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RADIOLOGICAL INVESTIGATIONS AT POTENTIAL DEER CONTAMINATION SITES

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ABSTRACT

Investigative radiological surveys of ten sites near the Oak Ridge National Laboratory (ORNL) that may potentially contaminate deer were conducted during the period March–September 1987. The objectives of these scoping surveys were: (1) to identify surface beta-gamma activity levels and determine the gross alpha, gross beta, and ^{90}Sr concentrations in selected soil samples and (2) to make site-specific recommendations for corrective actions to prevent deer intrusion onto areas found to have high levels of ^{90}Sr.

Results indicate significant ^{90}Sr contamination in soil sampled from two SWSA-5 seeps (S-11 and S-5) and two SWSA-4 seeps ("bathtub seeps" and the seep south of SWSA-4). These data were compared with ^{90}Sr concentrations in plants sampled at the same grid locations. In general, the results show a plant:soil ^{90}Sr concentration ratio of 2:1. Results of beta-gamma measurements taken in areas near Trench 7, including three low-level radioactive waste (LLW) line leak sites, indicate high levels of beta contamination (assumed to be primarily ^{90}Sr) in ground cover and other area vegetation. The highest level recorded (~70 mrad/h) was measured on contact with an American elm tree located near the LLW line leak site at the end of the Trench 7 Access Road. The results of radionuclide analyses of soil taken from the Trench 7 Access Road demonstrate significant surface contamination on the road as well as beside it, with gross beta and ^{90}Sr concentrations ranging from 140 to 12,000 pCi/g and 120 to 5400 pCi/g, respectively. Soil radionuclide analyses of surface samples from the Intermediate Pond Site show significant gross beta concentrations (ranging from 0.15 to 28 nCi/g), with ^{90}Sr being a minor contributor to the total amount of gross beta contamination.

Two basic approaches to corrective actions are suggested: (1) isolation of contamination by fencing the area, including measures to prevent and monitor any further dispersion of radioactivity, and (2) removal and burial of contaminated soil, ground cover, trees, and other vegetation and subsequent stabilization of the treated areas.

RADIOLOGICAL INVESTIGATIONS AT POTENTIAL DEER CONTAMINATION SITES

INTRODUCTION

Investigative radiological surveys of ten sites near the Oak Ridge National Laboratory (ORNL) that may potentially contaminate deer were conducted during the period March-September 1987 by the Environmental Assessments group of the Health and Safety Research Division (HASRD) of ORNL at the request of the Remedial Action Program (RAP) of ORNL. The objectives of this activity were: (1) to determine the gross alpha, gross beta, and ^{90}Sr concentrations in soil sampled from SWSA-4 and SWSA-5 seep locations; (2) to determine the relationship between ^{90}Sr soil concentrations and ^{90}Sr levels in plants at identical sampling locations; (3) to determine the gross alpha, gross beta, and ^{90}Sr concentrations in soil sampled from the Intermediate Pond Site; (4) to identify surface contamination (and contamination in area vegetation) as determined from measurements of beta-gamma activity near Trench 7 (excluding the groundwater seep on the eastern slope of Trench 7) and other vicinity sites; and (5) to make site-specific recommendations for corrective actions to prevent deer intrusion onto areas found to have high levels of ^{90}Sr or beta contamination assumed to be ^{90}Sr.

In 1986, areas of gamma radiation were identified in an EG&G aerial radiological survey conducted over the White Oak Creek Floodplain of the Oak Ridge Reservation (ORR).[1] A photograph from that survey, depicting ^{137}Cs* count rate isopleths was used in this study to prioritize the survey areas (see Fig. 1). In terms of deer contamination sites, ^{90}Sr is the primary radionuclide of interest, and, frequently, ^{90}Sr is associated with ^{137}Cs at many ORNL contaminated sites. Review of the inventory listing of major contaminants at ORNL Solid Waste Management Unit (SWMU) sites shows a frequent association of ^{90}Sr and ^{137}Cs.[2]

The following survey sites (Table 1) have been assigned a Waste Area Group (WAG) number and a SWMU identification number by the ORNL RAP.[2]

SURVEY METHODS

The radiological scoping survey at most of these sites included: (1) direct beta-gamma activity measurements on the ground surface and on contact with various tree parts; (2) gamma exposure rates during a scan of the contaminated areas; and (3) sampling and analysis of soil. Strontium-90 is analytically determined by radiochemical methods by ORNL Analytical Chemistry Division staff. All radionuclide concentrations in this report are dry weight (DW) values.

Beta-gamma measurements were taken with a portable Technical Associates (TA) mini-scaler/rate meter model RRS-3 with an HP-210 end-window (pancake) detector (<2 mg/cm^2 window thickness) and a side-window Geiger-Mueller (GM) survey meter (30 mg/cm^2 wall thickness). Measurements were taken in both open-window (beta-gamma) and closed-window (gamma) configurations, and beta radiation was determined by taking the difference between the two readings. In addition, a portable survey meter

*Barium-137 is actually the short-lived decay product of the beta-emitter ^{137}Cs.

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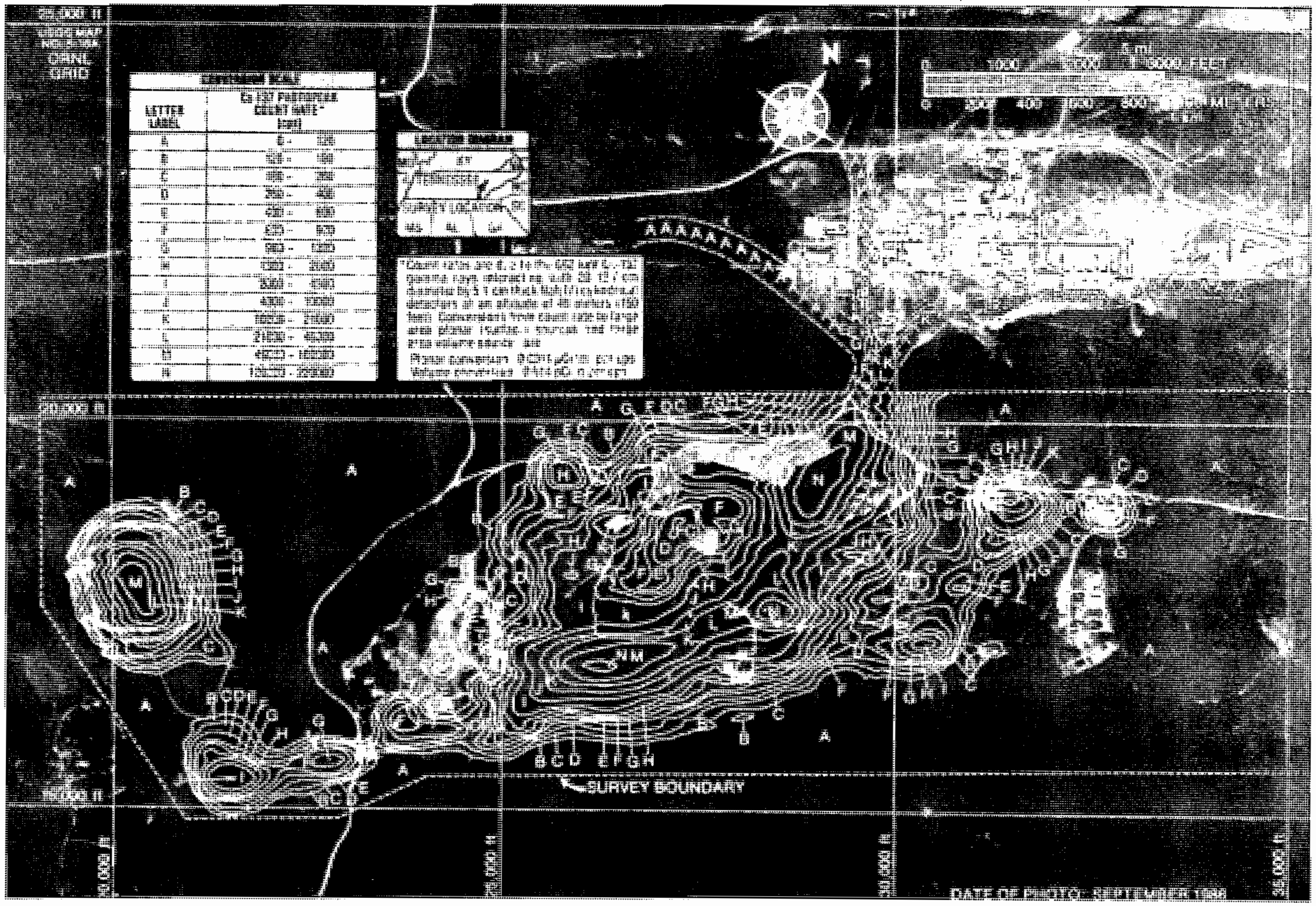

Fig. 1. Cesium-137 photopeak count rate isopleths of the White Oak Creek Floodplain, ORNL.

Table 1. Survey sites with respective Waste Area Group (WAG) and Solid Waste Management Unit (SWMU) identification numbers

Survey Site	Waste Area Group (WAG)	Solid Waste Management Unit (SWMU)
SWSA-5 (Seeps S-11, S-5)	5.0	5.7
SWSA-4 (Bathtub Seeps) (Seep South of SWSA-4)	4.0	4.3
Intermediate Pond	2.0	Not assigned
Trench 7	7.0	7.9
LLW Leak Site No. 2	7.0	7.4a
LLW Leak Site No. 1	7.0	7.4b
LLW Leak Site at the End of Trench 7 Access Road	7.0	7.4c
Valve Pit Station	7.0	Not assigned

using a NaI scintillation probe was used to detect gamma-radiation levels. The scintillation probe, connected to a Victoreen Model 470 Thyac III rate meter, was used to define the areal perimeter of contamination associated with gamma radiation.

A comprehensive description of the survey methods and instrumentation is presented in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program,* Oak Ridge National Laboratory, ORNL/TM-8600 (April 1987).[3]

SURVEY SITES

SWSA-5 (SWMU 5.7)

History of Site

SWSA-5 is located in Melton Valley south-southwest of the ORNL main plant area on a hillside east of White Oak Creek at latitude 35.91401, longitude 84.31295, and at ORNL grid coordinates (measured in feet) North 17,820 and East 29,560. SWSA-5 is a fenced area of ~323,750 m^2 (80 acres), but only ~202,340 m^2 (50 acres) have been used for waste disposal. The site has been divided into two distinct areas with different solid waste storage functions: SWSA-5 (south) and SWSA-5 (north).[2]

SWSA-5 (south), on a moderately sloping hillside, was used as a disposal site for low-level wastes generated at ORNL from 1959 to 1973. During the period 1955 to 1963, ORNL's solid waste storage areas were designated by the Atomic Energy Commission (AEC) as the Southeast Regional Burial Ground. SWSA-5 also received solid wastes from various off-site installations.[2]

SWSA-5 (north), on a relatively flat ridgetop,[4] comprises about 40,470 m^2 (10 acres) and was used for storage of transuranics (TRU). Transuranic wastes over 100 nCi/g had to be stored in a way that would allow retrieval at a later date.[2] The separation of TRU wastes began at ORNL in 1970, and burial in the northern section of SWSA-5 continued until 1979.[4]

ORNL Operations Division estimates that approximately 87,500 m^3 (3.09×10^6 ft^3) of waste containing <200,000 Ci of radioactivity has been buried in SWSA-5.[2] More than 96% of this volume consists of a heterogeneous mass of absorbent paper, all types of glassware, scrap metal, dirt, various filter media, lumber, powder, wire, piping, depleted uranium, animal carcasses from biological experiments, and experimental equipment that could not be economically decontaminated.[5] Low-level solid wastes were contaminated principally with ^{90}Sr, ^{244}Cm, ^{238}Pu, ^{106}Ru, ^{137}Cs, ^{60}Co, and ^{3}H. Retrievable wastes contained TRU isotopes and ^{233}U.[2]

Waste disposal at SWSA-5 (south) was similar to that at SWSA-4.[6] Beta-gamma contaminated wastes were put into trenches and covered with weathered shale.[7] Trenches were generally 12 to 152 m (40 to 500 ft) long, 3.7 m (12 ft) wide, and 4.6 m (15 ft) deep. The trenches were located at right angles to the strike of the shale to minimize collapse of the trench walls. Thus, the long axis of most trenches paralleled the slope of the hill, which later caused severe water infiltration problems. Transuranic wastes at SWSA-5 (north) were sealed in reinforced concrete casks at the point of origin, transported to the disposal area by tractor-trailer units, and unloaded by mobile crane into 3-m- (10-ft-) deep trenches. When filled to capacity, the trenches were covered with soil.[4]

Fairly high amounts of ^{90}Sr and measurable amounts of ^{244}Cm and ^{238}Pu have been found at the southeast corner of SWSA-5.[8] In 1975, water samples taken from 13 small seeps below the south edge of SWSA-5 contained measurable amounts of ^{90}Sr, ^{3}H, ^{125}Sb, and alpha radiation. Eleven of the samples contained concentrations of ^{90}Sr that ranged from 0.2 to 136.0 dpm/mL, with an average concentration of 22.5 dpm/mL (1.0×10^{-5} μCi/mL). The other two samples contained 3.1×10^4 and 3.5×10^2 dpm/mL of ^{90}Sr, with an average concentration of 1.6×10^4 dpm/mL (7.1×10^{-3} μCi/mL).[9]

Surface ^{90}Sr is of particular concern because strontium and calcium, with similar chemical properties, readily replace each other in chemical compounds and in animal calcareous tissues such as bone. For this reason ^{90}Sr is frequently called a "bone-seeking" radionuclide. When the 1986 organized deer hunts on the Oak Ridge Wildlife Management Area showed a 5.5-fold increase over the previous year in deer exceeding the confiscation limit of ~30 pCi/g ^{90}Sr in bone,[10] a need to locate the sources of contamination was recognized.

After the first 1986 deer hunt, ^{90}Sr levels in browse vegetation were examined at two seeps south of SWSA-5 that had been identified by Duguid in 1975 as possible sources of ^{90}Sr contamination.[9] The first site, seep S-11, was at the end of a service road on the south side of SWSA-5 near monitoring well T 117-1 at ORNL grid coordinates North 16,983 and East 29,928. Vegetation at the site was mostly herbaceous with a few trees.[10]

Seep S-11

The concentrations of ^{90}Sr (nCi/g) in vegetation and surface (0-15 cm) soil samples collected at seep S-11 grid locations are shown in Fig. 2. Plant samples were collected in November 1986 and the results published in June 1987 by Garten and Lomax.[10] The results of the soil sample analyses are shown in Table 2. The range of the plant:soil (surface) concentration ratios for ^{90}Sr is 0.53 to 2.1, with a geometric mean of 1.4. In general, there is a weak correlation between the highest surface meter readings (taken with a GM survey meter) and the highest gross beta and ^{90}Sr concentrations in soil.

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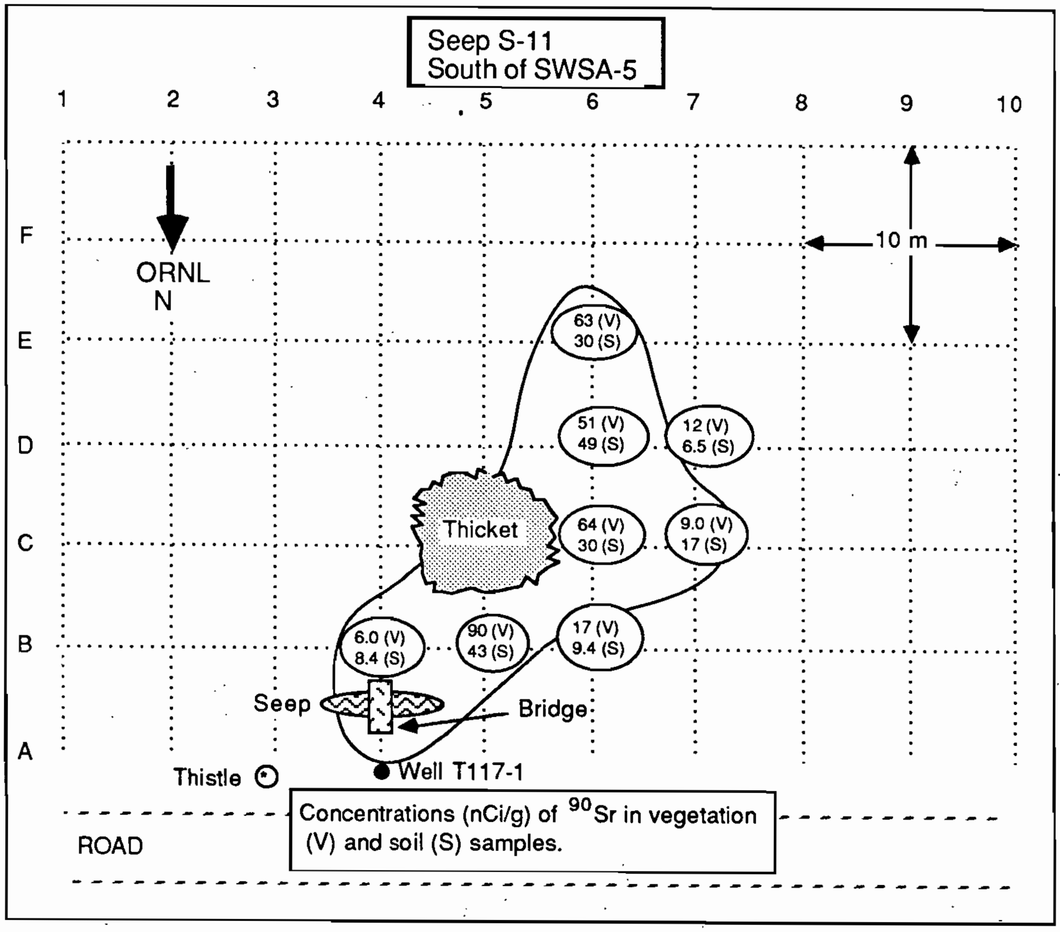

Fig. 2. Map of the study area at seep S-11, adjacent to SWSA-5, showing concentrations (nCi/g) of ^{90}Sr in vegetation (V) and surface soil (S) samples at various grid locations. Soil samples were collected in March 1987. Plant samples were collected in November 1986 by C. T. Garten, Jr., and R. D. Lomax [*Strontium-90 Contamination in Vegetation from Radioactive Waste Seepage Areas at ORNL, and Theoretical Calculations of ^{90}Sr Accumulation by Deer*, Oak Ridge National Laboratory, ORNL/TM-10453 (June 1987)].

Table 2. Gross alpha, gross beta, and ^{90}Sr concentrations in soil samples and ^{90}Sr in vegetation from seep S-11, south of SWSA-5[a,b]

Grid location	Soil sample ID	Soil depth (cm)	Gross alpha (nCi/g DW)	Gross beta (nCi/g DW)	^{90}Sr soil (nCi/g DW)	^{90}Sr vegetation (nCi/g DW)	Plant:Soil concentration ratio	Plant
B4	B4A	0-15	0.59	16	8.4	6.0	0.71	Honeysuckle
B4	B4B	15-30	0.40	12	5.7	6.0	-	Honeysuckle
B5	B5	0-15	3.5	97	43	90	2.1	Honeysuckle
B6	B6A	0-15	0.26	20	9.4	17	1.8	Honeysuckle
B6	B6B	15-30	0.049	6.2	3.0	17	-	Honeysuckle
C6	C6	0-15	3.0	59	30	64	2.1	Honeysuckle
C7	C7A	0-15	0.097	35	17	9.0	0.53	Honeysuckle
C7	C7B	15-30	0.27	73	32	9.0	-	Honeysuckle
D6	D6A	0-15	0.94	100	49	51	1.0	Honeysuckle
D6	D6B	15-30	0.15	39	17	51	-	Honeysuckle
D7	D7	0-15	0.89	14	6.5	12	1.8	Honeysuckle
E6	E6	0-15	0.65	65	30	63	2.1	Honeysuckle

[a]Grid sampling locations and concentrations of ^{90}Sr in plant samples (comprised of leaves and stems) are reported in C. T. Garten, Jr., and R. D. Lomax *Strontium-90 Contamination in Vegetation from Radioactive Waste Seepage Areas at ORNL, and Theoretical Calculations of ^{90}Sr Accumulation by Deer*, Oak Ridge National Laboratory, ORNL/TM-10453 (June 1987).

[b]Values are rounded to two significant digits.

Strontium-90 concentrations in six of eight surface soil samples were less than ^{90}Sr levels in honeysuckle samples collected at the same grid locations. The highest concentration of ^{90}Sr in honeysuckle was found at grid location B5 (90 nCi/g); the corresponding ^{90}Sr concentration in soil from the same grid point was 43 nCi/g. The highest beta-radiation readings [92,000 counts per minute (cpm)] at seep S-11 were also measured at this spot. At this location, gross beta was 97 nCi/g. Lower beta-radiation readings (69,000 cpm) were measured at grid location D6A, which had the highest gross beta (100 nCi/g) and ^{90}Sr concentrations (49 nCi/g). These differences may be attributable to the detection of high-energy beta-emitting radionuclides other than ^{90}Sr. Significant gross alpha concentrations (3.5 and 3.0 nCi/g) were found in soil sampled at grid markers B5 and C6, respectively.

Seep S-5

The second site, seep S-5, near ORNL grid coordinates North 17,000 and East 29,000, receives runoff from seep S-4, which overflows because of the "bathtub effect."[9] The site has many large trees and little herbaceous understory.[10]

The highest ground-level meter reading (beta radiation) at seep S-5 was measured at grid location B1 (26,000 cpm). The concentrations of ^{90}Sr (nCi/g) in vegetation and surface (0-15 cm) soil samples collected at grid locations of seep S-5 are shown in Fig. 3. Plant samples were collected in November 1986 and the results published in June 1987 by Garten and Lomax.[10] The results of the soil sample analyses are shown in Table 3.

Seep S-5 ^{90}Sr concentrations in all surface soil samples were less than ^{90}Sr levels in honeysuckle samples collected at the same grid locations. The range of the plant:soil (surface) concentration ratios for ^{90}Sr is 2.7 to 53, with a geometric mean of 10. The ratio of ^{90}Sr concentrations in soil to ^{90}Sr concentrations in honeysuckle samples may be influenced by the calcium status of the soil. Due to the chemical similarity of calcium and strontium, plants will uptake ^{90}Sr where there are low calcium levels in the soil. Another factor may be the presence of organic matter in the soil. Strontium-90 may bind with organic matter in soil and not be available for plant uptake. Highest concentrations of ^{90}Sr were found in samples collected at grid marker B1 in soil, 27 nCi/g, and honeysuckle, 72 nCi/g.

SWSA-4 (SWMU 4.3)

History of Site

SWSA-4, located in Melton Valley about 805 m (0.5 mi) southwest of the main ORNL complex, is bounded on the northern side by Lagoon Road. The site, at latitude 35.91586 and longitude 84.31989 and covering a 93,077-m^2 (23-acre) area, is located at ORNL grid coordinates North 19,220 and East 28,180. The landfill was used from February 1951 to July 1959 to bury an estimated 56,600 m^3 (2 million ft^3) of solid low-level radioactive waste including paper, glassware, scrap metal, dirt, filters, oils, powders, depleted uranium, animal carcasses, and large pieces of equipment. For a period of time, the landfill was designated as the Southern Regional Burial Ground by the AEC and

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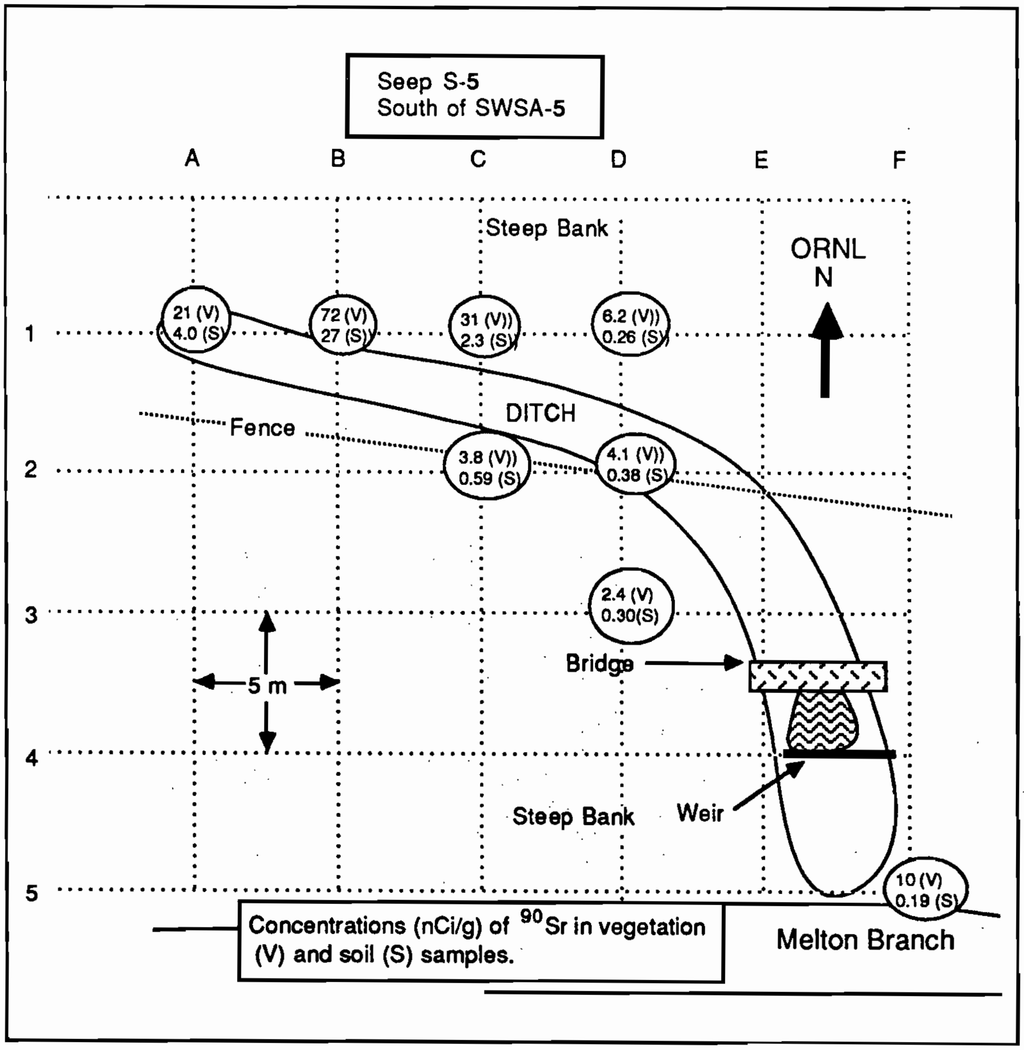

Fig. 3. Map of the study area at seep S-5, adjacent to SWSA-5, showing concentrations (nCi/g) of ^{90}Sr in vegetation (V) and surface soil (S) samples at various grid locations. Soil samples were collected in March 1987. Plant samples were collected in November 1986 by C. T. Garten, Jr., and R. D. Lomax [*Strontium-90 Contamination in Vegetation from Radioactive Waste Seepage Areas at ORNL, and Theoretical Calculations of ^{90}Sr Accumulation by Deer*, Oak Ridge National Laboratory, ORNL/TM-10453 (June 1987)].

received wastes from nuclear installations in the eastern United States. Records concerning the site were accidentally destroyed in a fire, but estimates suggest that ~90,000 to ~120,000 Ci of waste were buried, including ^{90}Sr, ^{137}Cs, ^{60}Co, ^{210}Po, ^{3}H, ^{125}Sb, and ^{239}Pu.[2]

The wastes were put in trenches ranging from 15 to 122 m (50 to 400 ft) long, 2 to 9 m (8 to 30 ft) wide, and 2 to 4 m (8 to 14 ft) deep. Alpha-emitting wastes were capped with 0.5 m (18 in.) of concrete, and beta- and gamma-emitting wastes were covered with

Table 3. Gross alpha, gross beta, and ^{90}Sr concentrations in soil samples and ^{90}Sr in vegetation from seep S-5, south of SWSA-5[a,b]

Grid location	Soil sample ID	Soil depth (cm)	Gross alpha (nCi/g DW)	Gross beta (nCi/g DW)	^{90}Sr soil (nCi/g DW)	^{90}Sr vegetation (nCi/g DW)	Plant:Soil concentration ratio	Plant
A1	A1A	0-15	0.0065	9.7	4.0	21	5.0	Honeysuckle
A1	A1B	15-30	0.0035	3.2	1.4	21	-	Honeysuckle
B1	B1	0-15	0.0040	59	27	72	2.7	Honeysuckle
C1	C1A	0-15	0.0027	5.1	2.3	31	13	Honeysuckle
C1	C1B	15-30	0.011	2.3	1.1	31	-	Honeysuckle
C2	C2A	0-15	0.0024	1.2	0.59	3.8	6.4	Honeysuckle
C2	C2B	15-30	0.0054	0.16	0.073	3.8	-	Honeysuckle
D1	D1	0-15	0.00081	0.57	0.26	6.2	24	Honeysuckle
D2	D2A	0-15	0.0054	0.78	0.38	4.1	11	Honeysuckle
D2	D2B	15-30	0.0027	1.2	0.59	4.1	-	Honeysuckle
D3	D3	0-15	0.011	0.67	0.30	2.4	8.0	Honeysuckle
F5	F5A	0-15	0.0040	0.43	0.19	10	53	Honeysuckle
F5	F5B	15-30	0.0081	0.11	0.051	10	-	Honeysuckle

[a]Grid sampling locations and concentrations of ^{90}Sr in plant samples (comprised of leaves and stems) are reported in C. T. Garten, Jr., and R. D. Lomax *Strontium-90 Contamination in Vegetation from Radioactive Waste Seepage Areas at ORNL, and Theoretical Calculations of ^{90}Sr Accumulation by Deer*, Oak Ridge National Laboratory, ORNL/TM-10453 (June 1987).

[b]Values are rounded to two significant digits.

soil. Approximately 50 auger holes, ranging from 0.3 to 0.6 m (1 to 2 ft) in diameter and some lined with concrete, were located in the northern part of the burial ground and used for recoverable higher-level waste. In addition, some special high-level waste was buried in individual stainless-steel containers. Compacting the waste with backhoes and bulldozers caused some of the containers to rupture.[9,11] Uncontaminated fill and construction debris were used as cover material, resulting in an increase in surface elevation of up to 6 m (20 ft) in the eastern end of the burial ground and, ultimately, increased water infiltration and a rise in the water table.[9,12]

Much of the waste in SWSA-4 is located in or very near the water table. Some of the trenches are inundated by groundwater during high water-table elevations in rainy periods. Water also drains down through the trenches from upslope runoff, pools in the lower end of the trench, and causes overflows. These leaky trenches, termed "bathtub seeps," are responsible for both surface and subsurface migration of contaminants from the trenches. SWSA-4 contributes about 35 to 50% of the ^{90}Sr that is discharged yearly from White Oak Creek basin at White Oak Dam. A surface runoff collector and diversion system was constructed in SWSA-4 in 1975; a second system was constructed in 1983. Stream gravel surveys have shown that SWSA-4 is a significant source of ^{90}Sr and ^{137}Cs.[2] Surface soil samples taken in 1986 at a SWSA-4 study area showed ^{90}Sr concentrations up to 51,350 pCi/g.[13]

In 1986 ^{90}Sr levels in browse vegetation were examined at two sites associated with SWSA-4 where deer might ingest contaminated vegetation. The first site was in SWSA-4 proper in the vicinity of the "bathtub seeps," and the second site was south of SWSA-4 on a floodplain receiving drainage from the burial ground (near ORNL grid coordinates North 19,106 and East 27,917). Deer had frequently been seen grazing in the area of the "bathtub seeps," and deer beds, digs, and evidence of browsing had been observed in the area just south of SWSA-4.[10]

Bathtub Seeps

The "bathtub seeps" area showed maximum ground-level readings (using a "pancake" beta-gamma survey meter) of 10,000 cpm (beta radiation) at grid point D4. The concentrations of ^{90}Sr (nCi/g) in surface soil (0-15 cm) and vegetation samples collected at grid locations of the bathtub seeps are shown in Fig. 4. Plant samples were collected in November 1986 and the results published in June 1987 by Garten and Lomax.[10] The results of the soil sample analyses are shown in Table 4.

Strontium-90 concentrations in six of eight surface soil samples were greater than ^{90}Sr levels in fescue samples collected at the same grid locations. The range of the plant:soil (surface) concentration ratios for ^{90}Sr is 0.17 to 1.5, with a geometric mean of 0.56. The difference in ratios of ^{90}Sr in soil to ^{90}Sr in fescue samples at this seep, and in honeysuckle samples collected at other seeps, may be attributed to the differences in plant-specific absorption properties (e.g., depth of the plant root systems). The highest concentrations of ^{90}Sr were found in soil and fescue samples at grid point D4, 5.1 and 2.0 nCi/g, respectively.

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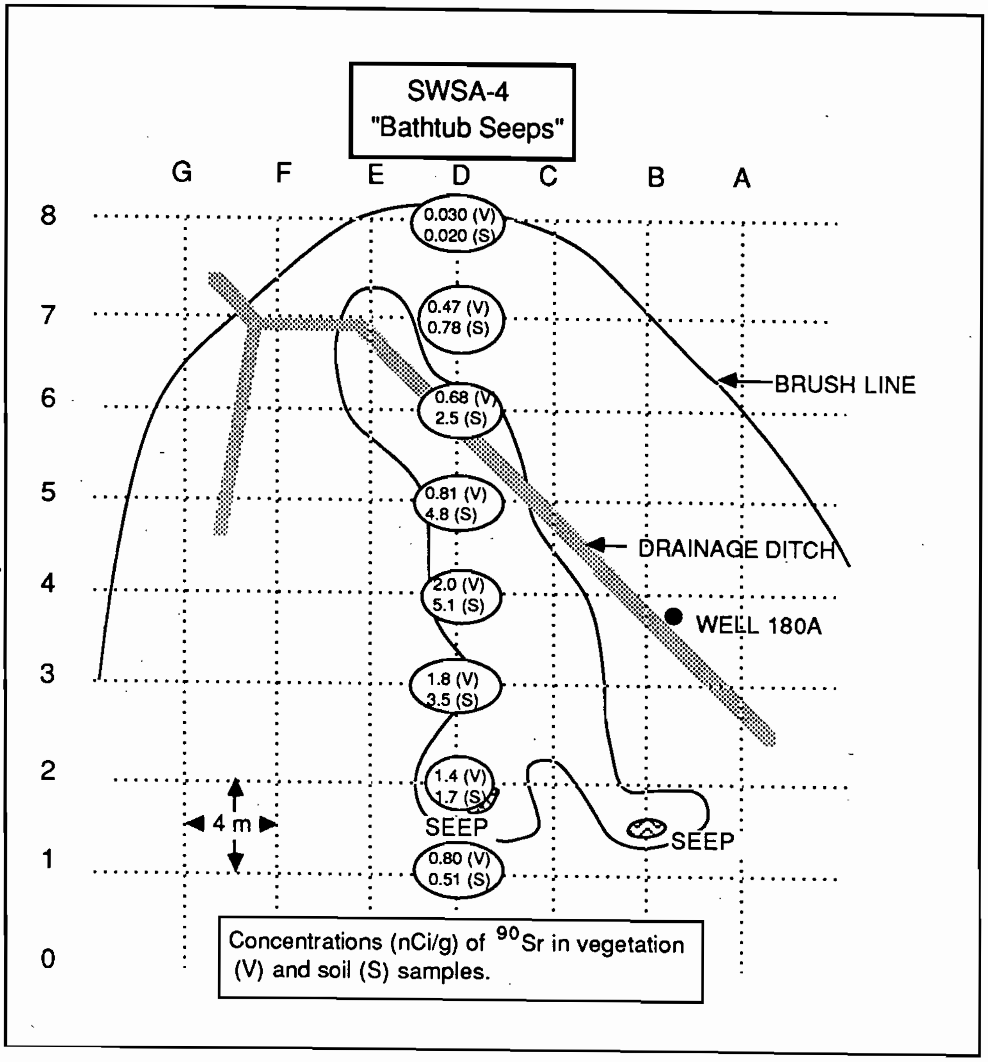

Fig. 4. Map of the study area associated with the "bathtub seeps" on SWSA-4 showing concentrations (nCi/g) of ^{90}Sr in vegetation (V) and surface soil (S) samples at various grid locations. Soil samples were collected in March 1987. Plant samples were collected in November 1986 by C. T. Garten, Jr., and R. D. Lomax [*Strontium-90 Contamination in Vegetation from Radioactive Waste Seepage Areas at ORNL, and Theoretical Calculations of ^{90}Sr Accumulation by Deer*, Oak Ridge National Laboratory, ORNL/TM-10453 (June 1987)].

Seep South of SWSA-4

The highest ground-level meter reading (beta radiation) at the seep south of SWSA-4 was measured at grid point D10 (22,000 cpm). The concentrations of ^{90}Sr (nCi/g) in surface soil (0-15 cm) and vegetation samples collected at grid locations of this seep are shown in Fig. 5. Plant samples were collected in November 1986 and the results published

Table 4. Gross alpha, gross beta, and ^{90}Sr concentrations in soil samples and ^{90}Sr in vegetation from the "bathtub seeps" area on SWSA-4[a,b]

Grid location	Soil sample ID	Soil depth (cm)	Gross alpha (nCi/g DW)	Gross beta (nCi/g DW)	^{90}Sr soil (nCi/g DW)	^{90}Sr vegetation (nCi/g DW)	Plant:Soil concentration ratio	Plant
D1	D1A	0-15	0.013	1.0	0.51	0.80	1.5	Fescue
D1	D1B	15-30	0.021	1.1	0.54	0.80	-	Fescue
D2	D2	0-15	0.054	5.9	1.7	1.4	0.82	Fescue
D3	D3A	0-15	0.11	8.9	3.5	1.8	0.51	Fescue
D3	D3B	15-30	0.021	3.5	1.5	1.8	-	Fescue
D4	D4	0-15	0.15	27	5.1	2.0	0.39	Fescue
D5	D5A	0-15	0.19	21	4.8	0.81	0.17	Fescue
D5	D5B	15-30	0.059	5.1	1.2	0.81	-	Fescue
D6	D6	0-15	0.13	11	2.5	0.68	0.27	Fescue
D7	D7A	0-15	0.0050	1.7	0.78	0.47	0.60	Fescue
D7	D7B	15-30	0.051	0.38	0.16	0.47	-	Fescue
D8	D8	0-15	0.016	0.10	0.020	0.030	1.5	Fescue

[a]Grid sampling locations and concentrations of ^{90}Sr in plant samples (comprised of leaves and stems) are reported in C. T. Garten, Jr., and R. D. Lomax *Strontium-90 Contamination in Vegetation from Radioactive Waste Seepage Areas at ORNL, and Theoretical Calculations of ^{90}Sr Accumulation by Deer*, Oak Ridge National Laboratory, ORNL/TM-10453 (June 1987).

[b]Values are rounded to two significant digits.

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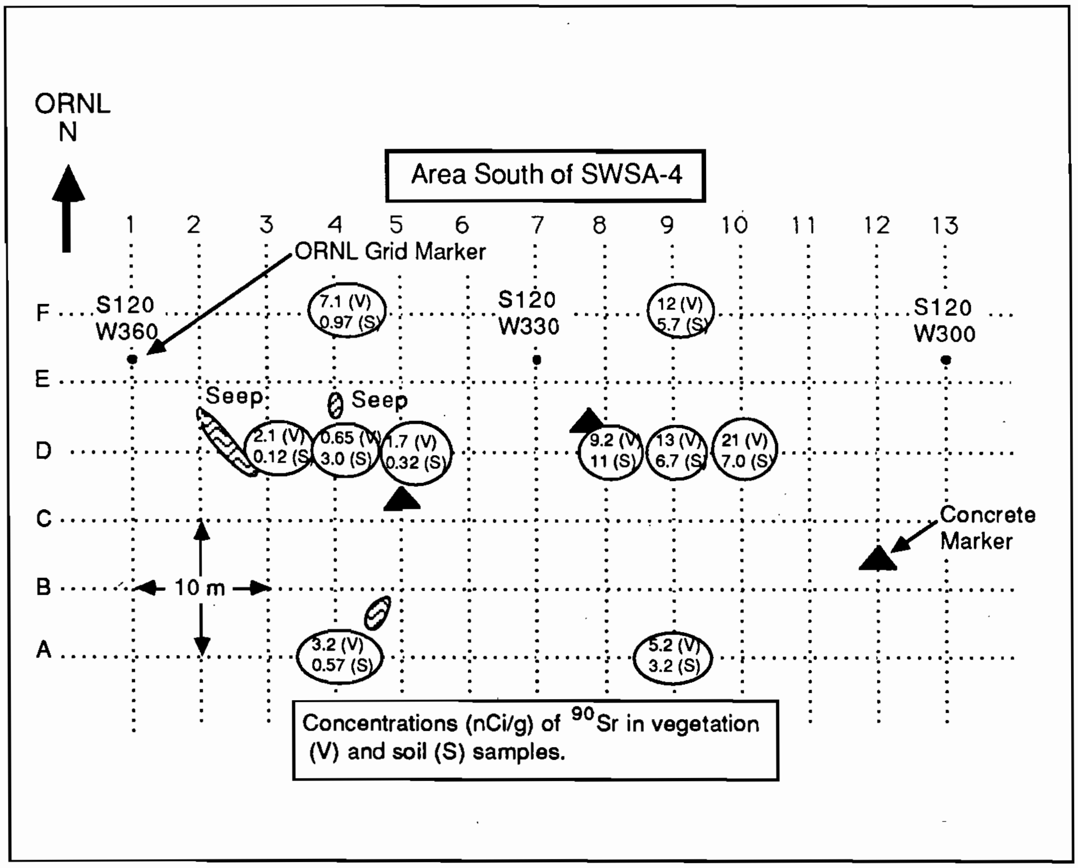

Fig. 5. Map of the study area south of SWSA-4 showing concentrations (nCi/g) of ^{90}Sr in vegetation (V) and surface soil (S) samples at various grid locations. Soil samples were collected in March 1987. Plant samples were collected in November 1986 by C. T. Garten, Jr., and R. D. Lomax [*Strontium-90 Contamination in Vegetation from Radioactive Waste Seepage Areas at ORNL, and Theoretical Calculations of ^{90}Sr Accumulation by Deer*, Oak Ridge National Laboratory, ORNL/TM-10453 (June 1987)].

in June 1987 by Garten and Lomax.[10] The results of the soil sample analyses are shown in Table 5.

In general, soil ^{90}Sr concentrations were less than ^{90}Sr values in plant samples collected at the same grid locations. The range of the plant:soil (surface) concentration ratios for ^{90}Sr is 0.21 to 17, with a geometric mean of 2.6. However, due to the variety of plants sampled (honeysuckle, grass/sedge, and blackberry), plant:soil concentration ratios of ^{90}Sr varied. A grass/sedge sample from grid point D4 had lower concentrations of ^{90}Sr (0.65 nCi/g) in comparison with a honeysuckle sample (5.2 nCi/g at grid point A9), where surface soil had approximately equal concentrations of ^{90}Sr (3.0 nCi/g). Highest concentrations of ^{90}Sr in surface soil (11 nCi/g) were found at grid marker D8. Blackberry shoots sampled from the same location showed ^{90}Sr levels of 9.2 nCi/g.[10] Surface soil ^{90}Sr concentrations were generally lower than previously reported soil ^{90}Sr values.[6,13]

Table 5. Gross alpha, gross beta, and ^{90}Sr concentrations in soil samples and ^{90}Sr in vegetation from the seep south of SWSA-4[a,b]

Grid location	Soil sample ID	Soil depth (cm)	Gross alpha (nCi/g DW)	Gross beta (nCi/g DW)	^{90}Sr soil (nCi/g DW)	^{90}Sr vegetation (nCi/g DW)	Plant:Soil concentration ratio	Plant
A4	A4A	0-15	0.049	1.2	0.57	3.2	5.6	Honeysuckle
A4	A4B	15-30	0.051	1.2	0.59	3.2	-	Honeysuckle
A9	A9A	0-15	0.022	7.8	3.2	5.2	1.6	Honeysuckle
A9	A9B	15-30	0.027	6.5	2.7	5.2	-	Honeysuckle
D3	D3A	0-15	<0.025	0.21	0.12	2.1	17	Honeysuckle
D3	D3B	15-30	0.0054	0.15	0.097	2.1	-	Honeysuckle
D4	D4	0-15	0.22	7.6	3.0	0.65	0.21	Grass/Sedge
D5	D5A	0-15	0.030	1.0	0.32	1.7	5.3	Honeysuckle
D5	D5B	15-30	0.022	0.65	0.43	1.7	-	Honeysuckle
D8	D8A	0-15	0.057	22	11	9.2	0.84	Blackberry
D8	D8B	15-30	0.022	7.6	3.8	9.2	-	Blackberry
D9	D9	0-15	0.13	14	6.7	13	1.9	Blackberry
D10	D10	0-15	0.078	15	7.0	21	3.0	Honeysuckle
F4	F4	0-15	0.022	2.1	0.97	7.1	7.3	Honeysuckle
F9	F9A	0-15	0.030	12	5.7	12	2.1	Honeysuckle
F9	F9B	15-30	0.040	12	5.7	12	-	Honeysuckle

[a]Grid sampling locations and concentrations of ^{90}Sr in plant samples (comprised of leaves and stems) are reported in C. T. Garten, Jr., and R. D. Lomax *Strontium-90 Contamination in Vegetation from Radioactive Waste Seepage Areas at ORNL, and Theoretical Calculations of ^{90}Sr Accumulation by Deer*, Oak Ridge National Laboratory, ORNL/TM-10453 (June 1987).

[b]Values are rounded to two significant digits.

DISCUSSION OF SEEP SURVEY RESULTS

Most of the contamination at these seeps is associated with beta-emitting radionuclides with approximately half of the soil gross beta concentrations attributed to ^{90}Sr. Although there are seep-specific variations in plant:soil concentration ratios for ^{90}Sr, these data conservatively demonstrate a 2:1 (plant to soil) ^{90}Sr concentration ratio. The variability of ^{90}Sr uptake by the same plant species at different sampling locations is most likely due to differences in soil properties. Comparison of the plant:soil concentration ratios from seeps S-11 and S-5 shows a significant difference in ^{90}Sr uptake by honeysuckle.

Garten and Lomax (1987) suggest that a mean ^{90}Sr level of ~5 pCi/g in vegetation could theoretically contaminate a 45-kg buck at levels which exceed the confiscation limit of ~30 pCi/g ^{90}Sr in bone, assuming the deer browses on contaminated vegetation on a regular basis. The results of this investigation suggest that ^{90}Sr concentrations in soil would, in addition, be an effective parameter for estimating potential area plant contamination and site contamination in the absence of terrestrial plants. It is proposed that an "action level" parameter [i.e., ^{90}Sr concentration level in surface soil (0-15 cm)] be established as a guideline for implementing site-specific corrective and/or remedial actions to exclude deer from contaminated areas on the ORR. However, a more detailed radiological characterization of these seeps and subsequent statistical analysis of data would be required to establish such a guideline, taking into consideration: (1) the chemical status of the soil; (2) the types of vegetation at each site; and (3) any change in the current deer confiscation limit. Garten and Lomax (1987) have reported that soil-to-plant transfer of ^{90}Sr may be related to the status of exchangeable calcium in soil (plant concentration decreases with increasing exchangeable soil calcium) and the soil pH (plant uptake of ^{90}Sr is greater from acid soils, pH <6).

RECOMMENDATIONS FOR CORRECTIVE ACTIONS FOR SEEPS

The areal perimeter of surface contamination at these seeps should be more precisely determined. Isolation of the contamination by fencing, including measures to prevent and monitor any further dispersion of radioactivity, is recommended. The following are suggestions for corrective actions to limit human exposures, exclude deer from the contaminated area, and minimize the dispersion of contamination (i.e., leaching and/or resuspension of radioactivity). A more detailed survey would be required to fully characterize the radiological status of the seeps and address the most appropriate methods for effective long-term remedial measures. Specific recommendations should be considered individually, although a combination of measures might be selected.

- Emplace a deer exclusion fence on the perimeter of the ground-surface beta-radiation contamination area, with controlled access for environmental monitoring.
- Attach "Radiation Hazard – Keep Out" signs to the permanent fence boundary. This type of sign is recommended by ORNL Health Physics personnel for use "in areas outside the main confines of the Laboratory and where members of the general public should be warned" (see Sect. 2.3 of Ref. 14).

- Maintain institutional control of this fenced area for a specified period of time to allow for radioactive decay. Long-term institutional control (~300 years) would result in a 99.9% reduction of ^{90}Sr activity (~10 half-lives). Periodic monitoring of radioactivity in trees, soil, surface water, and groundwater should be performed.
- Identify contaminated trees, if any, inside the fenced area with yellow or magenta paint using a predetermined configuration placed at some specific height on the tree trunk. Contaminated trees could additionally be identified with a "Contaminated Foliage" tag denoting the radiation hazard and date. A beta-gamma activity level of 1 mrad/h (measured on contact with any part of the tree) is suggested as the criterion level for such action.
- Minimize the dispersion of radioactivity by leaves from contaminated trees. One option is to chemically kill the contaminated trees, leave them standing, and periodically monitor the contamination in and around the trees.

INTERMEDIATE POND SITE

History of Site

The Intermediate Pond Site, located on White Oak Creek, is a short distance downstream from SWSA-4 in the vicinity of ORNL grid coordinates North 18,700 and East 29,000. In the spring of 1944, several years before the opening of SWSA-4, a small (90-m) earth-fill dam was constructed across White Oak Creek at mile 2.0 to create the Intermediate Pond. The pond was to serve as a settling basin for radionuclide-contaminated sediments released from ORNL and traveling down White Oak Creek toward White Oak Lake. On September 29, 1944, the dam was breached by high water, and the pond was greatly diminished in size. A residual pond existed behind the dam until 1951. During the existence of the residual pond, ~0.5 m (1.5 ft) of sediment accumulated. The sediment was initially contaminated by radioactivity released from the Laboratory and later contaminated by ^{90}Sr, ^{60}Co, and ^{137}Cs from SWSA-4.[9] The bed of the Intermediate Pond covered an area of about 33,590 m^2 (8.3 acres).[13,15] The residual pond covered ~4,850 m^2 (1.2 acres) and was 0.3 to 0.9 m (1 to 3 ft) deep.[16]

Seven soil samples taken at the area in 1975 contained alpha contamination, ^{90}Sr, ^{60}Co, ^{137}Cs, and minor amounts of ^{125}Sb. Strontium-90 ranged from 1.3×10^2 to 1.5×10^3 dpm/g, ^{60}Co from 33.4 to 9.9×10^2 dpm/g, ^{137}Cs from 1.5×10^2 to 1.8×10^5 dpm/g, and ^{125}Sb from 0.0 to 18.3 dpm/g.[9] Soil cores taken in the residual pond in 1975 contained 374 dpm/g of ^{239}Pu (0.168 μCi/kg) at depths of 0.0 to 0.1 m (0.0 to 5.0 in.). A sample from the area flooded during the summer of 1944 contained 135 dpm/g (0.061 μCi/kg) of ^{239}Pu.[9]

Vegetation at the area in 1975, including jewel weed, iron weed, marsh grass, honeysuckle, and cattail, contained ^{90}Sr levels ranging from 2.3×10^2 to 2.1×10^3 dpm/g (100°C oven-dried weight), ^{137}Cs ranging from 5.8 to 5.4×10^2 dpm/g, and minor amounts of ^{60}Co.[9]

Paired samples of surface soil (0-7 cm) and plants were collected on the floodplain at 27 stations in 1983. Levels of ^{90}Sr in soil samples ranged from 0.10 to 0.29 nCi/g with a mean of 0.17 nCi/g. Concentrations of ^{90}Sr in plant samples (unidentified grasses and honeysuckle) ranged from 0.058 to 0.75 nCi/g with a mean of 0.27 nCi/g in June and a mean of 0.17 nCi/g in August. Mean ^{90}Sr concentrations in plants were approximately equal to or 1.5 times greater than the mean concentration in surface soil.[10]

Discussion of Survey Results

Figure 6 shows the survey area with soil sample hole numbers at the Intermediate Pond Site. Gross alpha, gross beta, and ^{90}Sr concentrations in soil and selected vegetation samples shown in Table 6 indicate significant levels of beta contamination, primarily at the southwest portion of the site (where soil samples 28 through 40 were taken, Fig. 6). Strontium-90 concentrations were determined in 15 surface soil samples and compared with gross beta levels from the same samples.

The results show ^{90}Sr to be a minor contributor to the total amount of gross beta contamination in surface soil (0-15 cm). Strontium-90 concentrations in soil are less (by a mean factor of 70) than gross beta concentrations in the same surface samples. Although ^{90}Sr is not the dominant beta-emitting radionuclide in surface soil at the Intermediate Pond area, a mean concentration of 0.24 nCi/g (240 pCi/g) from 15 surface soil samples demonstrates a significant amount of radioactivity with respect to area plant and consequent deer contamination.

It is interesting to note that ^{90}Sr concentrations in five vegetation samples collected from selected areas at the pond site averaged 140 pCi/g, whereas corresponding gross beta concentrations averaged 350 pCi/g in the same plant samples. The highest gross alpha (0.35 nCi/g) and gross beta (28 nCi/g) concentrations were found in surface soil sample #33.

Recommendations for Corrective Actions

The areal perimeter of surface contamination along White Oak Creek and encompassing the Intermediate Pond Site (particularly at the southwest portion of the site) should be more precisely determined. Isolation of the contamination by fencing the area, including measures to prevent and monitor any further dispersion of radioactivity, is recommended. The following are suggestions for corrective actions to limit human exposures, exclude deer from the contaminated area, and minimize the dispersion of contamination (i.e., leaching and/or resuspension of radioactivity). A more detailed survey would be required to fully characterize the radiological status of the site and address the most appropriate methods for effective long-term remedial measures. Specific recommendations should be considered individually, although a combination of measures might be selected.

- Emplace a deer exclusion fence on the perimeter of the ground-surface beta-radiation contamination area, with controlled access for environmental monitoring.

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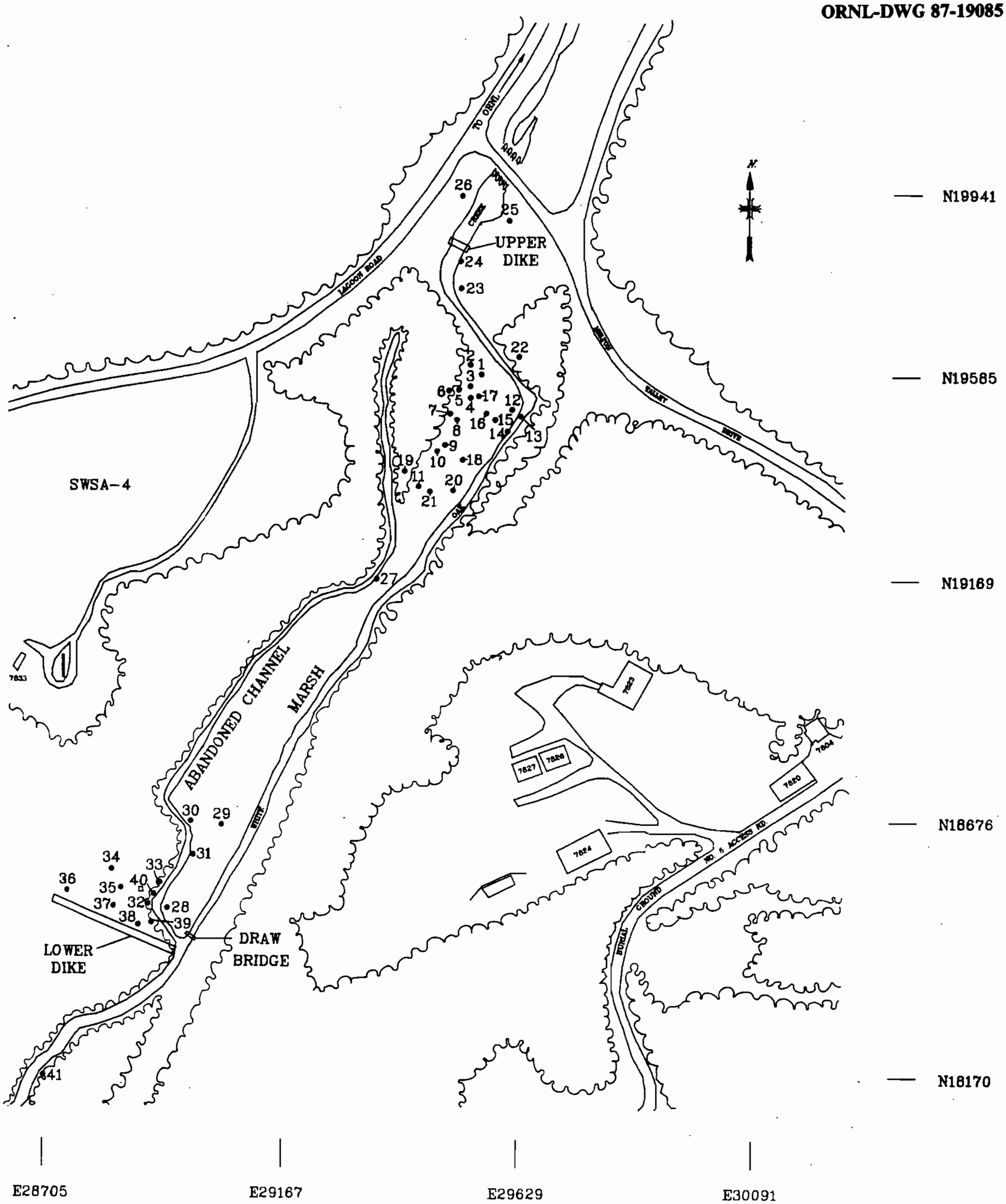

Fig. 6. Locations of soil sample hole numbers at the Intermediate Pond Site.

Table 6. Gross alpha, gross beta, and ^{90}Sr concentrations in soil and selected vegetation samples from the Intermediate Pond Site

Sample ID[a,b]	Location North	Location East	Soil depth (cm)	Gross alpha (nCi/g DW)	Gross beta (nCi/g DW)	^{90}Sr (nCi/g DW)
1A	19585	29549	0-15	<0.027	1.5	c
1B	19585	29549	15-30	0.054	2.1	c
2A	19601	29528	0-15	0.054	1.8	c
2B	19601	29528	15-30	0.11	6.5	c
3	19563	29527	0-15	<0.027	1.2	c
4	19535	29528	0-15	<0.027	1.6	c
5A	19548	29503	0-15	<0.027	1.3	c
5B	19548	29503	15-30	0.11	4.5	c
6A	19548	29489	0-15	0.054	11	0.10
6B	19548	29489	15-30	0.081	2.9	c
6V	19548	29489	-	0.0068	0.30	0.092
7A	19504	29488	0-15	<0.027	1.3	c
7B	19504	29488	15-30	0.19	5.5	c
8	19489	29502	0-15	0.027	1.6	c
9A	19439	29480	0-15	0.11	7.8	0.15
9B	19439	29480	15-30	0.054	2.6	c
9V	19438	29479	-	0.0057	0.32	0.089
10A	19428	29466	0-15	0.11	10	0.21
10B	19428	29466	15-30	0.14	11	c
11A	19358	29426	0-15	0.081	7.3	0.23
11B	19358	29426	15-30	0.054	4.9	c
11V	19358	29426	-	0.0046	0.15	0.046
12A	19514	29613	0-15	0.30	6.1	0.35
12B	19514	29613	15-30	0.11	8.9	c
13A	19501	29629	0-15	0.054	0.86	c
13B	19501	29629	15-30	0.054	1.1	c
14	19473	29602	0-15	<0.027	0.62	c
15A	19491	29582	0-15	<0.027	1.2	c
15B	19491	29582	15-30	0.19	3.2	c
16	19502	29561	0-15	0.11	4.3	c
17	19541	29545	0-15	<0.027	1.1	c
18	19409	29515	0-15	0.081	2.3	c
19A	19386	29497	0-15	0.081	3.8	c
19B	19386	29497	15-30	0.19	3.9	c
20	19354	29498	0-15	0.054	2.1	c
21A	19346	29452	0-15	0.081	3.0	c
21B	19346	29452	15-30	0.32	4.9	c
22A	19618	29621	0-15	0.16	11	0.19
22B	19618	29621	15-30	0.11	9.7	c
22V	19618	29621	-	0.017	0.65	0.32

Table 6 (continued)

Sample ID[a,b]	Location North	Location East	Soil depth (cm)	Gross alpha (nCi/g DW)	Gross beta (nCi/g DW)	^{90}Sr (nCi/g DW)
23	19752	29506	0-15	0.027	2.4	c
24	19806	29501	0-15	0.054	11	0.097
25	19896	29596	0-15	<0.027	0.43	c
26A	19941	29501	0-15	<0.027	4.1	c
26B	19941	29501	15-30	<0.027	1.3	c
27V	19169	29352	-	0.0068	0.32	0.13
28A	18505	28950	0-15	0.16	18	0.18
28B	18505	28950	15-30	0.16	14	c
29A	18677	29051	0-15	0.027	0.84	c
29B	18677	29051	15-30	<0.027	0.43	c
30A	18676	28991	0-15	0.19	15	0.19
30B	18676	28991	15-30	0.14	12	c
31A	18611	28998	0-15	0.081	16	0.40
31B	18611	28998	15-30	0.081	15	c
32A	18511	28909	0-15	0.027	28	0.40
32B	18511	28909	15-30	0.054	9.0	c
33	18556	28930	0-15	0.35	28	0.32
34	18582	28839	0-15	0.054	4.4	c
35A	18540	28855	0-15	0.027	19	0.38
35B	18540	28855	15-30	0.027	2.6	c
36	18536	28749	0-15	<0.027	2.5	c
37	18509	28845	0-15	0.027	2.1	c
38	18474	28892	0-15	0.081	5.3	c
39A	18478	28917	0-15	0.22	22	0.24
39B	18478	28917	15-30	0.16	16	c
40A	18536	28919	0-15	0.081	25	0.21
40B	18536	28919	15-30	<0.027	3.5	c
41	18170	28705	0-15	0.027	2.5	c

[a]Soil sample hole numbers are shown on Fig. 6.
[b]Vegetation samples are represented by the letter "V."
[c]Not analyzed.

- Attach "Radiation Hazard – Keep Out" signs to the permanent fence boundary. This type of sign is recommended by ORNL Health Physics personnel for use "in areas outside the main confines of the Laboratory and where members of the general public should be warned" (see Sect. 2.3 of Ref. 14).
- Maintain institutional control of this fenced area for a specified period of time to allow for radioactive decay. Long-term institutional control (~300 years) would result in a 99.9% reduction of ^{90}Sr activity (~10 half-lives). Periodic monitoring of radioactivity in trees, soil, surface water, and groundwater should be performed.

- Identify contaminated trees, if any, inside the fenced area with yellow or magenta paint using a predetermined configuration placed at some specific height on the tree trunk. Contaminated trees could additionally be identified with a "Contaminated Foliage" tag denoting the radiation hazard and date. A beta-gamma activity level of 1 mrad/h (measured on contact with any part of the tree) is suggested as the criterion level for such action.
- Minimize the dispersion of radioactivity by leaves from contaminated trees. One option is to chemically kill the contaminated trees, leave them standing, and periodically monitor the contamination in and around the trees.

TRENCH 7 (SWMU 7.9)

History of Site

Trench 7 is one of seven ORNL seepage pits and trenches that were used to dispose of ~159 million L (~42 million gal) of radioactive liquid wastes between 1951 and 1966. Trench 7, located at ORNL grid coordinates North 17,440 and East 27,600, is composed of two independent units, each 30.5 m (100 ft) long by 3.6 m (12 ft) wide, tapering to 1.2 m (4 ft) wide at the bottom, and 5 m (16 ft) deep. The two units are 9.1 m (30 ft) apart.[17] Construction was completed in August 1962, and, after pretreatment with 189,250 L (50,000 gal) of 4% sodium hydroxide to enhance the adsorption of ^{90}Sr, the trench was put into operation on October 4, 1962. The trench received ~36 million L (~9.5 million gal) of waste containing approximately 231,000 Ci of ^{137}Cs, 48,000 Ci of ^{90}Sr, 3400 Ci of ^{106}Ru, and 1500 Ci of ^{60}Co, which were divided about equally between the two units. Trench 7 was used until 1966 when hydrofracture disposal, considered to be more environmentally sound than seepage pit disposal, was put into operation. In 1970, approximately 18% of the area was covered with asphalt.[18]

Very little ^{90}Sr and ^{137}Cs have been found in groundwater in the vicinity of Trench 7, but the inventory of ^{90}Sr in the trench is of concern because concentrations and discharges might change in the future. Treatments to retain ^{90}Sr may have increased the mobility of ^{233}U. Most of the radioactivity in groundwater near the trench was ^{233}U, ^{3}H, ^{60}Co, and ^{99}Tc. High concentrations of ^{99}Tc have also been found in leaves of trees whose roots are apparently very efficient at extracting ^{99}Tc from the soil and groundwater.[19] Plutonium-238, ^{239}Pu, and ^{240}Pu found in the soil suggest that plutonium contamination has resulted from the migration of ^{242}Cm and ^{244}Cm followed by decay to ^{238}Pu and ^{240}Pu, respectively, rather than from the migration of plutonium.[2]

Corrective actions were taken at Trench 7 in 1985 and 1986 to reduce the discharge of high levels of ^{60}Co at a groundwater seep on the eastern side of the drainage area. These actions included recontouring and widening the asphalt cap on the trench to 36% of the area, rerouting surface runoff away from the trench via a drain and culvert to a wet-weather stream about 30 m (98 ft) downgrade, excavating and sealing the waste transfer line just north of the trench, and injecting a grout curtain into the ground on the eastern and northern sides of the site.[18]

Discussion of Survey Results

Surface contamination on the north and northeast ends and the west side of Trench 7 is contiguous with contamination from the LLW Leak Site at the end of Trench 7 Access Road (SWMU 7.4c, Fig. 7). It is believed that SWMU 7.4c is the primary source of the

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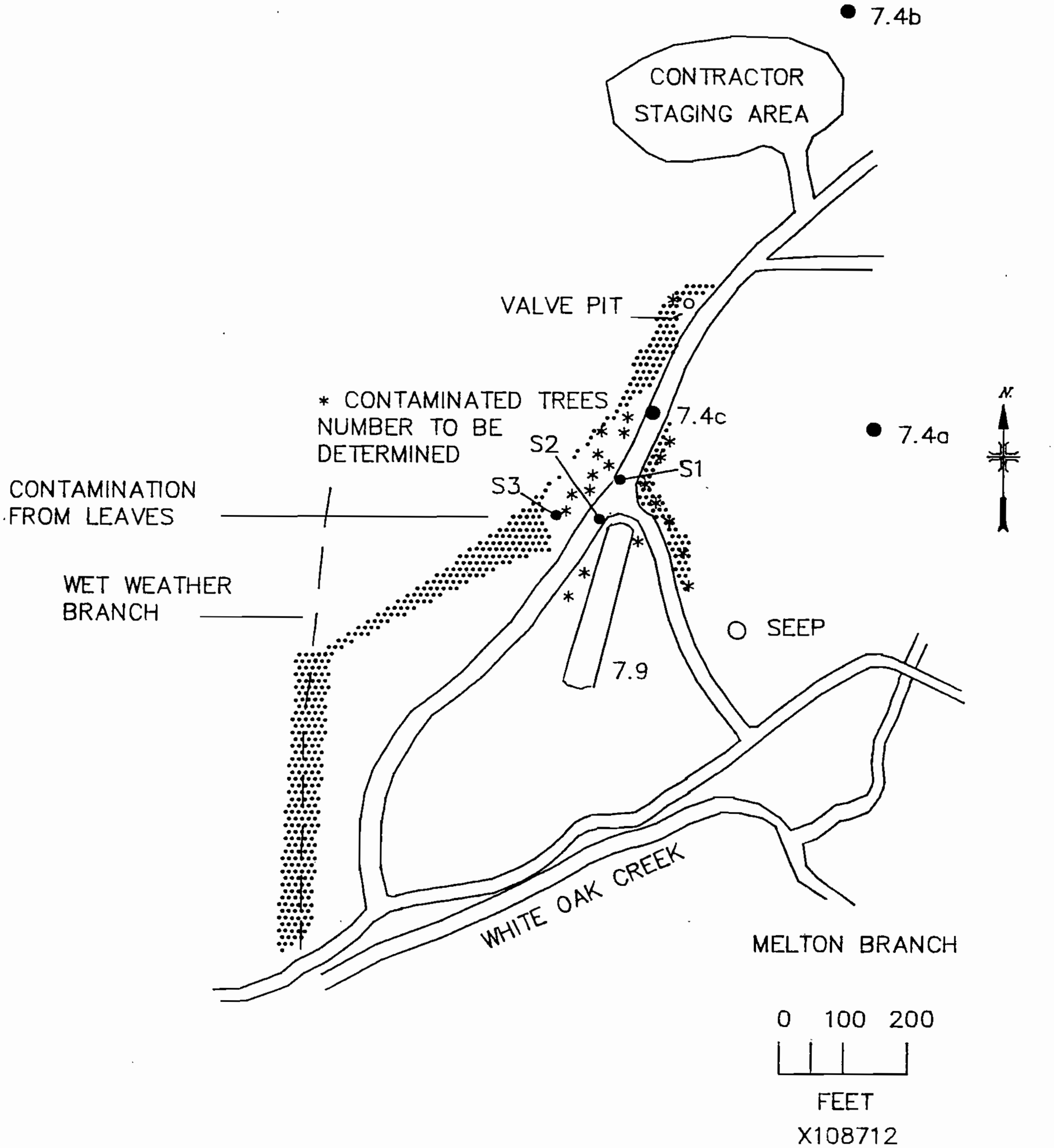

Fig. 7. Contaminated areas associated with the LLW Leak Site at the end of the Trench 7 Access Road (SWMU 7.4c) and the valve pit station.

contamination at these identified areas near Trench 7. It should be noted that SWMU 7.4c is ~10.7 to ~12 m (~35 to ~40 ft) higher in elevation than the eastern seep associated with Trench 7.

Generally, beta-gamma measurements taken on the ground surfaces and selected tree trunks at the western slope of Trench 7 ranged from background to ~1 mrad/h.

At the north end of Trench 7, beta-gamma measurements were taken on contact with several species of trees known to have deep root systems. Dose-rate measurements generally ranged from 8 to 14 mrad/h.

Radiological measurements taken on contact with the north end of the asphalt trench cap show low levels of gamma radiation. A small group of decaying leaves on the surface of the asphalt cap were found to have significant beta activity, which is believed to be the result of uptake of residual soil radionuclides (most likely ^{90}Sr) by trees in the contaminated area.

Recommendations for Corrective Actions

Two basic approaches to corrective actions for the north and northeast ends and the west side of Trench 7 are: (1) isolation of contamination by fencing the area, including measures to prevent and monitor any further dispersion of radioactivity and (2) removal and burial of contaminated soil, ground cover, trees, and other vegetation and subsequent stabilization of the treated areas. Specific recommendations are listed below under these two categories. Corrective actions would not necessarily involve implementation of all recommendations in one or the other category; rather, the recommendations are to be considered individually, although a combination of measures might be selected.

The following are suggestions for corrective actions to limit human exposures, exclude deer from the contaminated area, and minimize the dispersion of contamination (i.e., leaching and/or resuspension of radioactivity). A more detailed survey would be required to fully characterize the radiological status of the site and address the most appropriate methods for effective long-term remedial measures.

Isolation of the contaminated site

- Emplace a deer exclusion fence on the perimeter of the ground-surface beta-radiation contamination area, with controlled access for environmental monitoring. The areal perimeter of surface contamination should be more precisely determined (see Fig. 8).
- Attach "Radiation Hazard – Keep Out" signs to the permanent fence boundary. This type of sign is recommended by ORNL Health Physics personnel for use "in areas outside the main confines of the Laboratory and where members of the general public should be warned" (see Sect. 2.3 of Ref. 14).
- Maintain institutional control of this fenced area for a specified period of time to allow for radioactive decay. Long-term institutional control (~300 years) would result in a 99.9% reduction of ^{90}Sr activity (~10 half-lives). Periodic monitoring of radioactivity in trees, soil, surface water, and groundwater should be performed.

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Fig. 8. View of contaminated area northwest of Trench 7 (SWMU 7.9) and south of SWMU 7.4c (August 1987).

- Identify contaminated trees inside the fenced area with yellow or magenta paint using a predetermined configuration placed at some specific height on the tree trunk. Contaminated trees could additionally be identified with a "Contaminated Foliage" tag denoting the radiation hazard and date. A beta-gamma activity level of 1 mrad/h (measured on contact with any part of the tree) is suggested as the criterion level for such action.
- Minimize the dispersion of radioactivity by leaves from contaminated trees. One option is to chemically kill the contaminated trees, leave them standing, and periodically monitor the contamination in and around the trees.
- Consider some type of barrier to prevent surface (downslope) runoff of contamination into a known wet-weather branch that drains into White Oak Creek (see Fig. 7).
- Pave the Trench 7 Access Road with asphalt to minimize the resuspension of contaminated dust and possible vehicle contamination.

Removal and burial of contaminated materials

- Bulldoze contaminated soil, ground cover, trees, and other vegetation into a nearby ravine. Some land stabilization procedures (e.g., earthen caps, soil covers, reforestation with pine trees) should be considered for the remediated site and the partially filled ravine. The ravine area, however, would most likely become a new SWMU site.
- Remove contaminated soil, ground cover, trees, and other vegetation and bury them in a radioactive waste disposal site (SWSA-6).

A detailed discussion of contaminated land cleanup methodologies, estimates of cleanup costs, and the importance of establishing cleanup priorities is given by Baes et al. (1986).[20]

LLW LEAK SITE NO. 2 (SWMU 7.4A)

History of Site

Leak Site No. 2 is one of two significant leak sites that have been identified along the LLW line that from 1952 to 1975 transferred liquid wastes to the pits and trenches and to the first hydrofracture site.[18] Leak No. 2, also referred to as the South Leak Site, is located northwest of Building 7852 and approximately 61 m (200 ft) west of White Oak Creek at ORNL coordinates North 17,680 and East 28,000 (see Fig. 9). The first leak occurred July 9, 1970, at a mechanical, neoprene-gasketed joint. Liquid waste reached the ground-surface and spread laterally over a small area. Routinely this liquid waste contained ^{90}Sr, ^{137}Cs, ^{106}Ru, ^{60}Co, various rare earths, and some plutonium, uranium, and transuranic isotopes.[2]

Soil samples, analyzed in 1973, contained up to 422 μCi/g of ^{90}Sr and a total gamma activity of 621 μCi/g, with the highest levels observed at the point of the leak. The highest total alpha count in one soil sample equated to 3.65 μCi/g and included the radionuclides ^{244}Cm, ^{241}Am, ^{238}Pu, and ^{239}Pu.[21] Installation of two groundwater monitor-

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Fig. 9. View of LLW Leak Site No. 2 (SWMU 7.4a) looking southeast (August 1987).

ing wells along the creek bank established that the site was contributing to groundwater contamination, resulting in the removal of ~97 m^3 (~3,415 ft^3) of contaminated soil during July and August, 1973. After the soil removal, sampling of the two wells through October 1973 showed a decline in both ^{137}Cs and ^{90}Sr.[18]

A 1979 survey showed surface soil contamination suggesting either additional leakage or inadequate removal in 1973.[18] Beta-gamma exposure rates ranged from 240 to 800 mrad/h at 1 m (3.3 ft) above the surface.[22] An area approximately 3 × 8 m (10 × 25 ft) contained the most significant contamination.[18]

In 1983, the pipeline was cut, short sections of pipe were removed, and the open ends were sealed. Gamma exposure levels in the disturbed soil directly over the leak reached 10 R/h. More contaminated soil and vegetation were removed before a subsurface bentonite clay cap and a surface asphaltic concrete cap were installed at the site. The covered area was fenced with barbed wire and the remaining disturbed area seeded with grass.[18]

Discussion of Survey Results

The total area of contamination at this site is ~13.9 m^2 (~150 ft^2). Surface measurements indicate primarily gamma activity along a narrow ditchline ~12.2 m (~40 ft) in length, leading from the leak site to a contaminated drainage area of the Trench 7 seep (eastern slope of Trench 7). Surface gamma activity levels, measured with a gamma scintillation meter, ranged from background to ~200,000 cpm.

Recommendations for Corrective Actions

Although the results of this investigation show low levels of surface beta radiation, recommendations for corrective actions at this leak site are made based on the following rationale: (1) the possibility exists for the resuspension of ^{90}Sr and consequent deer contamination, (2) ^{90}Sr is a known constituent of liquid waste at this LLW leak site, (3) surface measurements show significant levels of gamma-radiation contamination, and (4) soil samples taken at the point of the leak in 1973 contained significant amounts of ^{90}Sr (up to 422 μCi/g).[21]

Recommendations for corrective actions previously outlined for the north and northeast ends and the west side of Trench 7 would generally apply to this leak site, keeping in mind that the contamination is mostly gamma-emitting radionuclides in soil.

LLW LEAK SITE NO. 1 (SWMU 7.4B)

History of Site

Leak Site No. 1 is the second of the two significant leak sites identified along the LLW line that from 1952 to 1975 transferred liquid wastes to the pits and trenches and to the first hydrofracture site.[18] Leak Site No. 1, also known as the North Leak Site, is located approximately 46 m (150 ft) south of Trench 6 at ORNL coordinates North

18,363 and East 27,976 (see Fig. 10). The leak at a connector between adjacent sections of pipe was reported in July 1973 but apparently had occurred at an earlier date. Wastes carried in the system were evaporator-concentrated laboratory LLW routinely containing ^{90}Sr, ^{137}Cs, ^{106}Ru, ^{60}Co, various rare earths, and some plutonium, uranium, and transuranic isotopes.[2]

Nine soil samples taken at the site in 1973 showed beta-gamma activity ranging from <0.01 to 50 μCi/g and gross alpha levels up to 1 nCi/g. The beta-gamma activity was due primarily to ^{137}Cs and ^{90}Sr. The main alpha emitter was ^{244}Cm, with minor amounts of ^{241}Am, ^{238}Pu, and ^{239}Pu.[18,20] In 1979, beta-gamma measurements at 1 m (3.3 ft) above the ground surface ranged from 240 mrad/h to 1 rad/h,[22] with an area about 6 $\times$ 6 m (20 $\times$ 20 ft) containing most of the radiation.[18]

Efforts to restrict the flow of surface water through the site, begun in 1983, were identical to those used at Leak Site No. 2. The pipeline was cut, short sections were removed, and the open ends were sealed. Contaminated soil and vegetation were removed before a subsurface bentonite clay cap and a surface asphaltic concrete cap were installed. The covered area was fenced with barbed wire and the remaining disturbed area seeded with grass.[18]

Discussion of Survey Results

Surface measurements show low levels of gamma activity over an area of ~18.6 m^2 (~200 ft^2) that extends along the southwest base of the asphalted site. This contaminated area is grassy and is mostly covered with cut trees, vegetative debris, and fill dirt.

Recommendations for Corrective Actions

Although the results of this investigation show low levels of surface beta-radiation, recommendations for corrective actions at this leak site are made based on the following rationale: (1) the possibility exists for the resuspension of ^{90}Sr and consequent deer contamination, (2) ^{90}Sr is a known constituent of liquid waste at this LLW leak site, and (3) surface measurements show elevated levels of gamma-radiation contamination.

Recommendations for corrective actions previously outlined for the north and northeast ends and the west side of Trench 7 would generally apply to this leak site, keeping in mind that the contamination is mostly gamma-emitting radionuclides in soil.

LLW LEAK SITE AT THE END OF TRENCH 7 ACCESS ROAD (SWMU 7.4C)

History of Site

SWMU 7.4c is the site of a leak along the LLW line that developed in April 1966 when a section of plastic pipeline ruptured and approximately 11,356 L (3000 gal) of evaporator-concentrated LLW was spilled in an area just north of Trench 7. The total activity was estimated at 100 Ci, consisting mainly of cesium and cerium and about 10 Ci

ORNL-PHOTO 6303-87

Fig. 10. View of LLW Leak Site No. 1 (SWMU 7.4b) looking north (August 1987).

of strontium. The contamination was covered with approximately 1.5 m (5 ft) of soil, and the area was contoured to prevent leaching of surface water. Reportedly, none of the contamination was permitted to reach the creek.[23]

In 1973, a small sweet gum tree located near the north end of Trench 7 measured ~60 mrad/h. Analysis of the leaves showed ^{90}Sr as the dominant radionuclide, with a concentration of 5.9×10^{-1} $\mu Ci/g$.[24] Analyses of near-surface soil collected in this area indicate substantial concentrations of ^{90}Sr, ^{60}Co, and ^{137}Cs and high alpha-activity levels. It is further reported that plant uptake of ^{90}Sr in this contaminated area is due to (1) low concentrations of calcium in the soil and (2) chemical similarity of calcium and strontium.[24]

Discussion of Survey Results

Results of this survey indicate that ~61 m (~200 ft) of the Trench 7 Access Road is contaminated at the road surface. The ratio of beta to gamma radioactivity, as determined by taking the difference between open- and closed-window readings of a GM survey meter, indicates significant levels of beta-emitting radionuclides (most likely ^{90}Sr). The total area of contamination at the spill site is estimated to be ~3035 m^2 (~0.75 acre).

The surface contamination at the spill site is contiguous with areas of contamination found on the north and northeast ends and the west side of Trench 7 (see Figs. 7 and 11). At the contaminated area west of the Trench 7 Access Road, surface beta-gamma measurements averaged ~3.5 mrad/h, whereas ~1 mrad/h readings were recorded at 1 m (3.3 ft). It is believed that at the time of the leak a large volume of liquid waste was transported (by means of surface runoff) downhill (south) to the north and northeast ends and the west side of Trench 7.

Although the spill area was covered with ~1.5 m (~5 ft) of soil and contoured to prevent contaminant leaching by surface water, contamination continues to be recharged into the immediate environs. Tree growth and plant root systems close to the spill site transport and recycle residual contaminants via the hydrologic cycle and various ecological mechanisms (e.g., groundwater flow, foliage growth, and decay) to the ground surface.

Beta-gamma measurements on contact with the trunk of an American elm tree, found west of the Trench 7 Access Road, ranged as high as ~60 mrad/h, and the leaves of this tree measured ~3 mrad/h. Generally, readings at the tree were found to increase with the height at which the measurement was taken. The highest level measured above the trunk portion of the tree was ~70 mrad/h.

The results of analysis of three surface soil samples (0-15 cm), taken from the Trench 7 Access Road and adjacent contaminated area, demonstrate significant gross beta and ^{90}Sr contamination. Highest values (12,000 pCi/g of gross beta and 5400 pCi/g of ^{90}Sr) were measured in a sample taken adjacent to the road (sample S3). The sampling locations are shown in Fig. 7, and the results of sample analysis are presented in Table 7. It should be noted that the Trench 7 Access Road has recently been closed to routine traffic by ORNL Health Physics personnel, and activities at the contractor staging area have ceased.

ORNL-PHOTO 6302-87

Fig. 11. View of Trench 7 Access Road looking south toward the LLW Leak Site at the end of Trench 7 Access Road (SWMU 7.4c). This photograph was taken from the east side of the valve pit (August 1987).

Table 7. Concentration of parameters in soil samples from the Trench 7 Access Road and contaminated area associated with the LLW Leak Site at the end of the Trench 7 Access Road (SWMU 7.4c)[a]

Parameter	Surface sample S1 (pCi/g DW)	Surface sample S2 (pCi/g DW)	Surface sample S3 (pCi/g DW)
Gross beta	200 ± 20	140 ± 20	12,000 ± 300
^{90}Sr	140 ± 5	120 ± 5	5,400 ± 300

[a]Soil sampling locations are shown on Fig. 7. Samples were taken at depths of 0 to 15 cm.

Recommendations for Corrective Actions

Recommendations for corrective actions previously outlined for the north and northeast ends and the west side of Trench 7 would generally apply to this leak site.

VALVE PIT STATION

History of Site

The valve pit has not been previously identified in the RAP as a contaminated site and therefore has no SWMU identification number. Two metal identification tags were found at the valve pit site with the inscriptions V-120 and V-121. This finding may indicate that two separate valves are housed in the pit. A portion of an old pipe with an attached valve was found on the ground near the pit area. Radiological examination of the pipe revealed only low levels of gamma activity. The vertical end of the terra-cotta-tiled pit area is presented at the ground surface and is currently filled with dirt (see Fig. 12).

Discussion of Survey Results

Surface measurements taken at the valve pit indicate primarily gamma activity on the ground surface. Backfill dirt was present as a result of past excavation activities (e.g., pipeline repair and/or replacement). Closed-window readings on this soil indicate low levels of beta contamination. However, surface beta-gamma measurements in a small area on the northwest side of the pit showed readings ranging to ~83 mrad/h. Additionally, a large green ash tree found near the west side of the pit measured ~10 mrad/h in spots on contact with the trunk and attached leaves.

ORNL-PHOTO 6301-87

Fig. 12. View of the valve pit looking southwest (August 1987).

Recommendations for Corrective Actions

Although the results of this investigation survey show low levels of surface beta radiation, recommendations for corrective actions at the valve pit site are based on the following rationale: (1) the possibility exists for the resuspension of ^{90}Sr and consequent deer contamination, (2) ^{90}Sr is a known constituent of liquid waste carried in the LLW system, (3) surface measurements show significant levels of gamma-radiation contamination, and (4) significant beta-gamma activity levels were measured on contact with a green ash tree near the west side of the pit.

Recommendations for corrective actions previously outlined for the north and northeast ends and the west side of Trench 7 would generally apply to the valve pit station.

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