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Surface Radiological Investigations at Environmental Research Area 11, ^{137}Cs- and ^{60}Co-Contaminated Plots at Oak Ridge National Laboratory, Oak Ridge, Tennessee

M. S. Uziel
P. F. Tiner
J. K. Williams

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Surface Radiological Investigations at Environmental Research Area 11, ^{137}Cs- and ^{60}Co-Contaminated Plots at Oak Ridge National Laboratory, Oak Ridge, Tennessee

M. S. Uziel
P. F. Tiner
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EXECUTIVE SUMMARY

A surface radiological investigation at the ^{137}Cs- and ^{60}Co-contaminated forest area (Chestnut Ridge east and west plots) was conducted from January 1992 through August 1992. Results of the survey revealed numerous spots and small areas of surface contamination that followed the original placement of feeders used for ^{60}Co- and ^{137}Cs-labeled seeds in a 1969–1970 study. Surface gamma exposure rates reached 380 μR/h at the east plot and 400 μR/h at the west plot, but approximately one-half and one-third, respectively, of the identified anomalies did not exceed 39 μR/h. (Typical background surface gamma exposure rates on the Oak Ridge Reservation range from 10 to 17 μR/h.)

Highest gamma exposure rates at 1 m above the ground surface reached 30 μR/h at the east plot and 35 μR/h at the west plot. If a worker spends 8 hours/day, 5 days/week, and 50 weeks/year at the 35-μR/h spot, he/she would receive ~70* mrem/year, which is well below the allowed 100 mrem/year for public exposure. More than half of the 1-m measurements at both plots fell within the range of typical background levels for the Oak Ridge Reservation.

Results of soil sample analyses demonstrated that ^{137}Cs and ^{60}Co were responsible for the elevated radiation levels. Radionuclides were found below the surface at soil sample locations, in some cases at depths below 18 in. The same pattern of subsurface contamination may be present at other elevated surface spots at both plots.

A 20- to 40-ft-wide swath had been cleared around both the east and the west plots in preparation for the placement of a fence scheduled for erection by July 31, 1993. At the outer perimeter of the cleared area, brush and uprooted trees covered the ground surface, preventing a thorough surface survey. Four contaminated spots were identified in this area, and it is possible that other spots of contamination are covered by the surface debris. No contaminated spots were identified beyond the area of brush and felled trees. All identified spots of contamination at the sites will be enclosed by the proposed fence.

These survey results show that current radiological conditions at the site remain an environmental problem. Recommendations for corrective actions are included.

*Assuming 1 R = 1 rad = 1 rem.

1. INTRODUCTION

A surface radiological investigation at the ^{137}Cs- and ^{60}Co-contaminated forest area (Chestnut Ridge east and west plots) was conducted from January 1992 through August 1992. This survey was performed by the Measurement Applications and Development Group, Health and Safety Research Division, Oak Ridge National Laboratory (ORNL) at the request of ORNL Environmental Restoration Program personnel. The purposes of this survey were (1) to determine the presence, nature, and extent of surface radiological contamination and (2) to recommend interim corrective actions to limit human exposures to radioactivity and minimize the potential for contaminant dispersion.

The ^{137}Cs- and ^{60}Co-contaminated forest area has been designated as a nonsolid waste management unit environmental research (ER) area and assigned the code ER-11 by the ORNL Environmental Restoration staff.[1] Figure 1.1 shows the general location of the Chestnut Ridge east and west plots (ER-11) in relation to other landmarks in the Oak Ridge area.

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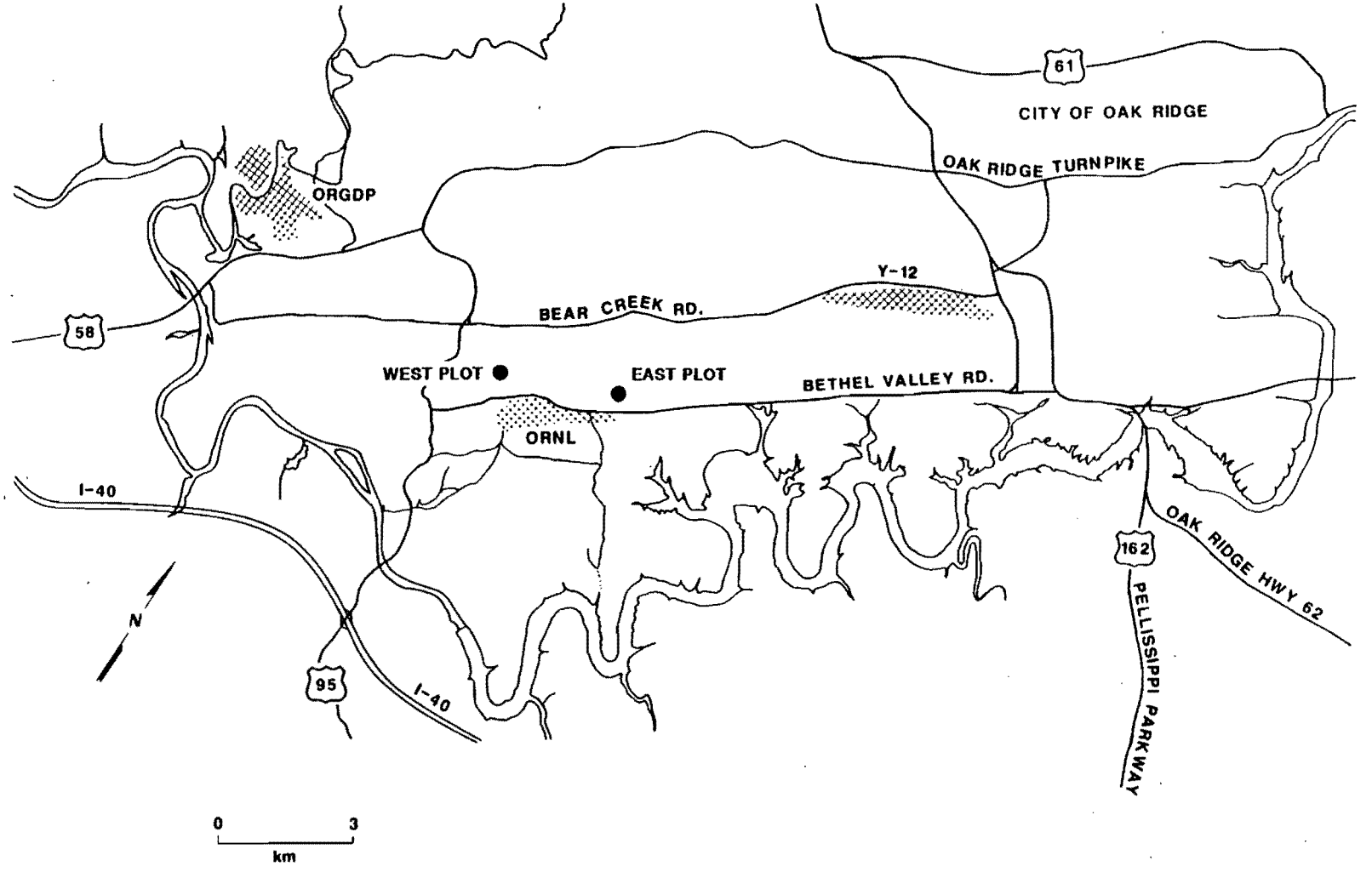

Fig. 1.1. Diagram showing general location of the Chestnut Ridge east and west plots.

2. SITE HISTORY

In 1969 and 1970, white pine seeds labeled with ^{137}Cs and ^{60}Co were used to study annual and seasonal food consumption by small forest mammals. In the laboratory, white-footed mice were chronically fed labeled seeds and the resultant uptake, equilibrium, and excretion patterns of the isotopes were used to infer food consumption rates. Labeled seeds were then made available in the field, and the isotopic uptake of trapped animals was correlated with the laboratory data to estimate seed consumption rates.[2]

In the field, three 140-m^2 forested plots were designated as (1) a control plot, (2) a live-trap plot, and (3) a snap-trap plot. All three plots were located along the crest of Chestnut Ridge in Roane County, Tennessee, on the Oak Ridge Reservation. In relation to Building 2001 at ORNL, the control plot was located 2.96 km (1.8 miles) on a bearing of S84° W, the live-trap was located 1.35 km (0.8 mile) on a bearing of N36° W, and the snap-trap plot was located 2.51 km (1.6 miles) on a bearing of N49° E. A distance of at least 2 km (1.2 miles) separated each plot so that movement of small mammals between plots would be unlikely. No additional food was placed on the control plot, which was used to examine population changes in mice and shrews. The remaining two plots each received radioactive pine seed at weekly intervals for 58 weeks. The live-trap plot was trapped periodically to examine uptake, equilibrium, and excretion characteristics of small forest mammals, as well as population changes. The snap-trap plot was trapped seasonally to obtain animals for tissue analyses. All captured animals from the live-trap and the control plots were returned to the point of capture, usually the same day.[2] In this report, the live-trap and snap-trap plots are referred to as the Chestnut Ridge west and east plots, respectively.

A 10-m grid system was established at each plot. All 225 grid locations on each plot were marked with aluminum stakes and numbered in a two-dimensional array code (Fig. 2.1). Wooden nest boxes were designed and installed at stakes with "even-even" numbers. The purpose of the nest boxes was to provide ready access to seed caches and to potential litters born on the plot. Feeders were installed at "odd-odd" numbered grid locations. The feeders were constructed of clear plastic boxes, assuming that the secretive mice would remove and store seeds rather than consume them within clear plastic feeders. Seeds were placed in a dish to prevent soaking by precipitation and to reduce the loss expected from larger mammals reaching through the entrances. These entrances were designed to allow access only to animals smaller than about 40 g in whole-body weight. Holes were drilled or melted in the dish and corners of each box to allow for drainage of liquids. All feeders were pinned to the ground with 10-gauge galvanized wire "wickets" to prevent disturbance by larger mammals.[2]

A total of 71 mCi of ^{137}Cs and 554 mCi of ^{60}Co were used for tagging 59 kg of pine seed. The seeds were subjected to a soaking procedure during which they acquired 62% of the ^{137}Cs and 74% of the ^{60}Co. The acid-leaching and rinsing procedures reduced the concentration in the seeds to 19% for ^{137}Cs and 21% for ^{60}Co of the initial soaking solution. This amounts to a total of 13.40 mCi of ^{137}Cs and 118.84 mCi ^{60}Co acquired by the 59 kg of seed. A portion of the tagged seeds was used for the laboratory experiments.[2]

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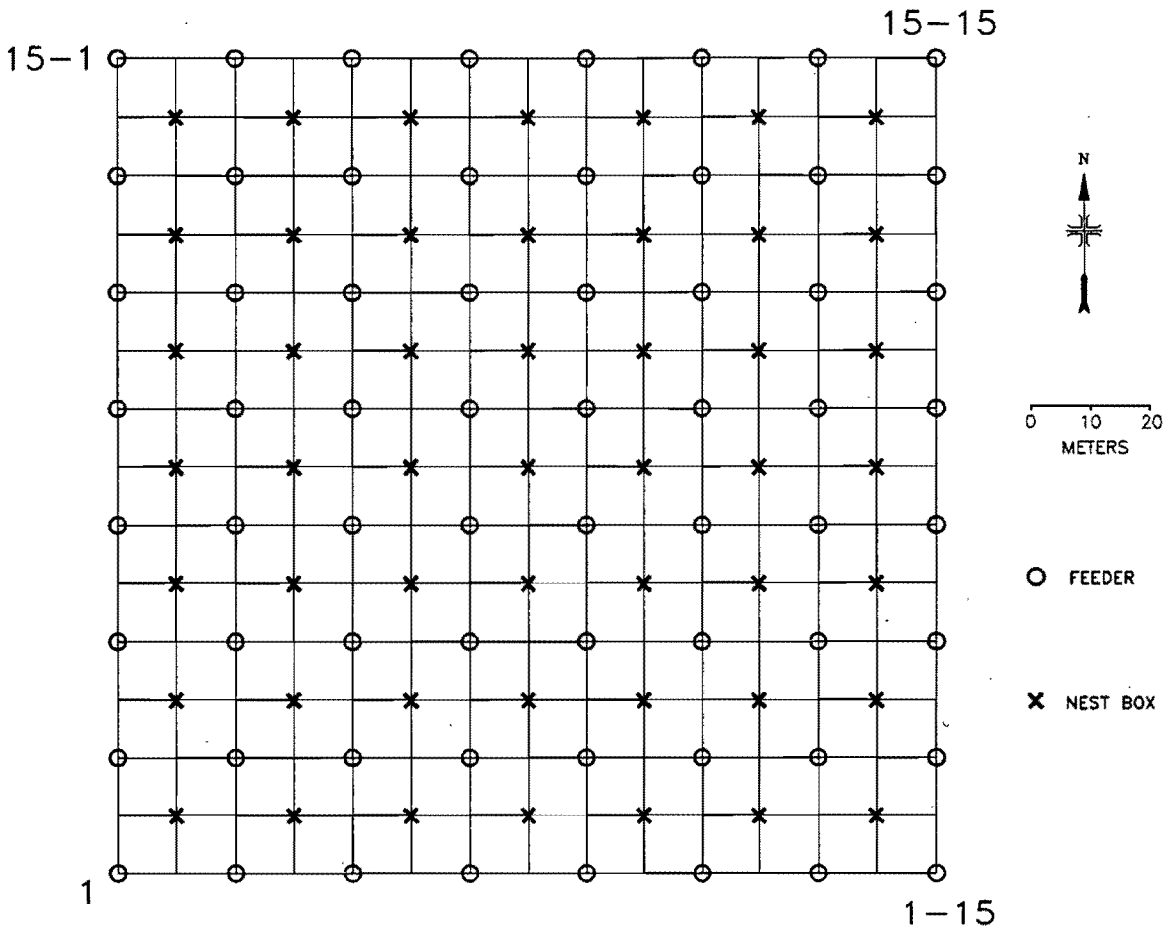

Fig. 2.1. Diagram showing grid system used in the 1969–1970 study. Note placement of nest boxes and feeders.

Feeding of radioactive seeds in the field began on July 24, 1969. Seeds were dispersed at 7-day intervals in 64 feeders on both the live-trap and the snap-trap plots. Total weight of seed per plot was 435.2 g per week, or 6.8 g per feeder. All seeds were weighed the day before being placed on the plot and were stored in numbered containers for transportation to the plots. All unused seeds in feeders were removed from the plots each week, feeders were cleaned, and the next week's seeds placed in the dish. After 58 weeks, a total of 25.24 kg of seeds had been placed on each plot, which is ~43% of the 59 kg of seed tagged. Feeding was terminated September 1, 1970.[2]

At the end of the field study, a germination check was made using both radioactive and uncontaminated seeds. In 60 days, 60% of the uncontaminated seeds had germinated, compared to 0% of the radioactive seed. No germinated seeds were observed on the field plots during the study.[2]

From this information, we can estimate that no more than 3.4 mCi of ^{137}Cs and 2.5 mCi of ^{60}Co remain on each of the plots today (Table 2.1). This is a most conservative estimate because it does not take into account the fact that only 71% of the seeds placed in the feeders was removed by animals or consumed on the live-trap (west) plot and 94% on the snap-trap (east) plot.[2] (The remaining unused seeds were collected and removed from the site.[2]) Also, this estimate does not consider the loss of radioactivity from the site by erosion, animals leaving the site, and other means. (Fifty-one small mammals were removed from the east plot over the span of one year.[2]) A more accurate estimate of the activity remaining on the site today (1992) would be ~2.5 mCi for ^{137}Cs and ~1.8 mCi for ^{60}Co at the west plot and ~3.2 mCi for ^{137}Cs and ~2.3 mCi for ^{60}Co at the east plot (see Table 2.1).

On November 9, 1974, an aerial radiological survey conducted at altitudes of 45 to 150 m provided a broad overview of the location and identification of gamma-producing radioactive contaminants in the Oak Ridge area. The spectrum taken over the Chestnut Ridge west plot clearly showed the presence of ^{60}Co with a small indication of ^{137}Cs. From the flyover data, the total apparent surface activity at the west plot was estimated to be 5 to 10 mCi of ^{60}Co (ref. 3).

In November 1989 the east and west plots were roped, and "Safety Area—No Hunting" signs were placed on the rope. In November 1991 an area ranging from 20 to 40 ft in width was cleared around the outside of the rope. All cleared trees and undergrowth were pushed away from the rope boundary, leaving piles of brush and uprooted trees on the ground surface encompassing the extremity of the cleared area. The clearing was conducted in preparation for placement of an 8-ft chain-link fence with two-strands of barbed wire at the top to enclose both the east and the west plots. The fence, scheduled for completion by July 31, 1993, is designed to exclude deer hunters and unauthorized personnel and to minimize intrusion by animals. Photographs of the Chestnut Ridge west plot taken in January and August 1992 are shown in Figs. 2.2 through 2.8.

Table 2.1. Estimated ^{137}Cs and ^{60}Co remaining at the Chestnut Ridge east and west plots as a result of the 1969–1970 seed consumption study

	^{137}Cs	^{60}Co
Activity of original seed-soaking solution	71 mCi	554 mCi
Percent of original soaking solution retained by the seeds	19%	21%
Activity of the total batch of final rinsed seed (59 kg) (p. 34, ref. 2)	13.40 mCi	118.84 mCi
Activity of the seed supplied to each plot (25.24 kg)	5.7 mCi	50.8 mCi
Half-life of isotope	30.17 years	5.271 years
Total activity remaining after 23 years (1992) with 25.24 kg seed left on site	3.4 mCi	2.5 mCi
	West plot	
Total activity of the 18.713 kg of seed removed by animals or consumed at the west plot	4.25 mCi	37.7 mCi
Total activity remaining after 23 years (1992) with 18.713 kg of seed left on site	2.5 mCi	1.8 mCi
	East plot	
Total activity of the 23.622 kg of seed removed by animals or consumed at the east plot	5.4 mCi	47.6 mCi
Total activity remaining after 23 years (1992) with 23.622 kg of seeds left on site	3.2 mCi	2.3 mCi

ORNL-PHOTO 6865-92

Fig. 2.2. View of an aluminum grid stake and the flags marking three contaminated spots at the Chestnut Ridge west plot (August 1992).

ORNL-PHOTO 6866-92

Fig. 2.3. View of understory at the Chestnut Ridge west plot (August 1992).

ORNL-PHOTO 6863-92

Fig. 2.4. View of a feeder used for labeled white pine seed in the 1969–1970 study (August 1992). The feeder is located at the base of grid stake 40N, 160E at the Chestnut Ridge west plot.

ORNL-PHOTO 6946-92

Fig. 2.5. View looking north at the cleared area at the Chestnut Ridge west plot (January 1992).

ORNL-PHOTO 4947-92

Fig. 2.6. View looking southeast at the rope and the cleared area at the Chestnut Ridge west plot (January 1992).

ORNL-PHOTO 4948-92

Fig. 2.7. View of brush and uprooted trees that encompassed the cleared area and prevented a thorough surface survey in this region (January 1992). View looking north from east side of the Chestnut Ridge west plot.

ORNL-PHOTO 4949-92

Fig. 2.8. View of brush and debris looking east from south side of the Chestnut Ridge west plot (January 1990).

3. SURVEY METHODS

A comprehensive description of the methods and instrumentation used in this survey is presented in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program.*[4] All direct-measurement results presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations measured in environmental samples. Radionuclide concentrations in soil samples were analyzed using gamma spectrometry. Field personnel were checked for alpha and beta-gamma radiation prior to each exit from the survey site.

3.1 GAMMA RADIATION

Ground surface gamma radiation was measured with a sodium iodide (NaI) scintillation probe connected to a Victoreen Model 490 Thyac III ratemeter. Because NaI gamma scintillators are energy-dependent, measurements of gamma radiation levels made with these instruments must be normalized to pressurized ionization chamber (PIC) measurements to estimate gamma exposure rates. The function developed for these conversions is

$$y = x \times \mathrm{CF}$$

where

y = the exposure rate (μR/h),

x = the scintillometer measurements in thousand counts per minute (kcpm),

CF = the slope of the regression line calculated by plotting a selected number of PIC measurements (μR/h) vs scintillometer measurements (kcpm) at the same locations.

For this site, CF = 2.5.

3.2 BETA-GAMMA RADIATION

A Bicron miniscaler/ratemeter with a Geiger-Mueller pancake detector was also used to detect beta-gamma radiation. After calibration of the detectors to a known source, beta radiation detection levels in counts per minute were converted to dose rates in millirads per hour using the following relationship:

2800 cpm = 1 mrad/h .

3.3 GRID

For convenience in reporting results, the 10-m grid system used during the 1969–1970 study was reestablished (Fig. 3.1). Points on the plots are identified by a north and an east coordinate (e.g., 33N, 96E)

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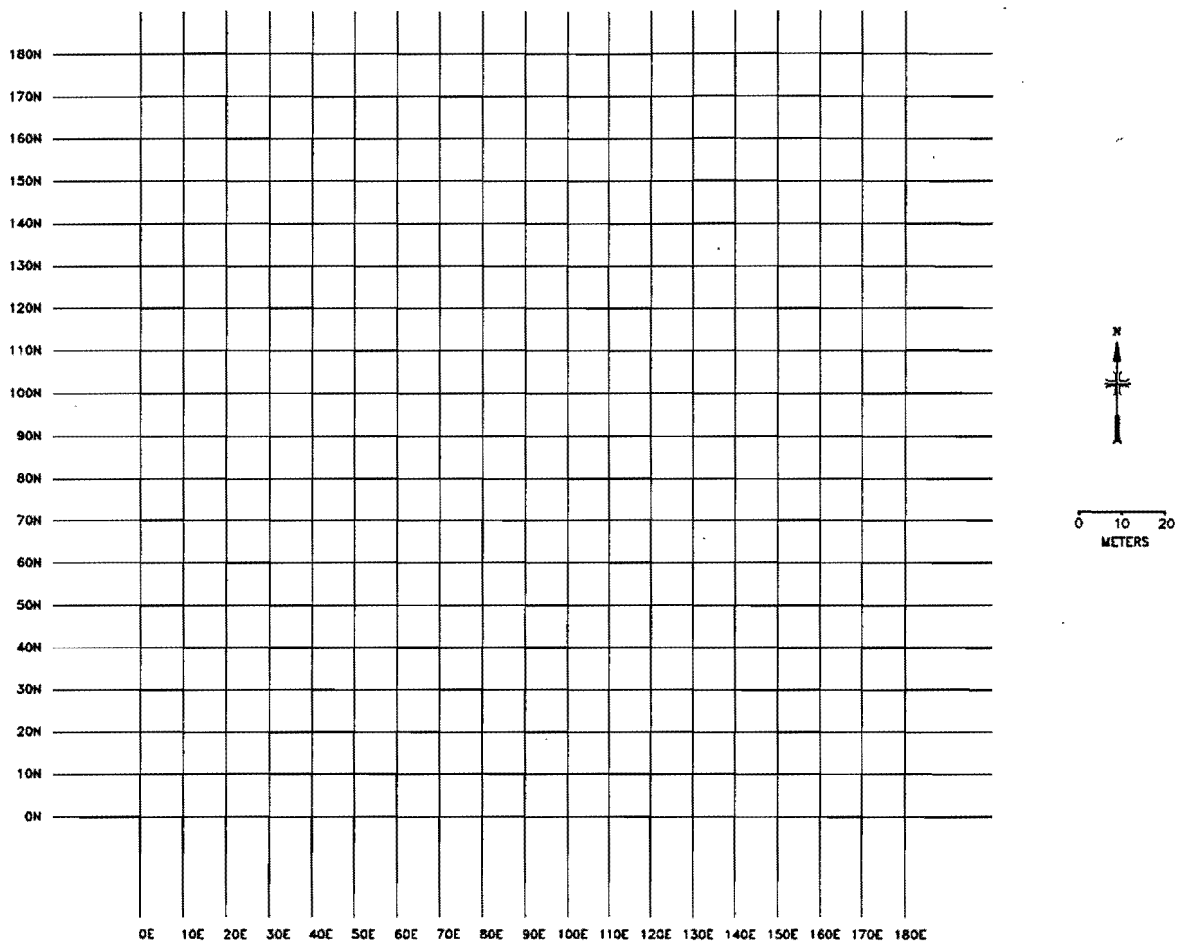

Fig. 3.1. Diagram of the grid used at the Chestnut Ridge east and west plots.

3.4 SCOPE OF THE SURVEY

The survey at each plot included the following:

- A surface gamma scan of the cleared area around the rope and accessible areas within the rope. (One grid block and three other smaller areas were inaccessible at the east plot.)

- A surface gamma "spot check" in the area covered by brush and uprooted trees encompassing the cleared area. The materials covering the ground surface prevented a thorough survey in this area (Figs. 2.6 through 2.8).

- A cursory surface gamma scan extending ~10 ft into the level forested areas beyond the brush and felled trees at the perimeter of the cleared area.

- Measurement of gamma exposure rates at the ground surface at all areas with elevated gamma levels.

- Measurement of gamma exposure rates at 1 m above the point with the highest ground-surface radiation levels at most areas with elevated radiation.

- Beta-gamma and gamma measurements of vegetation collected at selected hot spots.

- Radionuclide analysis using gamma spectrometry of three soil samples collected in the cleared area at the west plot and two soil samples collected beyond the perimeter of the cleared area at the east plot.

4. SURVEY RESULTS

4.1 BACKGROUND LEVELS

Background gamma exposure rates measured at uncontaminated outdoor areas on the Oak Ridge Reservation are listed in Table 4.1. Eighteen measurements taken at nine locations ranged from 8 to 13 μR/h (average 10 μR/h) at 1 m above the ground surface and from 10 to 17 μR/h (average 13 μR/h) at the surface.

Table 4.1 Radiation levels measured in uncontaminated areas on the Oak Ridge Reservation

Type of radiation[a]	Radiation level (μR/h)	
	Range	Average
Gamma exposure rate at 1 m above the ground surface	8–13	10
Gamma exposure rate at ground surface	10–17	13

[a]Values were obtained from 18 measurements taken from 9 locations on the Oak Ridge Reservation.

At the Chestnut Ridge east plot, surface background measurements in the cleared area and inside the rope generally ranged from 5 to 11 μR/h. Highest background measurements ranged from 5 to 13 μR/h in a few (~7%) scattered grid blocks. At the Chestnut Ridge west plot, surface background measurements in the cleared area and inside the rope generally ranged from 5 to 10 μR/h with a few (~6%) scattered grid blocks measuring 5 to 8 μR/h. Surface background levels at both plots were generally lower than background levels measured on the Oak Ridge Reservation (Table 4.1).

4.2 GAMMA EXPOSURE RATE MEASUREMENTS AT ONE METER

Results of gamma exposure rate measurements at 1 m above the ground surface at the east plot and the west plot are shown in Figs. 4.1 and 4.2, respectively. These measurements were made at 1 m above the spot with the highest surface measurement at most, but not all, contaminated areas. At the east plot, 61% of the 1-m measurements fell within typical background levels for the Oak Ridge Reservation (8 to 13 μR/h, Table 4.1). Another 33% of the 1-m measurements ranged from 14 to 20 μR/h, and 6% were over 20 μR/h. The highest 1-m measurement, 30 μR/h, was recorded only one time.

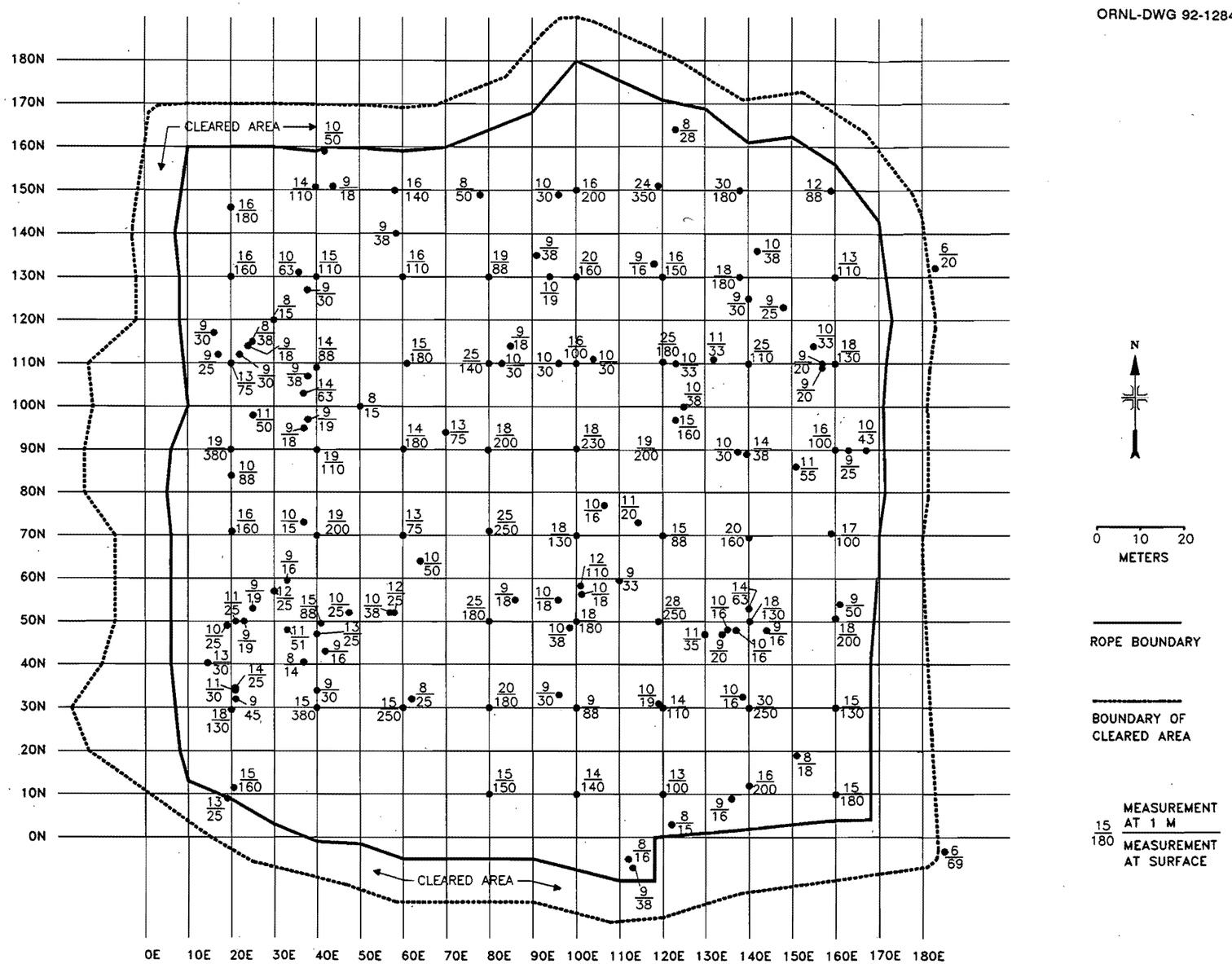

Fig. 4.1. Diagram showing gamma exposure rates (μR/h) at the ground surface and at 1 m above the surface at selected areas of the Chestnut Ridge east plot. NOTE: All areas with elevated radiation levels are not represented on this diagram.

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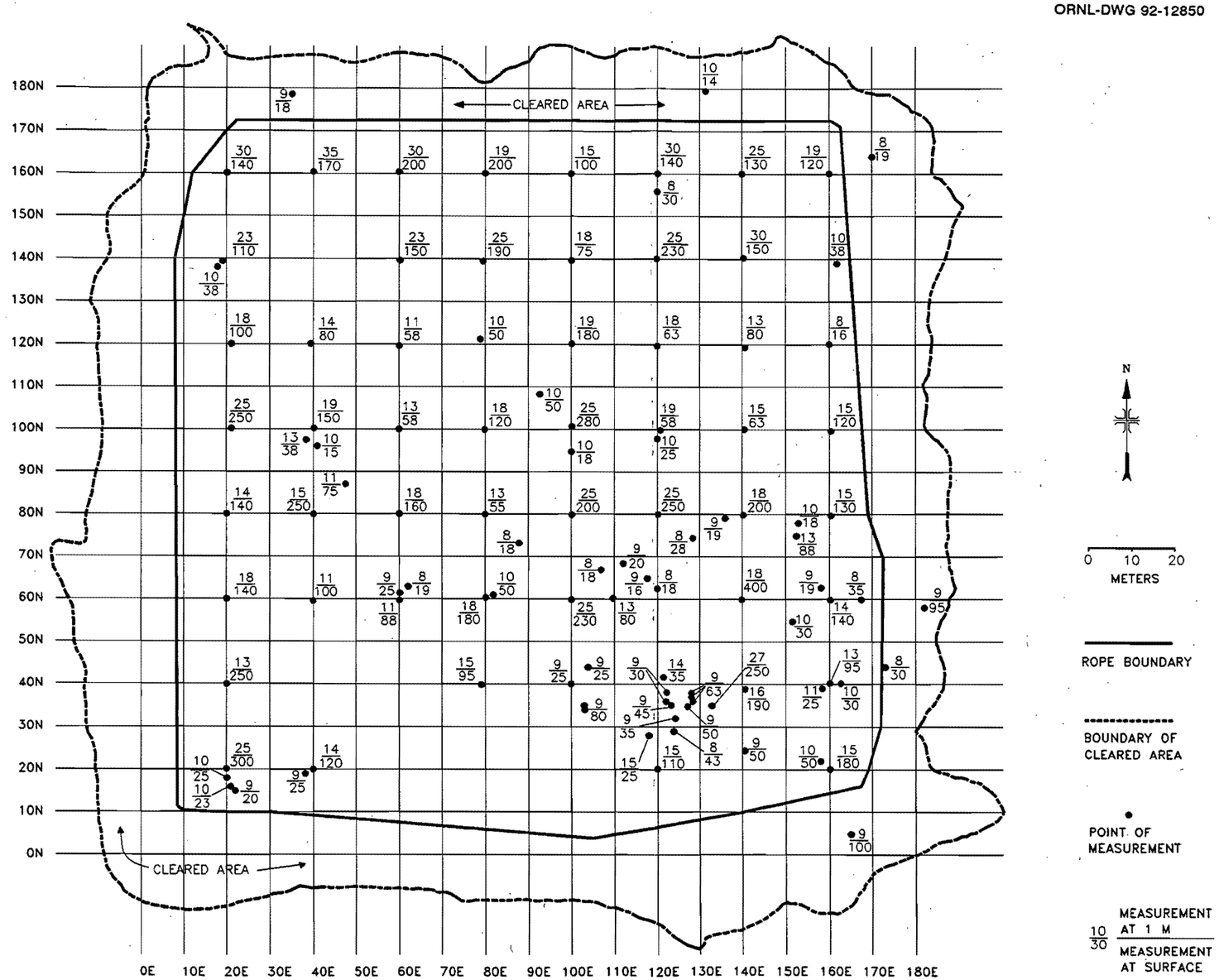

Fig. 4.2. Diagram showing gamma exposure rates (μR/h) at the ground surface and at 1 m above the surface at selected areas of the Chestnut Ridge west plot. NOTE: All areas with elevated radiation levels are not represented on this diagram.

At the west plot, 56% of the 1-m measurements fell within typical background levels for the Oak Ridge Reservation (8 to 13 μR/h, Table 4.1). Another 27% of the 1-m measurements ranged from 14 to 20 μR/h, and 17% were over 20 μR/h. The highest 1-m measurement, 35 μR/h, was recorded only one time.

4.3 SURFACE GAMMA EXPOSURE RATE MEASUREMENTS

Results of the surface gamma scan at the east and west plots are shown in Figs. 4.3 and 4.4, respectively. The pattern of surface contamination at both plots clearly followed the original placement of white pine seed feeders in the 1969–1970 study (Fig. 2.1). Although radioactivity from pine seed, excrement, and/or dead animals was obviously scattered over the site (e.g., elevated gamma levels inside old stumps at the east plot), most of the remaining contamination is concentrated at former feeder locations.

The east plot contained ~148 spots or areas with elevated surface gamma exposure rates. At 47% of these locations, the highest surface gamma levels were below 39 μR/h. Gamma exposure rates at 12% of the elevated locations ranged from 43 to 80 μR/h, 31% ranged from 88 to 180 μR/h, and the remaining 10% ranged from 190 to 380 μR/h.

The west plot contained ~116 spots or areas with elevated surface gamma exposure rates. At 35% of these locations, the highest surface gamma levels were below 39 μR/h. Gamma exposure rates at 23% of the elevated locations ranged from 43 to 80 μR/h, 28% ranged from 88 to 180 μR/h, and 12% ranged from 190 to 280 μR/h. The two remaining spots (2%) measured 300 and 400 μR/h.

4.4 ELEVATED SURFACE GAMMA EXPOSURE RATES OUTSIDE THE ROPE BOUNDARY

At the east plot, two spots with elevated surface gamma exposure rates of 15 μR/h were identified outside the rope, and four spots measuring 20 to 69 μR/h were identified beyond the perimeter of the cleared area (Fig. 4.3). At the west plot, seven spots with elevated surface gamma exposure rates ranging from 13 to 100 μR/h were identified outside the rope but within the cleared area (Fig. 4.4). A thorough survey at the perimeter of the cleared area was impossible at both the east and the west plot because brush and felled trees covered the ground surface. A cursory survey extending ~10 ft into level accessible areas beyond the brush and uprooted trees revealed no elevated surface gamma levels. During an escorted tour around the perimeter of both sites, all elevated spots detected outside the rope at both plots were identified for personnel responsible for erecting the fence. The planned fence will enclose these spots.

4.5 SOIL SAMPLE ANALYSES

Results of soil sample analysis are given in Table 4.2, and sample locations are identified in Figs. 4.3 and 4.4. At the east plots, two contaminated spots located beyond the cleared area

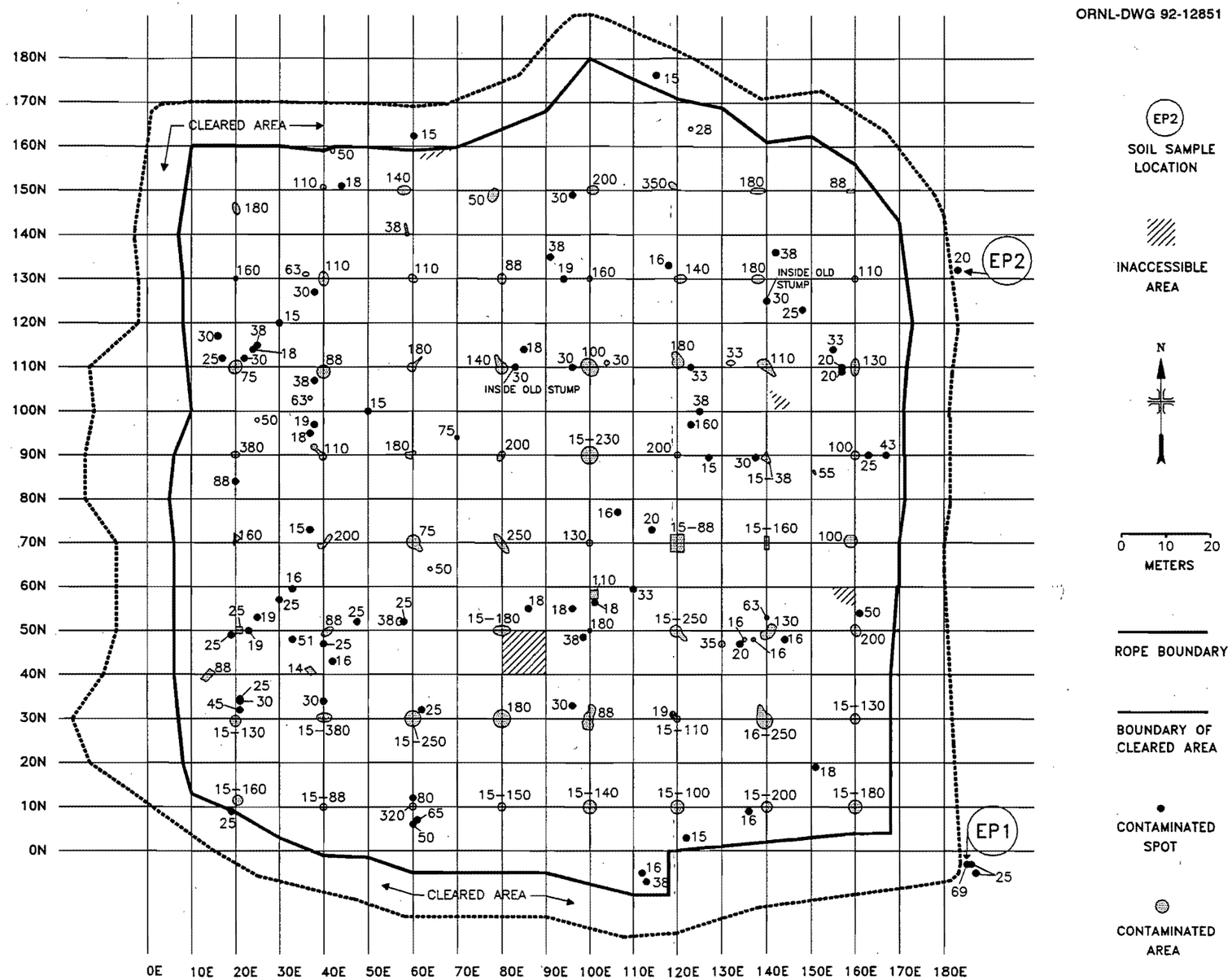

Fig. 4.3. Diagram showing areas with elevated surface gamma exposure rates (μR/h) at the Chestnut Ridge east plot. Soil sample locations are also designated.

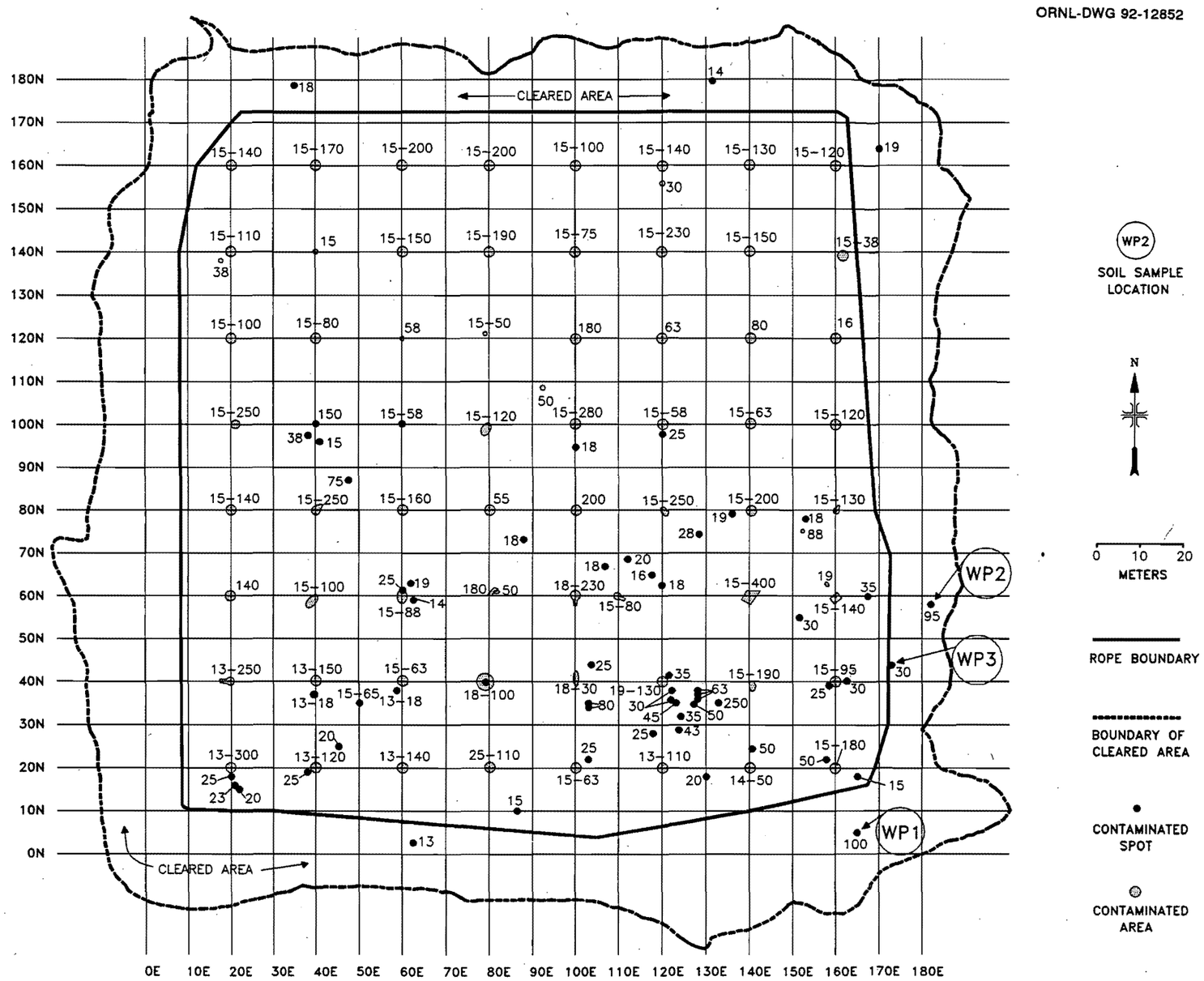

Fig. 4.4. Diagram showing areas with elevated surface gamma exposure rates (μR/h) at the Chestnut Ridge west plot. Soil sample locations are also designated.

Table 4.2. Concentrations of ^{60}Co, ^{137}Cs, ^{226}Ra, ^{232}Th, and ^{238}U in soil samples collected at the Chestnut Ridge plots

Sample No.	Depth (cm)	Radionuclide concentration (pCi/g)				
		^{60}Co	^{137}Cs	^{226}Ra	^{232}Th	^{238}U[a]
		Chestnut Ridge east plot[b]				
EP1	18–23	120 ±0.8	290 ±1	1.0±0.3	0.8±0.5	<32
EP2	15–25	25 ±0.2	49 ±0.3	1.2±0.1	0.7±0.2	<10
		Chestnut Ridge west plot[c]				
WP1A	0–5	190 ±3	160 ±0.8	1.8±0.3	<0.7	<38
WP1B	5–15	140 ±0.8	120 ±1	1.4±0.3	<0.9	<47
WP1C	15–30	140 ±0.7	150 ±0.9	1.4±0.3	<0.8	<41
WP2	0–5	120 ±0.6	110 ±0.7	1.8±0.2	0.8±0.4	<31
WP3A	0–5	0.25±0.02	1.6±0.1	1.2±0.04	0.8±0.1	<2.3
WP3B	20–30	55 ±1	120 ±0.6	1.3±0.2	1.0±0.3	<18
WP3C	30–46	10 ±0.1	18 ±0.2	1.1±0.1	0.8±0.1	<6.9

[a]These results were obtained using short counting times. Most probable concentrations of ^{238}U are similar to typical background levels for this area.
[b]East plot sample locations are shown on Fig. 4.3.
[c]West plot sample locations are shown on Fig. 4.4.

contained 120 and 25 pCi/g of ^{60}Co and 290 and 49 pCi/g of ^{137}Cs, indicating that the 1969–1970 seed study was responsible for these hot spots. Similarly at the west plot, soil samples from elevated spots in the cleared area also contained ^{60}Co and ^{137}Cs. Highest concentrations at the west plot were 190 pCi/g of ^{60}Co and 160 pCi/g of ^{137}Cs found at WP1A. Sample WP3 from an area of undisturbed soil contained only a small amount of surface contamination but noticeably elevated ^{60}Co and ^{137}Cs at subsurface levels. This situation might possibly have resulted from an animal storing seeds in a hole or some disturbance at the area in previous years.

Gamma exposure rate measurements at soil sample locations are shown in Table 4.3. The geometry of the measurement changes when the scintillator probe is placed below the ground surface; therefore, subsurface measurements in this table cannot be compared directly with measurements at or above the surface. However, these subsurface measurements do indicate that the contamination extends below the ground surface, in some cases to depths below 30 and 46 cm (12 and 18 in.). These samples were collected outside the roped area, but the same pattern of subsurface contamination is very likely present at elevated areas within the roped areas at both the east and the west plot.

4.6 VEGETATION

Vegetation found growing at three contaminated areas at each plot was transported to an uncontaminated area where gamma exposure rates and beta-gamma dose rates of the vegetation could be measured. No elevated radiation levels were detected on contact with the vegetation. The vegetation came from areas with surface gamma exposure rates of 180, 320, and 320 μR/h at the east plot and 280, 250, and 200 μR/h at the west plot.

Table 4.3. Gamma exposure rate measurements at soil sample locations at the Chestnut Ridge east and west plots

Sample ID[a]	Measurement position	μR/h	Date
	Chestnut Ridge east plot		
EP1	1 m above ground surface	6	1/30/92
	Surface	70	1/30/92
	Depth of 23 cm	130	1/30/92
EP2	1 m above ground surface	6	1/30/92
	Surface	20	1/30/92
	Depth of 20 cm	63	1/30/92
	Chestnut Ridge west plot		
WP1	1 m above ground surface	10	1/27/92
	Surface	110	1/27/92
	Depth of 5 cm	180	1/27/92
	Depth of 5 cm	160	2/5/92
	Depth of 15 cm	180	2/5/92
	Depth of 30 cm	190	2/5/92
WP2	1 m above ground surface	10	1/27/92
	Surface	75	1/27/92
	Depth of 10 cm	110	1/27/92
WP3	1 m above ground surface	8	1/27/92
	Surface	14	1/27/92
	Depth of 8 cm	25	1/27/92
	Depth of 20 cm	63	1/20/92
	Depth of 30 cm	63	1/20/92
	Depth of 46 cm	38	1/20/92

[a]Sample locations are shown on Figs. 4.3 and 4.4.

5. SIGNIFICANCE OF FINDINGS

The surface radiological survey of accessible areas at the Chestnut Ridge east and west plots revealed numerous spots and small areas of contamination. The pattern of surface contamination at both plots clearly followed the original placement of white pine seed feeders in the 1969–1970 study. Surface gamma exposure rates ranged up to 380 μR/h at the east plot and 400 μR/h at the west plot, but approximately one-half and one-third, respectively, of the identified anomalies did not exceed 39 μR/h. (Typical background surface gamma exposure rates on the Oak Ridge Reservation range from 10 to 17 μR/h.)

Highest gamma exposure rates at 1 m about the ground surface reached 30 μR/h at the east plot and 35 μR/h at the west plot. If a worker spends 8 hours/day, 5 days/week, and 50 weeks/year at the 35-μR/h spot, he/she would receive ~70* mrem/year, which is well below the allowed 100 mrem/year for public exposure. More than half of the 1-m measurements at both plots fell within the range of typical background levels for the Oak Ridge Reservation.

Vegetation collected from three contaminated spots at the east plot and another three contaminated spots at the west plot did not appear to be contaminated, based on field measurements in an area with background radiation levels.

Gamma spectroscopic analysis of soil samples demonstrated that ^{137}Cs and ^{60}Co were responsible for the elevated radiation levels. Radionuclides were found below the surface at soil sample locations, in some cases at depths below 18 in. Soil samples were only taken outside the rope boundary, but the same pattern of subsurface contamination may be present at other elevated surface spots inside the rope at both plots.

Generic guidelines for residual concentrations of ^{137}Cs have been estimated to be 15 pCi/g averaged over the first 15 cm of soil below the surface and 45 pCi/g averaged over 15-cm-thick layers at depths greater than 15 cm (ref. 5). These generic guidelines apply to concentrations averaged over an area of 100 m^2 (ref. 5). The generic guidelines for residual radioactive material in soil include two provisions for localized sources. First, in contaminated areas of 25 m^2 or less, the generic guideline for any surface or subsurface area is given by the generic guideline for widespread contamination multiplied by a factor of $(100/A)^{1/2}$, where A is the area of the contamination in square meters. Second, every reasonable effort shall be made to remove any material in which radionuclide concentrations exceed 30 times the generic guideline for widespread contamination, regardless of the average concentration in soil.[5] On the basis of the generic guideline for widespread ^{137}Cs contamination given above (15 and 45 pCi/g), the limits on residual concentrations of ^{137}Cs in any localized area have been estimated to be about 500 pCi/g in the first 15 cm below the surface and 1500 pCi/g at depths more than 15 cm below the surface.[5]

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*Assuming 1 R = 1 rad = 1 rem.

Soil samples collected outside the rope boundary at the Chestnut Ridge east and west plots contained maximum ^{137}Cs concentrations of 290 and 160 pCi/g, respectively. Four contaminated spots were identified in the area of uprooted trees and brush, and it is entirely possible that other spots of contamination are covered by the surface debris in this area. However, based on data from analyzed samples, any additional localized spots of contamination would probably not exceed the estimated limits on residual concentrations of ^{137}Cs in any localized area (500 pCi/g in the first 15 cm below the surface and 1500 pCi/g at depths more than 15 cm below the surface). No contamination was identified beyond the area of brush and felled trees. All identified spots of contamination outside the rope will be enclosed by the proposed fence.

6. RECOMMENDATIONS FOR CORRECTIVE ACTIONS

The presence of elevated gamma radiation levels at the ground surface and verified ^{137}Cs and ^{60}Co contamination in sampled soil warrant corrective action measures. This conclusion is based exclusively on the results of this survey, which should be considered an interim assessment pending a more detailed radiological characterization of the ER-11 area. Because a scoping survey is considered a limited, cursory investigation, the data and subsequent assessment of data presented in this report should be considered only a "snapshot" representation of the site during the dates of the survey.

Two basic approaches to interim corrective actions are (1) isolation of the entire ER-11 area (e.g., fencing), including measures to minimize the dispersion and/or redistribution of soil contamination, and (2) removal, treatment (if required), and disposal of contaminated material (e.g., soil and ground cover), and subsequent stabilization of the treated areas. Health risk assessments should be conducted and used in the evaluation of remedial action options.

Corrective action options listed below consist of ground-surface measures to limit human exposures, minimize surficial dispersion of radiological contamination, and monitor any such dispersion. Not every contamination situation would involve the implementation of all recommendations listed below; rather, the recommendations should be considered individually or in appropriate combinations. The primary concern in assessing appropriate corrective actions is the minimization of exposures of personnel to radiation as well as preventing movement of the contaminants into pathways that might result in exposure to the general public. These recommendations are in accordance with the radiation safety policy of ORNL to conduct all operations in such a manner that personnel exposures to radiation are maintained at a level as low as reasonably achievable (ALARA).

It is not within the scope of this investigation to identify and/or correlate federal and state environmental laws and their applicability for a suggested corrective action; however, it is important to mention that any removable and/or remedial action at the Chestnut Ridge site must be in accord with applicable federal and state laws and DOE orders. The reference section includes two detailed sources listing major environmental laws[6] and proposed guidance for remedial action strategies at sites previously contaminated with radioactive materials at ORNL.[7]

Isolation of soil contamination

- Radiation control measures at the ER-11 area boundary are recommended. A fence encompassing the ER-11 area, currently under installation, should be placarded with "Radiation Hazard—Keep Out" signs. This type of warning sign is used primarily to warn the general Laboratory population and the public where access to an area is limited to authorized personnel who have the training necessary to safely perform their job functions within the area. The placement of the fence should encompass surface "hot spots" identified in this survey.

- Currently, the Chestnut Ridge west plot can be accessed by vehicle by way of a gravel road leading from Highway 95. This road has a gate that does not succeed in preventing vehicular access. The west plot can also be reached by hiking in from Highway 95, Bethel Valley Road, or Bear Creek Road. The east plot can be accessed by vehicle by way of a gravel road, which has a gate that is seldom locked during normal working hours. The east plot can also be reached by hiking in from Bethel Valley Road or Bear Creek Road. The existence of contaminated surface soil warrants selective entrance requirements (e.g., metal gates). Access into the Chestnut Ridge site should be restricted and the number of zone portals (point of entrance and exit) limited. Because the area is accessed only for maintenance and monitoring activities, a controlled "exclusion area" should be considered until decisions are reached for appropriate site corrective measures and/or remedial actions.

- A weatherproof diagram of the radiological surface conditions of ER-11, depicting current surface radiation levels including surface hot spots (such as Figs. 4.3 and 4.4), should be maintained, updated, and made readily available to authorized personnel requiring access into these areas. Consideration should be given to posting such information at a highly visible location on site (e.g., where the road leading to the plot terminates). Instructions to contact responsible area personnel (e.g., ORNL Office of Radiation Protection or Environmental Restoration Program personnel), along with current telephone numbers, should be included.

- If remedial or cleanup actions are not implemented, institutional control measures should be maintained for a specified period of time to allow for radioactive decay of the intermediate-lived fission product ^{137}Cs. Long-term institutional control (~300 years) would result in a 99% reduction of ^{137}Cs activity (~10 half-lives). The half-life of ^{60}Co is 5.271 years and the half-life of ^{137}Cs is 30.17 years. Periodic monitoring for fugitive radionuclides in soil and vegetation should be performed.

- Radiation protection measures (e.g., personal radiation monitoring devices) should be considered for personnel not affiliated with Martin Marietta Energy Systems, Inc., who are involved with activities at the Chestnut Ridge site. (Note: Energy Systems personnel are required to wear badge dosimeters). All activities that disturb and/or disperse radioactivity at ER-11 should cease if personnel involved with such operations (e.g., grass mowing) do not wear some type of radiation monitoring devices and protection gear. Personal respirators would minimize the potential for inhalation of dust particles from radioactively contaminated soil and/or ground cover.

- External radiation levels could be reduced at contaminated areas by covering contaminated ground-surface areas with clean, uncontaminated soil. However, if eventual remedial action requires removal of contaminated soil, the added cover would increase the volume of waste to be disposed of.

- Because many areas of the Chestnut Ridge site (e.g., where tree and ground-surface debris were deposited from fence route clearing activities) were not accessible for surface gamma scanning, it is recommended that systematic sampling of vegetation and

subsequent radionuclide analysis be conducted. Contaminated vegetation would serve as biomarkers for surface or subsurface soil contamination.

Removal, treatment, and disposal of contaminated soil

- Contaminated soil should be removed, treated (if required), and disposed of in a designated radioactive waste disposal site. Excavation and removal of the contaminated material must be carried out in full compliance with current guidelines. It is recommended that personnel from the ORNL Office of Radiation Protection be present to monitor activities associated with any disturbance of soil at the Chestnut Ridge site.

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