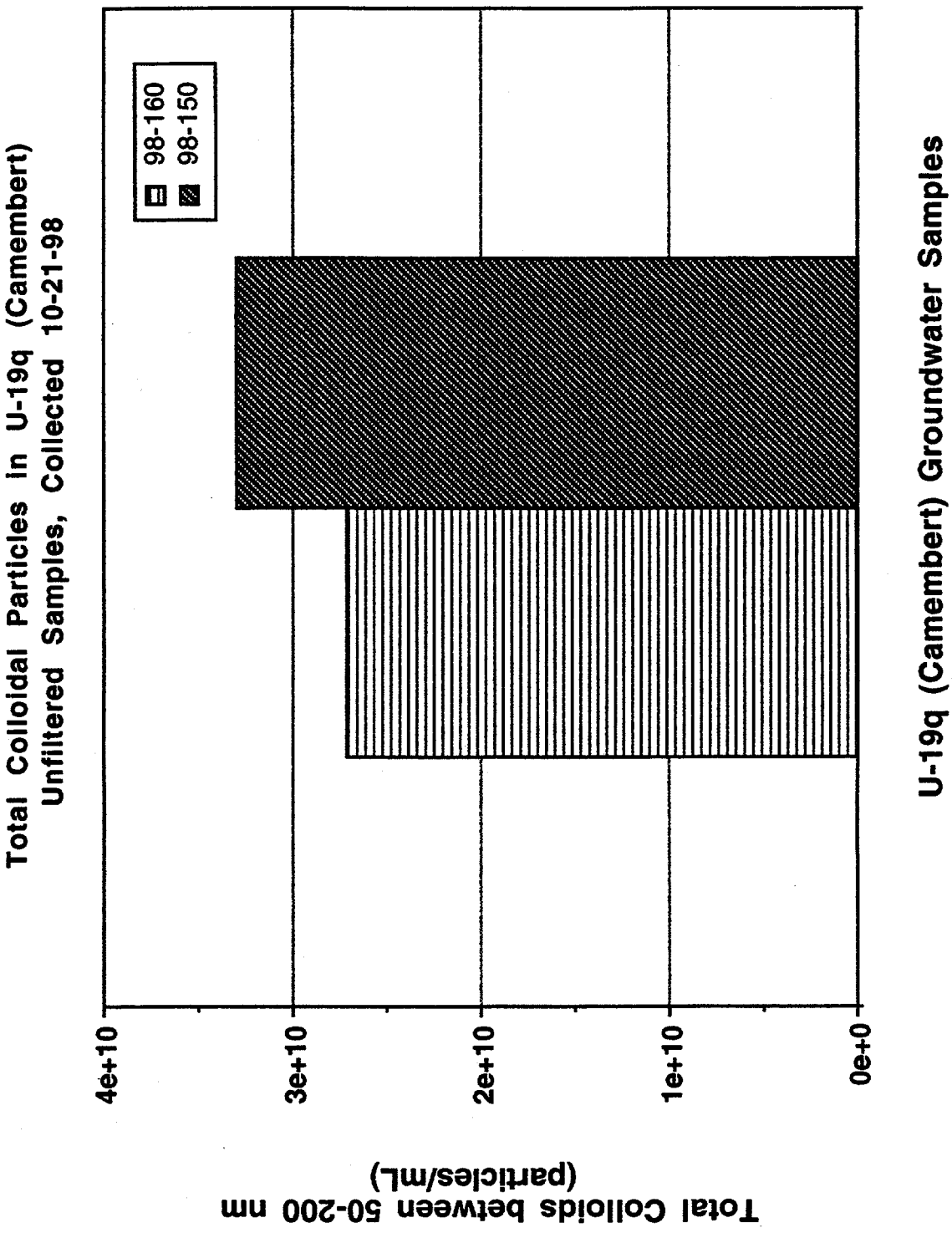

Figure 2. Total colloidal particles in Camembert. Unfiltered samples collected 21 Oct 98.

There seems to be more variation in radionuclide concentrations than we normally encounter for samples taken in close time proximity. Also, the colloid concentration appeared to be varying during the 21 Oct pumping. Perhaps this hole had not been pumped long enough for concentrations to reach a steady state. We also note that the $^{3}H/^{85}Kr$ ratio is about an order of magnitude lower than what we have generally measured at similar test sites. The absence of radionuclides other than the volatile ^{3}H, ^{85}Kr, and ^{137}Cs (which has volatile precursors) suggests that appreciable radionuclide transport by groundwater upward into the chimney region has not taken place at the Camembert site. The formation from which water was pumped and sampled is not well known, but it was more than 200 m above the working point. We note that LLNL reported about 2E-2 pCi/L of $^{239,240}Pu$ in water collected from Camembert at the same time as the above samples.[42] We have reviewed our alpha spectroscopy and mass spectroscopy data and conclude that we have less than 3.7E-6 Bq/L (1E-4 pCi/L) in the 208-L drum that we analyzed.

B. Cheshire (U-20n)

The Cheshire site was studied in 1976 and in 1983-87 to measure the migration of radionuclides from the cavity/chimney region. We utilized a drill back hole (U-20n ps1 ddh) to collect water samples. During 1983-84, a total of 1.3E4 m^3 of water was pumped from perforations in the liner of this slant hole that passed through the cavity near the working point (at 1167 m vertical depth or about 1230 m slant depth). In 1985 a bridge plug was set above these perforations, and new perforations were made over the interval 812- to 913-m slant depth, corresponding to a zone of high hydrologic transmissivity in the surrounding rock strata. A total of 2.2E4 m^3 of water was pumped from this upper horizon. In 1987 a down gradient hole (UE-20n #1) was drilled about 300 m southwest of U-20n ps1 ddh, and 1.7E3 m^3 of water was pumped from it. Water samples were collected during all of these pumping campaigns, and a number of radionuclides were identified. Filtration experiments established a link between colloids and radionuclide migration. Detailed reports concerning our early work at Cheshire are given in references from LANL [7-11] and LLNL.[43,44] Also, we have recently published a summary report on our work at this site.[29] Pumping operations ceased at the Cheshire site in 1988 when the down gradient hole became contaminated with ferric hydroxide, but we continued to sample water in U-20n ps#1 ddh with bailers (2-L stainless steel pressure tubes) on an occasional basis. Our studies at the Cheshire site gave us insights concerning radionuclide movement away from large, below-the-water-table nuclear tests situated in the fractured rhyolite and layered tuffs of Pahute Mesa. In 1998 we re-visited this site in order to determine how the concentrations of the radionuclides in the hydrologic source term had changed and in the hope that we could better characterize actinide speciation in collected samples.

Chimney samples. In July 1998 a pump was inserted in U-20n ps#1 ddh and about 3.9E1 m^3 of water were pumped out; samples were collected in 208-L drums and in 2-L pressure tubes. This water was drawn in through the existing perforations over the interval 812 to 913 m slant depth. We observed[22] that the tritium and the ^{85}Kr concentrations had dropped by a factor of 3 to 4 over the

13-year period when the hole was not pumped. The ratio of tritium to krypton was very similar in 1998 to what it was in 1985. In contrast, the ^{125}Sb and ^{137}Cs greatly diminished in concentration from 1985 to 1998—the antimony by a factor of 20 and the cesium by a factor of 88. The antimony is believed to be present as an antimonate anion that does not sorb readily on the rock surfaces, whereas cesium does sorb strongly on NTS rocks. Plutonium was measured in the chimney water at a concentration of 1.4E-4 Bq/L (±15%).

Cavity samples. In August and September of 1998 the liner in U-20n ps1 ddh was configured to allow water samples to be withdrawn from the cavity horizon. The plug at 945 m slant depth was milled out; the liner was perforated over the interval 1244 to 1253 m slant depth; and a bridge packer was set from 789 to 931 m slant depth. These changes made it possible to pump water in through the bottom perforations without a contribution of water from the perforations higher in the liner. A pump with an intake at 767 m slant depth and capacity about 30 gpm began operation in mid-September. About 8.12E2 m^3 of water were pumped prior to sample collection. We believe this was enough to flush out the lower horizon of the well and to offset any effect of the 5.3E2 m^3 of water added to the top of the well during the milling operation. Samples were collected in 2-L pressure tubes and in 208-L drums; also, grab samples were taken in 1-L bottles for colloid analyses. The 2-L samples were analyzed for tritium and ^{85}Kr. The 208-L samples were taken to dryness, and the residue analyzed for gamma-emitting radionuclides. This residue was then further analyzed by alpha spectroscopy and mass spectrometry for actinides. Our data showed[22] that the tritium concentration at the cavity horizon had dropped by about a factor of two during the interval 1984 to 1998. In contrast, the gamma-emitting radionuclides increased somewhat in concentration, probably due to leaching of melt glass or desorption from rock surfaces in the cavity region.

The Cheshire site was not sampled during FY 1999, but we did complete some analyses of samples collected in 1998 and did some work with a sample archived from 1984. Our new data are given in Tables II and III along with previously reported values for comparison.

Table II. Representative concentrations of gamma-emitting radionuclides in water pumped from the interval 1244 to 1253 m slant depth in U-20n s1 ddh (referenced to t_o = 14 February 1976).

Sample ID	^{60}Co	^{125}Sb	^{137}Cs	^{152}Eu	^{154}Eu
	Bq/L (pCi/L)	Bq/L (pCi/L)	Bq/L (pCi/L)	Bq/L (pCi/L)	Bq/L (pCi/L)
1984 (852-9-84-003)	5.2E-3 (1.4E-1)	1.0E2 (2.7E3)	5.6E1 (1.5E3)	4E-3 (1E-1)	2E-2 (5E-1)
1998 (8521-98-180)	2.2E-1 (6E0)	1.3E2 (3.5E3)	9.6E1 (2.6E3)	1.4E-1 (4E0)	1.6E-1 (1.4E1)
1998 (8521-98-170)	7E-2 (2E0)	1.2E2 (3.2E3)	5.6E1 (1.5E3)	1E-1 (3E0)	1E-1 (4E0)
1999 (8521-99-140)	—	6.0E1 (1.6E3)	1.00E2 (2.7E3)	1E-1 (3E0)	1E-1 (4E0)

In 1983 we sought to identify plutonium which might be associated with particulate material. One sample consisted of stacked 293-mm diameter 400-nm pore filters through which 176 L of water was pumped as it emerged from the well. Another 208-L sample from 1983 was serially filtered in the laboratory through 1000-nm and 50-nm filters. The filters were dissolved; then the plutonium was isolated and analyzed by mass spectrometry. We also attempted to concentrate plutonium from 20-L water samples and measure its concentration by alpha spectrometry. Results of these analyses are shown in Table III. In 1998 we again used both alpha spectrometry and mass spectrometry to measure plutonium (and americium, as well) in the residue produced by drying a 208-L water sample. It appears that the plutonium concentration in the 1998 sample was not very different from that filtered from the cavity water in 1983. Finally, we include in Table III recent analyses of plutonium and americium from the ER20-5 #1 well. The data show that the plutonium content of this water, 1.3 km from its source in the Benham cavity, is about the same as water pumped from the Cheshire cavity. Yet at Cheshire, the concentration of plutonium in groundwater at the upper sampling horizon is two orders of magnitude lower than at the cavity, showing a considerable loss in a relatively short distance. Americium is present in water at both Cheshire and ER20-5 #1. We presently do not understand why the plutonium seems to behave differently at these two sites. It would be helpful if we could obtain water samples from the cavity and chimney regions at Benham to directly compare with those from Cheshire.

Table III. Actinide concentrations in water pumped from the interval 1244 to 1253 m slant depth in U-20n ps1 ddh (referenced to t_o = 14 February 1976).

Sample ID	**^{239,240}Pu Bq/L**	**^{241}Am Bq/L**
1983 (field filtration)	2.3E-2 (±30%)	not analyzed
1983 (852-9-83-006)	4.0E-2 (±30%)	not analyzed
1984 (852-9-84-003)	~7E-3	not analyzed
1998 (8521-98-180)	2.1E-2 (±15%)	5.0E-3 (±9%)
1997 (2051-97-110) ER20-5 #1	2.3E-2 (±9%)	4E-3 (±24%)
1998 (2051-98-110) ER20-5 #1	2.2E-2 (±9%)	not analyzed

We have a 208-L drum water sample collected from Cheshire in 1984 which we intend to use in filtration studies to correlate the actinide and colloid content. Prior to initiating these studies we sampled the drum (which had been sitting undisturbed for about four years) by withdrawing water from each quadrant, starting with the top quadrant and working downward. The total colloid population in each quadrant was approximately constant as shown in

Figure 3. We then moved the drum into another laboratory, shaking up the contents considerably in the process, and sampled the water again. We found that the colloid abundance and size distribution in this drum were not strongly affected by the move, and that these parameters were remarkably similar to those measured on a water sample withdrawn from the Cheshire cavity horizon in July 1998. The data are shown in Figure 4. Thus it appears that the colloids present in groundwater from the Cheshire cavity are very stable and neither aggregate nor sorb on a polyethylene drum liner during many years of storage.

C. Dalhart (U-4u ps2a)

This drill back hole was completed in 1990, entering the chimney of the Dalhart test cavity. The working point of the test was at a vertical depth of 640 m; the 7.3-cm OD tube inserted into the drill back hole had slots from 472 to 501 m. Water samples collected from the drill back hole starting in 1992 contained high concentrations of particulates (residues from drilling fluids), and attempts to clean the hole were unsuccessful.[22] In 1998 we placed tandem Bennett pumps in the tube and collected a 208-L water sample.[22] During 1999 we made repeated attempts to continue purging this hole, but various equipment malfunctions prevented us from removing more than a few cubic meters of additional water. Although relatively little purging of the hole has taken place, the measured radionuclide concentrations appear to have dropped by about a third between the pumping in 1998 and 1999 (reference Table IV below). We still hope to be able to clean out the residual water from U-4u ps2a and measure the ambient groundwater radionuclide concentrations.

Table IV. Radionuclides in water from U-4u ps2a. All activities are corrected to t_o = 13 October 1988.

Sample ID	Sample Date	^{3}H Bq/L (pCi/L)	^{60}Co Bq/L (pCi/L)	^{125}Sb Bq/L (pCi/L)	^{137}Cs Bq/L (pCi/L)
1112-98-120	23 Sep 98	1.40E6 (3.8E7)	1.0E0 (2.7E1)	3.3E1 (8.9E2)	3.3E0 (8.9E1)
1112-99-110	16 Aug 99	1.03E6 (2.7E7)			
1112-99-130	17 Aug 99	1.00E6 (2.7E7)	5.8E-1 (1.6E1)	2.4E1 (6.5E2)	2.0E0 (5.4E1)

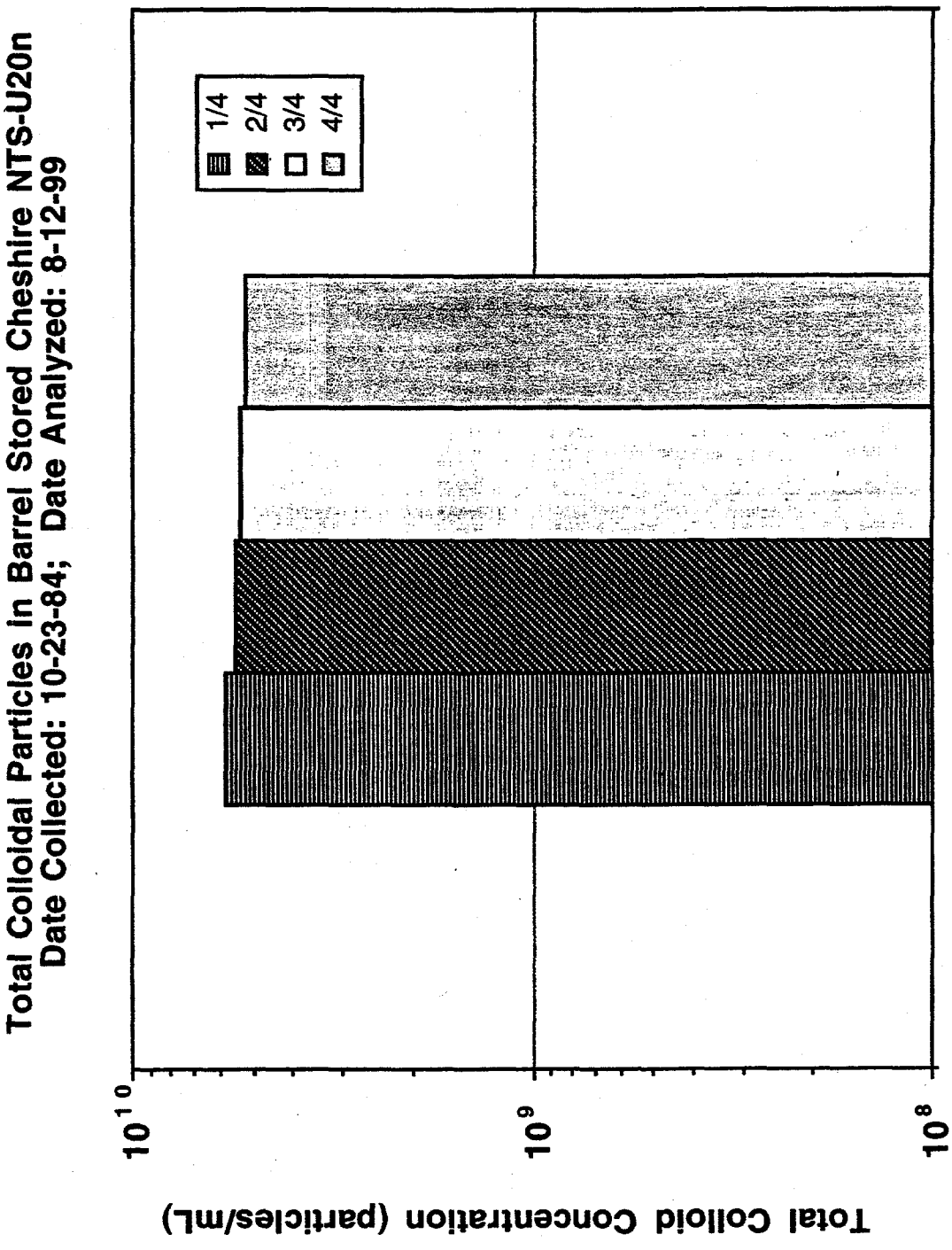

Figure 3. Total colloid concentrations by quadrants in Cheshire cavity water from an archived drum (1/4 is the top quadrant; 4/4, the bottom).

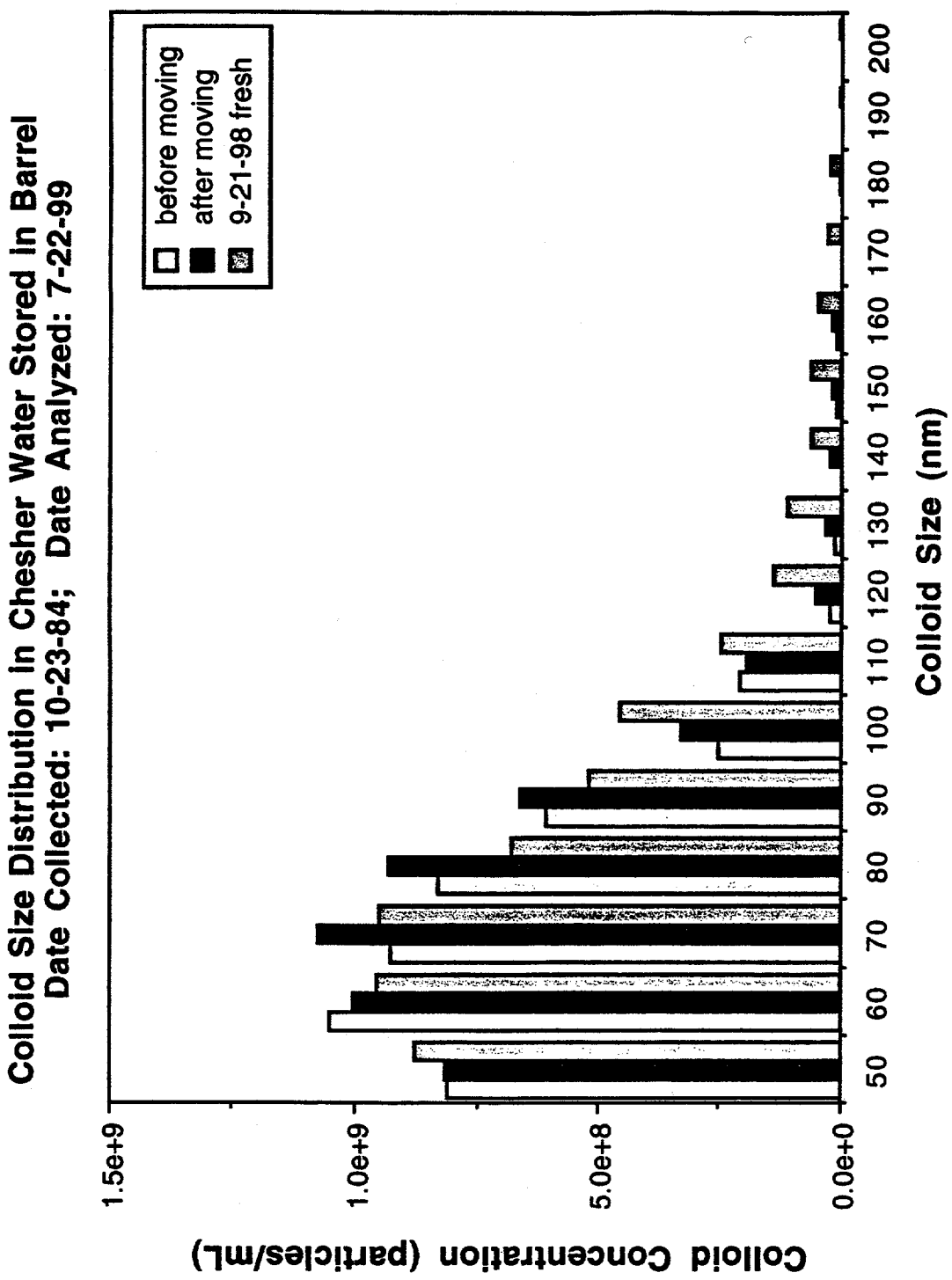

Figure 4. Colloid concentration and size distribution in an archived water sample from the Cheshire cavity before and after mixing and in comparison with a recently collected sample.

D. Cambric (RNM-2S)

This hole was pumped from 1975 to 1991 to determine what radionuclides would be mobilized from the cavity of the Cambric test located 91 m away. Since 1991 the hole has been periodically sampled, often with limited pumping. We have discovered that if the pump is run for about 4 hours, the tritium concentration reaches a constant value approximately the same as when continuous pumping ceased in 1991.[18,20] In October 1999 we had the opportunity to collect samples from RNM-2S while the pump was running at the request of another agency. We anticipated that the pump would be on for a period of several months, so we planned to sample during pumping start up and then after many days of pumping. Unfortunately, the agency cancelled the long-term pumping, and we were not able to complete our sampling. Hopefully, we will be able to do so during the next year.

The results of the tritium analyses of these initial samples are in conformity with our previous experience: there are small changes during the early hours of pumping, but eventually the concentrations reach a steady value similar to previous pumped samples. Note that the last values in Table V are the same as the concentration of tritium when continuous pumping was ended in 1991.[15]

Table V. Radionuclides in water collected during initial pumping of RNM-2S in October 1999 (activity at t_o = 14 May 65).

Sample ID	Elapsed Time	Sample Type	^{3}H	
			Bq/L	(pCi/L)
4342-99-210	13 min.	pressure tube	5.6E4	(1.5E6)
4342-99-110	47 min.	grab	5.7E4	(1.5E6)
4342-99-120	48 min.	grab	5.6E4	(1.5E6)
4342-99-130	78 min.	grab	6.0E4	(1.6E6)
4342-99-140	108 min.	grab	6.1E4	(1.6E6)
4342-99-150	138 min.	grab	6.0E4	(1.6E6)
4342-99-160	168 min.	grab	6.0E4	(1.6E6)
4342-99-170	198 min.	grab	6.2E4	(1.7E6)
4342-99-180	228 min.	grab	6.1E4	(1.6E6)
4342-99-190	6 days	grab	4.9E4	(1.3E6)
4342-99-191	6 days	grab	4.9E4	(1.3E6)

The grab samples were also analyzed for their colloid concentrations; these data are displayed in Figure 5 and Figure 6. There is a steady decrease in colloid concentrations during the first hours of pumping; the concentration after 6 days is relatively low. The pump rate is approximately 600 gpm, and the equilibrium colloid concentration at this pumping rate is rather similar to values measured at the J-13 well when it is in continuous operation.[45]

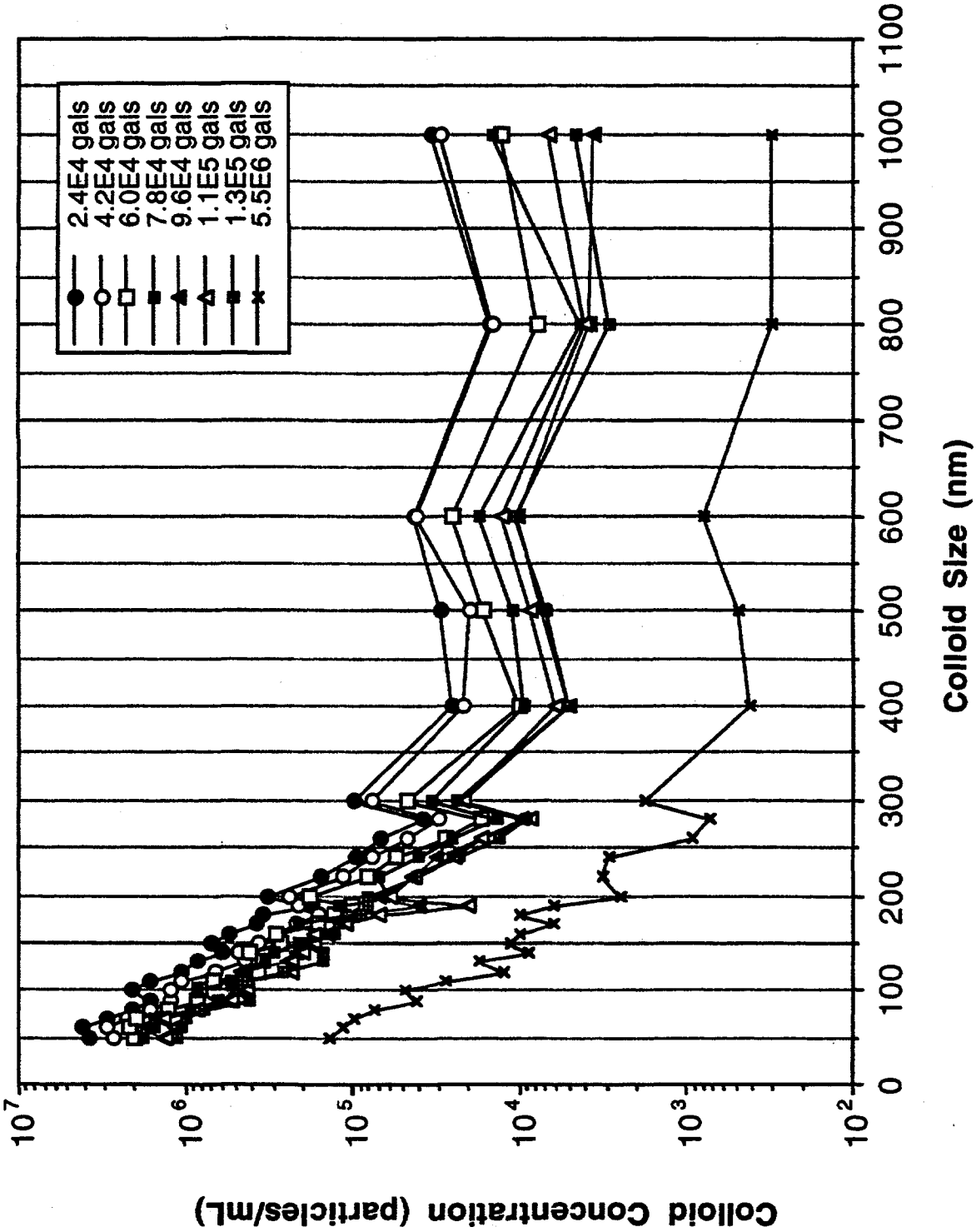

Figure 5. Colloid size distribution in Cambric RNM-2S water measured during extended pumping.

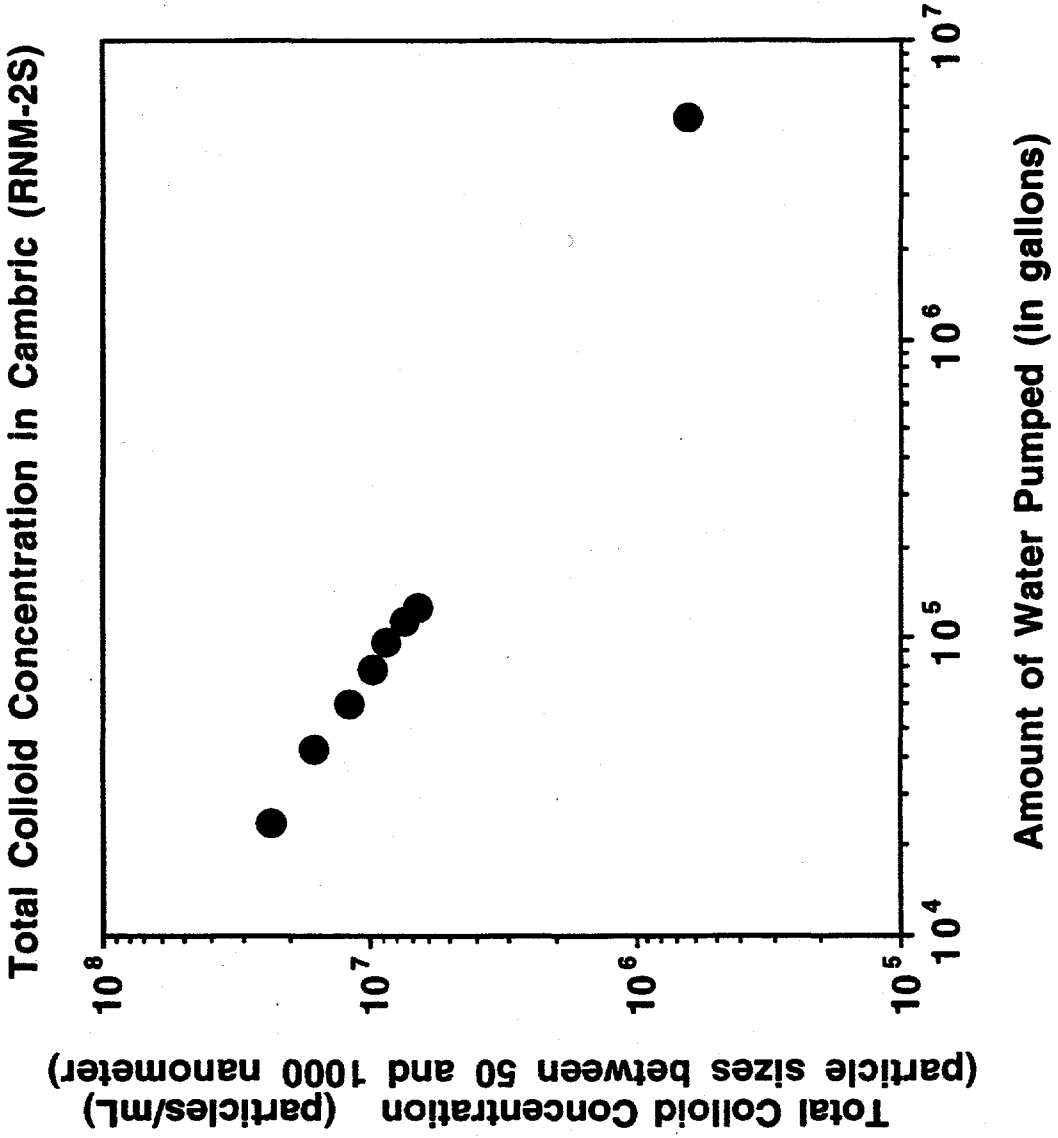

Figure 6. Total colloid concentration in Cambric RNM-2S water as a function of the volume pumped at 600 gpm pumping rate.

E. UE-5n

This exploratory hole was drilled to a depth of 514 m in March 1976 and completed with a 27-cm casing to a depth of 464 m. In September 1999 we participated with DRI and LLNL in sampling water withdrawn with a Bennett pump from about 3 m below the water level, which was at 214 m. The pumping rate was 1.9 L per minute; a modest (<50 m^3) purging of the hole took place prior to sample collection. The LANL samples consisted of small-volume grab samples for tritium and colloid analyses, pressure tubes for tritium and ^{85}Kr analyses, and a 208-L drum for fission product analysis. The ^{85}Kr counting is ongoing; the results of our other analyses are reported here.

Table VI. Radionuclides in Water from UE-5n. Activities at counting time November 1999.

Sample ID	Sample Type	^{3}H		^{137}Cs	
		Bq/L	(pCi/L)	Bq/L	(pCi/L)
4343-99-110	grab	5.5E3	(1.5E5)		
4343-99-120	drum	5.0E3	(1.4E5)	3E-3	(9E-2)
4343-99-210	pressure tube	4.6E3	(1.3E5)		
4343-99-220	pressure tube	5.3E3	(1.45E5)		

The presence of a trace amount of ^{137}Cs in water from this hole is surprising in view of our experience at RNM-2S, where we were unable to move ^{137}Cs 91 m from the Cambric test in the course of 17 years of pumping groundwater.[26] We have recounted our samples and eliminated the possibility of counter contamination. There is a small chance of cross-contamination from a previous sample during the boil-down process or for contamination of the sample at the time of collection. We are anxious to obtain another water sample from this hole to resolve these possibilities. The broader issue as to the source of the tritium and ^{85}Kr activity is also not entirely clear. The unlined ditch down which the effluent from RNM-2S ran from 1975 to 1991 passes within about 100 m from UE-5n. The hole itself is almost equidistant between the Cambric test (U5e) and Diluted Waters (U5b), both about 565 m away. At the Cambric site there is apparently very little water movement at the cavity depth (about 300 m) since the radionuclides residual to the test in 1965 were still present at their expected concentrations when the cavity was re-entered in 1974. If such low water movement were also true at the Diluted Waters cavity, then it would seem that the activity at UE-5n would most likely come from lateral diffusion from the ditch. The tritium activity in ditch water peaked at about 7E6 pCi/L (corrected to Cambric t_o = 14 May 1965) in 1980 and had declined to 1.3E6 pCi/L when pumping was stopped in 1991. Present levels of tritium activity at RNM-2S are approximately the same as when pumping was stopped (that is, 1.3E6 pCi/L corrected to t_o or 1.9E5 pCi/L at present time). The current tritium content at UE-5n is somewhat below that at RNM-2S. It will be interesting to track concentration changes at this site in future years, particularly to see if it rises

above that at RNM-2S. This would suggest that diffusion of higher concentration tritium from the ditch was occurring. Also, when we obtain the ^{85}Kr values we may get an indication of the origin of the water at UE-5n since the $^{3}H/^{85}Kr$ ratio for ditch water should be higher than values from RNM-2S where the water was never exposed to the atmosphere.

One sample was collected at UE-5n for colloid analysis. The distribution of colloid sizes from 50 to 1000 nm was like samples from RNM-2S (see Figure 5), and the colloid concentration was intermediate between samples taken initially and after several days of pumping at RNM-2S. The colloid results probably are related to the relatively low pump rate at UE-5n and the relatively small volume of water purged from that hole. In general, the colloid content of water from the Frenchman Flat region is low relative to that in water from Pahute Mesa. The low colloid abundance and limited water movement in the alluvial rock in Frenchman Flat favors minimal radionuclide transport in this region.

E. Almendro (U-19v)

The Almendro test took place on 6 June 1973. The re-entry hole is cased with 168-mm pipe extending to near the bottom of the cavity that is at about 1.16E3 m vertical. Although the cavity/chimney is filled with water, it has remained quite hot. The temperature of the water was so high that we could not sample it until 1993, and then not to the bottom of the hole. On 16 December 1996, Atlas Wireline Services ran a probe to about 1.09E3 m vertical and measured the temperature to be 157°C. In September 1998 personnel from LANL, LLNL, and the USGS collected water samples in 2-L pressure tubes at a slant depth of 1.09E3 m (1.02E3 m vertical). The water level was about 6.19E2 m vertical. The same group revisited this hole in August 1999 and collected samples in pressure tubes from a depth of 9.14E2 m. Our analyses of these samples are shown in Table VII.

Table VII. Tritium and ^{85}Kr activities in water from U-19v. Activities are corrected to the Almendro t_o = 6 June 1973.

Sample ID	Sample Date	Sample Depth Vertical (m)*	^{3}H Bq/L (pCi/L)	^{85}Kr Bq/L (pCi/L)
7910-98-210	22 Sep 98	1.02E3	2.9E7 (7.8E8)	1.0E4 (2.7E5)
7910-98-220	22 Sep 98	1.02E3	2.9E7 (7.8E8)	sample lost in processing
7910-99-110	17 Aug 99	9.14E2	2.7E7 (7.3E8)	
7910-99-210	17 Aug 99	9.14E2	2.3E7 (6.2E8)	
7910-99-220	17 Aug 99	9.14E2	2.1E7 (5.6E8)	
7910-99-230	18 Aug 99	9.14E2	2.3E7 (6.1E8)	1.1E3 (3.0E4)

*This assumes slant depth x 0.936 = vertical depth.

The tritium concentrations measured in 1998 were almost identical to those measured in the 1996 sampling at similar depths.[20] However, the values obtained in 1999 were appreciably lower and varied among different samples more than in previous years. The 1999 samples were collected 106 m higher than in 1998, which may account for the lower tritium concentration. The cause of variability in concentration is not known.

IV. PROGRAM SUPPORT ACTIVITIES

A. Document Review/Meetings

One way in which we support the DOE/NV mission in Defense Programs and Environmental Restoration is to serve as "expert reviewers" of documents generated for the HRMP or UGTA programs. During the past year we reviewed two reports from DRI: "Evaluation of Recharge Potential at Subsidence Crater U19b, Central Pahute Mesa, Nevada Test Site" by Hokett and French; and "Reconnaissance Estimate of Recharge based upon an Elevation-dependent Chloride-enrichment Method and Comparison to Previous Reconnaissance Methods for Estimating Recharge" by Russell and Minor. We reviewed a number of documents pertaining to the Frenchman Flat Corrective Action Unit, including the "Evaluation of the Hydrologic Source Term from Underground Nuclear Tests in Frenchman Flat at the Nevada Test Site: The CAMBRIC Test" from LLNL. Los Alamos personnel participated in semiannual HRMP planning and review meetings and in a number of UGTA Technical Working Group sessions.

B. Presentations/Publications

Two presentations made at international meetings during the past year.

- "Radionuclides in Groundwater: A Study of the 1976 Nuclear Test Cheshire" by J. L. Thompson, D. L. Finnegan and D. K. Smith.

- "Hydrogeological Investigations and Radionuclide Migration in Groundwater at the Nevada Test Site" by W. L. Hawkins, J. L. Thompson and D. L. Finnegan. This paper will be published in a NATO ASI series titled *Nuclear Physical Methods in Radioecological Investigations of Nuclear Test Sites.*

Our annual report for FY 1998 was published in March and titled "Laboratory and Field Studies Related to Radionuclide Migration at the Nevada Test Site, October 1, 1997–September 30, 1998," Los Alamos National Laboratory report LA-13576-PR (March 1999).

We published a summary report on our work at the Cheshire site: "The Cheshire Migration Experiment" by D. A. Sawyer, J. L. Thompson and D. K. Smith, Los Alamos National Laboratory report LA-13555-MS (October 1999).

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