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Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility: Construction Phase (1996 through 1999)

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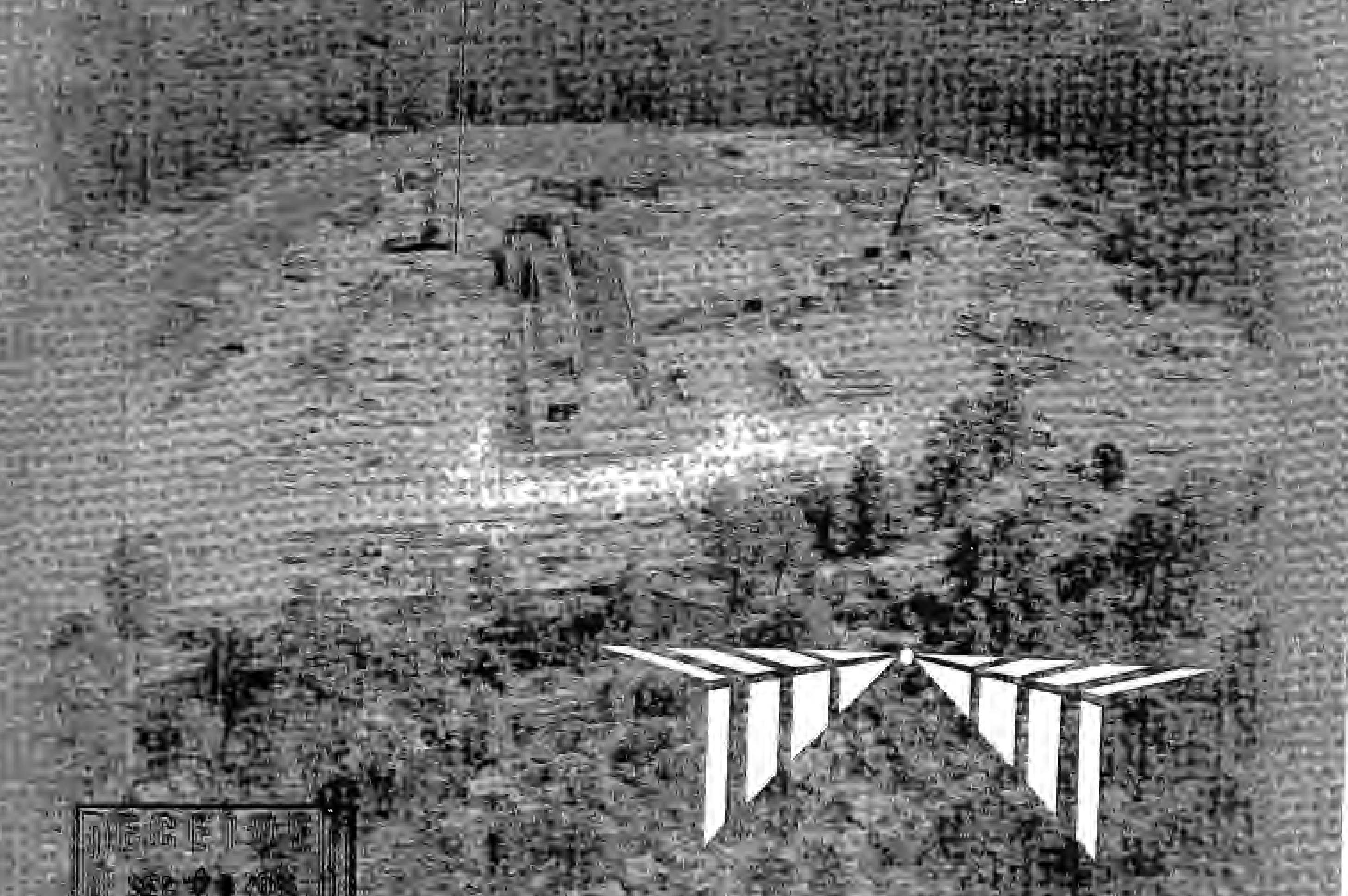

Los Alamos
NATIONAL LABORATORY

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July 2001

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Dual-Axis Radiographic
Hydrodynamic Test Facility

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J. W. Nyhan, P. R. Fresquez, K. D. Bennett, T. K. Haarmann, D. C. Keller, J. R. Biggs, and H. T. Haagenstad

ABSTRACT

The Mitigation Action Plan resulting from the Environmental Impact Statement for the construction and operation of the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility mandates measurement and monitoring of concentrations of radioactive and stable materials in the environment around the facility. This environmental monitoring is accomplished through the collection and analysis of soils and vegetation, invertebrates, plants, mammals, birds, and animals killed accidentally on roads traversing Los Alamos National Laboratory. This report provides the monitoring baseline for the construction phase of the DARHT facility, and is divided into one background section for each of the following media: soils, sediments, and vegetation; small mammals; birds; and honey bees. The results in this report represent the monitoring baseline for comparison to future analyses during the operational phase of the DARHT facility.

BACKGROUND INFORMATION ON THE DARHT FACILITY AND OBJECTIVE OF REPORT

by
J. W. Nyhan and H. T. Haagenstad

ABSTRACT

The objectives of the Dual-Axis Radiographic Hydrodynamic Test facility at Los Alamos National Laboratory are discussed, as well as a description of the location and construction activities. A short description of the construction activities and the regulatory histories is presented by way of introduction to the mandated establishment of baseline concentrations for potential environmental contaminants described in subsequent sections of this report.

A. DARHT FACILITY BACKGROUND INFORMATION

Objectives of DARHT Facility

An essential component of the improved physical measurements needed by the Stockpile Stewardship and Management Program is an enhanced radiographic hydrotesting capability. This technique has been used at Los Alamos since 1943 and is a crucial part of the nuclear weapons design laboratories at Los Alamos and Livermore. Radiographic hydrotesting utilizes very intense x-ray sources to radiograph a full-scale, non-nuclear mock-up of a nuclear weapon's primary during the late stages of the explosively driven implosion of the device. The extremely complicated processes that take place at time-scales of millionths of a second within a nuclear weapon exceed our ability to exactly predict them computationally. Actual measurements of what happens, using x-rays to determine shapes, densities, and material distribution, are thus essential for surveillance of the stockpile and the predictions of the nuclear safety, performance, and reliability upon which certification of the stockpile depends. The Nation's existing radiographic hydrotesting capabilities are not adequate to meet the needs of the Stockpile Stewardship and Management Program.

Completion of the Dual-Axis Radiographic Hydrodynamics Test (DARHT) facility at Los Alamos National Laboratory (LANL) is essential to begin to provide the radiographic hydrodynamics testing information required for continued certification of the Nation's nuclear deterrent without underground nuclear testing. The DARHT facility will include two high-intensity x-ray machines oriented at right angles. Each machine has been designed to generate radiographs that will produce data of far higher resolution than previously obtainable. For the first time ever, the dual-axis nature of the facility will allow researchers to obtain three-dimensional or time-resolved information. Coupled with LANL's unique special materials testing capability, the DARHT facility will be used to better infer nuclear performance characteristics in support of stockpile stewardship without underground nuclear testing.

Location

The DARHT facility site is located in the southeastern part of LANL Technical Area (TA) 15 on Threemile Mesa. TA-15 is located in the center of the high-explosives research, development, and testing area, in the southwestern part of LANL, which makes up about 20 mi^2 (52 km^2), or about half of the area of LANL. The total area for the DARHT facility is about 8 ac (2.3 ha). This area includes about 1 ac (0.4 ha) previously disturbed under the Radiographic Support Laboratory contract for the DARHT facility access road and utilities and 7 ac (2.3 ha) disturbed by the DARHT facility construction. Previous DARHT facility construction activities through 1994 account for the clearing of 14,000 board feet of lumber. At this site, the mesa is about 1,600 ft (490 m) wide. Water Canyon bounds it on the south, Cañon de Valle on the west, and Potrillo Canyon on the north (Figure 1). The site lies only a few hundred feet from the mesa rim for Water Canyon.

Facility Description and Construction

Phase I construction of the DARHT facility included a 39,650-ft^2 (3,568-m^2) Hydrotest Firing Site of cast-in-place concrete, two accelerator halls and power supply halls, control room, detection chamber, optics area, and support spaces (Figure 2). Additional construction included the first of two flash x-ray machines, a prototype containment vessel system, a cleanout unit, and a 20,750-ft^2 (1,867-m^2) Radiographic Support Laboratory that houses the Integrated Test Stand (occupied 11/90).

Phase II construction provided for a multi-pulse second axis accelerator, modifications to the hydrotest firing site including a 1,300-ft^2 (117-m^2) addition for a larger second axis machine, a containment vessel system, a confinement vessel system, waste treatment capability, and a permanent Vessel Preparation Facility.

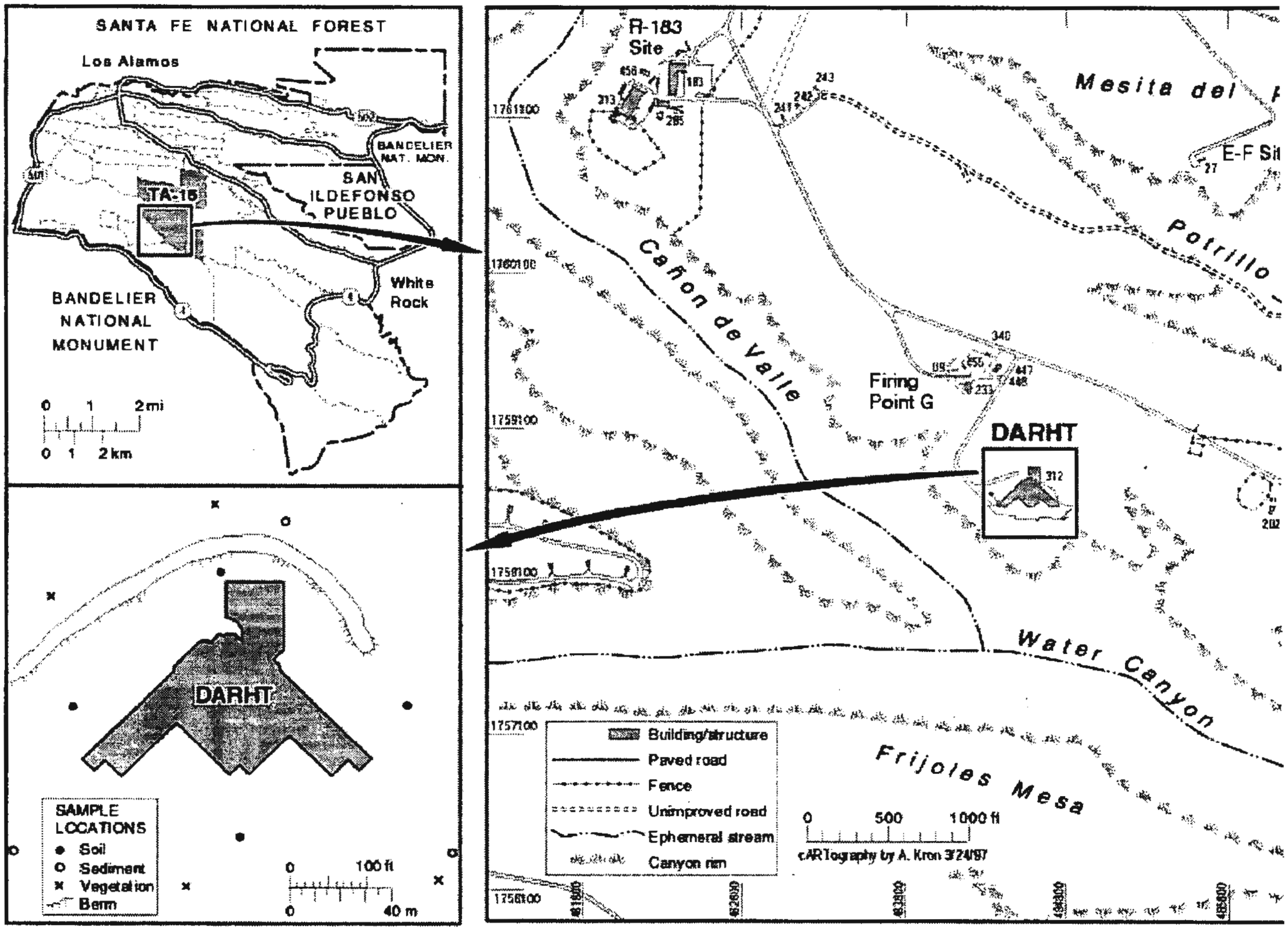

Figure 1. The DARHT facility at TA-15.

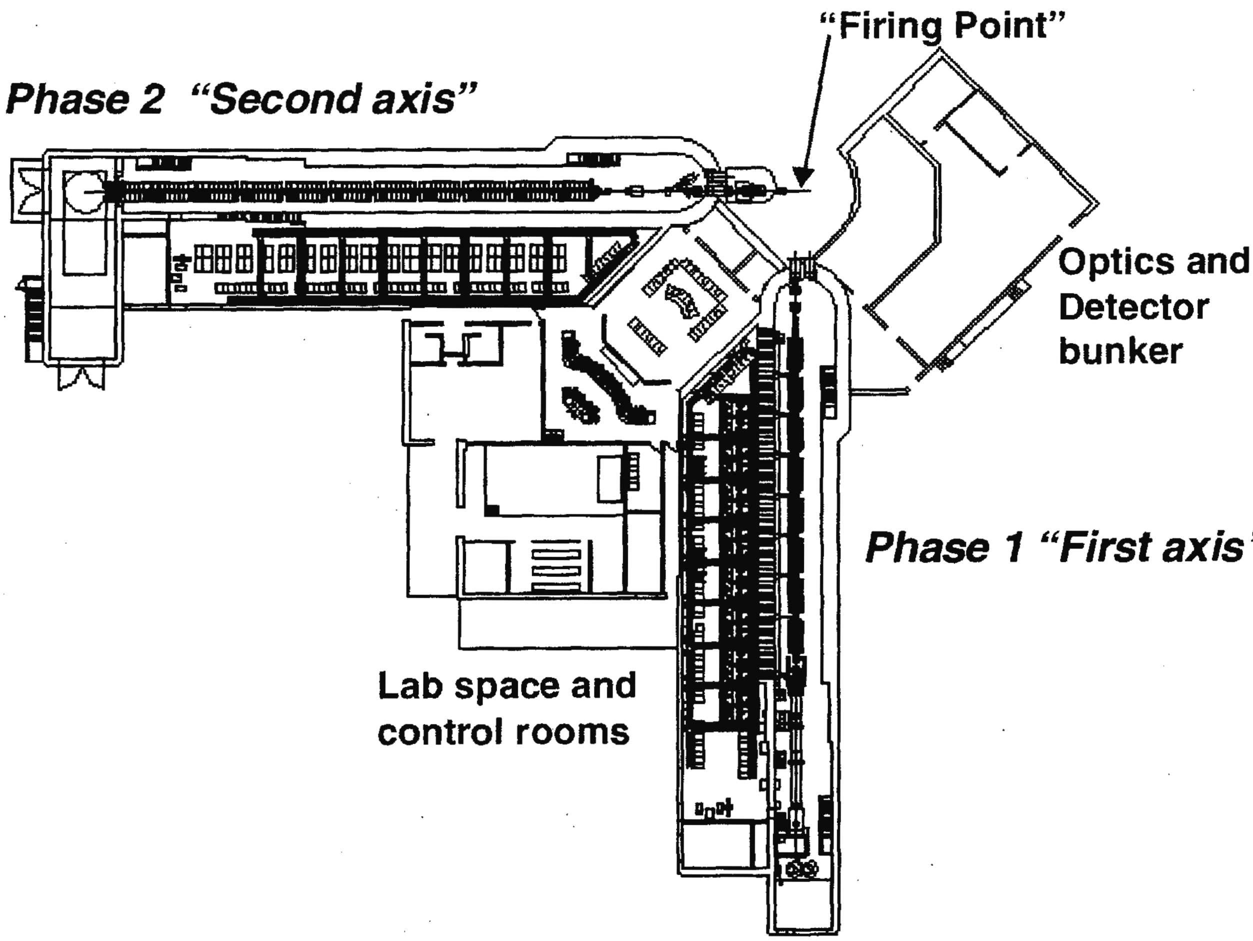

Figure 2. Phases 1 and 2 of DARHT facility construction.

Construction/Regulatory History

Construction of the DARHT Hydrotest Firing Site began in May 1994, and construction was halted on January 27, 1995, by preliminary injunction from the U.S. District Court, Albuquerque, New Mexico. Senior U.S. District Judge Edwin Mechem issued a preliminary injunction against continuation of the project until the Department of Energy (DOE) completed an adequate environmental impact statement (EIS) and record of decision (ROD) for the DARHT facility and until a judicial review of that process was completed. At that time, approximately 34 percent of the construction of the Hydrotest Firing Site was complete. The completed construction included installation of an earthen berm on the northern side of the DARHT site as a radiation protection measure.

In August 1995, DOE published a Final EIS on the DARHT facility at LANL, DOE/EIS-0228 (USDOE, 1995a). This EIS was prepared according to National Environmental Policy Act (NEPA) regulations established by the Council on Environmental Quality (42 U.S.C. 4321 et seq. of 1969; 40 CFR Parts 1500–1508). DOE published a ROD on this Final EIS in the Federal Register (60 FR 53588) on October 16, 1995 (USDOE, 1995b). In January 1996, in conjunction with the ROD, DOE issued a mitigation action plan for DARHT facility design, construction, and operations. The court ordered injunction on DARHT facility construction was lifted on April 16, 1996, and DOE authorized resumption of construction activities on April 26, 1996. The DARHT facility construction contractor was fully mobilized on August 23, 1996, and full-scale construction was authorized and began on September 30, 1996. In July 1999, with the appropriate DOE authorization, the DARHT Project Office initiated facility operations on the 1st axis.

The DARHT facility Mitigation Action Plan (MAP) is being implemented consistent with DOE regulations under the NEPA as stated in DOE's Final Rule and Notice for implementing NEPA [10 CFR 1021, section 331(a), revised July 9, 1996]. The functions of the MAP are to (1) document potentially adverse environmental impacts of the Phased Containment Option delineated in the Final EIS, (2) identify commitments made in the Final EIS and ROD to mitigate those potential impacts, and (3) establish Action Plans to carry out each commitment (USDOE, 1996).

The DARHT facility MAP is divided into eight sections: Sections I through V provide background information regarding the NEPA review of the DARHT project and an introduction to the associated MAP. Section VI references the Mitigation Action Summary Table, which summarizes the potential impacts and mitigation measures; indicates whether the mitigation is design-, construction-, or operational-related; summarizes the organization responsible for the mitigation measure; and summarizes the projected or actual completion date for each mitigation measure. Sections VII and VIII discuss the MAP annual report and tracking system commitment and the potential impacts, commitments, and action plans.

Under Section VIII of the MAP, potential impacts are categorized into five areas of concern: general environment, including impacts to air and water; soils, especially impacts affecting soil loss and contamination; biotic resources, especially impacts affecting threatened and endangered species; cultural/paleontological resources, especially impacts affecting the archeological site known as Nake'muu; and human health and safety, especially impacts pertaining to noise and radiation. Each potential impact includes a brief statement of the nature of the impact and its cause(s). The commitment made to mitigate the potential impact is identified and the action plan for each commitment is described in detail, with a description of actions to be taken, pertinent time frames for the actions, verification of mitigation activities, and identification of agencies/organizations responsible for satisfying the requirements of the commitment (USDOE, 1996).

The DARHT facility MAP identifies the potential for toxic and radioactive materials to be released to the general environment surrounding the DARHT facility. According to the MAP, toxic and radioactive materials could be released to the general environment through the following mechanisms: a structural failure of containment vessels or during open air firing operations; release of various types of waste as a result of cleaning out the containment vessels; release of various hazardous materials as a result of spills within the DARHT facility; and release of hazardous levels of various substances as a result of discharges of contaminated water from the DARHT facility.

Under DARHT facility MAP Section VIII.A.1 (a), DOE is obligated to collect baseline data on any contaminants present at the facility and in the surrounding areas, as well as at a control site away from the DARHT facility, from soils, invertebrates, plants, mammals, birds, and roadkill. On behalf of DOE, the Ecology group (ESH-20) has collected and analyzed soil, sediment, and vegetation samples around the DARHT facility throughout the construction phase since 1996. In 1997, ESH-20 began collecting honey bee, bird, and small mammal tissue samples around the DARHT facility. All samples have been analyzed for a comparable suite of toxic and radioactive chemicals. The analytical results indicate that concentrations of toxic and radioactive materials are below or comparable to the regional statistical reference levels identified as part of LANL's Environmental Surveillance Program. The surface water sampling requirements have been addressed through the implementation of the Storm Water Pollution Prevention Plan for the DARHT facility. The DARHT facility environmental sampling will continue on an annual basis throughout the operational phase (about 30 years). This technical report provides the complete compilation of environmental baseline monitoring results for the entire construction phase of the DARHT facility. It will be used as the baseline standard against which future operations baseline monitoring trends will be assessed.

In the late fall of calendar year 2000 the first major uncontained hydrotest using the DARHT 1st axis was performed. Also, during the late summer of calendar year 2000 two very simple experiments using 16 pounds of high explosives were performed. The purpose of these two experiments was to acquire accelerometer data from the Nake'muu archeological site. Additionally, during FY 2000 the DARHT Project started the major installation of the injector and accelerator components of the 2nd axis of the DARHT facility.

An aerial photograph of the construction at the DARHT site taken on October 23, 1997, is shown on the cover of this report to generally document what the site looked like at this time. Additional aerial photographs of construction activities and a Phase I operational test at the DARHT facility taken between 1996 and 2000 are presented in Figures 3–5.

B. REPORT OBJECTIVES

The initial task identified in MAP Section VIII.A.1 (a) mandates measurement of baseline concentrations of radioactive and stable materials through the collection and analysis of soils, invertebrates, plants, mammals, birds, and animals killed accidentally on LANL roads near the DARHT facility during the construction phase.

The construction phase at the DARHT facility was completed in the summer of 1999. This compendium of papers reports all of the baseline activities conducted at the DARHT facility during the years 1996 through 1999.

Figure 3. Aerial photograph of the DARHT facility taken on July 31, 1996.

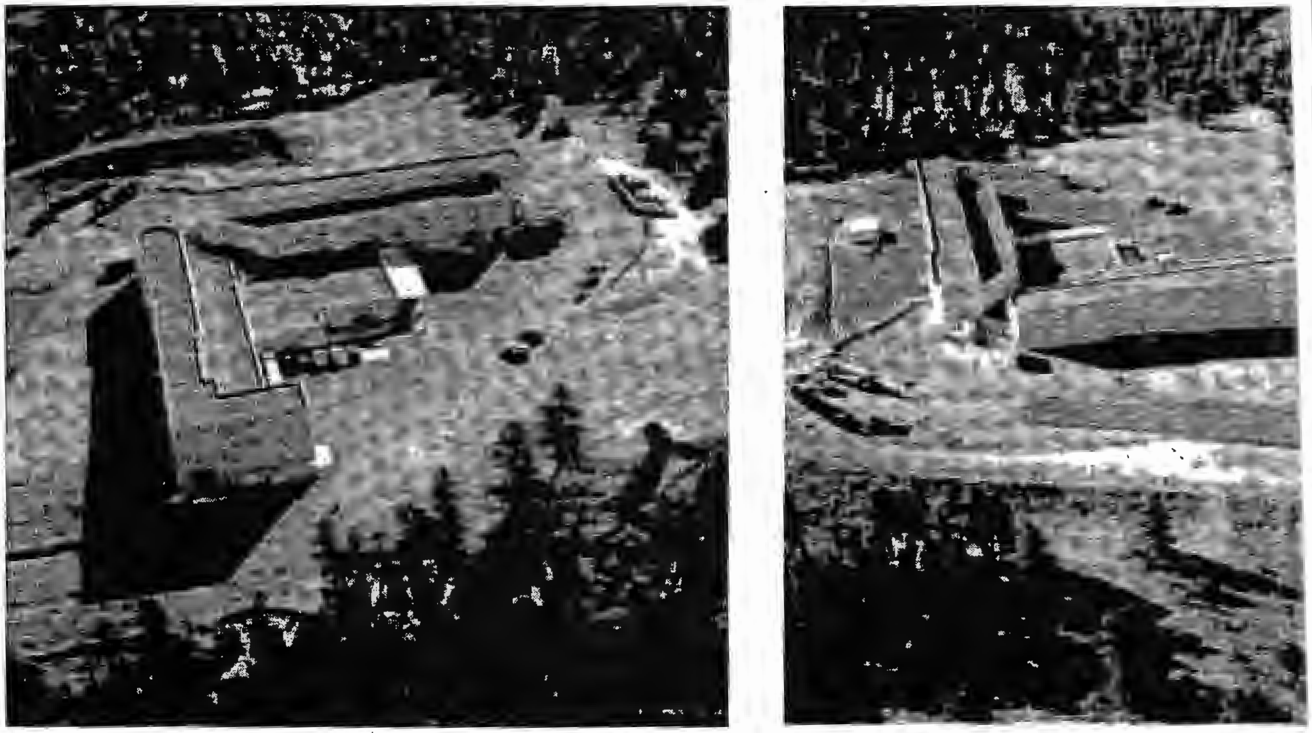

Figure 4. Aerial photographs of the DARHT facility taken on May 5, 1999.

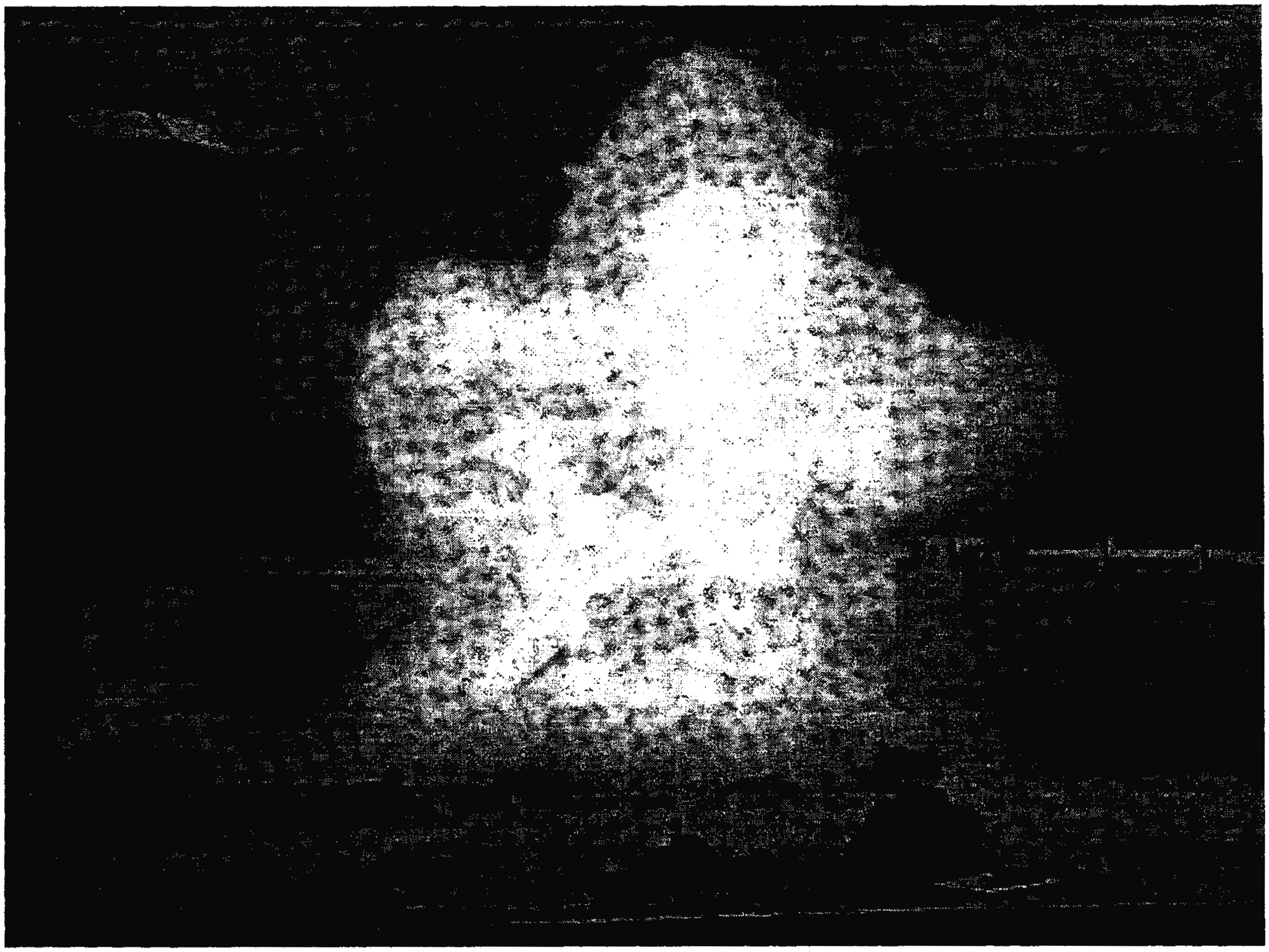

Figure 5. Photograph of DARHT facility taken on October 6, 1999, showing a Phase I operational test inv

C. REFERENCES

United States Department of Energy (USDOE), "Final Environmental Impact Statement: Dual-Axis Radiographic Hydrodynamic Test Facility," USDOE/EIS-0228 (1995a).

United States Department of Energy (USDOE), "Dual-Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement Record of Decision," USDOE/EIS-0228 (1995b).

United States Department of Energy (USDOE), "Dual-Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement Mitigation Action Plan," USDOE/EIS-0228 (1996).

BASELINE CONCENTRATIONS OF RADIONUCLIDES AND TRACE ELEMENTS IN SOILS, SEDIMENTS, AND VEGETATION AROUND THE DARHT FACILITY

by
P.R. Fresquez, J.W. Nyhan, and H.T. Haagenstad

ABSTRACT

The Mitigation Action Plan for the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos National Laboratory mandates the establishment of baseline concentrations for potential environmental contaminants. To this end, concentrations of ^{3}H, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and ^{tot}U and Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl were determined in soils, sediments, and vegetation (overstory and understory) around the DARHT facility during the construction phase. Soil and sediment samples were also collected in 1998 for the analysis of volatile and semivolatile organic compounds. These concentrations of radionuclides, trace elements, and organic compounds now represent preoperational baseline statistical reference levels, which are calculated from the mean DARHT facility sample concentration plus two standard deviations.

A. INTRODUCTION

The objective of this study was to determine preoperational baseline concentrations of radionuclides and total trace elements in soils, sediments, and vegetation around the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility, performed in response to a mitigation action plan and a record of decision concerning the DARHT Environmental Impact Statement (USDOE, 1995a, 1995b, 1996). The determinations of baseline concentrations of volatile and semivolatile organic compounds (VOC and SVOC, respectively) in soils were also established. Whereas individual annual efforts have been reported previously (Fresquez et al., 1997a, 1998, 1999), this report summarizes statistics and environmental data collected during the construction phase of the DARHT facility, thus establishing baseline statistical reference levels (BSRLs) for each radionuclide, trace element, and organic compound studied. In addition, the soils and vegetation data are compared with similar data from regional background (RBG) stations and the results of similar regional studies.

B. METHODS AND MATERIALS

Surface Soil and Sediment Sampling

Soil samples were collected within the bermed area approximately 80 ft (24 m) away from the north, east, south, and west sides of the DARHT facility (Fresquez et al., 1996a, 1997a; see Figures 1 and 2). From 1996 to 1999 four composite soil surface samples were collected annually at each site with a stainless steel soil ring 4 in. (10 cm) in diameter driven 2 in. (5 cm) into the soil (ASTM, 1990). Samples were collected from the center and corners of a square area 32 ft (10 m) per side; the five subsamples were combined and mixed thoroughly in a three-gallon Ziploc® bag to form a composite sample. In addition, four subsurface samples—one on the east, one on the west, and two from the berm on the north side of the facility—were collected in 1998 with a stainless steel auger at the 0- to 12-in. (0- to 30-cm) depth.

From 1996 to 1999 three sediment grab samples were collected annually at the 0- to 6-in. (0- to 15-cm) depth with a stainless steel scoop within three drainage channel/ponding areas originating from the DARHT facility on the north, east, and southwest sides. In addition, a sediment sample was collected in 1999 on the south side of the DARHT facility. Most of the sediment material on the north side was a result of erosion from the berm wall, whereas sediments from the other sites originated from the grounds themselves.

All soil and sediment samples collected for radiological and total trace elements analyses were placed in prelabeled 500-mL and 125-mL polypropylene bottles, respectively. The soil and sediment samples collected in 1998 for the analysis of VOC and SVOC were collected with stainless steel scoops at the 0- to 6-in. (0- to 15-cm) depth; samples were placed into 500-mL amber glass containers and 125-mL amber septum glass containers. All containers were fitted with chain-of-custody tape, placed into individual Ziploc® plastic bags, and transported to the laboratory in a locked ice chest cooled to approximately 4°C. All samples were then submitted to the Environmental Chemistry Group (CST-9) at Los Alamos National Laboratory for the

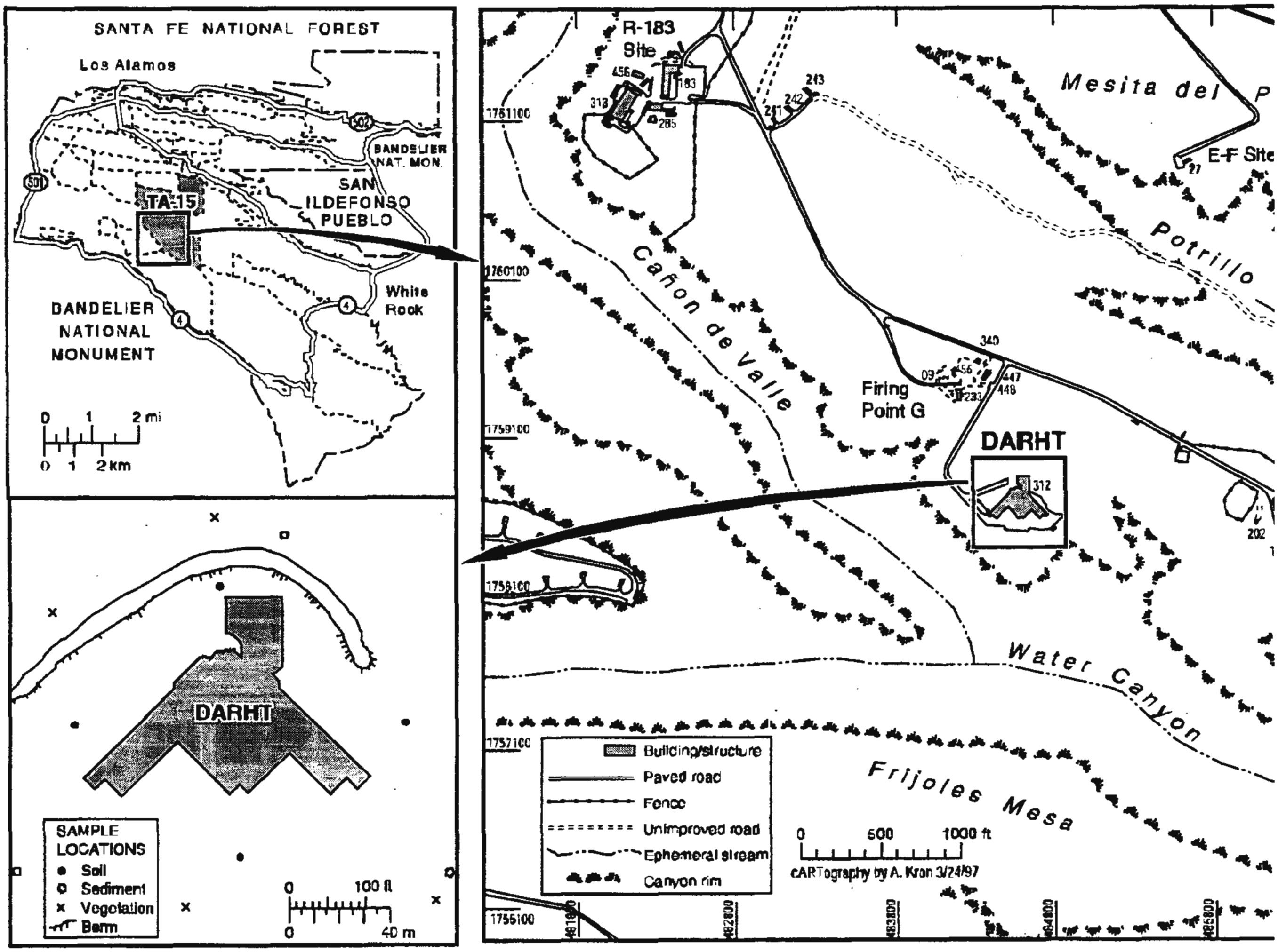

Figure 1. Sampling locations at the DARHT facility at TA-15.

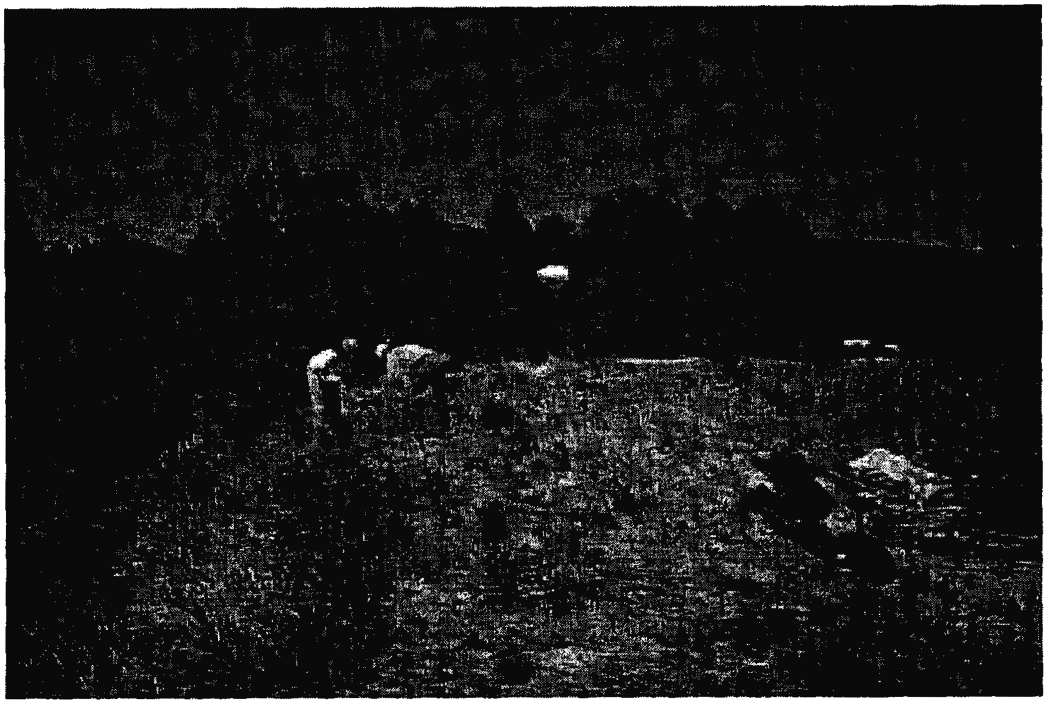

Figure 2. Collecting samples at the DARHT site during 1998.

analysis of ^{3}H, ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{90}Sr, ^{241}Am, ^{tot}U (total uranium), total trace elements (Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl), and SVOC and VOC. All methods of radionuclide (Purtymun et al., 1987, Fresquez et al., 1996a) and trace element (Fresquez et al., 1996b) analyses have been previously reported; uranium, however, was analyzed by kinetic phosphorescence analysis. Results are reported in pCi mL^{-1} (of soil moisture) for ^{3}H, $\mu g\ g^{-1}$ dry soil for ^{tot}U and heavy metals, and pCi g^{-1} dry soil for all the other radioisotopes. SVOC and VOC were prepared and analyzed according to American Society for Testing and Materials method SW 846 (and method ANC 609 for SVOC and 8260 for VOC) by gas chromatography/mass spectrometry (ASTM, 1990; Fresquez et al., 1999).

Vegetation Sampling

Vegetation samples were collected from overstory and understory materials as close as possible to the soil sampling locations (Fresquez, 1996). Overstory samples, mostly ponderosa pine (*Pinus ponderosa*), consisted of tree-shoot tips approximately 1 to 2 in. (2.5 to 5 cm) in length at the 4- to 5-ft (1.2- to 1.5-m) height (Fresquez et al., 1996c). Understory samples, mostly top growth of grass and forb species, were collected from the center and corners of a 32- by 32-ft (10- by 10-m) plot. One pine selected for overstory sampling was used as the center of the understory sample plot. Samples were 2 to 3 lb (0.9 to 1.4 kg) of fresh, composited material and were double bagged in labeled Ziploc® plastic bags before transport to the Ecology group laboratory in locked ice chests. At the laboratory, each unwashed sample was divided into three subsamples for preparation and analyses of ^{3}H, other radionuclides, and trace elements.

Subsamples for ^{3}H analysis were placed in an apparatus to collect distillate water (Salazar, 1984). Vegetation subsamples for trace element analysis were dried at 70°C for 48 h then ground in a Wiley mill equipped with a 40-mm screen. The remaining portion of each subsample was placed in a 1-L glass beaker, ashed at 500°C for 120 h, pulverized and homogenized after ashing, transferred to a labeled 500-mL polypropylene bottle, and, with the corresponding distillate sample, submitted to CST-9 under full chain-of-custody. Results were reported in pCi mL^{-1} of tissue moisture for ^{3}H, $\mu g\ g^{-1}$ ash for total uranium, pCi g^{-1} of ash for the other radionuclides; and as $\mu g\ g^{-1}$ dry for trace elements. Results in grams of ash are usually two to four orders of magnitude greater than live (wet) weight.

C. RESULTS

Soils and Sediments

Baseline radionuclide concentrations in soils and sediments over a four-year period at the DARHT facility (1996 to 1999) can be found in Table 1 and Figures 3 and 4, which show the mean and two standard deviations of the concentrations of ^{3}H, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and ^{tot}U. These concentrations of radionuclides are important because the mean DARHT facility sample concentrations plus two standard deviations represent the preoperational BSRLs.

The data presented in Figures 3 and 4 show that the BSRLs for each radionuclide in soils and sediments varied considerably. The BSRLs for DARHT facility soils varied from 0.003 to 0.34 pCi g^{-1} for ^{238}Pu and ^{90}Sr, respectively, whereas ^{238}Pu and ^{137}Cs data for DARHT facility sediments ranged from 0.005 to 0.51 pCi g^{-1}, respectively. However, even though the actual BSRL values for each radionuclide were slightly different for soils

Table 1. Mean (±SD) radionuclide (baseline) concentrations in soils, sediments, and vegetation colle DARHT facility from 1996 through 1999 (construction phase).

Sample Type	^{3}H (pCi mL^{-1})	^{90}Sr (pCi g^{-1})	^{tot}U (µg g^{-1})	^{137}Cs (pCi g^{-1})	^{238}Pu (pCi g^{-1})	$^{239,240}Pu$ (pCi g^{-1})	^{241}Am (pCi g
Soil (dry)	0.21	0.11 [a]	2.86	0.09	0.001	0.005	0.00
	(0.16)	(0.23)	(1.82)	(0.09)	(0.001)	(0.006)	(0.00
Soil BSRL[b]	0.53	0.34	6.50	0.27	0.003	0.017	0.00
Sediment (dry)	0.32	0.06[a]	5.09	0.23	0.001	0.010	0.00
	(0.29)	(0.20)	(2.45)	(0.14)	(0.002)	(0.008)	(0.00
Sediment BSRL	0.90	0.26	9.99	0.51	0.005	0.026	0.01
Vegetation (ash)							
Overstory (OS)	0.38	4.69[c]	0.97	0.49	0.004	0.002	0.00
	(0.32)	(1.67)	(0.50)	(0.42)	(0.012)	(0.002)	(0.00
OS BSRL	1.02	8.03	1.97	1.33	0.028	0.006	0.01
Understory (US)	0.25	2.55[c]	0.95	0.36	0.000	0.003	0.00
	(0.37)	(1.10)	(0.97)	(0.31)	(0.002)	(0.005)	(0.00
US BSRL	0.99	4.75	2.89	0.98	0.004	0.013	0.01

[a] The ^{90}Sr analyses for soils and sediments were found to have a strong positive bias resulting from analytical p samples collected during 1997, 1998, and 1999 (LANL 2000). Thus, we assumed that the samples collected at facility in 2000 represented baseline concentrations of ^{90}Sr along with the samples collected in 1996 and only u

[b] BSRL is baseline statistical reference level, which is calculated from the mean DARHT sample concent standard deviations.

[c] The ^{90}Sr analyses for both overstory and understory vegetation samples collected in 1997 were found to have negative bias resulting from analytical problems and were not used in these calculations.

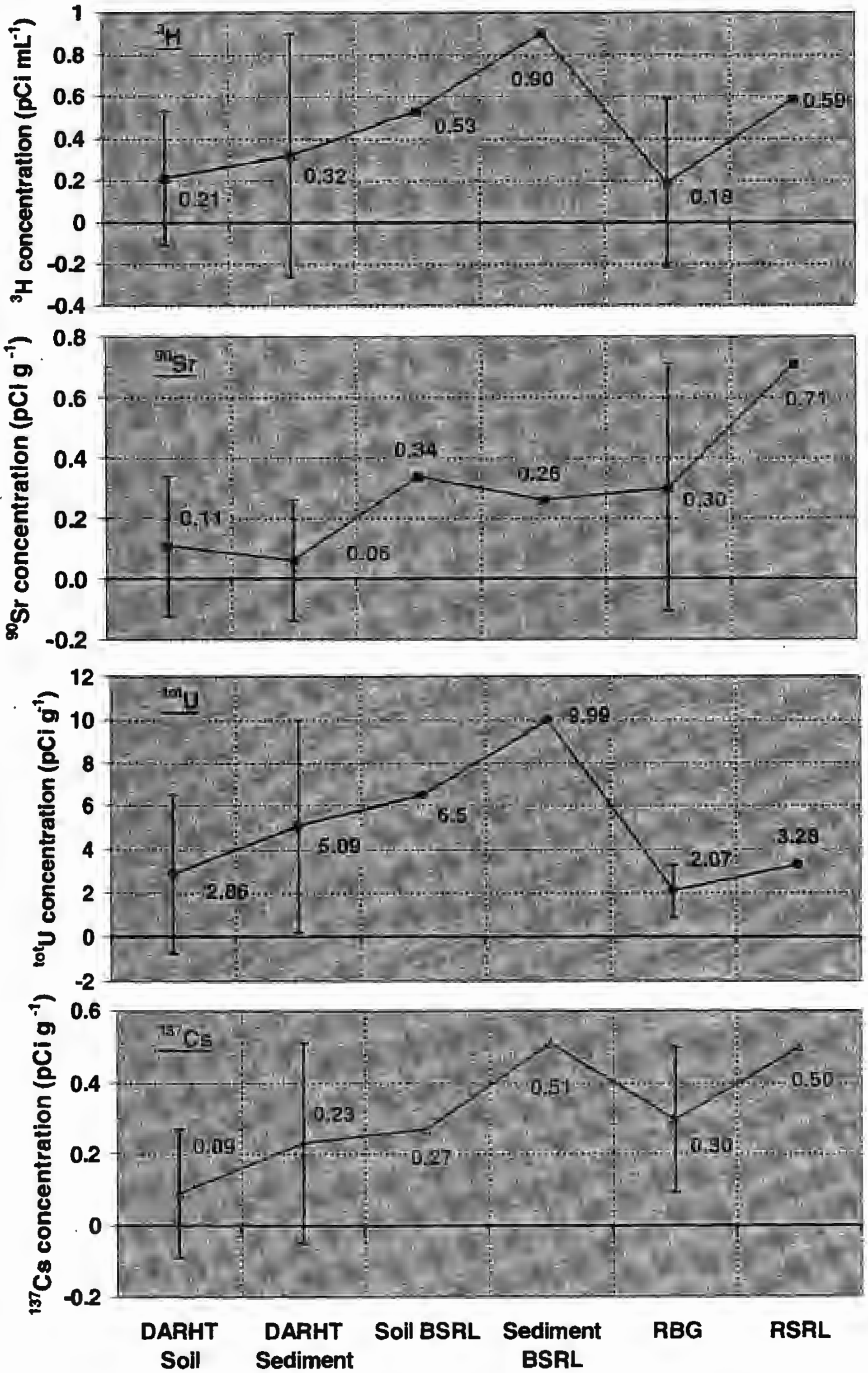

Figure 3. Concentrations of ^3H, ^{90}Sr, ^{tot}U, and ^{137}Cs in soils and sediments.

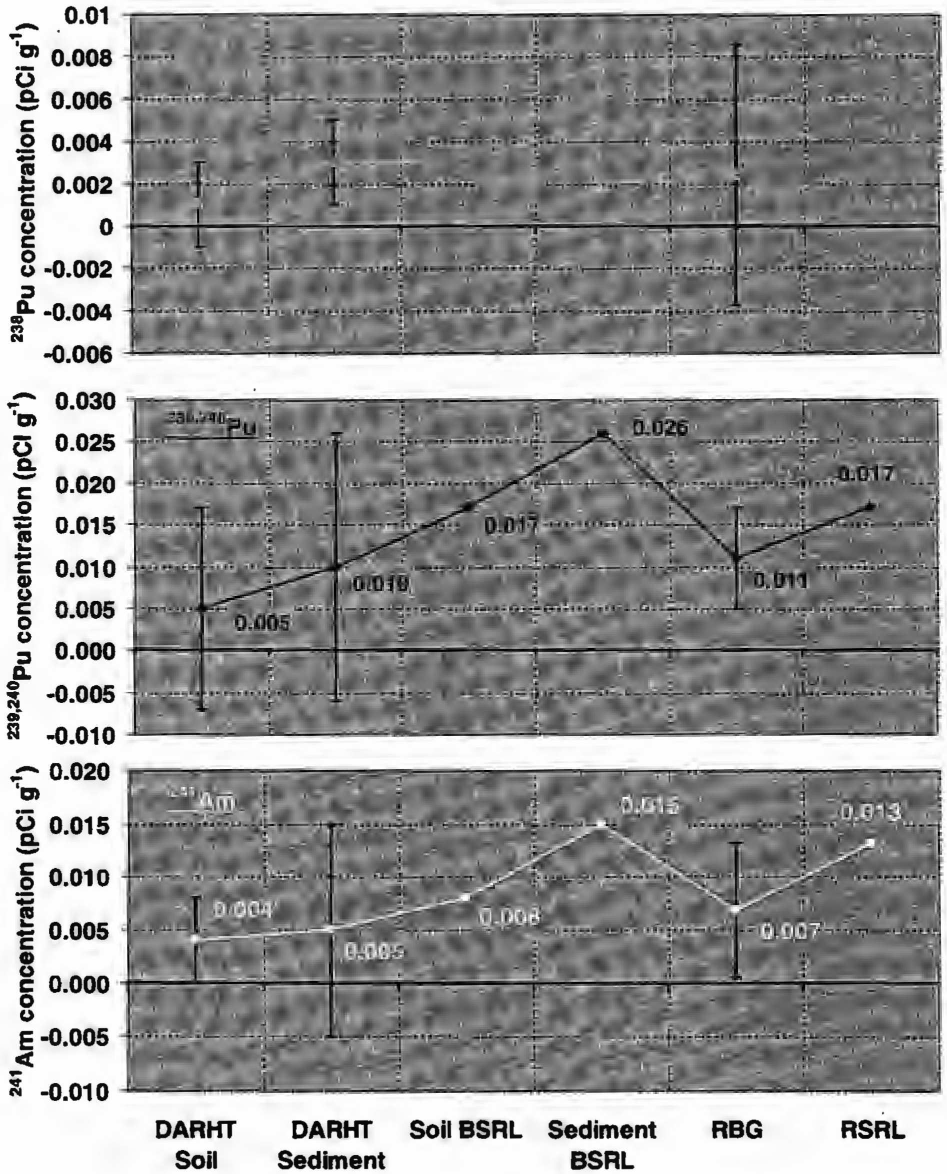

Figure 4. Concentrations of ^{238}Pu, ^{239,240}Pu, and ^{241}Am in soils and sediments.

and sediments, Figures 3 and 4 show that there was no significant difference in the mean concentrations of radionuclides between these two sample types.

We also compared soil and sediment samples from the DARHT facility with soils collected from RBG locations in northern New Mexico surrounding the Laboratory, where radionuclides, radioactivity, and trace elements are from natural and/or worldwide fallout events. These areas are located around Embudo to the north, Cochiti to the south, and Jemez to the southwest, and are all more than 20 mi (32 km) from the Laboratory, beyond the range of potential influence from normal Laboratory operations (USDOE, 1991). In this type of comparison, regional statistical reference levels (RSRLs) are established from data collected from 1995 through 1999 for worldwide fallout of ^{3}H, ^{90}Sr, ^{137}Cs, ^{241}Am, ^{238}Pu, $^{239,240}Pu$, and ^{tot}U, as described in the Laboratory's environmental surveillance reports (LANL, 1996–2000). Thus, the RSRL represents the upper (95%) limit background concentration (mean plus two standard deviations) for each radionuclide, and as such, represents a "hot measurement" test—meaning that site data that are greater than this value are "in excess" of normal maximum background concentration for a particular element. Figures 3 and 4 show that there were no significant differences between radionuclide concentrations found in DARHT facility soils and sediments verses those found in RBG samples.

Since background-element concentrations in soils forming on the Pajarito Plateau vary with parent material, the degree of soil development, and other factors, site-specific conditions must be considered to select the most appropriate samples that represent baseline conditions at the DARHT facility. In fact, Longmire et al. (1996) state:

Variations in background-soil elemental concentrations are related to climate, topography, parent material, soil age, surficial processes, pore-water chemistry and vegetation. Parent materials consist of alluvial fan deposits, sheetwash material, colluvium, El Cajete pumice, and-in some instances-the Bandelier Tuff. The age of the sampled deposits range from several thousand years to perhaps as old as one million years.

Well-developed soils contain more trace elements than the weakly developed soils found on the Pajarito Plateau. The B horizons are characterized by higher concentrations of trace elements than the A and C horizons. High abundances of clay *minerals and iron oxides, characterized by relatively high surface areas, within B horizons control trace-element distributions in soils. Soils have higher concentrations of Al, As, Ba, Ca, Cs, Co, Cr, and Fe than the Bandelier Tuff samples; the Bandelier Tuff, however, is higher in Be, Pb, Na, K, Th, and U.*

The results of chemical analyses discussed in this report represent the most appropriate specific published chemical data available to establish background-elemental distributions (BSRLs) in soils, sediments, and vegetation at the DARHT facility. Baseline trace element concentrations in DARHT facility soils and sediments over a four-year period are presented in Table 2 and Figures 5 through 8, which show the mean and two standard deviations of the concentrations of Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl. These concentrations of trace elements are important because the mean DARHT facility sample concentrations plus two standard deviations represent the preoperational BSRLs.

The BSRLs for each trace element in soils and sediments varied considerably (Table 2, Figures 5–8). The smallest and largest BSRLs were 0.04 and 147 $\mu g\ g^{-1}$ for Hg and Ba, respectively, for DARHT facility soils; similar data for DARHT facility sediments demonstrated values of 0.04 and 161 $\mu g\ g^{-1}$. Just as with the radionuclide data for DARHT facility soils and sediments, Figures 5 through 8 show that there was no significant difference in the mean concentrations of trace elements between these two sample types.

We also compared trace elements in DARHT facility soils and sediments with several other sources of information (Figures 5–8). The first comparison was with elemental values found at the same RBG and RSRL sampling stations from 1992 through 1999 discussed previously with the radionuclide data. The second comparison was with a comprehensive study performed at the Laboratory involving sampling the Bandelier Tuff and several soil profiles (identified as "BG (Lab)" in Figures 5–8) to determine background elemental concentrations (Longmire et al., 1996).

Figures 5 through 8 show that there were no significant differences between trace element concentrations found in DARHT facility soils and sediments and those found in RBG samples, with one exception. The RBG concentrations of copper found in soils were significantly higher than the copper levels found in the DARHT facility soil

Table 2. Mean (±SD) total trace element (baseline) concentrations (µg g^{-1} dry) in soils, sediments, and ve collected around the DARHT facility from 1996 through 1999 (construction phase).

Sample Type	Ag	As	Ba	Be	Cd	Cr	Cu	Hg	Ni	Pb	Sb
Soil	0.66	1.50	85.0	0.70	0.22	7.69	3.88	0.02	4.54	7.88	0.2
	(0.48)	(0.83)	(30.9)	(0.19)	(0.15)	(3.36)	(1.57)	(0.01)	(2.54)	(2.83)	(0.0
Soil BSRL[a]	1.62	3.16	147	1.08	0.52	14.4	7.02	0.04	9.62	13.5	0.4
Sediment	0.78	2.16	101	0.75	0.27	7.89	4.82	0.02	5.49	9.49	0.2
	(0.39)	(0.66)	(29.8)	(0.22)	(0.14)	(2.05)	(1.54)	(0.01)	(1.98)	(2.95)	(0.0
Sediment BSRL[a]	1.56	3.48	161	1.19	0.55	12.0	7.90	0.04	9.45	15.4	0.3
Vegetation											
Overstory (OS)	0.37	0.16	27.2	0.09	0.24	0.44	3.46	0.02	1.59	2.42	2.0
	(0.33)	(0.06)	(20.4)	(0.02)	(0.16)	(0.28)	(0.57)	(0.02)	(1.68)	(1.84)	(3.2
OS BSRL[a]	1.03	0.28	67.9	0.13	0.56	1.00	4.60	0.06	4.95	6.10	8.5
Understory (US)	0.41	0.16	45.4	0.08	0.24	0.39	7.69	0.03	1.84	1.05	2.1
	(0.35)	(0.06)	(18.3)	(0.02)	(0.16)	(0.19)	(2.35)	(0.03)	(1.87)	(1.07)	(3.2
US BSRL[a]	1.11	0.28	82.0	0.12	0.56	0.77	12.4	0.09	5.58	3.19	8.5

[a]BSRL is the baseline statistical reference level.

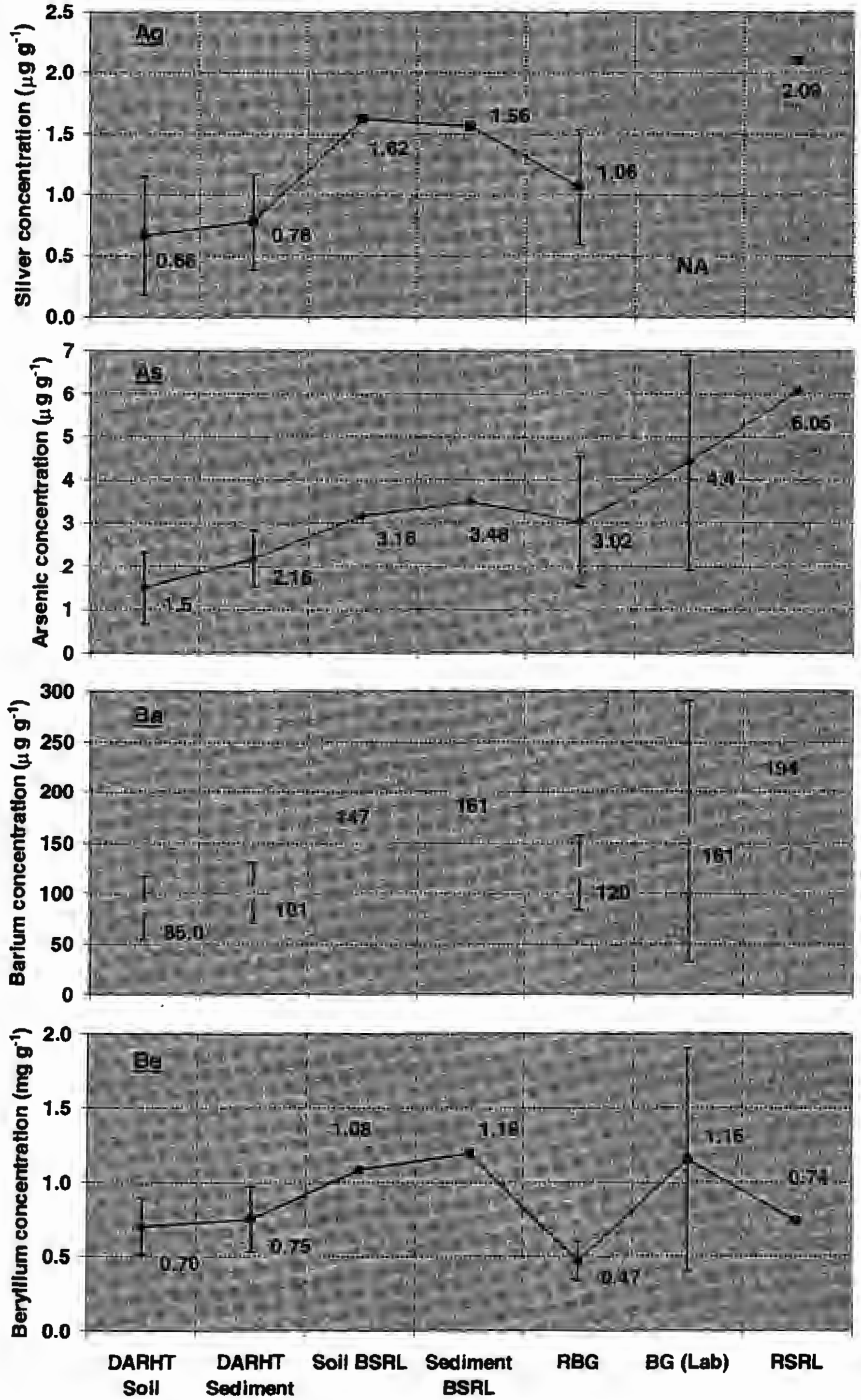

Figure 5. Concentrations of Ag, As, Ba, and Be in soils and sediments.

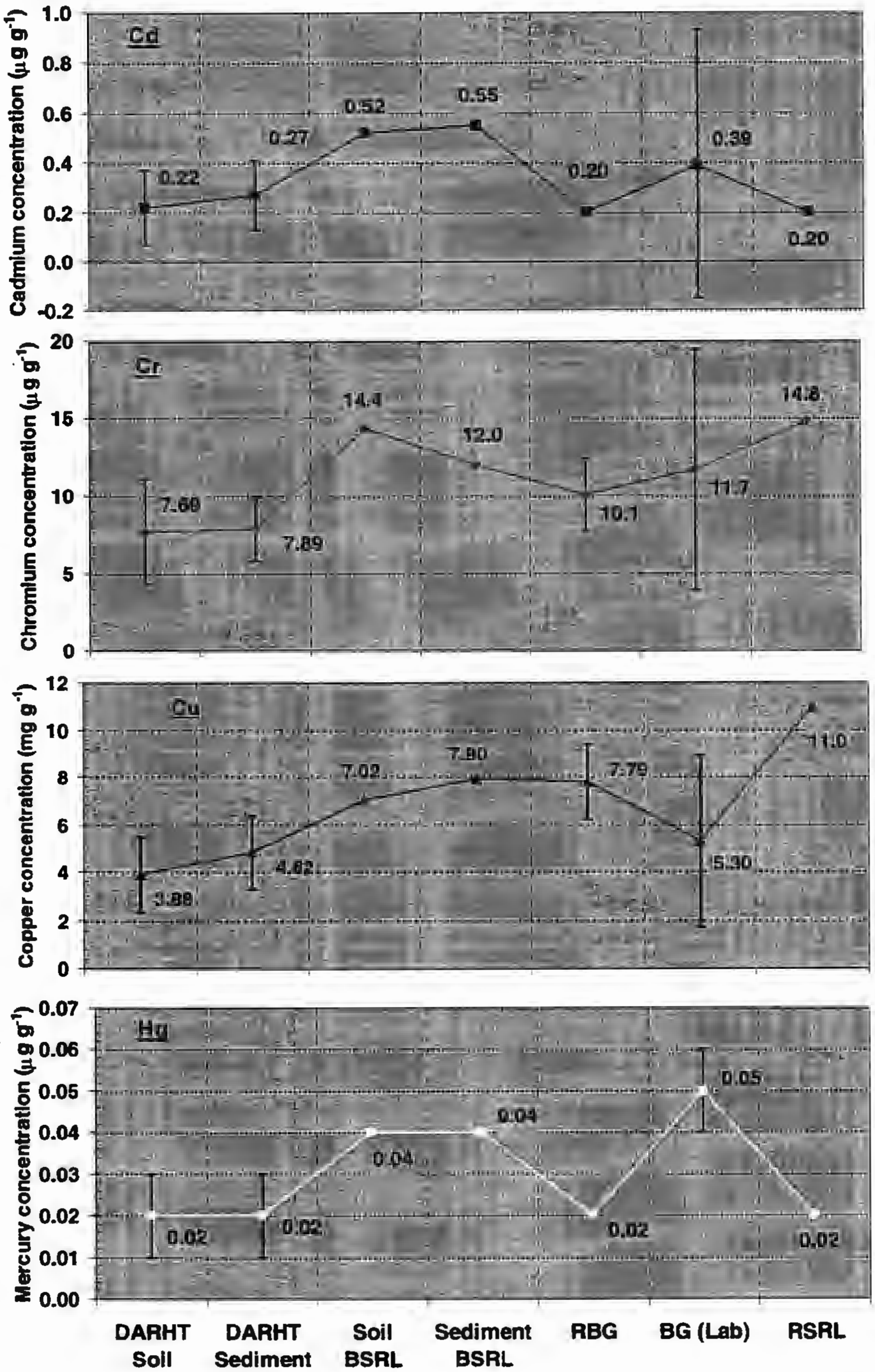

Figure 6. Concentrations of Cd, Cr, Cu, and Hg in soils and sediments.

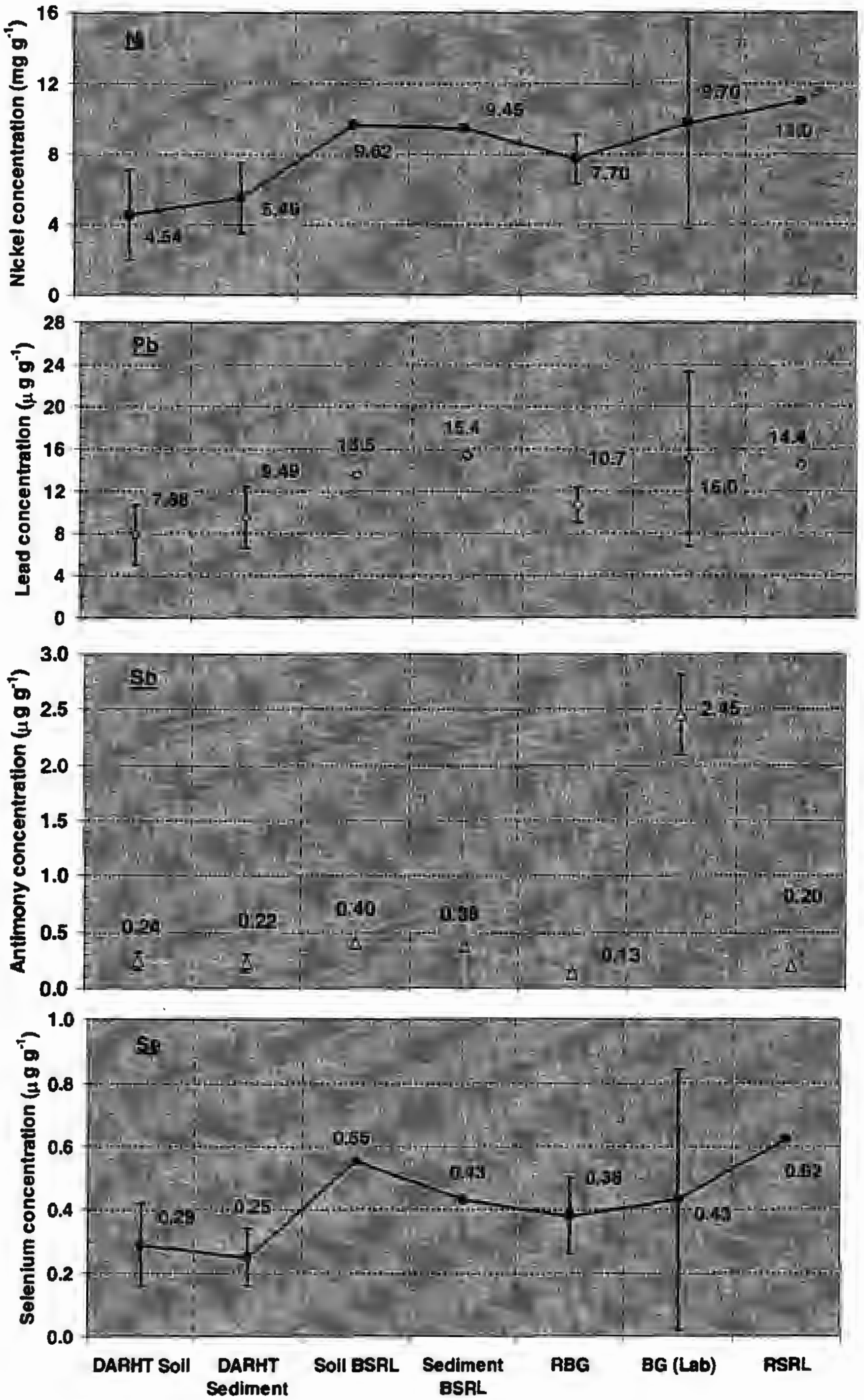

Figure 7. Concentrations of Ni, Pb, Sb, and Se in soils and sediments.

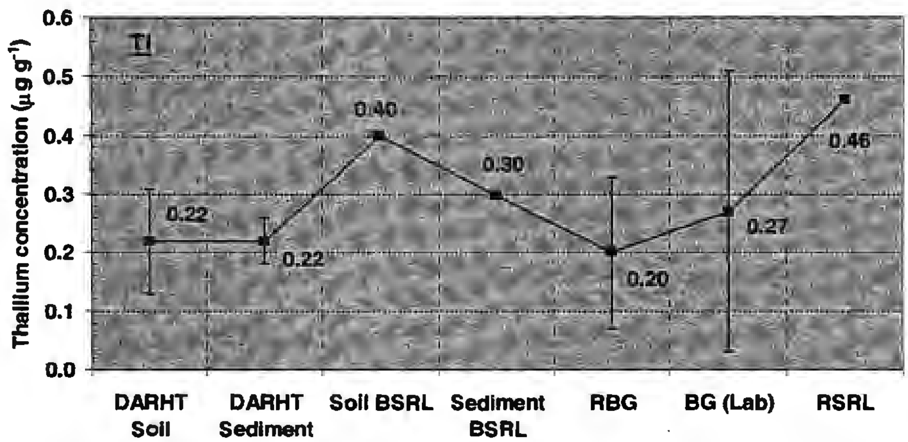

Figure 8. Concentrations of Tl in soils and sediments.

samples (Figure 6). Also, there was no significant difference between Longmire et al.'s BG (Lab) elemental concentrations verses those found in either DARHT facility soils and sediments or the RBG samples, with two exceptions. The BG (Lab) results for both mercury (Figure 6) and antimony (Figure 7) were both statistically higher than the DARHT facility soils, DARHT facility sediments, and RBG samples. The RSRL elemental concentrations were generally statistically larger than the corresponding trace element concentrations found in the DARHT facility soils and sediments with only three exceptions. In these three cases (beryllium, cadmium, and antimony) the elemental concentrations in the DARHT facility samples were only slightly elevated above the RSRL values (Figures 5–8).

SVOC and VOC assays were also performed on the DARHT facility soils and sediments (Fresquez et al., 1999). There were no VOCs detected in any of the soil or sediment samples collected around the DARHT facility and only trace amounts of a few SVOCs. The SVOCs detected were methylene chloride (25 $\mu g\ kg^{-1}$) in a soil sample collected at the north location and in a sediment sample (6.2 $\mu g\ kg^{-1}$) collected at the east location; styrene in a soil sample collected from the south location (2.1 $\mu g\ kg^{-1}$) and the east location (1.9 $\mu g\ kg^{-1}$); and chloroform (1.5 $\mu g\ kg^{-1}$) in a sediment sample collected at the north location.

Vegetation

One important component of this program is the assessment of vegetation growing within and around the DARHT facility for radiological contamination. The uptake of isotopes by vegetation, for example, may give some insight into surface (Hanson et al., 1980) and subsurface (Wenzel et al., 1987) contaminant pathways to humans. Trees, in particular, have been shown to be excellent indicators of subterranean ^{3}H migration out of waste disposal sites (Rickard and Kirby, 1987).

Baseline radionuclide concentrations in overstory and understory vegetation over a four-year period at the DARHT facility (1996 to 1999) can be found in Table 1 and Figures 9 and 10, which show the mean and two standard deviations of the concentrations of ^{3}H, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and ^{tot}U. These concentrations of radionuclides are important because the mean DARHT facility sample concentrations plus two standard deviations represent the preoperational BSRLs.

The data presented in Figures 9 and 10 show that the BSRLs for each radionuclide in vegetation samples varied considerably. The BSRLs for DARHT facility overstory vegetation varied from 0.006 to 8.03 pCi g^{-1} ash for $^{239,240}Pu$ and ^{90}Sr, respectively, whereas ^{238}Pu and ^{90}Sr data for DARHT facility understory vegetation ranged from 0.004 to 4.75 pCi g^{-1}, respectively. However, even though the actual BSRL values for each radionuclide were slightly different for overstory and understory vegetation, Figures 9 and 10 show that there was no significant difference in the mean concentrations of radionuclides between these two sample types.

A comparison was made between radionuclide concentrations found in DARHT facility unwashed overstory and understory vegetation samples and those found in RBG samples (Table 1, Figures 9 and 10). When radionuclide concentrations for either overstory or understory samples are compared, no significant differences were found between radionuclide concentrations found in DARHT facility vegetation samples verses those found in RBG samples, except for $^{239,240}Pu$. Average concentrations of $^{239,240}Pu$ found in RBG samples of overstory vegetation (0.051 pCi g^{-1}) were significantly higher than $^{239,240}Pu$ concentrations in overstory vegetation at the DARHT facility (0.002 pCi g^{-1}). Also notice that within the RBG vegetation

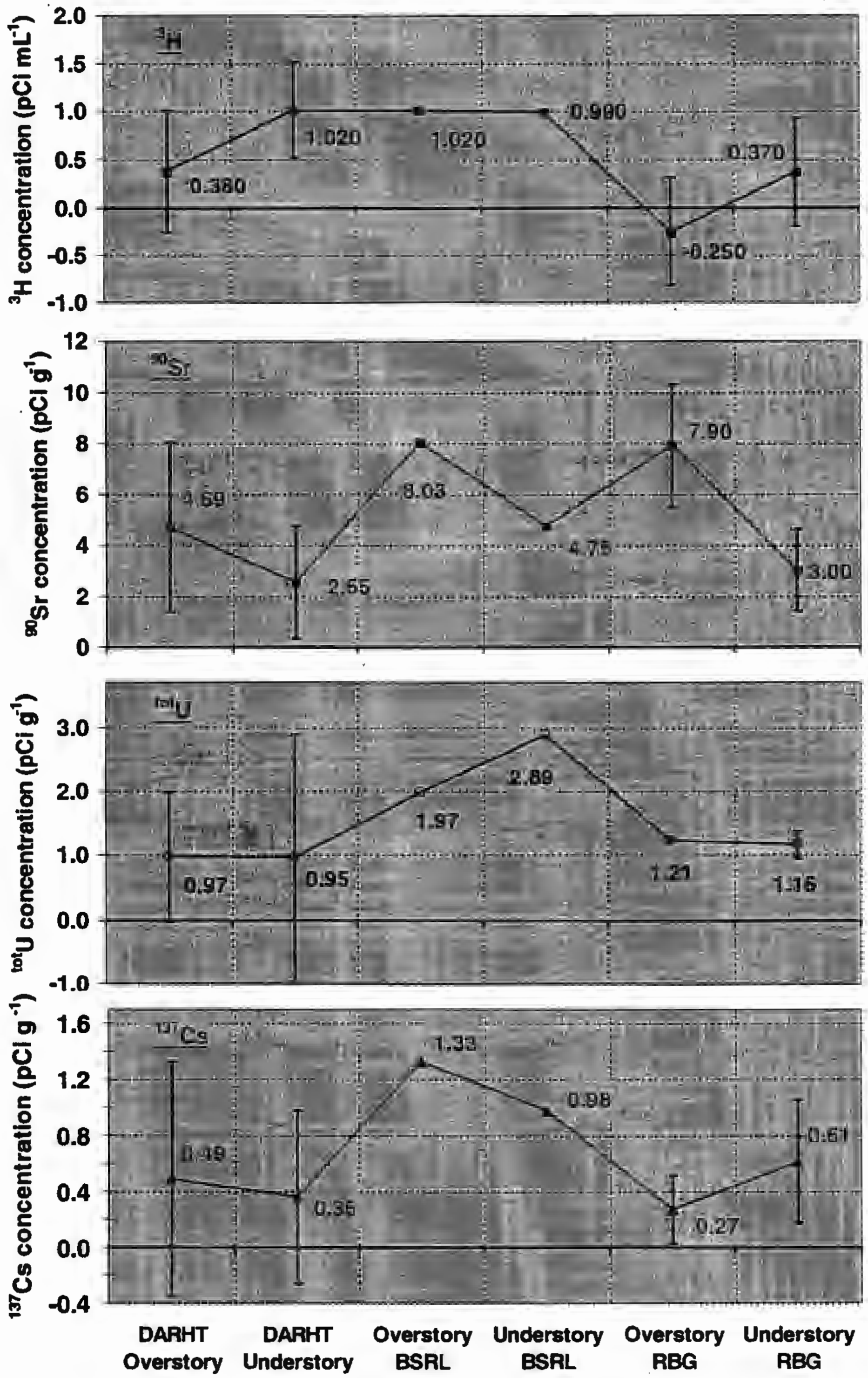

Figure 9. Concentrations of ^3H, ^{90}Sr, ^{tot}U, and ^{137}Cs in overstory and understory vegetation.

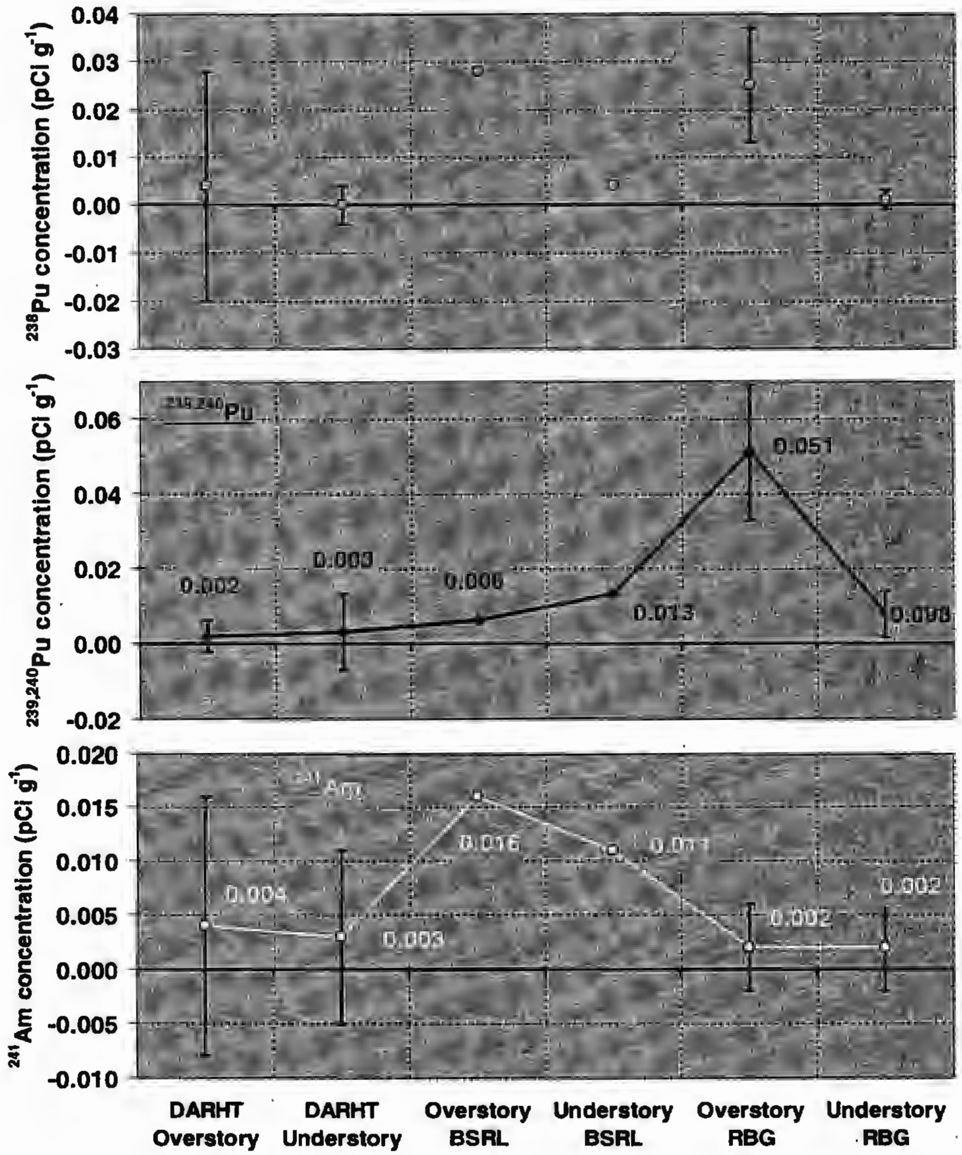

Figure 10. Concentrations of ^{238}Pu, ^{239,240}Pu, and ^{241}Am in overstory and understory vegetation.

samples, concentrations of ^{90}Sr, ^{238}Pu, and ^{239,240}Pu were statistically larger in overstory samples than understory samples.

The mineral nutrition of higher plants is of fundamental importance to agriculture and human health, yet many basic questions remain unanswered, particularly in relation to the accumulation of essential heavy metals. It is unclear how plants ensure that all tissues receive an adequate supply of the heavy metals required for vital cellular processes, yet prevent them from accumulating to toxic levels. At high concentrations these metals can become extremely toxic, as do the non-essential metals, causing symptoms such as chlorosis and necrosis, stunting, leaf discoloration, and inhibition of root growth (Marschner, 1995; vanAssche and Clijsters, 1990). Heavy metals such as Cu, Zn, Mn, Fe, Ni, and Co are essential micronutrients for plant metabolism but when present in excess, these, and non-essential metals such as Cd, Hg, and Pb, can become extremely toxic (Williams et al., 2000). For example, Cu is an essential trace element that is involved in a number of electron transport reactions in both photosynthesis and respiration, while a wide range of enzymes either contain or are activated by Zn and Mn (Marschner, 1995).

Trace element concentrations in overstory and understory vegetation at the DARHT facility are presented in Table 2 and Figures 11 through 15, which show the mean and two standard deviations of the concentrations of Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl. These concentrations of trace elements are important because the mean DARHT facility sample concentrations plus two standard deviations represent the preoperational BSRLs. The BSRLs for each trace element in overstory and understory vegetation varied considerably. The smallest and largest BSRLs were 0.06 and 67.9 $\mu g\ g^{-1}$ for Hg and Ba, respectively, for DARHT facility overstory samples; similar data for DARHT facility understory vegetation demonstrated values of 0.09 and 82 $\mu g\ g^{-1}$. Just as with the radionuclide data for DARHT facility vegetation, Figures 11 through 15 show that there was no significant difference between the mean concentrations of trace elements in DARHT facility overstory and understory samples.

We also compared trace elements in DARHT facility vegetation samples with several other sources of information (Figures 11–15). The first comparison was with RBG locations near Bandelier National Monument (BNM) approximately 3 mi (5 km) south of Area G (Fresquez et al., 1996c, 1997b; Nyhan et al., 2000), except for the understory RBG values (Fresquez et al., 1990). The BNM contaminant data collected for vegetation in the past shows this site to be beyond the range of potential influence from normal Laboratory operations. No statistically significant differences were found between trace element concentrations found in

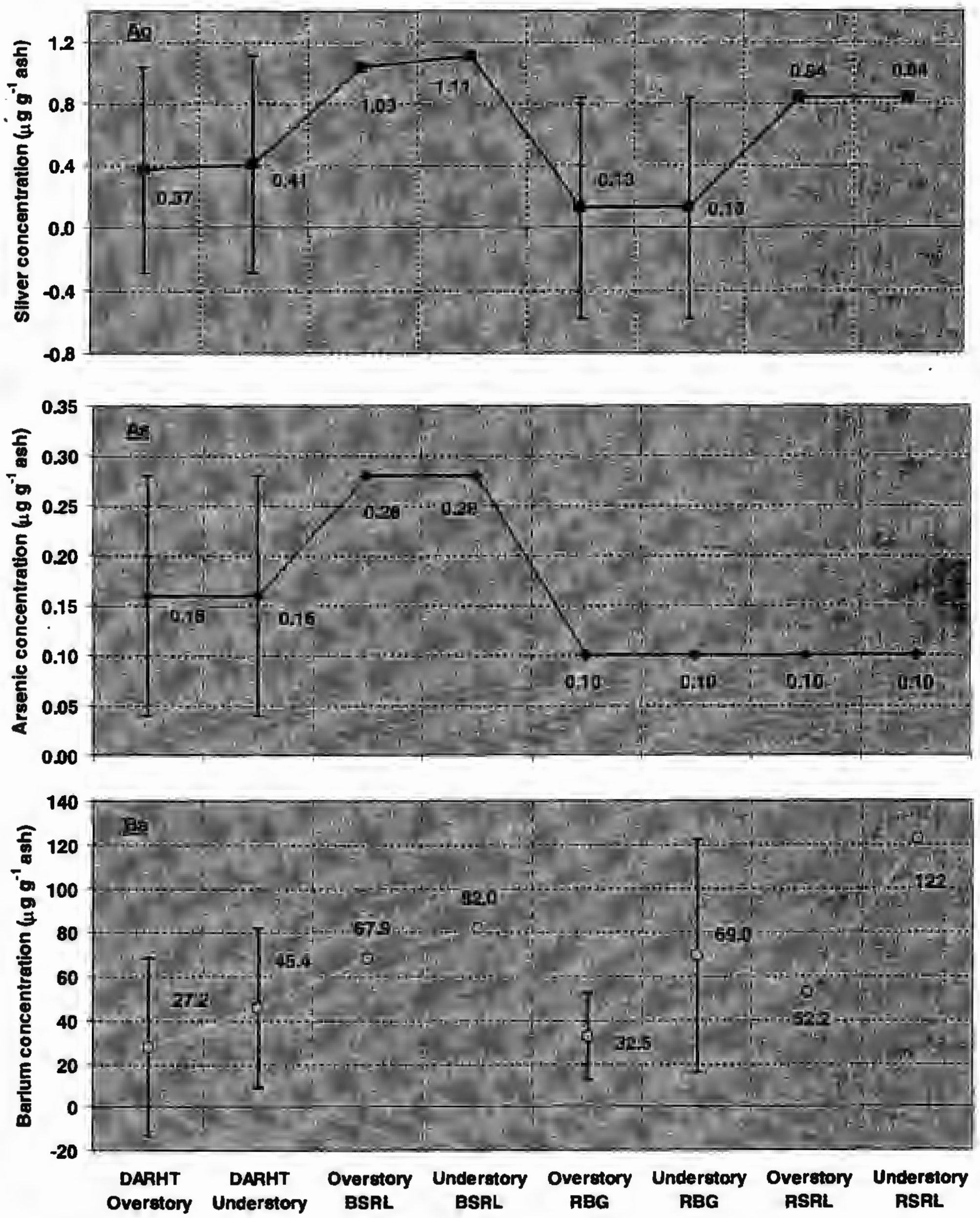

Figure 11. Concentrations of Ag, As, and Ba in overstory and understory vegetation.

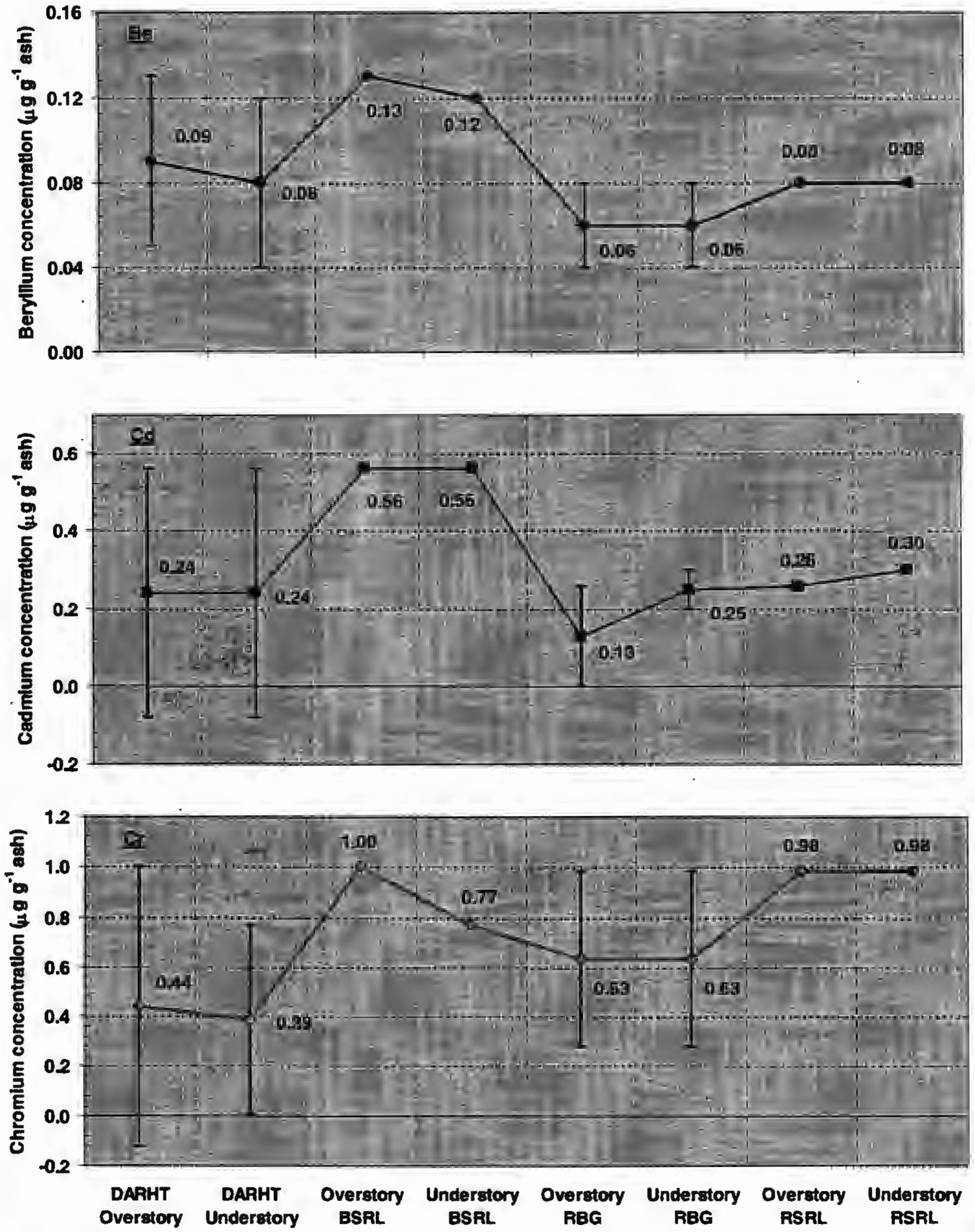

Figure 12. Concentrations of Be, Cd, and Cr in overstory and understory vegetation.

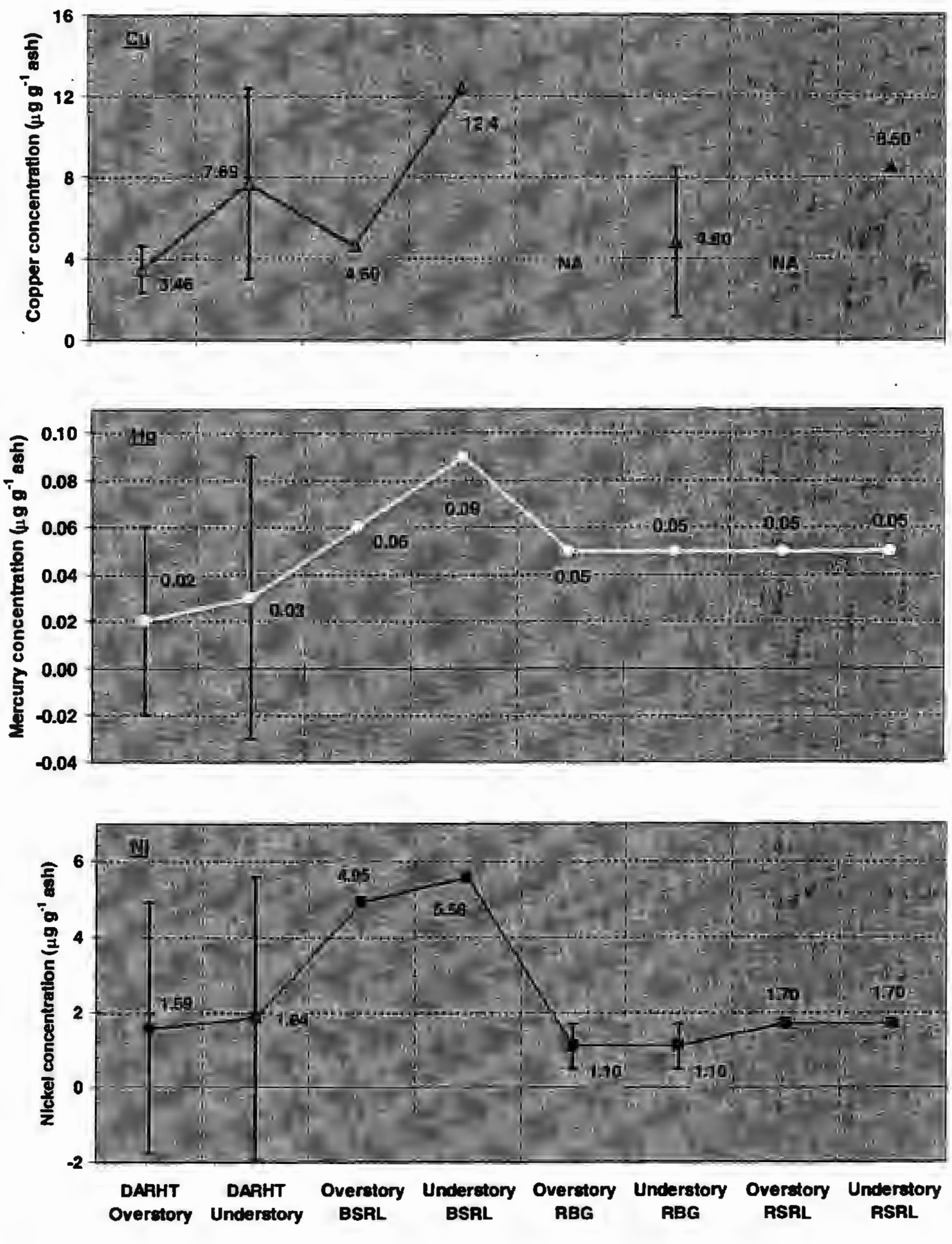

Figure 13. Concentrations of Cu, Hg, and Ni in overstory and understory vegetation.

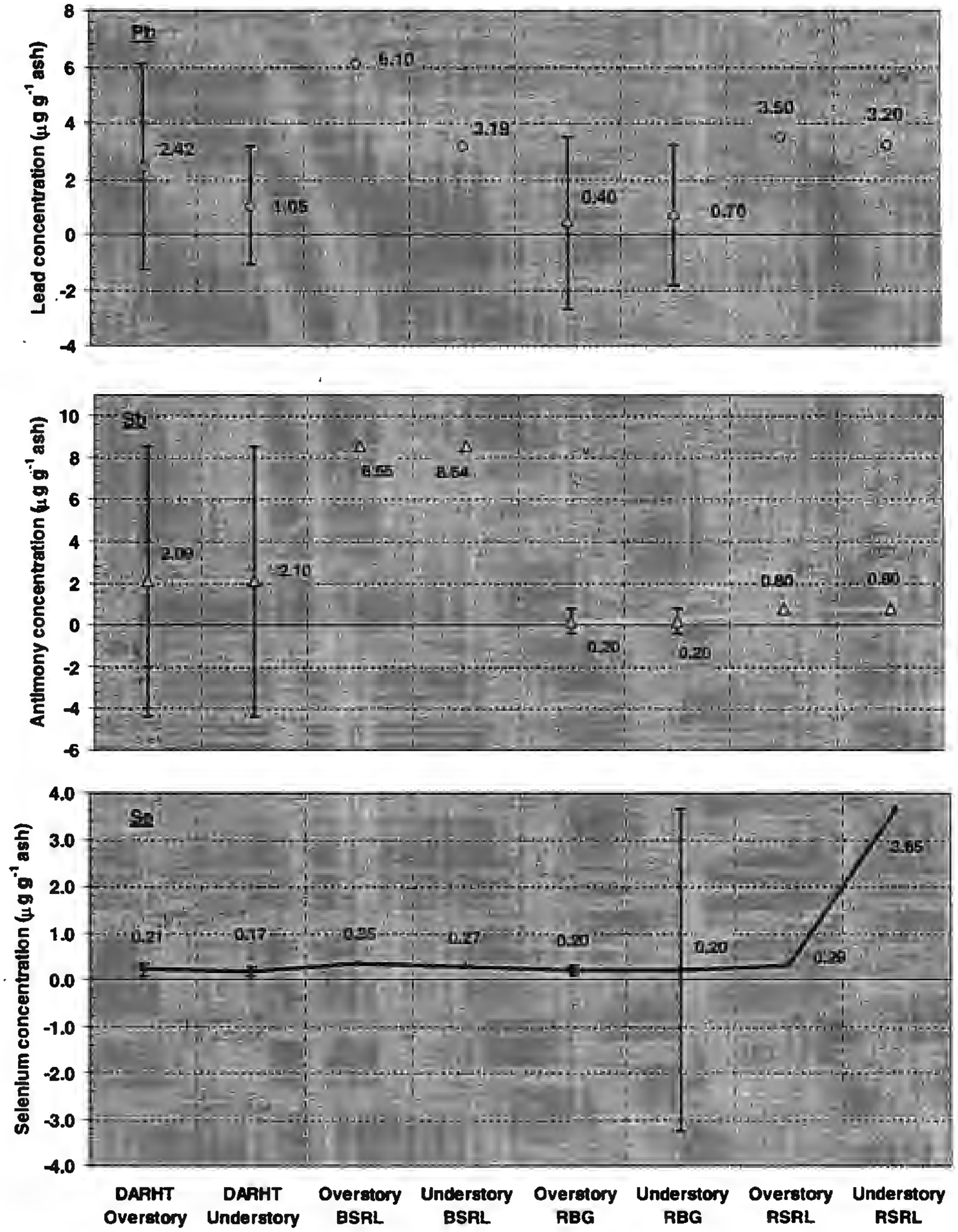

Figure 14. Concentrations of Pb, Sb, and Se in overstory and understory vegetation.

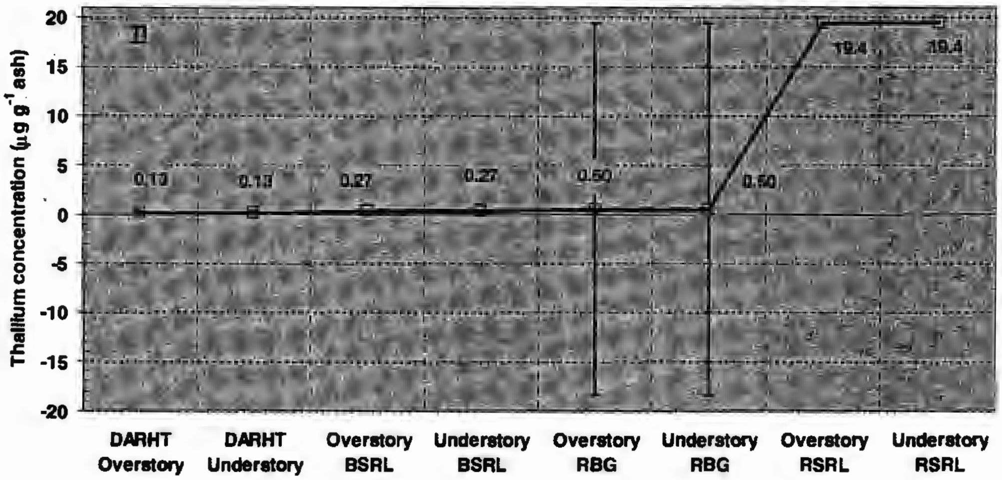

Figure 15. Concentrations of Tl in overstory and understory vegetation.

DARHT facility vegetation samples verses those found in RBG samples. Also, unlike the radionuclide results for vegetation discussed previously, there were no statistically significant differences between trace element concentrations in overstory verses understory samples collected at either the DARHT site or the RBG site.

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DARHT FACILITY SMALL MAMMAL BASELINE REPORT FOR RADIONUCLIDES (1997–1999)

by
K. Bennett, J. Biggs, P.R. Fresquez, and H.T. Haagenstad

ABSTRACT

Through a multi-year study (1997–1999), the Ecology group studied the baseline concentrations of ^{241}Am, ^{90}Sr, ^{238}Pu, ^{239,240}Pu, total U (^{tot}U), ^{137}Cs, and ^{3}H in small mammal (rodent) populations found in and around the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos National Laboratory. The collection and analysis of small mammals in the vicinity of the DARHT facility were intended to provide data to aid in meeting requirements of Department of Energy Order 5400.1, which specifies monitoring of contaminants at potential release sites. The objective of this study was to quantitatively estimate the amount of radionuclide uptake at the sampling locations by sampling carcasses of burrowing nocturnal small mammals and to calculate a baseline statistical reference level (BSRL) to make comparisons during the operational phase of the DARHT facility. Small mammals were sampled once per year and the carcasses were analyzed for radionuclides. Concentrations of radionuclides found in the carcasses of small mammals were compared over the three-year sampling period. Some radionuclides (^{tot}U, ^{241}Am, and ^{137}Cs) had statistically (α = 0.05) higher concentrations during 1997 than subsequent years. However, a statistically (α = 0.05) higher concentration of ^{3}H was found in small mammal carcasses in 1999 compared to those found in 1997 and 1998. From these data, a BSRL was calculated for each radionuclide analyzed. The BSRL will be used for future comparisons of small mammal carcasses sampled at the DARHT site during the operational years.

A. INTRODUCTION

Through a multi-year study, the Ecology group (ESH-20) studied the radionuclide baseline concentrations in small mammal (rodent) populations found in and around the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos National Laboratory (LANL). The collection and analysis of small mammals in the vicinity of the DARHT facility was intended to provide data to aid in meeting requirements of

Department of Energy Order 5400.1, which specifies monitoring of contaminants at potential release sites. The Order included as part of the DARHT Mitigation Action Plan (USDOE, 1996) commitment to protecting natural and cultural resources during the construction, operation, and future decommissioning phases of the DARHT facility.

Rodents are effective indicators of contaminant presence because of their feeding and activity habits (i.e., burrowing). Collection and analysis of small mammal tissues is currently in place at facilities within LANL Technical Areas that may be characterized as potential release sites. These studies are aimed at identifying radionuclides present and monitoring concentration amounts over time to obtain trend analysis. The collection and sampling of small mammals in the vicinity of the DARHT facility before the operation of the facility will provide a baseline of contaminant concentrations that can be compared to post-operational activities to determine if release of contaminants is occurring over time.

This study was used to quantitatively estimate the amount of radionuclide uptake at the sampling locations by sampling carcasses of burrowing nocturnal small mammals. This information will be used as a reference of baseline conditions before DARHT facility operation.

B. METHODOLOGY

Rodent sampling took place in May 1997, 1998, and 1999. Three trapping grids were placed immediately north of the DARHT facility; two grids south of the main paved road and the third grid north of the road (Figure 1). Each grid consisted of 100 snap or Sherman traps (Figure 2) placed approximately 10 m apart in a 10 by 10 design. Snap trapping took place over 3 to 4 nights (until at least 15 animals were captured at each site). Procedures for handling and field processing of small mammals with respect to potential infection of Hantavirus were given previously (Mills et al., 1995; Biggs and Bennett, 1995). These same safety procedures were followed for collecting tissue samples from snap-trapped or Sherman-trapped animals. Snap or Sherman traps were baited and set in late afternoon and checked in early morning. Animals were removed from traps, placed in plastic sealed bags (Figure 2), and taken to a central processing station where physical measurements were made and pelts removed.

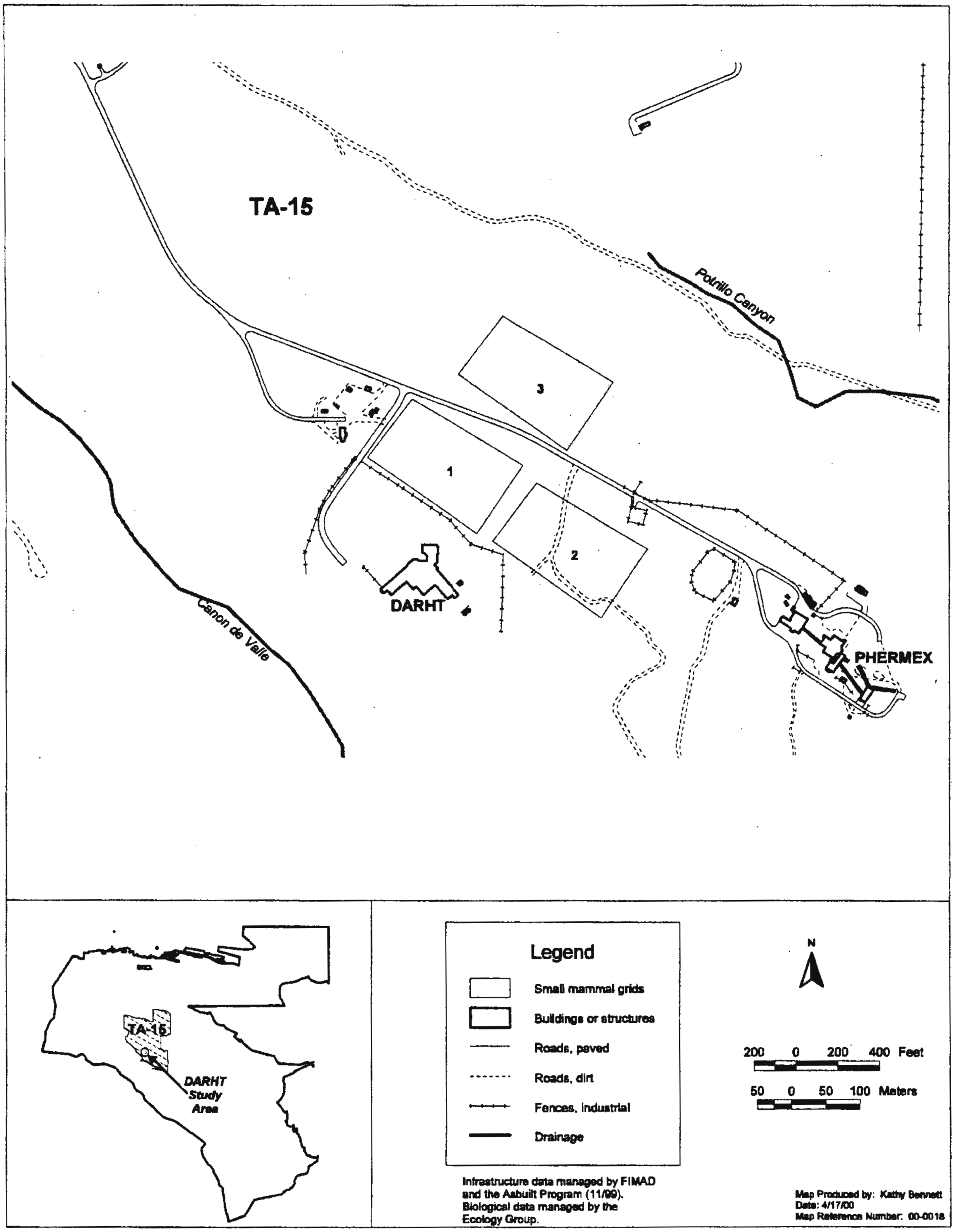

Figure 1. Location of the small mammal trapping areas around the DARHT facility.

Figure 2: A Sherman trap (left) and a deer mouse placed in a plastic bag (right).

Precautions during handling were taken to minimize cross contamination from carcass to pelt while removing pelts. All external hair was removed from the animal's appendages. The pelt was separated from the carcass of each animal and analysis was run on the carcass only for each radionuclide. The samples were placed into 1-L glass beakers and heated to collect distillated water for ^{3}H analysis (Salazar, 1987). In addition, the beaker contents were ashed at 500 °C for 120 h. The sample ash was pulverized and homogenized before it was submitted to a LANL Chemical Science and Technology Division analytical laboratory for the analysis of ^{241}Am, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{tot}U, and ^{137}Cs. All methods of radiochemical analysis have been described previously (Salazar, 1987). Results were reported in pCi L^{-1} of tissue moisture for ^{3}H, µg g^{-1} ash for total uranium, and pCi g^{-1} of ash for the other radionuclides.

Data from each grid were pooled and a General Linear Model (GLM) with a multiple range test (MRT) was used to determine if there were statistical differences in sample concentrations for each radionuclide between years. A baseline statistical reference level (BSRL) was also calculated for each radionuclide. All samples from the three-year sampling period were pooled and the mean and standard deviation calculated. The BSRL represents the mean sample concentration plus two standard deviations.

C. RESULTS

Radionuclide concentrations found in small mammal carcasses are summarized by year in Tables 1, 2, and 3. Concentrations are in pCi g^{-1} ash for all radionuclides with the exception of H^3, which are expressed in pCi L^{-1}. The tables list individual composite sample results with its analytical uncertainty as well as the mean concentration and standard deviation for each sampling grid. The mean ^{tot}U concentrations for the past three years ranged from 0.08 to 1.87 μg g^{-1}, whereas ^{241}Am ranged from 0.004 to 1.045 pCi g^{-1}. Concentrations of ^{238}Pu ranged from –0.04 to 3.578 pCi g^{-1}, compared with $^{239,240}Pu$ concentrations, which ranged from –0.001 to 63.1 pCi g^{-1}. Concentrations of ^{137}Cs ranged from –0.01 to 1.51 pCi g^{-1}, whereas ^{90}Sr ranged from –0.36 to 7.62 pCi g^{-1} and ^{3}H ranged from –283 to 423 pCi L^{-1}. Some of the highest radionuclide concentrations were found in animals taken from Grid 3.

BSRL values were calculated for ^{3}H, ^{tot}U, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, and ^{241}Am. BSRL was calculated using the site mean concentration plus two standard deviations (STD). The BSRL will be used for future comparisons of small mammal carcasses sampled at the DARHT site during the operational years. Table 4 gives the mean radionuclide concentration found in small mammal carcass by year and grid and the calculated BSRL for the DARHT site for each radionuclide.

Table 5 lists the results of the GLM and the MRT. The 1997 small mammal carcass concentrations of ^{tot}U, ^{241}Am, and ^{137}Cs were statistically higher than the 1998 or 1999 concentrations. However, H^3 concentrations in small mammal carcasses were found to be statistically higher in 1999 than the two previous years.

D. SUMMARY

The primary objective outlined in the FY97 statement of work was to collect and sample small mammal carcasses for radionuclide (^{3}H, ^{tot}U, ^{137}Cs, ^{90}Sr, ^{241}Am and $^{238,239}Pu$) concentrations. Baseline data were collected from 1997 to 1999. Some radionuclides (^{tot}U, ^{241}Am, and ^{137}Cs) had statistically higher concentrations during 1997 than subsequent years. However, a statistically higher concentration in ^{3}H was found in small mammal carcasses in 1999 compared to 1997 and 1998. From these data, a BSRL was calculated for each radionuclide analyzed. The BSRL will be used for future

Table 1. Total radionuclide concentrations in small mammal carcasses, DARHT project area, 1997. Values represent uncertainties.

Grid	Sample Number	^{tot}U (μg g^{-1})	^{241}Am (pCi g^{-1})	^{238}Pu (pCi g^{-1})	^{239,240}Pu (pCi g^{-1})	^{137}Cs (pCi g^{-1})	^{3}H (pCi L^{-1})	9 (pC
01	1	0.46	0.977	0.0367	0.0069	0.41	280	-(
		(0.05)	(0.044)	(0.0053)	(0.0029)	(0.61)	(780)	(1
01	2	0.68	0.075	0.0925	1.4052	0.44	320	-(
		(0.07)	(0.002)	(0.0056)	(0.0453)	(0.11)	(780)	(1
01	3	0.81	0.002	-0.0027	0.0121	0.21	200	-(
		(0.08)	(0.007)	(0.0023)	(0.0056)	(0.32)	(780)	(2
Mean		0.65	0.329	0.0422	0.4747	0.35	267	-(
(STD)		(0.85)	(0.005)	(0.01)	(0.01)	(0.32)	(185)	(1
02	1	1.40	0.573	0.0018	0.0172	0.13	410	-(
		(0.14)	(0.029)	(0.0013)	(0.0028)	(0.19)	(790)	(0
02	2	0.82	0.064	0.0001	0.0051	0.72	20	-1
		(0.08)	(0.007)	(0.0018)	(0.0025)	(0.17)	(770)	(2
02	3	1.09	0.003	0.0011	0.0027	0.57	190	-(
		(0.11)	(0.003)	(0.0012)	(0.0016)	(0.18)	(770)	(1
Mean		1.10	0.213	0.0010	0.0083	0.47	207	-(
(STD)		(0.29)	(0.31)	(0.001)	(0.01)	(0.31)	(195)	(0
03	1	1.35	1.37	10.7	189	1.80	230	2
		(0.14)	(0.891)	(6.037)	(105)	(0.38)	(780)	(21
03	2	2.33	0.628	0.0142	0.0104	1.02	110	0
		(0.23)	(0.040)	(0.0065)	(0.0066)	(1.53)	(770)	(1
03	3	1.93	1.14	-0.0006	-0.0066	1.70	-120	-(
		(0.19)	(0.069)	(0.0032)	(0.0036)	(0.47)	(760)	(2
Mean		1.87	1.05	3.58	63.1	1.51	73	7
(STD)		(0.49)	(0.38)	(6.18)	(109)	(0.42)	(177)	(1

Table 2. Total radionuclide concentrations in small mammal carcasses, DARHT project area, 1998. Va represent uncertainties.

Grid	Sample Number	^{tot}U (µg g^{-1})	^{241}Am (pCi g^{-1})	^{238}Pu (pCi g^{-1})	$^{239,240}Pu$ (pCi g^{-1})	^{137}Cs (pCi g^{-1})	^{3}H (pCi L^{-1})	9 (pC
G1	1	0.10	.0079	-.0003	.0082	-0.14	-230	1
		(0.01)	(.0029)	(.0010)	(.0021)	(0.11)	(690)	(0
G1	2	0.06	.0045	.0021	.0052	0.02	-30	1
		(0.01)	(.0034)	(.0034)	(.0031)	(0.03)	(700)	(0
G1	3	0.09	.0131	-.0004	.0016	-0.18	100	0
		(0.01)	(.0025)	(.0011)	(.0020)	(0.10)	(710)	(0
Mean		0.08	.0085	.0005	.005	-0.10	-53	0
(STD)		(0.02)	(.0043)	(.0014)	(.0033)	(0.11)	(166)	(0
G2	1	0.19	-.0014	-.0017	.0014	-0.11	-250	0
		(0.02)	(.0036)	(.0008)	(.0017)	(0.11)	(690)	(0
G2	2	0.18	.0001	.0003	.0008	0.48	-60	1
		(0.02)	(.0023)	(.0008)	(.0011)	(0.13)	(700)	(0
G2	3	0.15	.0116	-.0026	.0001	1.36	-40	0
		(0.02)	(.0025)	(.0009)	(.0013)	(2.04)	(700)	(0
Mean		0.17	.003	-.0013	.0008	0.58	-117	0
(STD)		(0.02)	(.007)	(.0015)	(.0007)	(0.74)	(116)	(0
		0.11	.0090	.0006	-.0003	0.90	-430	0
G3	1	(0.01)	(.0021)	(.0016)	(.0022)	(0.25)	(680)	(0
		0.15	.0119	.0018	.0037	-0.49	-140	0
G3	2	(0.01)	(.0032)	(.0031)	(.0051)	(0.11)	(700)	(0
		0.17	.0097	.0009	-.0016	-0.45	-280	0
G3	3	(0.02)	(.0022)	(.0012)	(.0011)	(0.10)	(690)	(0
Mean		0.14	.0102	.0011	.0006	-0.01	-283	0
(STD)		(0.03)	(.0015)	(.0006)	(.0028)	(0.79)	(145)	(0

Table 3. Total radionuclide concentrations in small mammal carcasses, DARHT project area, 1999. Values represent uncertainties.

Grid	Sample Number	^{tot}U ($\mu g\ g^{-1}$)	^{241}Am ($pCi\ g^{-1}$)	^{238}Pu ($pCi\ g^{-1}$)	$^{239,240}Pu$ ($pCi\ g^{-1}$)	^{137}Cs ($pCi\ g^{-1}$)	^{3}H ($pCi\ L^{-1}$)	9 (p(
G1	1	0.33	0.0122	0.0060	0.0079	0.108	330	3
		(0.03)	(0.0023)	(0.0030)	(0.0030)	(0.628)	(620)	(C
G1	2	0.34	0.0084	0.0098	0.0041	0.395	360	2
		(0.03)	(0.0043)	(0.0036)	(0.0053)	(0.162)	(620)	(C
G1	3	0.32	0.0041	0.0069	0.0028	0.174	130	4
		(0.03)	(0.0014)	(0.0025)	(0.0061)	(1.255)	(600)	(C
Mean		0.33	0.01	-0.01	-0.01	0.23	273	
(STD)		(0.01)	(0.004)	(0.002)	(0.003)	(0.15)	(125)	(C
G2	1	0.25	0.0036	0.0054	0.0048	0.221	370	3
		(0.03)	(0.0010)	(0.0023)	(0.0039)	(0.841)	(620)	(C
G2	2	0.20	0.0053	0.0031	0.0012	0.009	530	2
		(0.02)	(0.0014)	(0.0018)	(0.0020)	(0.648)	(630)	(C
G2	3	0.55	0.0123	-.0023	0.0024	0.355	370	1
		(0.06)	(0.0026)	(0.0016)	(0.0027)	(0.099)	(620)	(C
Mean		0.33	0.004	-0.004	-0.001	0.20	423	2
(STD)		(0.19)	(0.007)	(0.002)	(0.004)	(0.17)	(92.4)	(
G3	1	0.57	.0021	-0.0019	-0.0048	0.869	240	5
		(0.06)	(.0007)	(0.0048)	(0.0034)	(0.171)	(610)	(C
G3	2	0.26	.0038	-0.0242	-0.0139	0.00	400	N
		(0.03)	(.0011)	(0.0072)	(0.0061)	(1.29)	(620)	
G3	3	0.42	0.003	-0.0039	-0.0039	0.00	330	1
		(0.04)	(.001)	(0.0028)	(0.0037)	(1.56)	(620)	(C
Mean		0.42	0.03	-0.01	-0.01	0.29	323	3
(STD)		(0.16)	(0.00)	(0.01)	(0.01)	(0.50)	(80.0)	(2

N/A = Sample not available due to insufficient sample size.

Table 4. Mean radionuclide concentrations of small mammal carcasses from the DARHT study site and the in pCi g^{-1} for all samples except ^{3}H, which are in pCi L^{-1}.

	1997			1998			1999			DARHT 3-YEAR A		
Radio-nuclide	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
^{tot}U (µg g^{-1})	0.65	1.10	1.87	0.08	0.17	0.14	0.33	0.33	0.42	0.35	0.54	0.81
^{241}Am (pCi g^{-1})	0.33	0.21	1.04	0.01	0.00	0.01	0.01	0.01	0.003	0.12	0.07	0.35
^{238}Pu (pCi g^{-1})	0.04	0.00	3.6	0.00	0.00	0.00	-0.01	-0.004	-0.01	0.01	-0.002	1.19
^{239,240}Pu (pCi g^{-1})	0.47	0.01	63.1	0.01	0.00	0.00	-0.01	-0.001	-0.01	0.16	0.003	21.04
^{137}Cs (pCi g^{-1})	0.35	0.47	1.51	-0.10	0.58	-0.01	0.23	0.20	0.29	0.16	0.42	0.59
^{3}H (pCi L^{-1})	267	207	73	-53	-117	-283	273	423	323	162	171	37.78
^{90}Sr (pCi g^{-1})	-0.36	-0.89	7.62	0.94	0.82	0.54	3.4	2.62	3.35	1.33	0.85	3.90

[1]BSRL was calculated using the site mean concentration plus two standard deviations (STD).

Table 5. Results from the GLM and MRT statistical analysis.

Radionuclide	F Value	P	MRT ($\alpha = 0.05$)
^{tot}U	22.00	0.0001	1997 > 1999, 1998
^{241}Am	8.42	0.0017	1997> 1998, 1999
^{238}Pu	1.18	0.3258	NS
$^{239,240}Pu$	1.02	0.3766	NS
^{90}Sr	0.56	0.5800	NS
^{137}Cs	3.64	0.0415	1997 >1999, 1998
^{3}H	26.57	0.0001	1999 > 1997 > 1998

NS = not statistically different

comparisons of small mammal carcasses sampled at the DARHT site during the operational years.

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BIOLOGICAL CONTAMINANT BIRD SAMPLING AT THE DARHT FACILITY

by
D. C. Keller and J. W. Nyhan

ABSTRACT

Bird populations within the area of the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos National Laboratory were monitored for physical characteristics, population size, and survivorship. A small number of birds captured were analyzed for selected contaminants. These consisted of concentrations of ^{3}H, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and ^{tot}U, as well as Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl. This study was initiated in 1997 during the preoperational stages of construction of the DARHT facility, and the results were compared with similar data collected at a background site in the nearby Jemez Mountains. A total of 386 birds were captured from 1997 through 1999 and representative samples were taken and analyzed for preoperational baseline concentrations of radionuclides and trace elements.

A. INTRODUCTION

Beginning in 1997, biologists from the Ecology group (ESH-20) of the Los Alamos National Laboratory began to operate a Monitoring Avian Population and Survivorship (MAPS) station just to the north and west of the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility. The purpose of this station was two-fold: to begin long-term monitoring of the bird populations around the DARHT facility for population dynamics and survivorship population information and collect samples to determine the levels of contaminants initially in the environment surrounding this facility. The population information will take a minimum of 5 years to begin to develop trends in population and survivorship but contaminant sampling has given the Laboratory a baseline for the contamination that currently exists in the area of this new facility. Since birds vary greatly in their food habits and home range size, three target species of birds in two groups were analyzed for radionuclides and trace elements. The first group consisted of the American robin and the spotted towhee, two birds that spend most of their time foraging for insects on the ground in a localized area. The second group was represented by the western scrub jay, which forages off the ground on vegetation and insects in a wider area. These species were selected to provide an overall representation of contaminants in birds within the DARHT facility environs during the preoperational stages.

B. METHODS

A series of 15 bird mist nets were erected in the woods to the north and west of the DARHT facility (Figure 1). The nets were located on a one-mile-long transect near the DARHT facility, along the edge of Cañon de Valle and the confluence of Water Canyon. Corresponding background samples were collected in the Jemez Mountains approximately 30 miles from the Laboratory.

ESH-20 operates the nets by the MAPS standard of one netting day every 10 days from May through August. Each net is 12 meters long and three meters high and is stretched between two poles in areas likely to be frequented by birds. The nets are opened at first light and left open for at least 6 hours. The procedure then involves visiting each net at approximately half-hour intervals to check for birds, removing birds from the net, identification of the bird (National Geographic Society, 1983), collecting basic physical measurements on each individual, and banding the birds with a U.S. Fish and Wildlife Service band (Figure 2). Each bird is measured and weighed. Ages are determined based on feather molt characteristics (Pyle, 1997), and any unusual characteristics are noted. Species that have not been captured before are photographed for later reference. When one of the three target species is captured, all of the physical measurements are taken and the bird is sacrificed by CO_2 asphyxiation, placed in a plastic bag, and returned to the laboratory in an ice chest. The species, time, date, and collection location of the bird are noted on the sample bag.

Samples consisted of separate samples of skin with feathers and the carcass of each bird. The bird's skin was removed and combined with other skin samples to constitute a large enough sample for analysis, and each carcass was analyzed separately. The skin was separated from the carcass to determine any potential difference between ingested and surface contamination.

These samples were assayed for concentrations of ^{3}H, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and ^{tot}U, as well as Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl. All

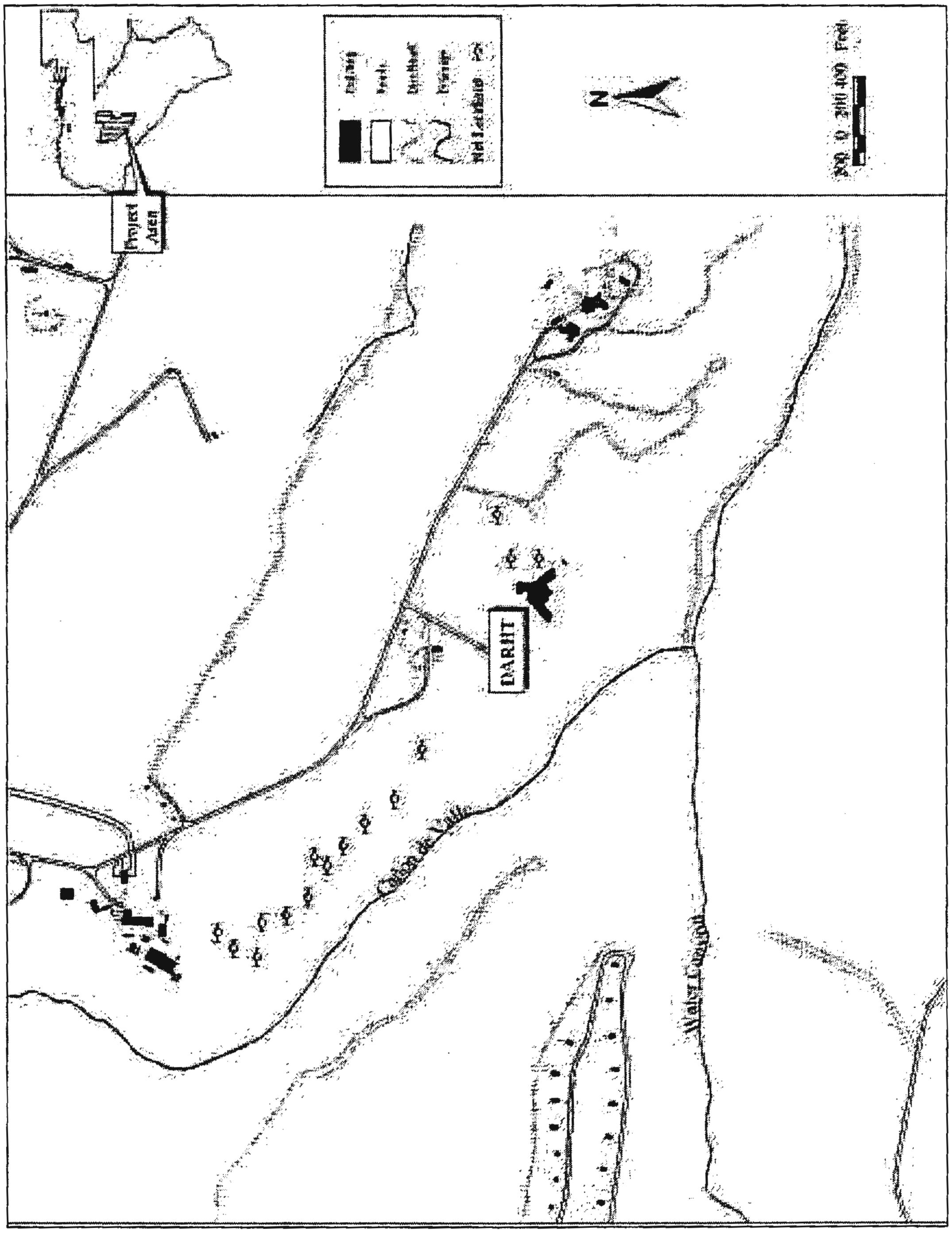

Figure 1. DARHT facility bird net locations.

Figure 2. Bird netting and characterization near the DARHT facility.

methods of radionuclide (Purtymun et al., 1987, Fresquez et al., 1996a) and trace element (Fresquez et al., 1996b) analyses have been previously reported; ^{tot}U, however, was analyzed by kinetic phosphorescence analysis. Results are reported in pCi L^{-1} (of soil moisture) for ^3H, $\mu g\ g^{-1}$ dry soil for ^{tot}U and heavy metals, and pCi g^{-1} dry soil for all the other radioisotopes.

C. RESULTS

During 1997, 120 birds were captured representing 23 species (Table 1). During this sampling period, the relative abundances of Virginia's warbler, chipping sparrow, and western bluebird were 24.2%, 12.5%, and 10.0%, respectively. Only nine target birds were captured: seven spotted towhees and two western scrub jays. None of these birds were sacrificed for contaminant assays.

During 1998 (Table 2), 139 individual birds were captured representing 30 species. Virginia's warbler, sage sparrow, chipping sparrow, and western bluebird had relative abundances of 15.1%, 15.1%, 13.0%, and 8.63%, respectively. Individual birds captured for contaminant analysis are not included in abundance totals. In 1998, eight target species were collected for analysis: one American robin, three spotted towhees, and four western scrub jays. In 1998, there were seven carcasses (two of the spotted towhee were combined to increase sample size) and seven skin samples (combined into one sample) tested for radiological and trace element contamination. Control samples for 1998 were not analyzed because of insufficient sample size. During 1999, 127 birds representing 31 species were captured, including an American kestrel that has not been previously caught at the DARHT facility before (Table 3). During this sampling period, the relative abundances of Virginia's warbler, chipping sparrow, and western bluebird were 11.02%, 5.51%, and 8.66%, respectively. Individual birds captured for contaminant analysis are not included in abundance totals. Thirteen birds from the target species were captured and sacrificed for contaminant analysis: nine spotted towhees and four American robins. In 1999, ten carcasses in seven samples and ten skins in two samples were assayed for radionuclides, and one tissue sample was assayed for trace elements. At the background site, three whole bird samples were analyzed for radionuclides along with one tissue sample for trace elements. The radionuclide analyses (Table 4) were

Table 1. Birds captured at the DARHT facility during 1997.

Species Name	Number Caught	Relative Abundance (%)
Ash-throated Flycatcher	2	1.67
Audubon's Warbler	3	2.50
Black-headed Grosbeak	7	5.83
Broad-tailed Hummingbird	5	4.17
Chipping Sparrow	15	12.50
Common Bushtit	8	6.67
Common Poorwill	1	0.83
Gray Flycatcher	4	3.33
Hermit Thrush	2	1.67
House Finch	1	0.83
Lark Sparrow	2	1.67
Lesser Goldfinch	1	0.83
Mountain Chickadee	7	5.83
Pine Siskin	1	0.83
Rufous Hummingbird	2	1.67
Western Scrub Jay	2	1.67
Spotted Towhee	7	5.83
Townsend's Solitaire	1	0.83
Vesper Sparrow	2	1.67
Virginia's Warbler	29	24.17
Warbling Vireo	1	0.83
Western Bluebird	12	10.00
Western Tanager	5	4.17
Total	**120**	**100.00%**

Table 2. Birds captured at the DARHT facility during 1998.

Species Name	Number Caught	Relative Abundance (%)
Acorn Woodpecker	1	0.72
Ash-throated Flycatcher	3	2.16
Audubon's Warbler	2	1.44
Black-headed Grosbeak	2	1.44
Broad-tailed Hummingbird	9	6.47
Calliope Hummingbird	1	0.72
Canyon Towhee	1	0.72
Chipping Sparrow	18	12.95
Gray Flycatcher	7	5.04
Green-tailed Towhee	1	0.72
Hermit Thrush	1	0.72
House Finch	1	0.72
Juniper Titmouse	1	0.72
Lesser Goldfinch	1	0.72
Mountain Chickadee	5	3.60
Pygmy Nuthatch	5	3.60
Ruby-crowned Kinglet	1	0.72
Red-shafted Flicker	4	2.88
Rufous Hummingbird	1	0.72
Sage Sparrow	21	15.11
Solitary Vireo	1	0.72
Spotted Towhee	5	3.60
Steller's Jay	1	0.72
Townsend's Solitaire	2	1.44
Violet-green Swallow	2	1.44
Virginia's Warbler	21	15.11
White-breasted Nuthatch	2	1.44
Western Bluebird	12	8.63
Western Tanager	4	2.88
Western Wood-Pewee	3	2.16
Total	**139**	**100.00**

Table 3. Birds captured at the DARHT facility during 1999.

Species Name	Number Caught	Relative Abundance (%)
Ash-throated Flycatcher	5	3.94
Audubon's Warbler	5	3.94
Black-headed Grosbeak	2	1.57
Broad-Tailed Hummingbird	11	8.66
Chipping Sparrow	7	5.51
Common Bushtit	2	1.57
Dusky Flycatcher	2	1.57
Gray Flycatcher	6	4.72
Green-tailed Towhee	1	0.79
Hairy Woodpecker	5	3.94
Hermit Thrush	1	0.79
American Kestrel	1	0.79
Mountain Bluebird	2	1.57
Mountain Chickadee	5	3.94
Pygmy Nuthatch	15	11.81
Red-shafted Flicker	3	2.36
Rufous Hummingbird	4	3.15
Sage Sparrow	6	4.72
Savannah Sparrow	3	2.36
Solitary Vireo	3	2.36
Spotted Towhee	2	1.57
Steller's Jay	2	1.57
Townsend Solitaire	2	1.57
Virginia's Warbler	14	11.02
Warbling Vireo	1	0.79
White-breasted Nuthatch	2	1.57
Western Bluebird	11	8.66
Western Tanager	1	0.79
Williamson's Sapsucker	1	0.79
Wilson's Warbler	1	0.79
Western Wood-Pewee	1	0.79
Total	**127**	**100.00**

generally within the range of the assays from the background site, with the exception of ^{tot}U, ^{90}Sr, and ^{3}H concentrations. These data for bird samples from the DARHT site were found to be statistically different than similar data from the background site using a two-tailed t-test that assumed unequal variance at the 95% confidence level.

Table 4. Radionuclides in birds collected at the DARHT facility during 1998 and 1999.

Year/ Media	^{3}H (pCi L^{-1})	^{90}Sr (pCi g^{-1})	^{tot}U (pCi g^{-1})	^{137}Cs (pCi g^{-1})	^{238}Pu (pCi g^{-1})	$^{239,240}Pu$ (pCi g^{-1})	^{241}Am (pCi g^{-1})
1998							
Carcass							
Mean	148.75	NS	0.23	0.22	0.00	0.00	NS
Std Dev	197.59	NS	0.16	1.05	0.00	0.01	NS
BSRL	178.09	3.36	0.19	0.63	0.02	0.02	0.67
Skin							
Mean	NS	NS	3.44**	0.16	0.00	0.01	NS
Std Dev	NS	NS	0.00	0.00	0.00	0.00	NS
BSRL*	178.09	3.36	0.19	0.63	0.02	0.02	0.67
1999							
Carcass							
Mean	274.29**	2.53	0.29	0.10	0.00	0.00	0.00
Std Dev	110.28	0.69	0.27	0.16	0.01	0.00	0.00
BSRL	178.09	3.36	0.19	0.63	0.02	0.02	0.67
Skin							
Mean	365.00	4.31	2.29	0.39	0.00	0.01	0.00
Std Dev	219.20	0.91	0.93	0.20	0.01	0.01	0.01
BSRL	178.09	3.36	0.19	0.63	0.02	0.02	0.67

* BSRL = baseline statistical reference level.
**Significantly different from similar data collected at the Background Site at 95% confidence level using a two-tailed t-test that assumed unequal variance.

Trace element assays on the bird samples captured in 1998 and 1999 (Table 5) were at or below the detection limits of the analyses. However, the concentration of Ag in one of the samples was well above the concentration observed at the background site and should be included in further sampling activities. Since most of the trace elements assays were less than the detection limit, the detection limits reported by the laboratory were reduced by one half and then submitted to a two-tailed t-test that assumed unequal variance at the 95% confidence level.

Table 5. Trace element assays for bird samples collected in 1998 and 1999.

		1998			1999	
		DARHT Site		Background Site	DARHT Site	
Sample Type	Trace element	Mean Concentration (μg g⁻¹)	Standard Deviation	Mean Concentration (μg g⁻¹)	Mean Concentration (μg g⁻¹)	Standard Deviat
Carcass	N/A*	NS**	NS	NS	**0.2**	**One Sample**
	N/A	NS	NS	NS	**0.1**	**One Sample**
	N/A	NS	NS	NS	NS	NS
	N/A	NS	NS	NS	**0.03**	**One Sample**
	N/A	NS	NS	NS	**0.1**	**One Sample**
	Cr	NS	NS	NS	**0.25**	**One Sample**
	Cu	NS	NS	NS	NS	NS
	Hg	NS	NS	NS	**0.025**	**One Sample**
	Ni	NS	NS	NS	**1**	**One Sample**
	Pb	NS	NS	NS	**0.25**	**One Sample**
	Sb	NS	NS	NS	NS	NS
	Se	NS	NS	NS	**0.6**	**One Sample**
	Tl	NS	NS	NS	**0.015**	**One Sample**
Skin	Ag	**16.76**	**10.60**	**0.2**	NS	NS
	As	**0.35**	**0.32**	**0.1**	NS	NS
	Ba	NS	NS	NS	NS	NS
	Be	**0.042**	**0.0174**	**0.03**	NS	NS
	Cd	**0.45**	**0**	**0.1**	NS	NS
	Cr	**0.45**	**0**	**0.25**	NS	NS
	Cu	NS	NS	NS	NS	NS
	Hg	**0.27**	**0.406**	**0.06**	NS	NS
	Ni	**2**	**0**	**1**	NS	NS
	Pb	**1.17**	**0.399**	**0.25**	NS	NS
	Sb	NS	NS	NS	NS	NS
	Se	**0.87**	**0.722**	**0.9**	NS	NS
	Tl	**0.037**	**0.073**	**0.015**	NS	NS

N/A - That element not tested for in that sample year.
NS – No sample was taken or the sample was not analyzed.
One Sample – Only one sample was analyzed and no Standard Deviation was available.

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BASELINE CONCENTRATIONS OF RADIONUCLIDES AND HEAVY METALS IN HONEY BEE SAMPLES COLLECTED NEAR THE DARHT FACILITY DURING 1997–1999

by

T. Haarmann

ABSTRACT

From 1997 through 1999, honey bees were collected from colonies located at Los Alamos National Laboratory's Dual-Axis Radiographic Hydrodynamic Test facility. Samples were analyzed for ^{3}H, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and ^{tot}U, as well as Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl. Baseline statistical reference levels of radionuclides and trace elements were calculated.

A. INTRODUCTION

As part of ongoing baseline studies at the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility (Fresquez et al., 1997a), samples of honey bees were collected from beehives located near the facility during the summers of 1997–1999. Honey bees can be thought of as mobile samplers that efficiently cover a large sample area and then return to a central location (Bromenshenk, 1992). Honey bees forage in an area with a radius as large as 3.6 mi (6 km) and often cover a total area up to 40 square mi (100 square km) (Leita et al., 1996; Visscher and Seeley, 1982). Each hive contains literally thousands of bees, most of whom will forage for nectar, water, pollen, and plant resins, which are all brought back into the hive. During these foraging flights, bees inadvertently contact and accumulate a wide array of pollutants, some of which are brought back to the colony (Bromenshenk et al., 1985). These contaminants often become incorporated into the bee tissue, the wax, the honey, or the hive itself (Wallwork-Barber et al., 1982).

Honey bee studies have been conducted on many different types of pollutants, including fluoride (Bromenshenk et al., 1988a; Mayer et al., 1988), lead (Migula et al., 1989), zinc (Bromenshenk et al., 1988b), nickel (Balestra et al., 1992), potassium (Barbattini et al., 1991), cesium (Bettoli et al., 1987; Tonelli et al., 1990), tritium (White et al., 1983; Fresquez et al., 1997b), and plutonium (Hakonson and Bostick, 1976).

Honey bee monitoring is an inexpensive form of monitoring, especially considering the many different sampling points the foraging bees visit. Sampling at one location (the hive) can provide a plethora of information from numerous points concerning the distribution and bioavailability of contaminants. Comparing the amounts of contaminants in honey bees with the known amounts of contaminants in the surrounding area could be useful for modeling the redistribution of contaminants through ecosystems. The very nature of honey bee ecology makes them an excellent living system from which to monitor the presence of contaminants. The objective of this study was to establish baseline reference concentrations of radionuclides and heavy metals in honey bees located near the DARHT facility.

B. METHODS

We monitored the DARHT facility using beehives consisting of a standard Langstroth hive stocked with Italian honey bees (*Apis mellifera ligustica*, see Figure 1). During 1997, two colonies were brought into the study site from an uncontaminated area and were established at the DARHT site approximately 330 ft (100 m) to the northwest (Figure 2). During September of 1997 and 1998, bee tissue samples were collected from all of the colonies. During 1999, three additional colonies were established at the study site, and bee tissue samples were collected from all five colonies at the DARHT facility. Separate samples were collected from each colony, each containing 100 g of bees. Each individual 100-g sample consisted of approximately 1,000 bees. Bee samples were collected using a small, rechargeable vacuum. Bees were vacuumed off frames that were removed from the honey supers, transferred to a plastic resealable bag, weighed, and double bagged into plastic resealable bags. All samples were kept in a cooler and frozen upon returning to the laboratory. With each sample collected, the vacuum collection area was thoroughly cleaned to avoid cross-contamination of samples.

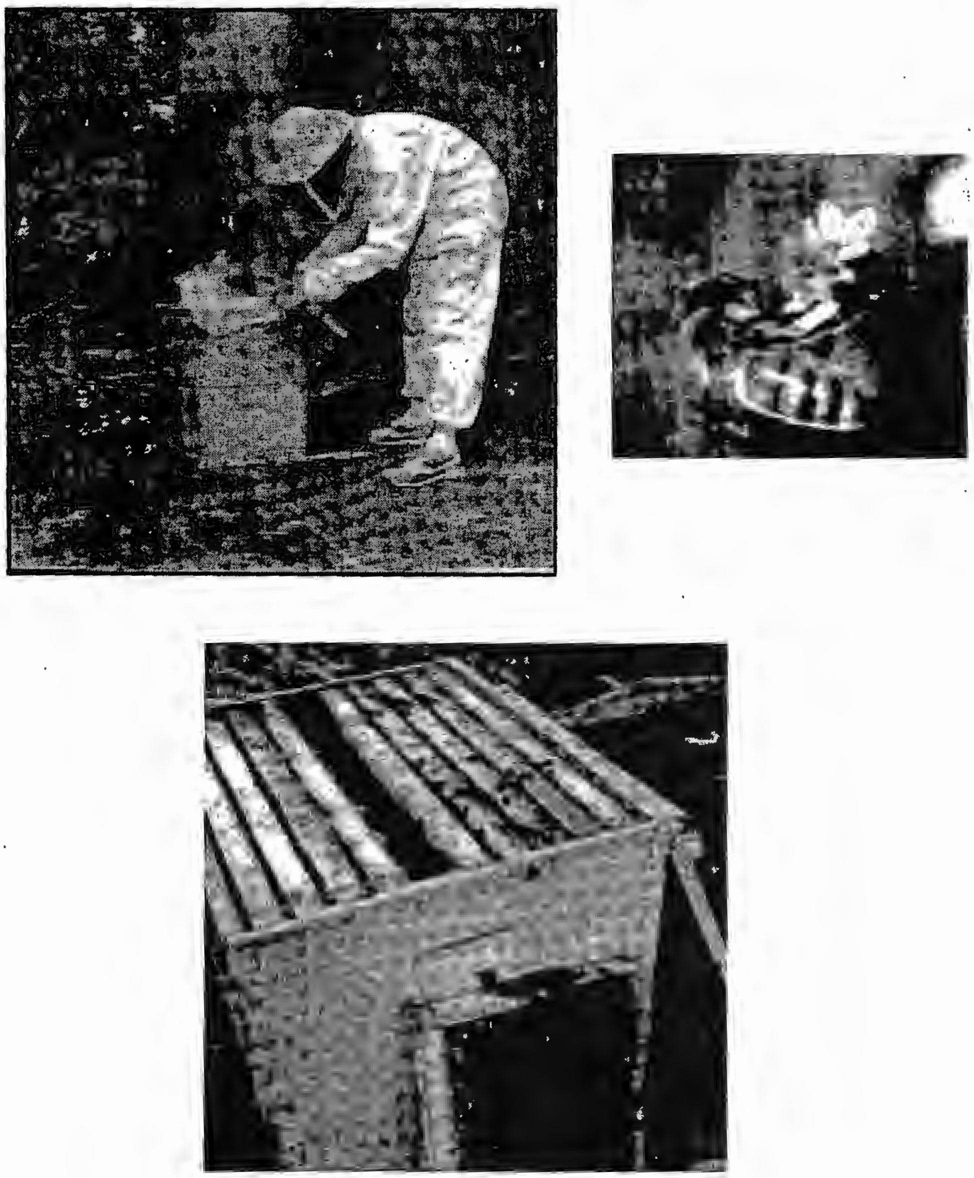

Figure 1. Sampling the standard Langstroth hive stocked with Italian honey bees used for this study.

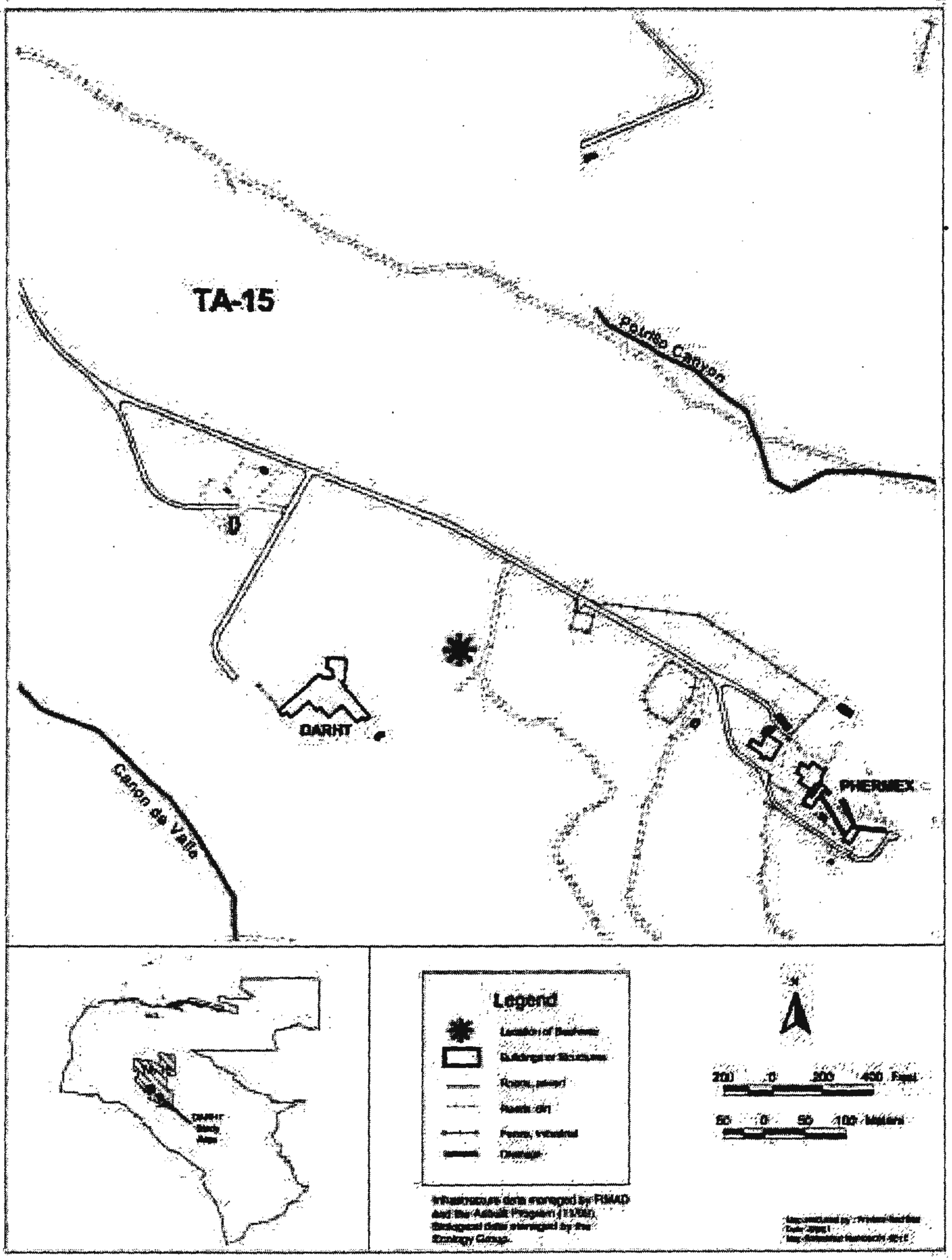

Figure 2. Location of the beehives near the DARHT facility.

Analytical Methods

All samples were analyzed by Los Alamos National Laboratory's Environmental Chemistry Group for ^{3}H, ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{90}Sr, ^{241}Am, ^{tot}U, and total trace elements (Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl), with the exception of the 1999 control sample, which was only analyzed for the heavy metals. Analytical methods have been previously described (Fresquez et al., 1997b). The bee ^{3}H samples were analyzed by liquid scintillation counting in the following manner: 5 ml of moisture was distilled from each sample, mixed with 15 ml of a scintillation solution, and counted on a scintillation counter for 50 minutes. The ^{238}Pu, $^{239,240}Pu$, and ^{241}Am samples were dissolved in nitric acid, isolated by anion exchange, electroplated onto stainless steel disks, and counted using an alpha spectrometer. The ^{tot}U was determined by kinetic phosphorescence analysis. All gamma-emitting radionuclide concentrations (except for ^{241}Am) were determined using high-resolution germanium detector gamma-ray spectrometry.

Heavy metal analysis was done using inductively coupled plasma atomic emission spectrometry for Ag, Ba, Be, Cd, Cr, Cu, and Ni; inductively coupled plasma mass spectrometry for Pb, Sb, and Tl; by electrothermal vaporation atomic absorption for As and Se; and by cold vapor atomic absorption for Hg. All laboratory quality control parameters were met.

C. RESULTS

Tables 1–8 contain a summary of the analytical results from samples collected near the DARHT facility. In particular, Tables 7 and 8 list the baseline statistical reference levels (BSRLs), which were calculated using the DARHT site mean concentrations + two standard deviations from 1997–99 (Haarmann, 1997, 1998).

Table 1. 1997 radionuclide analytical results from honey bee samples collected from colonies near the DARHT facility.

	Units	DARHT Colony 1	Analytical Uncertainty[1]	DARHT Colony 2	Analytical Uncertainty
^{137}Cs	pCi g^{-1}	-0.06	1.80	0.45	0.68
^{tot}U	µg g^{-1}	3.46	0.35	1.82	0.18
^{241}Am	pCi g^{-1}	0.0282	0.0078	0.0133	0.0040
^{238}Pu	pCi g^{-1}	0.0013	0.0025	-0.0010	0.0021
^{239,240}Pu	pCi g^{-1}	-0.0025	0.0020	0.0042	0.0023
^{3}H	pCi L^{-1}	760	730	5290	980
Gross Gamma	pCi g^{-1}	48.4	16.4	163.4	16.3

[1]Values are the uncertainty in the analytical results at the 65% confidence level (one sigma).
Note: Results are considered valid if they are >2 times the analytical uncertainty.

Table 2. 1998 radionuclide analytical results from honey bee samples collected from colonies near the DARHT facility.

	Units	DARHT Colony 1	Analytical Uncertainty[1]	DARHT Colony 2	Analytical Uncertainty
^{3}H	pCi L^{-1}	270	670	980	710
^{137}Cs	pCi g^{-1}	4.50	6.80	2.76	0.55
^{tot}U	µg g^{-1}	1.7	0.17	0.75	0.08
^{228}Ac	pCi g^{-1}	15.0	23.0	14.0	3.0
^{241}Am	pCi g^{-1}	0.0081	0.0034	0.0048	0.0094
^{7}Be	pCi g^{-1}	240.0	360.0	-12.0	20.0
^{214}Bi	pCi g^{-1}	14.0	2.0	6.6	1.2
^{57}Co	pCi g^{-1}	1.34	0.24	0.06	1.20
^{60}Co	pCi g^{-1}	3.09	0.72	3.30	0.68
^{40}K	pCi g^{-1}	400.0	50.0	260.0	30.0
^{54}Mn	pCi g^{-1}	5.4	1.1	3.2	5.0
^{22}Na	pCi g^{-1}	6.8	1.3	9.2	1.4
^{212}Pb	pCi g^{-1}	3.87	0.63	0.54	0.82
^{214}Pb	pCi g^{-1}	4.0	5.9	-1.3	2.1
^{208}Tl	pCi g^{-1}	4.29	0.84	2.47	0.56
^{238}Pu	pCi g^{-1}	0.0159	0.0031	0.005	0.0023
^{239,240}Pu	pCi g^{-1}	0.0213	0.004	0.0081	0.0028

[1]Values are the uncertainty in the analytical results at the 65% confidence level (one sigma).
Note: Results are considered valid if they are >2 times the analytical uncertainty.

Table 3. 1999 radionuclide analytical results from honey bee samples collected from colonies near the DAR

	Units	DARHT Colony 1	Analytical Uncertainty[1]	DARHT Colony 2	Analytical Uncertainty	DARHT Colony 3	Analytical Uncertainty	DARHT Colony 4	Analytical Uncertainty
^{3}H	pCi L^{-1}	-160	590	-10	600	-160	590	-210	580
^{90}Sr	pCi g^{-1}	3.17	1.09	-0.96	1.72	1.25	0.77	2.75	1.20
^{137}Cs	pCi g^{-1}	0.448	0.196	0.00	2.98	0.00	1.13	0.00	2.16
^{tot}U	µg g^{-1}	2.60	0.26	0.81	0.08	2.47	0.25	2.77	0.28
^{241}Am	pCi g^{-1}	-0.0005	0.0007	0.0140	0.0070	0.0373	0.0066	0.0034	0.0017
^{238}Pu	pCi g^{-1}	-0.0033	0.0127	-0.0166	0.0208	0.0224	0.0071	0.0105	0.0076
^{239,240}Pu	pCi g^{-1}	0.0048	0.0097	0.0129	0.0215	0.1137	0.0109	0.0385	0.0111

[1]Values are the uncertainty in the analytical results at the 65% confidence level (one sigma).

Note: Results are considered valid if they are >2 times the analytical uncertainty.

Table 4. 1997 heavy metal analytical results (mg kg^{-1}) from honey bee samples collected from colonies near the DARHT facility.

	DARHT Colony 1	Analytical Uncertainty[1]	DARHT Colony 2	Analytical Uncertainty
Ag	<2.00	0	<2.00	0
Ba	2.60	0.26	2.10	0.21
Be	<0.07	0	<0.07	0
Cd	<0.90	0	<0.90	0
Cr	<0.90	0	<0.90	0
Cu	7.00	1.00	7.00	1.00
Ni	<4.00	0	<4.00	0
Pb	<0.3	0	<0.3	0
Sb	<0.3	0	<0.3	0
Tl	<0.3	0	<0.3	0
As	0.2	0.2	<0.2	0
Se	<0.3	0	<0.3	0
Hg	<0.05	0	<0.05	0

[1]Values are the uncertainty in the analytical results at the 65% confidence level (one sigma).
Note: Results are considered valid if they are >2 times the analytical uncertainty.

Table 5. 1998 heavy metal analytical results (mg kg^{-1}) from honey bee samples collected from colonies near the DARHT facility.

	DARHT Colony 1	Analytical Uncertainty[1]	DARHT Colony 2	Analytical Uncertainty
Ag	<2.00	0	<2.00	0
Ba	2.90	0.29	3.90	0.390
Be	<0.2	0	<0.2	0
Cd	<1.00	0	<1.00	0
Cr	<1.00	0	<1.00	0
Cu	8.30	0	9.500	1.00
Ni	<2.00	0	<2.00	0
Pb	<1.00	0	<1.00	0
Sb	<1.00	0	2	1
Tl	<0.06	0	<0.06	0
As	<0.5	0	<0.5	0
Se	1.00	1.00	1.00	1.00
Hg	<0.05	0	<0.05	0

[1]Values are the uncertainty in the analytical results at the 65% confidence level (one sigma).
Note: Results are considered valid if they are >2 times the analytical uncertainty.

Table 6. 1999 heavy metal analytical results (mg kg^{-1}) from honey bee samples collected from colonies near facility.

	DARHT Colony 1	Analytical Uncertainty[1]	DARHT Colony 2	Analytical Uncertainty	DARHT Colony 3	Analytical Uncertainty	DARHT Colony 4	Analytical Uncertainty	DARH' Colony
Ag	3.500	3.1	4.000	3.1	8.600	3.1	4.500	3.1	4.100
Ba	2.800	0.280	2.800	0.280	1.600	0.160	3.500	0.350	2.600
Be	<0.060	0	<0.060	0	<0.060	0	<0.060	0	<0.06C
Cd	<0.200	0	<0.200	0	<0.200	0	<0.200	0	<0.20C
Cr	<0.500	0	<0.500	0	<0.500	0	3.500	0.500	<0.50C
Cu	4.200	0.420	4.500	0.459	5.900	0.590	6.400	0.640	5.500
Ni	<2.000	0	<2.000	0	<2.000	0	2.500	5.952	<2.00C
Pb	<4.000	0	<4.000	0	<4.000	0	<4.000	0	<4.00C
Sb	<0.04	0	<0.04	0	<0.04	0	<0.04	0	<0.04
Ti	1.700	0.364	1.700	0	2.900	0.300	7.200	0.720	0.650
As	<7.000	0	<7.000	0	<7.000	0	<7.000	0	<7.00C
Se	0.5	005	0.6	0.5	0.6	0.5	0.6	0.5	0.6
Hg	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01

[1]Values are the uncertainty in the analytical results at the 65% confidence level (one sigma).

Note: Results are considered valid if they are >2 times the analytical uncertainty

Table 7. Summary of 1997–99 radionuclide analytical results and associated BSRLs from honey bee samples collected from colonies near the DARHT facility.

	^{3}H (pCi L^{-1})	^{137}Cs (pCi g^{-1})	^{90}Sr (pCi g^{-1})	^{tot}U (µg g^{-1})	^{238}Pu (pCi g^{-1})	^{239,240}Pu (pCi g^{-1})	^{241}Am (pCi g^{-1})
Colony 1 (1997)	760	-0.06	-	3.46	0.0013	-0.0025	0.0282
Colony 2 (1997)	5290	0.45	-	1.82	-0.0010	0.0042	0.0133
Colony 1 (1998)	270	4.50	-	1.70	0.0159	0.0213	0.0081
Colony 2 (1998)	980	2.76	-	0.75	0.0050	0.0081	0.0048
Colony 1 (1999)	-160	0.45	3.17	2.60	-0.0033	0.0048	-0.0005
Colony 2 (1999)	-10	0.00	-0.96	0.81	-0.0166	0.0129	0.0140
Colony 3 (1999)	-160	0.00	1.25	2.47	0.0224	0.1137	0.0373
Colony 4 (1999)	-210	0.00	2.75	2.77	0.0105	0.0385	0.0034
Colony 5 (1999)	1490	0.00	0.67	2.21	-0.0013	0.0300	0.0108
Mean	916.67	0.90	1.38	2.07	0.0037	0.0257	0.0133
Stand. Dev.	1744.56	1.62	1.66	0.90	0.0115	0.0356	0.0122
BSRL[1]	4405.79	4.14	4.70	3.86	0.0267	0.0968	0.0377

[1]Baseline statistical reference level (mean + two standard deviations).

Table 8. Summary of 1997–99 heavy metal analytical results (mg kg^{-1}) and associated BSRLs from honey be collected from colonies near the DARHT facility.

	Ag	Ba	Be	Cd	Cr	Cu	Ni	Pb	Sb	Tl	As	Se
Colony 1 (1997)	1.00	2.60	0.035	0.45	0.45	7.00	2	0.15	0.15	0.15	0.20	0.15
Colony 2 (1997)	1.00	2.10	0.035	0.45	0.45	7.00	2	0.15	0.15	0.15	0.10	0.15
Colony 1 (1998)	1.00	2.90	0.100	0.50	0.50	8.30	1.000	0.50	0.50	0.03	0.25	1.00
Colony 2 (1998)	1.00	3.90	0.100	0.50	0.50	9.50	1.000	0.50	2	0.03	0.25	1.00
Colony 1 (1999)	3.50	2.80	0.030	0.10	0.25	4.20	1.000	2.00	0.02	1.70	3.50	0.5
Colony 2 (1999)	4.00	2.80	0.030	0.10	0.25	4.50	1.000	2.00	0.02	1.70	3.50	0.6
Colony 3 (1999)	8.60	1.60	0.030	0.10	0.25	5.90	1.000	2.00	0.02	2.90	3.50	0.6
Colony 4 (1999)	4.50	3.50	0.030	0.10	0.25	6.40	2.500	2.00	0.02	7.20	3.50	0.6
Colony 5 (1999)	4.10	2.60	0.030	0.10	0.25	5.50	1.000	2.00	0.02	0.65	3.50	0.6
Mean	3.19	2.76	0.05	0.27	0.35	6.48	1.39	1.26	0.32	1.61	2.03	0.58
Stand. Dev.	2.54	0.68	0.03	0.20	0.12	1.71	0.60	0.89	0.65	2.32	1.74	0.30
BSRL[1]	8.28	4.12	0.11	0.66	0.59	9.90	2.59	3.04	1.62	6.25	5.51	1.18

[1]Baseline statistical reference level (mean + two standard deviations).

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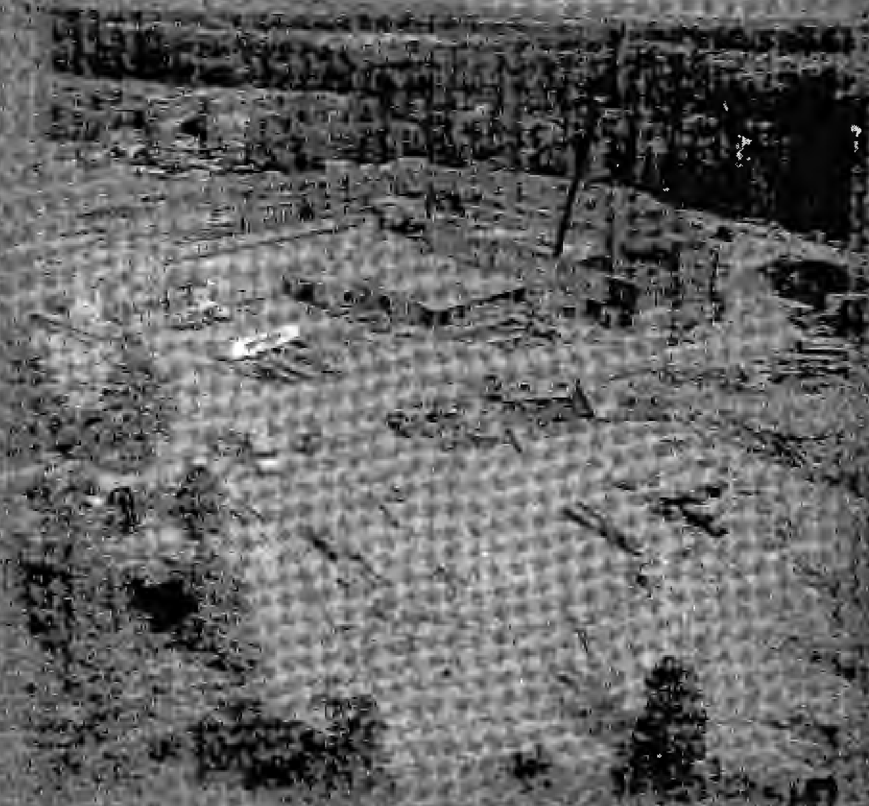

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