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COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY L

NIAGARA FALLS STORAGE SITE

LEWISTON, NEW YORK

B.P. ROCCO

Radiological Site Assessment Program
Manpower Education, Research, and Training Division

FINAL REPORT

May 1983

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Prepared for

U.S. Department of Energy
as part of the
Formerly Utilized Sites -- Remedial Action Program

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FINAL REPORT

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COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY L
NIAGARA FALLS STORAGE SITE
LEWISTON, NEW YORK

INTRODUCTION

Beginning in 1944, the Manhattan Engineer District and its successor, the Atomic Energy Commission (AEC), used portions of the Lake Ontario Ordnance Works (presently referred to as the Niagara Falls Storage Site (NFSS) and off-site properties) approximately 3 km northeast of Lewiston, New York, for storage of radioactive wastes. These wastes were primarily residues from uranium processing operations, however, they also included: contaminated rubble and scrap from decommissioning activities, biological and miscellaneous wastes from the University of Rochester, and low-level fission-product waste from contaminated-liquid evaporators at the Knolls Atomic Power Laboratory (KAPL). Receipt of radioactive waste was discontinued in 1954, and, following cleanup activities by Hooker Chemical Co., 525 hectares of the original 612 hectare LOOW site were declared surplus. This property was eventually sold by the General Services Administration to various private, commercial, and governmental agencies.[1]

The Department of Labor is the current owner of a tract from the NFSS, identified as off-site property L (see Figure 1). A radiological survey of that tract, conducted in August and September 1982, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property L. The property is rectangular in shape (375 m x 315 m) and occupies approximately 11.8 hectares. It is bounded on two sides by roads - Pletcher Road on the south and Campbell Street on the east. The northern boundary is the fence surrounding the Niagara Falls Storage Site. Niagara Mohawk owns the property immediately west of the site; there are no landmarks indicating this property line. The land is level with the exception of several drainage ditches along Campbell Street and crossing the northeast and

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northwest sections of the site. The Central Drainage Ditch originates on the property. Two paved unnamed roads traverse the property in east-west and north-south orientations. A small brick building, previously housing a radar station, and the remnants of a parking lot lie along the east-west road on the western portion of the property. A U-shaped concrete pad is located along the north-south road near the center of the property. Several storm sewer gratings, manholes, and fire hydrants are scattered through the site. The area is presently unused and is overgrown with brush and weeds.

Radiological History

There is no evidence of contaminated waste burials on property L. Three previous surveys of the area indicated the majority of the direct radiation was located along the northern boundary of the property and was probably due to shine from residues stored on the Niagara Falls Storage Site.[2,3,4] Other areas identifed as having slightly elevated radiation levels are along Pletcher Road and Campbell Street, possibly due to natural radioactivity from the slag used in the roadbed.

SURVEY PROCEDURES

The comprehensive survey of NFSS off-site property L was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during the periods of August 9-17, and September 13-15, 1982. The survey was in accordance with a plan dated June 22, 1982, approved by the Department of Energy's Office of Operational Safety. The objectives and procedures from that plan are presented in this section.

Objective

The objective of the survey was to provide a comprehensive assessement of the radiological conditions and associated potential health effects, if any, on property L. Radiological information collected included:

1. direct radiation exposure rates and surface beta-gamma dose rates,
2. locations of elevated surface residues,
3. concentrations of radionuclides in surface and subsurface soil,
4. concentrations of radionuclides in ground water, and
5. concentrations of radionuclides in water and sediment from storm sewers on the property.

Procedures

1. Site Preparation

   a. Brush and weeds were cleared as needed to provide access for gridding and surveying. This operation was performed under subcontact by Modern Disposal Co., Model City, NY.

   b. A 20 m grid system was established by McIntosh and McIntosh of Lockport, NY, under subcontract. This grid system is shown on Figure 2.

2. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at each accessible intersection of grid lines. Measurements were performed using portable gamma NaI (Tl) scintillation survey meters. Conversion of these measurements to exposure rates in microroentgens per hour (μR/h) was in accordance with cross calibration with a pressurized ionization chamber.

3. Beta-gamma dose rate measurements were performed 1 cm above the surface at each accessible grid line intersection. These measurements were conducted using thin-window (7 mg/cm^2) G-M detectors and portable scaler/ratemeters. Measurements were also obtained with the detector shielded to evaluate contributions of non-penetrating beta and low-energy gamma radiations. Meter readings were converted to dose-rate in microrads per hour (μrad/h) based on cross calibration with a thin-window ionization chamber using soil samples from the property.

4. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at each accessible grid line intersection. Additional samples were collected from the centers of grid blocks adjacent to the Niagara Falls Storage Site.

5. Walkover surface scans were conducted at 1-2 m intervals over all accessible areas of the property. Portable gamma scintillation survey meters were used for these scans. Locations of elevated contact radiation levels were noted and surface exposure rates were measured at these locations.

6. At 19 of the locations of elevated surface radiation levels, beta-gamma dose rates and exposure rates at 1 m above the surface were also measured. Surface soil samples were obtained from these locations and, following sampling, the surface exposure levels were remeasured to evaluate the effectiveness of shallow sampling on removal of the radiation source. The 19 locations where these additional measurements and samples were obtained are indicated on Figure 3.

7. Detection Sciences Group of Carlisle, MA, performed ground penetrating radar surveys. The purpose of these radar scans was to identify the presence of underground piping or utilities which would preclude borehole drilling. Ground radar would also identify other subsurface objects or anomalies which might be indicative of waste burials on the site.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Eight boreholes to ground water depth (2-6 m) and twelve shallower (0.5-1.5 m deep) boreholes were drilled by Site Engineers, Inc., of Voorhees, NJ, using a truck mounted 20 cm diameter hollow-stem auger. The shallow boreholes were primarily at locations where direct radiation measurements and ground penetrating radar had indicated possible residues. The locations of these boreholes are shown on Figure 4.

   Gamma scans of the boreholes were performed to identify elevated radiation levels which would indicate subsurface residues. Radiation profiles in the boreholes were then determined by measurements of gamma radiation at 30-50 cm intervals between the surface and ground water (deep holes) or the hole bottom (shallow holes). A collimated gamma scintillation detector and portable scaler were used for these measurements.

   Ground water samples of approximately 3.5 liters each were collected from all deep boreholes, containing ground water. Collection was performed using a hand bailer. Soil samples of approximately 1 kg each were collected from various depths in the holes by scraping the sides of the borehole with a specially constructed sampling tool.

9. Water samples of 3.5 liters were collected from an open manhole and two storm drains (see Figure 5).

10. Sediment samples (1 kg) were collected from two storm drains on the property (see Figure 5).

11. A walkover scan and four direct beta-gamma and alpha measurements were performed in the small brick building on the property (see Figure 6).

12. Twenty soil samples and seven water samples were collected from the Lewiston area (but not on the NFSS or associated off-site properties) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured at locations where baseline soil samples are collected. The locations of the baseline samples and background measurements are shown on Figure 7.

Sample Analyses and Interpretation of Results

Soil and sediment samples were analyzed by gamma spectrometry. Radium-226 was the major radionuclide of concern, although spectra were reviewed for Cs-137, U-235, U-238, and other gamma emitters.

Water samples were analyzed for gross alpha and beta concentrations. Isotopic analyses were performed on water samples exceeding the EPA drinking water standards for gross activity. Additional information concerning analytical equipment and procedures is contained in Appendix A.

Results of this survey were compared to applicable guidelines for formerly utilized radioactive materials handling sites as presented in Appendix B.

RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, determined for 20 locations (Figure 7) in the vicinity of the NFSS, are presented in Table 1-A. Exposure rates ranged from 6.8 to 8.8 μR/h (typical levels for this area of New York). Concentrations of radionuclides in soil were: Ra-226, <0.09* to 1.22 pCi/g (picocuries per gram); U-235, <0.14 to 0.46 pCi/g; U-238, <2.20 to 6.26 pCi/g; Th-232, <0.32 to 1.18 pCi/g; and Cs-137, <0.02 to 1.05 pCi/g. These concentrations are typical of the radionuclide levels normally encountered in surface soils.

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* *The less than symbol (<) indicates that the concentration measured was less than the minimum statistical detection limit of the procedure.*

Radioactivity levels in baseline water samples are presented in Table 1-B. The gross alpha and gross beta concentrations ranged from 0.55 to 1.87 pCi/l (picocuries per liter) and <0.63 to 14.3 pCi/l, respectively. These are typical of concentrations normally occurring in surface water.

Direct Radiation Levels

Direct radiation levels, systematically measured at grid line intersections, are presented in Table 2. The gamma exposure rates at 1 m above the surface ranged from 8.7 to 19 μR/h (average 13 ± 1.8). At surface contact the rates also ranged from 6.7 to 19 μR/h (average 13 ± 1.7). Beta-gamma dose rates ranged from 9 to 81 μrad/h (average 46). Measurements performed with the detector shielded averaged approximately 20% less than those with the unshielded detector. This indicates only a small portion of the surface dose rate is due to nonpenetating beta or low-energy photon radiations.

The walkover survey identified nineteen small isolated areas with elevated surface radiation levels. These locations are indicated on Figure 3. Direct radiation levels at these locations are presented in Table 3. The maximum contact exposure level measured was 280 μR/h at location B13. The surface dose rate at this location was 30,000 μrad/h. Sampling at this point identified a small piece of plaster-like debris. Removal of this material reduced the contact radiation level from 280 μR/h to 22 μR/h. Contact gamma exposure rates at the other eighteen locations ranged from 20 to 75 μR/h. Gamma exposure rates at 1 m above the surface and contact beta-gamma dose rates ranged from 13 to 19 μR/h and 68 to 790 μrad/h, respectively.

With the exception of locations B12 and B13, contact exposure rates were not reduced by soil sampling. At many points, exposure rates actually increased following sampling. These results indicate that most of the contamination is deeper than 15 cm below the surface and is diffused rather than in discrete particles.

Direct radiation levels at grid line intersections on property L were generally higher on the northern portion of the site and along Pletcher Road and Campbell Street. Areas of surface contamination, identified as elevated contact radiation levels, were limited to along Pletcher Road and Campbell Street, indicating that elevated radiation levels on the northern part of the area are due to shine from the adjacent Niagara Falls Storage Site.

Radionuclide Concentrations in Surface Soil

Tables 4 and 5 list the concentrations of radionuclides, measured in surface soil from the grid line intersections and from selected locations of elevated radiation levels on property L. The samples from grid line intersections (see Table 4) contained Ra-226 concentrations ranging from <0.08 to 5.43 pCi/g. The highest level was in sample 143 from grid location 280E, 160S. Several other samples (most along Campbell Street) had Ra-226 concentrations slightly higher than baseline levels. Concentrations of U-235, U-238, Th-232, and Cs-137 were not significantly different from those in baseline samples.

Eighteen surface soil samples, collected from locations of elevated contact radiation levels (refer to Table 5), all contained Ra-226 concentrations above those in baseline samples. The highest Ra-226 concentration, other than the small pieces of plaster-like debris, was in sample B11 (grid point 280E,189S); this sample contained a Ra-226 concentration of 40 pCi/g. In addition to containing 30 pCi/g Ra-226 sample B2 (grid point 281E, 58S) had 3.87 and 46 pCi/g U-235 and U-238, respectively. Other samples contained less than detectable amounts of U-238 and only slightly elevated levels of U-235. Cesium-137 concentrations were slightly elevated in most of these samples. Thorium-232 levels were either in the range of baseline samples or were below the detection sensitivities of the analytical procedures.

The Ra-226 activities determined in the two small plaster-like pieces of debris, samples B12 and B13, were 0.38 and 0.39 μCi respectively. Additional analysis of these samples indicated their chemical composition

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was either lead sulfate or lead sulfide. This suggests that they may be lead cake residues from Linde operations. Sample B2 also contained 96.3 pCi/g of Pa-231 along with its daughter products Ac-227, Th-227, Ra-223, Pb-211, and Bi-211. These radionuclides are members of the actinium decay series, originating with U-235. Lower levels of U-235, U-238, and Ra-226 in this sample suggests that this contamination may be material remaining after removal of radium from uranium separations residues. Similar material has been noted at several sites in St. Louis, MO, where such separations were performed.

Ground Penetrating Radar Findings

The subcontractor report, summarizing the ground penetrating radar survey results for property L is provided as Appendix C. (This report also includes the findings on property M, since the two properties were surveyed simultaneously.) This survey identified pipe and utility locations on the property, which corresponded with mapped locations available to ORAU. The ground penetrating radar also located a number of discrete buried objects at depths ranging from 0.8 to 1.4 m, having the same characteristics as buried pipe, although lacking the repetitive pattern from one radar line to another. In the northern portion of the property between 0 and 20S and 120E and Campbell Street, detected anomalies indicate the burials of reinforced concrete or gravel and a high dialectric, or non-electrically active material such as organic solvents or petroleum products. The anomalies were at a depth of 1.0 to 1.5 m below the surface. Pages 12 and 13, Figure 2, and Table IV of Appendix C provide additional information concerning these findings. The ground radar at some proposed borehole drilling locations did identify possible utility services, requiring slight relocations of these boreholes.

Borehole Gamma-Logging Measurements

The results of gamma scintillation measurements performed in boreholes indicated that contamination is confined to the upper 25-50 cm of soil. The gamma count rates determined by the borehole measurements were reliable indicators of elevated subsurface radionuclide levels. However, the gamma

logging data was not useful in quantifying radionuclide concentrations in the subsurface soil, because of the varying ratios of Ra-226, U-235, U-238, and Cs-137 occurring in soils from this site.

Radionuclide Concentrations in Subsurface Soil

Table 6 presents the radionuclide concentrations measured in soil samples from boreholes. The eight boreholes (H13-H20), located to provide a representative coverage of the property had subsurface radionuclide concentrations either in the range of baseline samples or less than the minimum detectable activity (MDA).

Boreholes H1-H12 were at locations where the walkover scan survey had identified probable surface contamination. Gamma radiation logging did not identify the presence of significant subsurface residues. Subsurface soil samples from most of the boreholes contained very slightly elevated Ra-226 concentrations; the maximum concentration was 2.06 pCi/g at the 0.5 m depth in borehole H6.

None of the subsurface samples contained elevated concentrations of U-238, U-235, Th-232, or Cs-137. No other gamma emitting radionuclides were identified in the borehole samples.

Radionuclide Concentrations in Water

Surface Water

Water samples from an open manhole and two storm drains on the property had gross alpha and gross beta concentrations in the same range as baseline levels (refer to Table 7).

Subsurface Water

Water was available from only three of the eight deep boreholes on this property (refer to Table 7). Samples W5 and W6 had gross alpha and gross beta concentrations above baseline levels but well within the EPA drinking water criteria of 15 pCi/l and 50 pCi/l, respectively. Sample W4

from borehole H20 had gross alpha and beta concentrations of 28.4 ± 13.6 pCi/l and 12.3 ± 13.1 pCi/l, respectively. High concentrations of dissolved solids in this sample resulted in residues, which adversely affected the detection sensitivities of the gross alpha and gross beta procedure. The sample was also analyzed for Ra-226 and contained 0.05 ± 0.04 pCi/l of that nuclide. This level does not exceed the 3 pCi/l Ra-226 EPA criteria.

Radionuclide Concentrations in Storm Sewer Sediments

Sediment samples from the storm sewers did not contain radionuclide levels significantly different from the levels in baseline soil (refer to Table 8).

Direct Radiation Levels Inside the Building

Direct alpha and beta-gamma levels measured at four random locations in the building are presented in Table 9. Alpha and beta-gamma levels ranged from <23-45 dpm/100 cm^2 and 1300-1800 dpm/100 cm^2, respectively. The dose rate associated with this range of beta-gamma levels is 38-49 μrad/h. The walkover survey did not detect any areas of elevated gamma exposure rates. These results indicate that the building surfaces are not contaminated and no additional measurements were performed in that structure.

Comparison of Survey Results With Guideline

The guidelines applicable to cleanup of the off-site properties at NFSS are presented in Appendix B. All exposure rates at 1 m above the ground surface on property L are less than 20 μR/h above the background level. The average level of 13 μR/h is well below the 60 μR/h criteria established by the Nuclear Regulatory Commission for open land areas.

Radium 226 concentrations in surface soil samples collected at isolated locations of elevated direct radiation levels exceed 5 pCi/g. The contaminated residues are mainly in a narrow strip (about 3 m wide) along

Campbell Street. Samples at grid line intersections along this strip, i.e. on the 280E grid line, are also above baseline soil levels. The average Ra-226 soil concentration based on levels in all samples from grid area 278E to 281E, 140S to 220S, an area of 240 m^2, is 12.8 pCi/g and exceeds the 5 pCi/g criteria level (Figure 8). The other locations of Ra-226 surface soil contamination are isolated from each other and the concentrations averaged over 100 m^2 would be below the 5 pCi/g level.

Borehole sampling indicates all subsurface soil concentrations are within the applicable guidelines of 15 pCi/g. Although ground-penetrating radar identified several areas of subsurface anomalies, borehole logging and sampling in the vicinity of some of these anomalies did not identify evidence of buried contaminated residues.

Radionuclide concentrations in surface and subsurface water are within the EPA Interim Drinking Water Standards.

An evaluation of the potential health effects associated with radiation levels and residual contamination on the property L is presented in Appendix D. This section compares these levels with background exposures in the Niagara, New York, area and the scientifically based guidelines established for the protection of radiation workers and the general public.

SUMMARY

A comprehensive survey of off-site property L at the Niagara Falls Storage Site was conducted during August and September 1982. The survey included surface radiation scans, measurements of direct radiation levels, and analyses of radionuclide concentrations in surface and subsurface soil samples and in surface and subsurface water samples. Ground penetrating radar was also used to identify subsurface anomalies which might suggest buried radioactive residues.

The results of the survey indicate isolated areas of surface soil contamination along the streets bordering the property on the south and east. The major contaminant is Ra-226; although, one area of uranium and U-235 daughter product contamination was noted. Subsurface sampling and measurements indicate that this contamination is limited to the top 25-50 cm of soil. Soil concentrations exceed the cleanup criteria only in a narrow strip (about 3 m x 80 m) along Campbell Street. This area could be brought into compliance with the criteria by removal of approximately 60-120 m^3 of soil. Other isolated areas of contamination could be eliminated by removal of very small amounts of surface soil.

Although there are small isolated areas of contaminated residues on portions of this property, the contaminants do not pose potential health risks. There is no evidence that migration of the radioactive materials is adversely affecting adjacent properties or the ground water.

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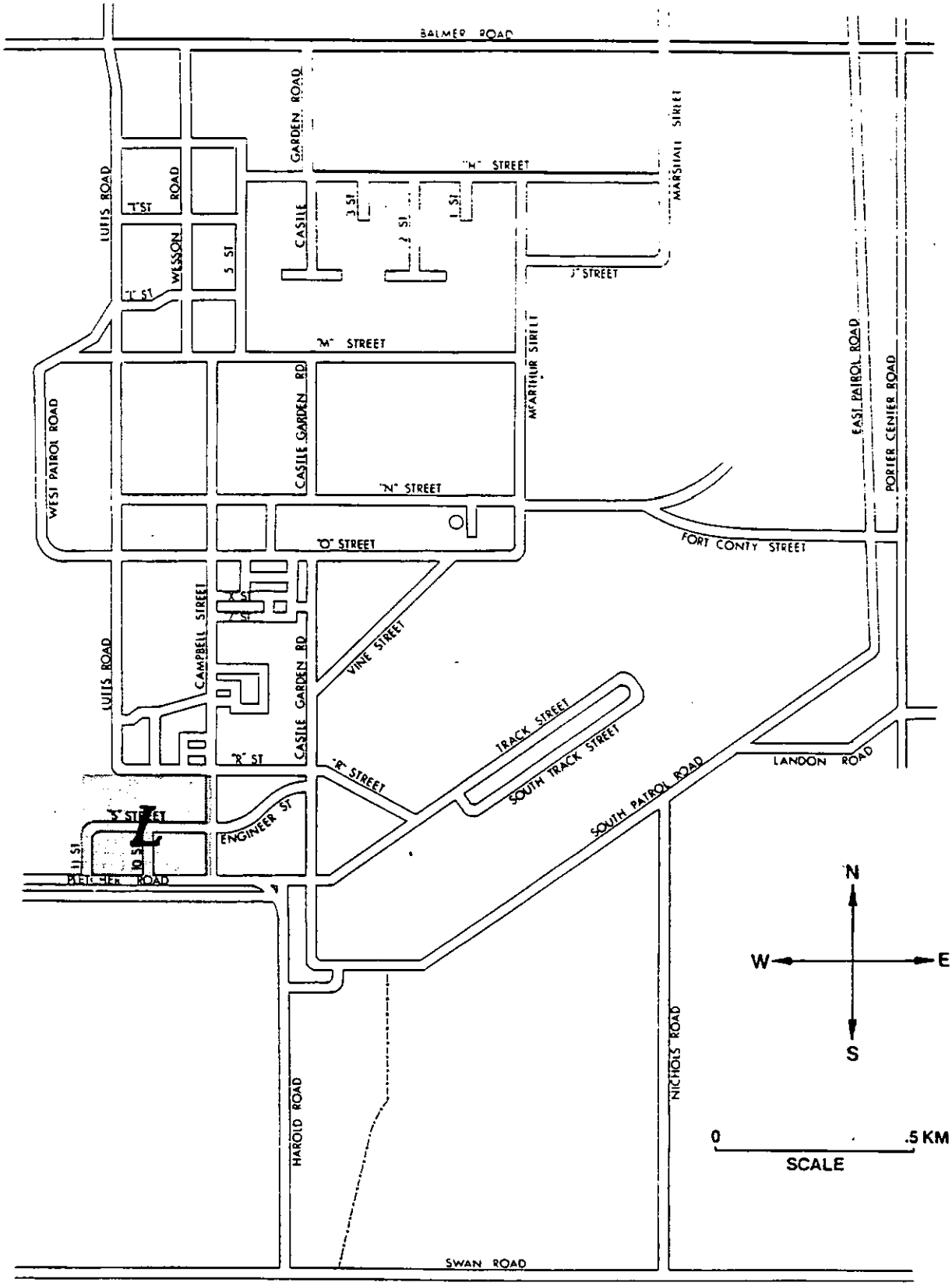

FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property L.

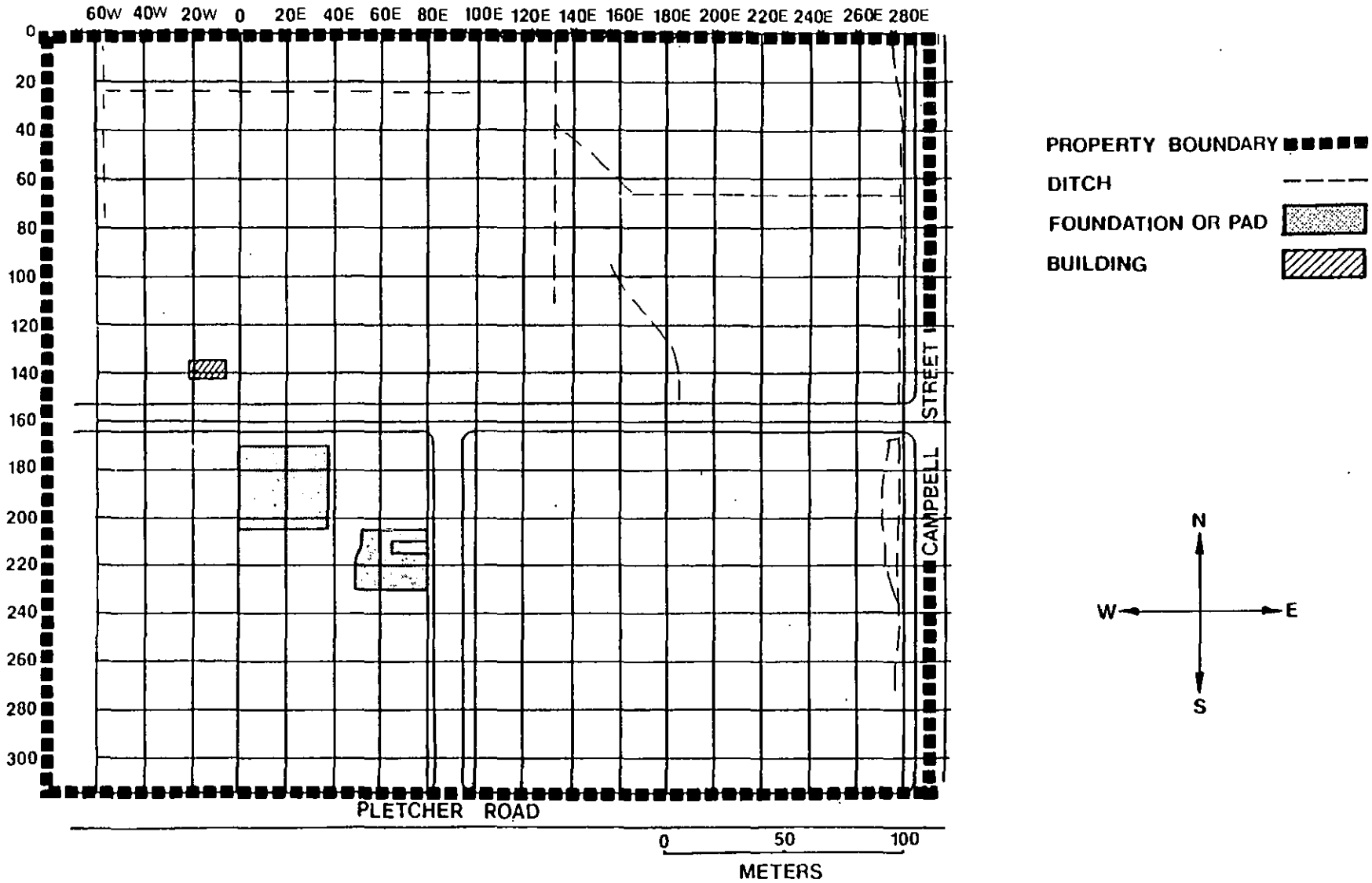

FIGURE 2. Plan View of NFSS Off-Site Property L, Indicating Prominent Surface Features and the Grid System Established for Survey Reference.

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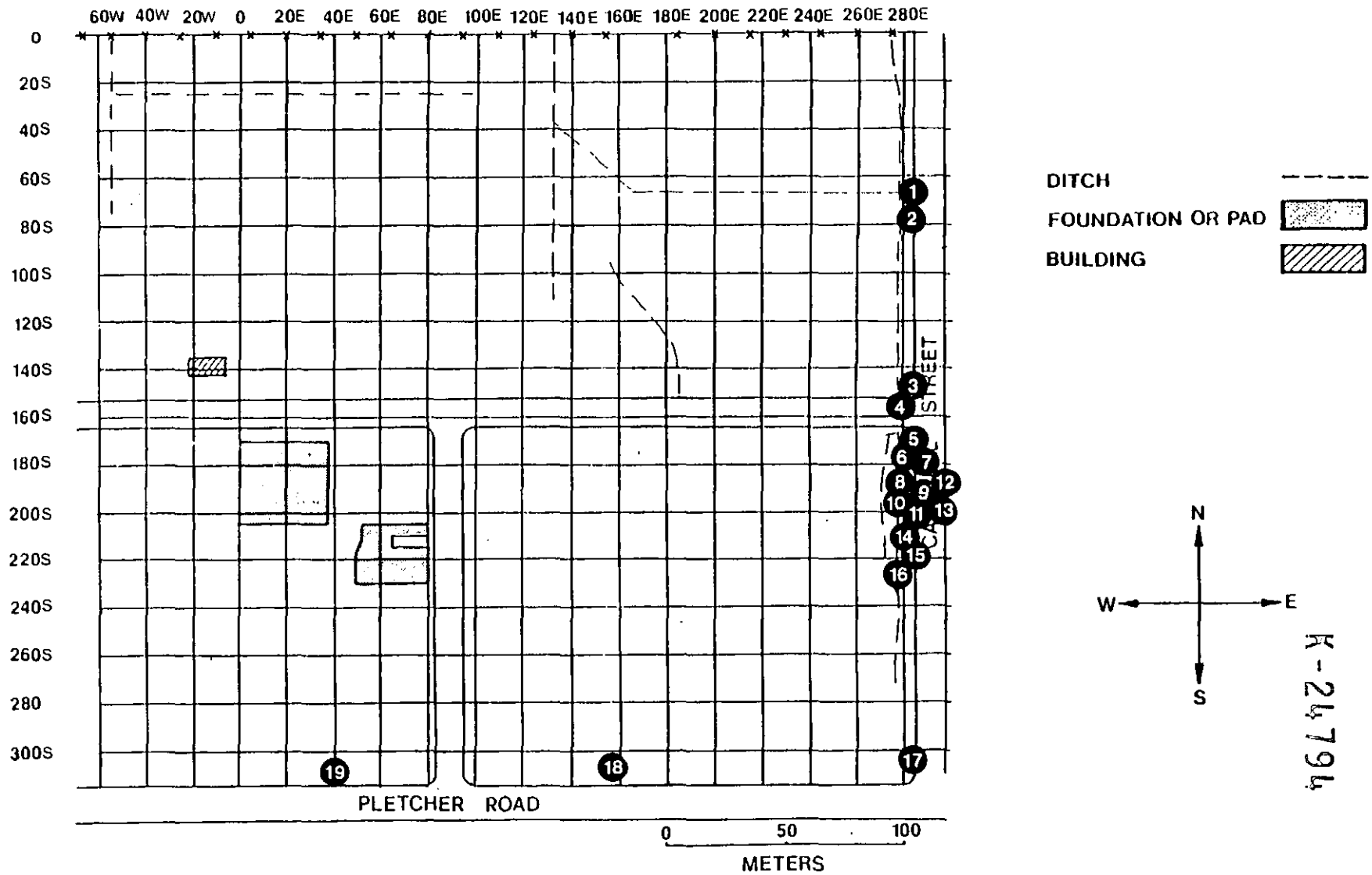

FIGURE 3. Locations of Areas of Elevated Direct Radiation Levels Selected for Further Measurements and Sampling.

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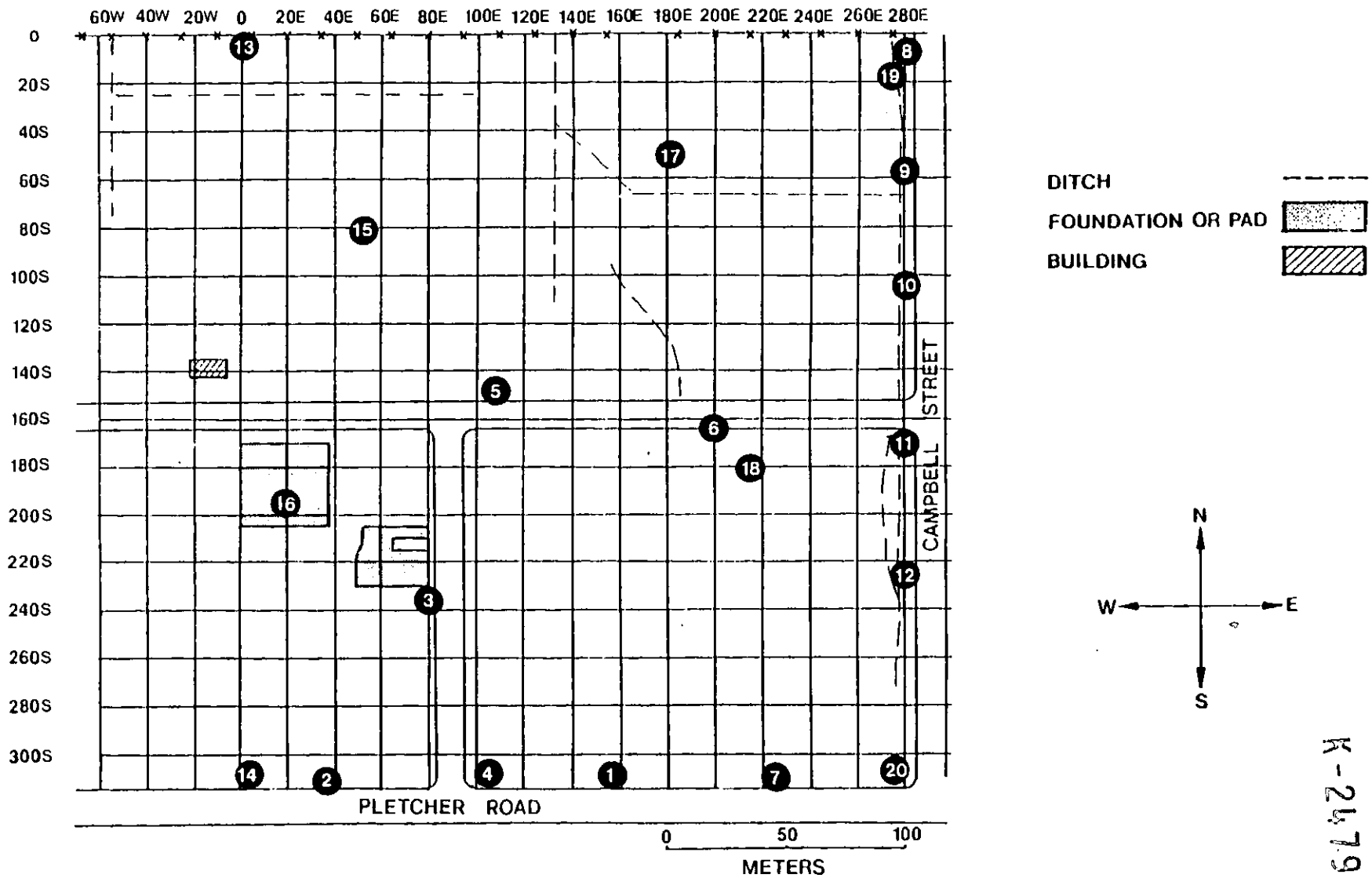

FIGURE 4. Locations of Boreholes for Subsurface Investigations.

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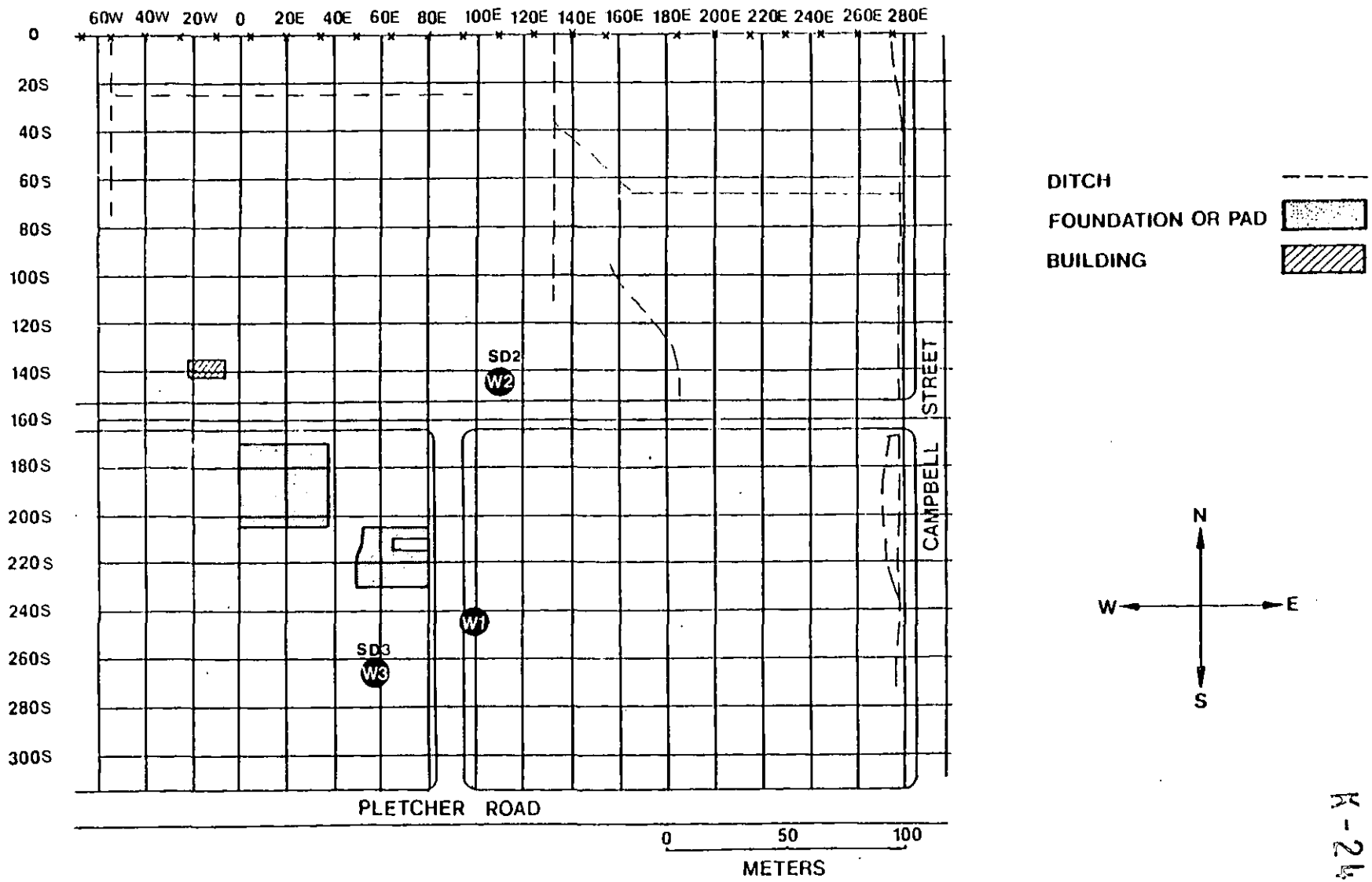

FIGURE 5. Locations of Storm Sewer Water (W1-W3) and Storm Sewer Sediment (SD2 & SD3) Samples.

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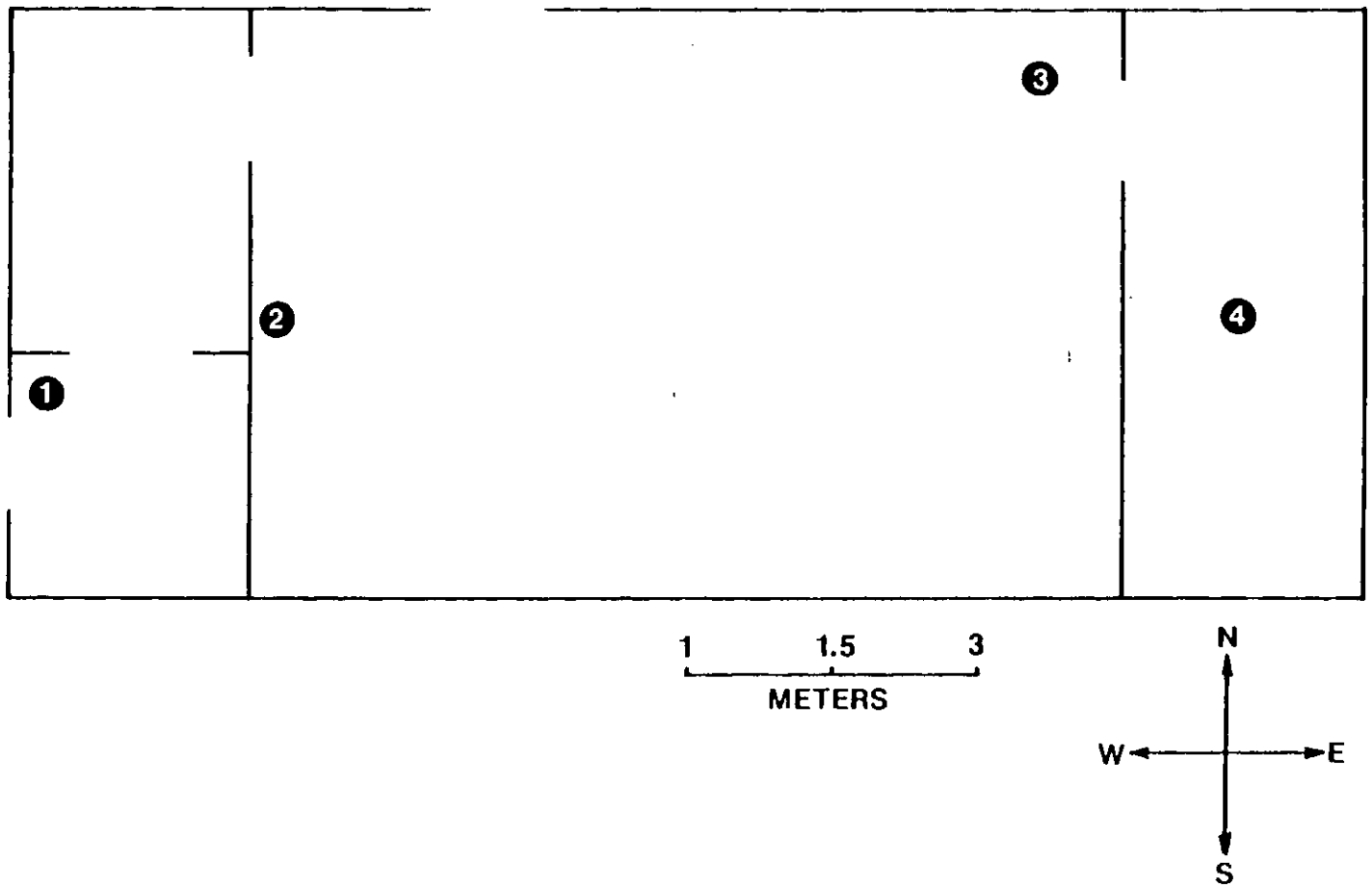

FIGURE 6. Locations of Direct Radiation Measurements in the Small Brick Building on Property L.

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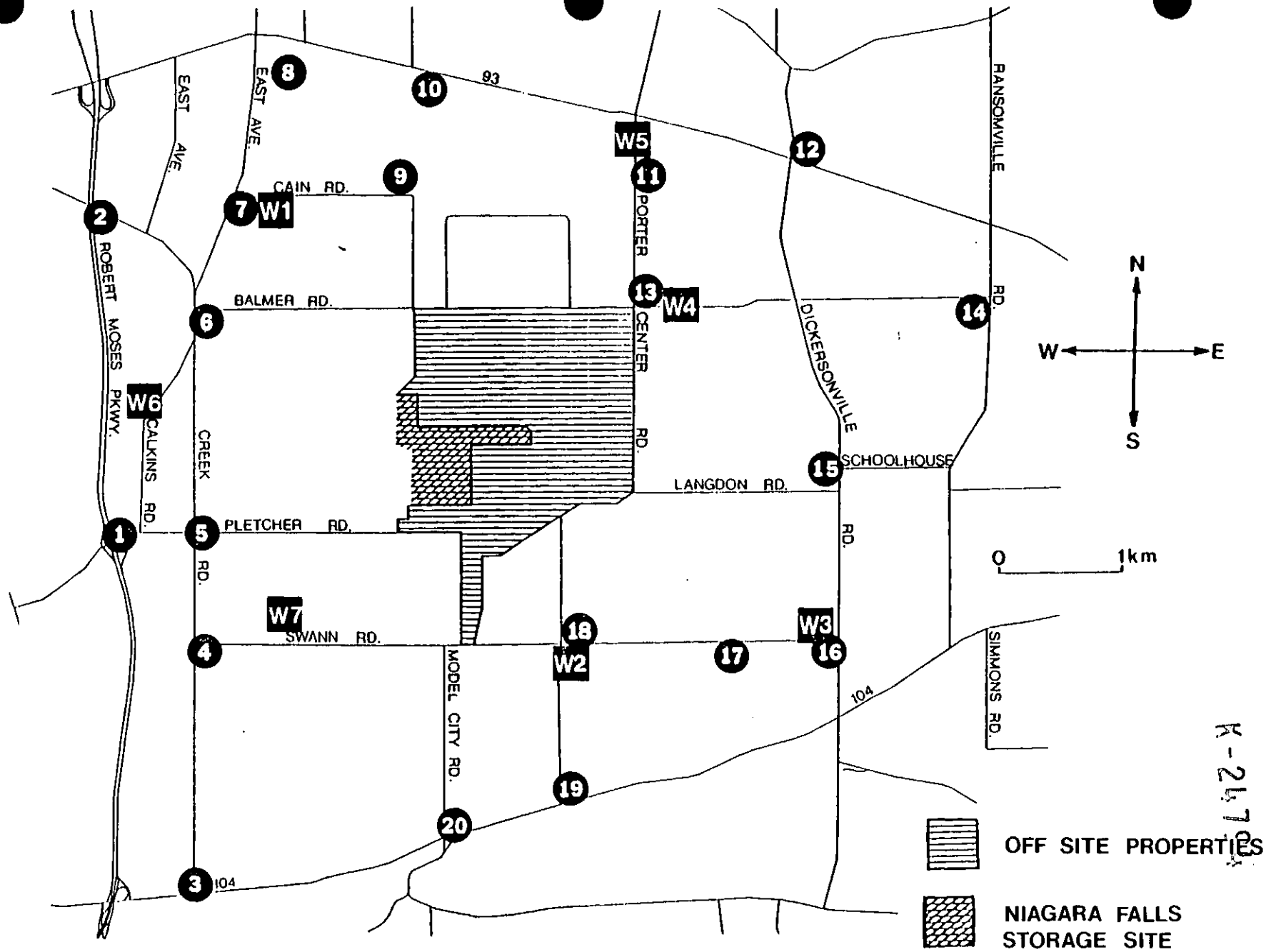

FIGURE 7. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples.

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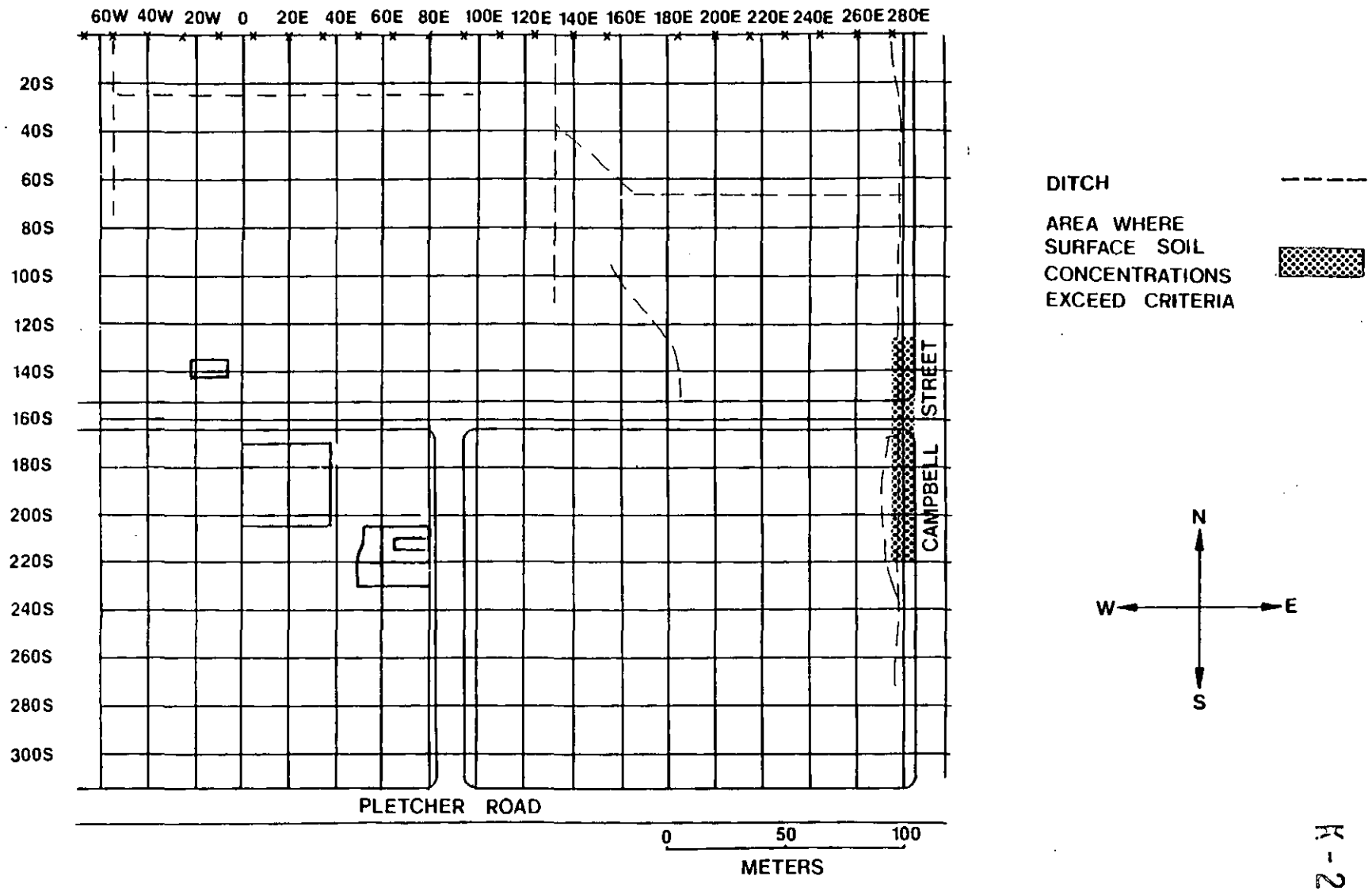

FIGURE 8. Map of NFSS Off-Site Property L Indicating the Areas Where Radionuclide Concentrations in Soil Exceed Criteria.

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TABLE 1-A

BACKGROUND EXPOSURE RATES
AND
BASELINE RADIONUCLIDE CONCENTRATIONS IN SOIL

Location[a]	Exposure Rate[b] (μR/h)	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
1	6.8	0.74 ± 0.16[c]	<0.19	<2.89	0.70 ± 0.46	0.29 ± 0.08
2	6.8	0.75 ± 0.19	<0.19	<3.35	0.84 ± 0.24	0.24 ± 0.08
3	8.3	0.71 ± 0.18	0.46 ± 0.41	<3.72	0.88 ± 0.33	0.34 ± 0.09
4	7.9	0.67 ± 0.18	<0.22	<4.10	1.18 ± 0.35	0.12 ± 0.07
5	7.3	0.70 ± 0.16	<0.17	<3.34	0.68 ± 0.24	0.14 ± 0.07
6	7.7	0.50 ± 0.15	<0.16	<2.33	0.52 ± 0.38	0.17 ± 0.09
7	7.7	0.63 ± 0.13	<0.17	<2.73	0.83 ± 0.24	0.35 ± 0.08
8	7.6	0.59 ± 0.12	<0.14	<2.20	0.54 ± 0.23	<0.02
9	7.1	0.63 ± 0.20	<0.23	<4.16	0.83 ± 0.38	0.69 ± 0.11
10	7.1	0.70 ± 0.16	<0.19	<2.98	0.59 ± 0.25	0.69 ± 0.10
11	6.7	<0.09	<0.19	<2.83	0.49 ± 0.31	0.48 ± 0.14
12	7.1	0.48 ± 0.13	<0.16	<2.84	0.65 ± 0.26	0.68 ± 0.10
13	6.7	0.57 ± 0.14	<0.17	<2.36	0.49 ± 0.26	0.41 ± 0.08
14	6.8	0.68 ± 0.17	<0.19	<3.24	0.67 ± 0.25	0.70 ± 0.10
15	8.2	0.65 ± 0.14	<0.17	<3.20	0.72 ± 0.35	0.23 ± 0.08
16	7.4	0.91 ± 0.17	<0.71	<3.58	0.83 ± 0.28	0.61 ± 0.09
17	7.0	0.48 ± 0.14	<0.16	<2.73	0.32 ± 0.22	0.38 ± 0.08
18	7.7	0.73 ± 0.16	<0.18	6.26 ± 9.23	1.01 ± 0.44	0.32 ± 0.12
19	8.8	1.22 ± 0.22	<0.23	<3.79	1.08 ± 0.49	1.05 ± 0.13
20	8.6	0.83 ± 0.17	<0.21	<3.59	0.84 ± 0.29	0.08 ± 0.07
Range	6.8 to 8.8	<0.09 to 1.22	<0.14 to 0.46	<2.20 to 6.26	0.32 to 1.18	<0.02 to 1.05

[a] Refer to Figure 6.
[b] Measured at 1 m above the surface.
[c] Errors are 2σ based on counting statistics.

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TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
W1	0.95 ± 0.93 [b]	4.79 ± 1.15
W2	0.95 ± 0.94	9.17 ± 1.31
W3	0.55 ± 0.78	2.73 ± 1.05
W4	0.63 ± 0.89	5.37 ± 1.17
W5	0.73 ± 0.68	<0.64
W6	1.87 ± 1.84	14.3 ± 2.4
W7	1.16 ± 0.66	<0.63
Range	0.55 to 1.87	<0.63 to 14.3

[a] Refer to Figure 7.
[b] Errors are 2σ based on counting statistics.

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TABLE 2

DIRECT RADIATION LEVELS
SYSTEMATICALLY MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at the Surface (μrad/h)
280E, 0S	15	15	54
260E, 0S	15	15	51
240E, 0S	15	15	38
220E, 0S	15	15	54
200E, 0S	15	16	43
180E, 0S	16	16	62
160E, 0S	18	16	55
140E, 0S	18	18	58
120E, 0S	18	18	68
100E, 0S	19	18	52
80E, 0S	18	18	54
60E, 0S	18	18	38
40E, 0S	18	18	46
20E, 0S	18	18	46
0E, 0S	17	15	48
20W, 0S	16	15	34
40W, 0S	16	16	37
60W, 0S	15	15	35
280E, 20S	14	15	43
260E, 20S	15	15	35
240E, 20S	15	15	55
220E, 20S	15	15	52
200E, 20S	16	16	35
180E, 20S	16	16	49
160E, 20S	16	16	43
140E, 20S	18	18	48
120E, 20S	18	18	52
100E, 20S	18	18	68
80E, 20S	18	18	52
60E, 20S	18	19	49
40E, 20S	18	19	52
20E, 20S	16	17	25
0E, 20S	16	15	42
20W, 20S	16	15	37
40W, 20S	16	16	32
60W, 20S	15	15	38
280E, 40S	13	15	45
260E, 40S	12	15	54
240E, 40S	15	15	57
220E, 40S	15	15	45
200E, 40S	16	15	46

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TABLE 2, cont.

DIRECT RADIATION LEVELS
SYSTEMATICALLY MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at the Surface (μrad/h)
180E, 40S	17	17	51
160E, 40S	17	17	46
140E, 40S	18	18	43
120E, 40S	18	18	60
100E, 40S	17	17	40
80E, 40S	17	16	46
60E, 40S	18	18	51
40E, 40S	18	18	37
20E, 40S	18	17	51
0E, 40S	16	15	38
20W, 40S	15	14	45
40W, 40S	15	15	42
60W, 40S	14	15	34
280E, 60S	16	16	49
260E, 60S	15	15	63
240E, 60S	13	15	31
220E, 60S	15	15	54
200E, 60S	15	15	81
180E, 60S	15	15	49
160E, 60S	15	15	45
140E, 60S	15	15	46
120E, 60S	16	16	65
100E, 60S	15	16	34
80E, 60S	15	16	38
60E, 60S	15	16	58
40E, 60S	16	16	51
20E, 60S	15	15	52
0E, 60S	15	14	54
20W, 60S	15	14	34
40W, 60S	15	15	48
60W, 60S	14	15	42
280E, 80S	15	15	54
260E, 80S	13	13	45
240E, 80S	13	13	49
220E, 80S	15	15	48
200E, 80S	13	15	48
180E, 80S	13	15	42
160E, 80S	13	15	58
140E, 80S	13	15	69
120E, 80S	15	15	52
100E, 80S	15	15	52

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TABLE 2, cont.

DIRECT RADIATION LEVELS
SYSTEMATICALLY MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at the Surface (μrad/h)
80E, 80S	13	15	58
60E, 80S	15	15	54
40E, 80S	13	15	45
20E, 80S	13	15	43
0E, 80S	13	13	32
20W, 80S	13	13	49
40W, 80S	15	14	49
60W, 80S	14	14	49
280E,100S	13	15	29
260E,100S	15	15	55
240E,100S	15	15	40
220E,100S	15	15	43
200E,100S	15	15	38
180E,100S	15	14	35
160E,100S	15	15	65
140E,100S	14	15	52
120E,100S	14	15	54
100E,100S	14	13	48
80E,100S	15	15	37
60E,100S	15	14	43
40E,100S	15	15	52
20E,100S	15	14	43
0E,100S	14	14	42
20W,100S	14	13	54
40W,100S	13	15	37
60W,100S	12	13	37
280E,120S	15	15	62
260E,120S	13	13	49
240E,120S	15	15	54
220E,120S	14	14	71
200E,120S	13	13	57
180E,120S	14	13	54
160E,120S	15	14	45
140E,120S	15	14	52
120E,120S	13	13	63
100E,120S	14	14	42
80E,120S	13	13	31
60E,120S	15	15	57
40E,120S	13	13	51
20E,120S	14	14	55
0E,120S	12	13	54

TABLE 2, cont.

DIRECT RADIATION LEVELS
SYSTEMATICALLY MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at the Surface (μrad/h)
20W,120S	12	12	42
40W,120S	12	13	34
60W,120S	13	13	48
280E,140S	13	13	48
260E,140S	12	12	45
240E,140S	12	12	65
220E,140S	12	12	54
200E,140S	13	13	52
180E,140S	12	12	57
160E,140S	12	12	48
140E,140S	12	13	49
120E,140S	12	12	34
100E,140S	12	13	62
80E,140S	12	12	57
60E,140S	13	13	57
40E,140S	12	12	39
20E,140S	12	13	48
0E,140S	12	12	60
20W,140S	--[a]	--	--
40W,140S	12	13	31
60W,140S	12	12	29
280E,160S	16	16	60
260E,160S	13	12	40
240E,160S	12	12	54
220E,160S	10	12	42
200E,160S	10	10	42
180E,160S	10	12	35
160E,160S	10	12	29
140E,160S	10	10	40
120E,160S	10	12	40
100E,160S	12	12	34
80E,160S	12	12	26
60E,160S	10	10	34
40E,160S	12	12	29
20E,160S	10	10	22
0E,160S	11	10	37
20W,160S	11	10	48
40W,160S	11	12	29
60W,160S	10	8.7	32
280E,180S	12	12	52
260E,180S	12	12	38

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TABLE 2, cont.

DIRECT RADIATION LEVELS
SYSTEMATICALLY MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at the Surface (μrad/h)
240E,180S	12	12	60
220E,180S	12	12	58
200E,180S	12	12	40
180E,180S	13	13	51
160E,180S	13	13	52
140E,180S	13	13	58
120E,180S	12	12	51
100E,180S	12	12	49
80E,180S	11	11	34
60E,180S	12	12	48
40E,180S	10	10	23
20E,180S	8.7	9.8	31
0E,180S	9.8	10	45
20W,180S	9.8	10	20
40W,180S	10	10	35
60W,180S	10	9.8	40
280E,200S	13	13	43
240E,200S	12	12	30
220E,240S	12	12	35
220E,240S	12	12	22
200E,240S	12	12	37
180E,240S	12	12	43
160E,240S	12	13	38
140E,240S	12	13	51
120E,240S	12	13	55
100E,240S	12	12	42
80E,240S	11	11	29
60E,240S	12	12	48
40E,240S	11	12	48
20E,240S	12	12	46
0E,240S	11	12	45
20W,240S	12	12	45
40W,240S	12	12	31
60W,240S	11	12	38
280E,260S	13	13	9
260E,260S	11	12	34
240E,260S	12	13	42
220E,260S	12	12	49
200E,260S	12	12	43
180E,260S	12	12	49
160E,260S	13	12	43

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TABLE 2, cont.

DIRECT RADIATION LEVELS
SYSTEMATICALLY MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at the Surface (μrad/h)
140E,260S	13	12	58
120E,260S	12	13	42
100E,260S	12	12	38
80E,260S	12	11	43
60E,260S	12	12	42
40E,260S	12	12	45
20E,260S	12	12	37
0E,260S	11	11	40
20W,260S	11	11	32
40W,260S	10	10	34
60W,260S	12	12	38
280E,280S	12	13	54
260E,280S	12	12	58
240E,280S	12	12	49
220E,280S	12	12	45
200E,280S	11	12	32
180E,260S	11	12	40
160E,280S	12	12	51
140E,280S	13	12	46
120E,280S	12	12	35
100E,280S	12	12	42
80E,280S	12	12	37
60E,280S	12	12	46
40E,280S	12	12	34
20E,280S	11	9.8	32
0E,280S	12	11	23
20W,280S	12	12	28
40W,280S	12	12	35
60W,280S	12	12	34
280E,300S	12	12	63
260E,300S	12	15	55
240E,300S	12	11	49
220E,300S	12	12	58
200E,300S	12	13	52
180E,300S	12	12	31
160E,300S	12	13	42
140E,300S	13	13	58
120E,300S	12	13	29
100E,300S	12	12	28
80E,300S	13	15	48
60E,300S	12	12	51

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TABLE 2, cont.

DIRECT RADIATION LEVELS
SYSTEMATICALLY MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at the Surface (μrad/h)
40E,300S	12	12	51
20E,300S	10	6.7	37
0E,300S	12	12	45
20W,300S	12	13	34
40W,300S	12	13	32
60W,300S	12	12	28
280E,Pletcher Rd	12	12	40
260E,Pletcher Rd	12	12	28
240E,Pletcher Rd	12	13	38
220E,Pletcher Rd	12	13	40
200E,Pletcher Rd	12	12	43
180E,Pletcher Rd	13	12	26
160E,Pletcher Rd	14	13	26
140E,Pletcher Rd	13	13	29
120E,Pletcher Rd	12	11	31
100E,Pletcher Rd	12	11	31
80E,Pletcher Rd	11	11	38
60E,Pletcher Rd	13	12	57
40E,Pletcher Rd	13	13	46
20E,Pletcher Rd	11	13	37
0E,Pletcher Rd	12	13	54
20W,Pletcher Rd	13	13	28
40W,Pletcher Rd	14	19	47
60W,Pletcher Rd	15	15	50

[a] Measurement not performed due to building.

TABLE 3

DIRECT RADIATION LEVELS AT SELECTED LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Location[a]	Grid Point	Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Soil Sample[b]	Contact Exposure Rate after Sample Removal (μR/h)
		Contact	1 m above surface			
1	281E, 57S	28	16	140	B 1	26
2	281E, 58S	75	19	350	B 2	77
3	280E,147S	26	15	71	B 3	39
4	278E,151S	28	18	100	B 4	28
5	279E,168S	26	18	98	B 5	26
6	281E,170S	20	16	120	B 6	20
7	282E,178S	22	15	80	B 7	22
8	281E,184S	22	15	68	B 8	22
9	280E,186S	24	15	114	B 9	24
10	281E,188S	29	18	260	B10	29
11	280E,189S	61	18	230	B11	61
12	279E,192S	45	13	790	B12	24
13	280E,192S	280	15	30,000	B13	22
14	280E,214S	20	13	100	B14	20
15	281E,218S	22	15	94	B15	20
16	281E,221S	22	15	86	B16	20
17	278E,302S	35	18	130	B17	39
18	156E,309S	69	15	350	B18	79
19	38E,310S	24	15	110	B19	26

[a] Refer to Figure 3.
[b] Soil concentrations presented in Table 4.

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TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM GRID LINE INTERSECTIONS

Sample No.	Grid Location[a]	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
1	280E, 0S	2.47 ± 0.23[b]	<0.21	<2.8	0.25 ± 0.20	1.61 ± 0.13
2	260E, 0S	0.94 ± 0.29	<0.35	<5.0	0.78 ± 0.66	0.64 ± 0.18
3	240E, 0S	0.89 ± 0.29	<0.33	<5.2	0.85 ± 0.78	0.56 ± 0.14
4	220E, 0S	0.90 ± 0.28	<0.28	<5.8	0.53 ± 0.49	0.32 ± 0.12
5	200E, 0S	0.83 ± 0.27	<0.34	<6.7	0.89 ± 0.50	0.52 ± 0.15
6	180E, 0S	0.69 ± 0.24	<0.61	<5.9	0.93 ± 0.32	0.55 ± 0.18
7	160E, 0S	1.16 ± 0.28	<0.32	<4.8	0.50 ± 0.77	0.83 ± 0.16
8	140E, 0S	0.95 ± 0.29	<0.56	<5.0	1.39 ± 0.44	0.44 ± 0.15
9	120E, 0S	0.62 ± 0.26	<0.31	<4.5	0.68 ± 0.59	0.67 ± 0.17
10	100E, 0S	0.87 ± 0.29	<0.24	<4.0	0.55 ± 0.43	0.40 ± 0.12
11	80E, 0S	0.54 ± 0.24	<0.53	14 ± 15	1.23 ± 0.60	0.59 ± 0.19
12	60E, 0S	0.98 ± 0.29	0.57 ± 0.54	<4.8	0.78 ± 0.55	0.59 ± 0.18
13	40E, 0S	0.71 ± 0.35	0.38 ± 0.60	<5.2	0.78 ± 0.37	0.68 ± 0.16
14	20E, 0S	0.73 ± 0.12	<0.38	<5.2	1.09 ± 0.52	0.54 ± 0.16
15	0E, 0S	0.40 ± 0.24	<0.24	<5.0	0.90 ± 0.60	0.59 ± 0.16
16	20W, 0S	2.01 ± 0.41	<0.39	<6.6	0.82 ± 0.66	<0.06
17	40W, 0S	0.78 ± 0.22	<0.40	10 ± 10	0.59 ± 0.48	0.72 ± 0.16
18	60W, 0S	0.48 ± 0.22	<0.41	<4.7	0.11 ± 0.48	0.15 ± 0.09
19	280E,20S	3.12 ± 0.53	<0.46	<5.0	1.21 ± 0.78	1.61 ± 0.28
20	260E,20S	4.13 ± 0.42	<0.30	<4.7	0.87 ± 0.49	0.50 ± 0.13
21	240E,20S	0.75 ± 0.23	<0.28	<5.6	0.72 ± 0.67	0.69 ± 0.15
22	220E,20S	0.48 ± 0.25	<0.27	<4.9	1.22 ± 0.47	0.37 ± 0.18
23	200E,20S	0.31 ± 0.21	<0.53	<4.1	0.80 ± 0.38	0.59 ± 0.15
24	180E,20S	0.63 ± 0.21	<0.31	<5.6	0.77 ± 0.43	0.32 ± 0.13
25	160E,20S	0.78 ± 0.20	0.26 ± 0.65	<3.2	0.90 ± 0.40	0.13 ± 0.09
26	140E,20S	0.73 ± 0.23	0.45 ± 0.55	<4.3	1.34 ± 0.43	0.59 ± 0.19
27	120E,20S	0.59 ± 0.26	<0.29	<5.6	0.80 ± 0.47	1.01 ± 0.20
28	100E,20S	0.60 ± 0.24	<0.28	<6.3	0.56 ± 0.38	0.84 ± 0.16
29	80E,20S	0.42 ± 0.24	<0.28	<4.8	0.90 ± 0.44	0.59 ± 0.15
30	60E,20S	0.61 ± 0.25	<0.31	6.1 ± 9.4	1.08 ± 0.44	0.29 ± 0.22
31	40E,20S	0.50 ± 0.11	<0.26	<4.1	0.70 ± 0.55	0.54 ± 0.14
32	20E,20S	0.79 ± 0.26	<0.27	<5.0	1.05 ± 0.59	0.90 ± 0.21
33	0E,20S	0.71 ± 0.23	0.48 ± 0.62	<6.1	0.65 ± 0.41	0.62 ± 0.17
34	20W,20S	0.52 ± 0.26	<0.27	<4.3	0.61 ± 0.39	0.66 ± 0.16
35	40W,20S	0.63 ± 0.24	<0.62	<4.9	0.90 ± 0.65	0.26 ± 0.16
36	60W,20S	0.55 ± 0.21	<0.25	<3.8	0.87 ± 0.45	<0.04
37	280E,40S	1.64 ± 0.32	<0.31	<5.7	0.61 ± 0.65	0.74 ± 0.17
38	260E,40S	0.75 ± 0.26	<0.29	<6.3	0.99 ± 0.52	0.62 ± 0.17
39	240E,40S	0.71 ± 0.24	<0.29	<4.3	0.85 ± 0.42	0.26 ± 0.13
40	220E,40S	0.63 ± 0.25	<0.29	<4.2	1.37 ± 0.57	0.59 ± 0.16
41	200E,40S	0.47 ± 0.24	<0.30	<5.0	0.87 ± 0.50	0.66 ± 0.16
42	180E,40S	0.53 ± 0.33	<0.28	<3.5	0.97 ± 0.50	0.47 ± 0.15

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TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM GRID LINE INTERSECTIONS

Sample No.	Grid Location	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
43	160E,40S	0.61 ± 0.22	<0.27	<4.2	0.77 ± 0.41	0.45 ± 0.13
44	140E,40S	0.54 ± 0.18	<0.27	<3.4	0.94 ± 0.42	0.28 ± 0.14
45	120E,40S	0.51 ± 0.25	<0.29	<5.4	0.90 ± 0.50	0.96 ± 0.22
46	100E,40S	0.45 ± 0.27	<0.28	11 ± 12	0.57 ± 0.43	0.73 ± 0.16
47	80E,40S	0.53 ± 0.23	<0.26	<4.9	0.72 ± 0.36	0.31 ± 0.13
48	60E,40S	0.73 ± 0.30	0.36 ± 0.53	<5.0	0.93 ± 0.51	0.73 ± 0.18
49	40E,40S	0.52 ± 0.21	0.57 ± 0.55	<5.5	1.11 ± 0.36	0.55 ± 0.14
50	20E,40S	0.79 ± 0.30	<0.53	<4.9	0.82 ± 0.45	0.51 ± 0.16
51	0E,40S	0.51 ± 0.24	<0.27	<4.3	0.81 ± 0.37	0.68 ± 0.17
52	20W,40S	0.56 ± 0.29	<0.46	<6.5	0.72 ± 0.52	1.12 ± 0.20
53	40W,40S	0.43 ± 0.29	<0.29	<4.4	0.58 ± 0.78	0.48 ± 0.22
54	60W,40S	0.54 ± 0.19	<0.30	<3.9	0.76 ± 0.51	<0.04
55	280E,60S	2.03 ± 0.33	<0.34	<4.7	1.12 ± 0.43	0.52 ± 0.14
56	260E,60S	0.55 ± 0.20	<0.25	<5.5	0.81 ± 0.43	0.37 ± 0.16
57	240E,60S	0.52 ± 0.23	<0.28	<1.8	0.64 ± 0.43	0.37 ± 0.12
58	220E,60S	0.50 ± 0.24	<0.27	<5.4	0.69 ± 0.52	0.46 ± 0.14
59	200E,60S	0.58 ± 0.25	<0.26	8.3 ± 11	0.64 ± 0.36	0.31 ± 0.11
60	180E,60S	0.73 ± 0.11	<0.26	<3.7	0.93 ± 0.37	<0.04
61	160E,60S	0.62 ± 0.11	<0.26	<3.7	0.45 ± 0.37	0.20 ± 0.10
62	140E,60S	0.57 ± 0.31	<0.26	<4.5	1.01 ± 0.52	0.80 ± 0.18
63	120E,60S	0.70 ± 0.24	<0.23	<4.7	0.75 ± 0.57	0.13 ± 0.10
64	100E,60S	0.72 ± 0.23	<0.34	<4.7	0.94 ± 0.49	0.99 ± 0.18
None	80E,60S	---[c]	---	---	---	---
65	60E,60S	0.61 ± 0.41	<0.32	<4.6	1.49 ± 0.74	0.41 ± 0.15
66	40E,60S	0.62 ± 0.21	<0.30	<4.6	0.65 ± 0.72	0.91 ± 0.17
67	20E,60S	<0.18	<0.29	<5.6	0.82 ± 0.54	0.41 ± 0.16
68	0E,60S	0.66 ± 0.24	<0.30	<6.0	1.02 ± 0.44	0.95 ± 0.17
69	20W,60S	1.84 ± 0.37	<0.36	<6.0	0.75 ± 0.60	<0.05
70	40W,60S	0.64 ± 0.27	<0.48	<3.9	0.51 ± 0.44	0.31 ± 0.13
71	60W,60S	0.50 ± 0.21	<0.24	<3.4	0.78 ± 0.38	0.63 ± 0.15
72	280E,80S	1.35 ± 0.27	<0.33	<5.0	0.70 ± 0.45	0.58 ± 0.20
73	260E,80S	0.63 ± 0.24	<0.27	<3.8	1.03 ± 0.57	<0.05
74	240E,80S	0.60 ± 0.12	<0.27	<4.7	1.04 ± 0.48	0.13 ± 0.08
75	220E,80S	0.68 ± 0.22	<0.44	<3.7	1.33 ± 0.43	0.46 ± 0.17
76	220E,80S	0.54 ± 0.26	<0.27	<5.2	1.10 ± 0.56	0.23 ± 0.15
77	180E,80S	0.93 ± 0.26	<0.29	<4.8	0.94 ± 0.58	0.39 ± 0.15
78	160E,80S	0.50 ± 0.23	<0.30	<5.2	1.18 ± 0.46	0.54 ± 0.14
79	140E,80S	0.57 ± 0.20	<0.24	<5.4	0.59 ± 0.41	<0.04
80	120E,80S	0.52 ± 0.22	<0.28	<3.3	0.85 ± 0.39	0.11 ± 0.10
81	100E,80S	0.68 ± 0.23	<0.28	<4.9	0.79 ± 0.38	0.26 ± 0.13
82	80E,80S	0.64 ± 0.34	<0.28	<4.6	1.00 ± 0.40	0.46 ± 0.15
83	60E,80S	0.63 ± 0.23	<0.27	<5.2	0.95 ± 0.42	0.70 ± 0.15

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TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM GRID LINE INTERSECTIONS

Sample No.	Grid Location	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
84	40E,80S	0.64 ± 0.22	<0.26	<4.9	0.97 ± 0.40	0.29 ± 0.13
85	20E,80S	0.50 ± 0.22	0.49 ± 0.68	<3.7	1.27 ± 0.43	0.59 ± 0.16
86	0E,80S	0.70 ± 0.35	0.34 ± 0.72	<3.6	1.15 ± 0.53	0.69 ± 0.21
87	20W,80S	0.47 ± 0.25	0.41 ± 0.69	<3.5	0.62 ± 0.46	0.82 ± 0.18
None	40W,80S	---	---	--	---	---
88	60W,80S	0.51 ± 0.22	<0.39	<4.8	0.69 ± 0.40	0.67 ± 0.16
89	280E,100S	1.35 ± 0.30	<0.33	<6.8	0.83 ± 0.42	0.61 ± 0.14
90	260E,100S	1.03 ± 0.33	<0.34	<4.3	1.01 ± 0.57	0.76 ± 0.18
91	240E,100S	0.85 ± 0.26	<0.44	<3.9	1.26 ± 0.46	0.15 ± 0.93
92	220E,100S	0.75 ± 0.21	<0.29	<4.3	0.71 ± 0.44	0.35 ± 0.11
93	200E,100S	0.61 ± 0.30	<0.46	<5.2	1.03 ± 0.41	0.27 ± 0.12
94	180E,100S	0.59 ± 0.18	<0.27	<4.4	0.87 ± 0.54	0.15 ± 0.10
95	160E,100S	0.52 ± 0.27	<0.46	<4.4	1.49 ± 0.44	0.05 ± 0.10
96	140E,100S	0.62 ± 0.23	<0.24	<4.8	1.09 ± 0.67	<0.03
97	120E,100S	0.59 ± 0.23	<0.25	<4.9	1.13 ± 0.30	<0.03
98	100E,100S	0.62 ± 0.25	<0.24	<5.0	0.86 ± 0.62	0.15 ± 0.12
99	80E,100S	0.61 ± 0.21	0.25 ± 0.67	<2.8	0.73 ± 0.41	0.21 ± 0.09
100	60E,100S	0.61 ± 0.25	<0.29	<4.6	1.13 ± 0.66	0.48 ± 0.16
101	40E,100S	0.74 ± 0.22	<0.24	<4.8	1.08 ± 0.42	<0.04
102	20E,100S	0.44 ± 0.36	<0.51	<4.5	0.78 ± 0.44	0.43 ± 0.19
103	0E,100S	0.42 ± 0.23	<0.26	<5.7	0.47 ± 0.48	0.76 ± 0.14
104	20W,100S	1.66 ± 0.33	<0.32	<5.4	0.68 ± 0.54	<0.05
105	40W,100S	0.62 ± 0.16	<0.33	<2.8	0.68 ± 0.49	<0.03
106	60W,100S	0.61 ± 0.20	<0.26	<3.7	0.42 ± 0.40	0.52 ± 0.13
107	280E,120S	1.52 ± 0.45	0.54 ± 0.82	<7.0	1.03 ± 0.50	0.57 ± 0.11
108	260E,120S	0.69 ± 0.22	<0.27	<4.7	1.16 ± 0.42	0.15 ± 0.11
109	240E,120S	0.61 ± 0.23	<0.22	<2.0	1.11 ± 0.48	0.22 ± 0.10
110	220E,120S	0.70 ± 0.23	<0.26	<4.0	0.85 ± 0.42	0.06 ± 0.09
111	200E,120S	1.04 ± 0.25	<0.28	8.6 ± 8.8	1.57 ± 0.48	0.26 ± 0.14
112	180E,120S	0.79 ± 0.23	<0.41	<3.9	1.14 ± 0.49	0.06 ± 0.08
113	160E,120S	0.54 ± 0.29	<0.27	4.7 ± 13	1.00 ± 0.44	0.10 ± 0.08
114	140E,120S	0.86 ± 0.22	<0.24	<2.7	1.64 ± 0.51	<0.05
115	120E,120S	0.71 ± 0.20	<0.26	7.2 ± 11	0.80 ± 0.41	0.28 ± 0.12
116	100E,120S	0.84 ± 0.38	<0.27	<5.0	1.38 ± 0.60	0.27 ± 0.13
117	80E,120S	0.58 ± 0.23	<0.27	<4.6	0.84 ± 0.50	0.21 ± 0.10
118	60E,120S	0.79 ± 0.26	<0.26	<4.5	0.95 ± 0.39	0.07 ± 0.10
119	40E,120S	0.66 ± 0.26	<0.27	6.5 ± 12	0.86 ± 0.40	0.13 ± 0.12
120	20E,120S	0.81 ± 0.24	<0.26	7.2 ± 13	0.35 ± 0.44	0.25 ± 0.14
121	0E,120S	0.77 ± 0.24	<0.30	<5.9	0.96 ± 0.72	0.51 ± 0.15
122	20W,120S	<0.08	<0.36	<5.5	0.82 ± 0.58	<0.05
123	40W,120S	<0.18	<0.28	<6.2	0.51 ± 0.67	<0.05
124	60W,120S	0.62 ± 0.24	<0.48	<3.4	1.05 ± 0.43	0.65 ± 0.14

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TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM GRID LINE INTERSECTIONS

Sample No.	Grid Location	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
125	280E,140S	2.66 ± 0.42	<0.47	<6.0	1.16 ± 1.02	0.53 ± 0.19
126	260E,140S	0.33 ± 0.25	<0.20	5.3 ± 11	<0.14	0.31 ± 0.11
127	240E,140S	0.58 ± 0.24	<0.27	<4.3	0.69 ± 0.47	0.51 ± 0.14
128	220E,140S	2.42 ± 0.38	<0.36	<6.2	0.96 ± 0.41	0.23 ± 0.12
129	220E,140S	0.79 ± 0.23	<0.29	<4.9	1.05 ± 0.40	<0.04
130	200E,140S	0.79 ± 0.24	<0.26	8.7 ± 8.5	0.89 ± 0.47	0.23 ± 0.14
131	160E,140S	0.60 ± 0.20	<0.24	<3.7	0.97 ± 0.34	0.09 ± 0.10
132	140E,140S	0.66 ± 0.27	<0.26	5.0 ± 22	1.05 ± 0.45	0.19 ± 0.11
133	120E,140S	0.55 ± 0.27	<0.22	6.1 ± 11	0.75 ± 0.37	0.50 ± 0.13
134	100E,140S	0.75 ± 0.24	<0.27	<4.5	0.90 ± 0.60	0.40 ± 0.15
135	80E,140S	0.51 ± 0.25	<0.26	<4.9	1.07 ± 0.50	0.07 ± 0.09
136	60E,140S	0.50 ± 0.23	<0.27	<4.3	0.78 ± 0.46	0.40 ± 0.14
137	40E,140S	0.47 ± 0.24	<0.24	<3.6	0.54 ± 0.32	<0.04
138	20E,140S	0.63 ± 0.18	<0.24	<3.8	1.03 ± 0.40	0.08 ± 0.11
139	0E,140S	0.71 ± 0.31	<0.26	<4.4	0.62 ± 0.38	0.28 ± 0.11
140	20W,140S	0.36 ± 0.29	<0.22	<3.9	0.49 ± 0.59	0.52 ± 0.14
141	40W,140S	1.69 ± 0.34	<0.33	<5.5	0.69 ± 0.55	<0.05
142	60W,140S	0.80 ± 0.21	0.44 ± 0.47	<3.4	0.74 ± 0.38	0.46 ± 0.15
143	280E,160S	5.43 ± 0.51	<0.49	<6.2	0.72 ± 0.51	1.78 ± 0.21
None	260E,160S	---	---	---	---	---
None	240E,160S	---	---	---	---	---
None	240E,160	---	---	---	---	---
None	220E,160S	---	---	---	---	---
None	200E,160S	---	---	---	---	---
None	180E,160S	---	---	---	---	---
None	160E,160S	---	---	---	---	---
None	140E,160S	---	---	---	---	---
None	120E,160S	---	---	---	---	---
None	100E,160S	---	---	---	---	---
None	80E,160S	---	---	---	---	---
None	60E,160S	---	---	---	---	---
None	40E,160S	---	---	---	---	---
None	20E,160S	---	---	---	---	---
None	0E,160S	---	---	---	---	---
144	20W,160S	1.43 ± 0.29	<0.28	<4.7	0.59 ± 0.47	<0.04
145	40W,160S	0.38 ± 0.14	<0.17	<2.8	0.20 ± 0.36	0.73 ± 0.13
146	60W,160S	1.03 ± 0.30	<0.39	<4.4	0.35 ± 0.32	2.68 ± 0.25
147	280E,180S	3.91 ± 0.50	<0.47	<8.1	1.76 ± 0.72	0.95 ± 0.21
148	260E,180S	0.39 ± 0.22	<0.46	<5.8	0.78 ± 0.46	0.45 ± 0.14

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TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM GRID LINE INTERSECTIONS

Sample No.	Grid Location	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
149	240E,180S	0.42 ± 0.18	<0.27	<5.0	0.71 ± 0.46	<0.04
150	220E,180S	<0.14	<0.25	<2.4	0.73 ± 0.49	0.08 ± 0.10
151	200E,180S	0.54 ± 0.23	<0.26	<4.6	0.98 ± 0.48	0.10 ± 0.09
152	180E,180S	0.62 ± 0.22	<0.26	<4.7	0.78 ± 0.38	0.27 ± 0.12
153	160E,180S	0.71 ± 0.22	<0.26	<4.1	0.49 ± 0.35	0.21 ± 0.12
154	140E,180S	0.64 ± 0.26	<0.27	<6.4	1.23 ± 0.50	0.12 ± 0.13
155	120E,180S	0.60 ± 0.29	<0.28	<4.9	1.13 ± 0.56	0.30 ± 0.11
156	100E,180S	0.72 ± 0.26	<0.36	<4.7	0.86 ± 0.39	0.38 ± 0.19
157	80E,180S	0.67 ± 0.27	<0.26	<5.5	0.75 ± 0.39	0.80 ± 0.15
158	60E,180S	0.37 ± 0.25	<0.64	<4.8	0.47 ± 0.64	1.14 ± 0.22
159	40E,180S	0.57 ± 0.23	<0.26	<5.3	0.82 ± 0.41	0.04 ± 0.10
160	20E,180S	0.17 ± 0.16	<0.25	<2.9	<0.12	0.76 ± 0.13
161	0E,180S	0.25 ± 0.17	<0.17	<3.2	0.27 ± 0.35	0.60 ± 0.11
162	20W,180S	0.19 ± 0.21	<0.16	3.2 ± 12	0.31 ± 0.23	0.53 ± 0.10
163	40W,180S	<0.08	<0.15	<1.3	0.44 ± 0.25	0.73 ± 0.15
164	60W,180S	0.49 ± 0.21	<0.24	<4.4	0.53 ± 0.35	0.64 ± 0.14
None	280E,200S	---	---	---	---	---
165	260E,200S	1.00 ± 0.26	<0.32	<4.3	1.32 ± 0.80	<0.04
166	240E,200S	0.41 ± 0.22	<0.28	<5.4	1.28 ± 0.51	0.18 ± 0.14
167	220E,200S	0.65 ± 0.23	<0.29	<4.7	0.86 ± 0.44	0.13 ± 0.09
168	200E,200S	0.64 ± 0.30	<0.30	<5.0	0.93 ± 0.47	<0.04
169	180E,200S	0.87 ± 0.26	0.33 ± 0.59	<6.9	0.71 ± 0.70	0.06 ± 0.12
170	160E,200S	0.56 ± 0.24	<0.27	<5.1	1.06 ± 0.48	0.11 ± 0.12
171	140E,200S	1.08 ± 0.28	<0.30	<5.0	1.12 ± 0.38	0.08 ± 0.11
172	120E,200S	0.60 ± 0.24	<0.29	8.6 ± 11	1.03 ± 0.60	0.45 ± 0.13
173	100E,200S	0.66 ± 0.35	<0.32	<5.8	1.04 ± 0.66	0.63 ± 0.18
174	80E,200S	0.40 ± 0.18	<0.18	<2.7	0.29 ± 0.31	1.79 ± 0.16
175	60E,200S	0.23 ± 0.14	<0.14	<3.4	0.38 ± 0.21	0.41 ± 0.10
176	40E,200S	0.78 ± 0.24	<0.27	<4.4	1.13 ± 0.42	0.52 ± 0.12
177	20E,200S	0.54 ± 0.23	<0.27	<4.3	0.47 ± 0.67	0.79 ± 0.17
178	0E,200S	0.61 ± 0.24	<0.25	<1.5	0.44 ± 0.27	1.41 ± 0.17
179	20W,200S	1.38 ± 0.28	<0.27	<4.5	0.56 ± 0.45	<0.04
180	40W,200S	1.43 ± 0.29	<0.28	<4.7	0.59 ± 0.47	<0.04
181	60W,200S	0.43 ± 0.18	<0.35	<3.6	0.61 ± 0.28	0.52 ± 0.12
182	280E,220S	3.44 ± 0.42	<0.39	<6.4	1.11 ± 0.55	0.43 ± 0.25
183	260E,220S	<0.18	<0.27	<5.3	0.76 ± 0.51	0.54 ± 0.14
184	240E,220S	0.54 ± 0.24	<0.29	<5.1	1.11 ± 0.44	0.09 ± 0.14
185	220E,220S	0.61 ± 0.22	<0.53	<4.3	1.14 ± 0.45	<0.04
186	200E,220S	0.43 ± 0.21	<0.24	<4.8	1.67 ± 0.46	0.07 ± 0.08
187	180E,220S	0.26 ± 0.23	<0.28	<4.7	1.05 ± 0.68	0.55 ± 0.17

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TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM GRID LINE INTERSECTIONS

Sample No.	Grid Location	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
188	160E,220S	0.73 ± 0.31	<0.34	<5.6	0.79 ± 0.79	0.91 ± 0.21
189	140E,220S	0.48 ± 0.20	<0.28	<4.8	0.83 ± 0.43	0.06 ± 0.14
190	120E,220S	0.64 ± 0.29	<0.29	<3.8	1.05 ± 0.56	0.46 ± 0.13
191	100E,220S	0.53 ± 0.25	<0.26	<6.1	0.76 ± 0.55	0.29 ± 0.16
None	80E,220S	---	---	---	---	---
None	60E,220S	---	---	---	---	---
192	40E,220S	0.57 ± 0.24	<0.29	7.6 ± 9.4	0.86 ± 0.43	0.50 ± 0.14
193	20E,220S	0.50 ± 0.23	<0.37	<4.5	0.56 ± 0.39	0.31 ± 0.14
194	0E,220S	0.61 ± 0.34	<0.26	<5.3	0.99 ± 0.49	0.52 ± 0.14
195	20W,220S	0.46 ± 0.20	<0.25	<3.8	0.84 ± 0.42	<0.05
196	40W,220S	0.53 ± 0.24	<0.23	<3.7	0.85 ± 0.39	0.10 ± 0.13
197	60W,220S	0.66 ± 0.23	<0.24	<3.8	0.67 ± 0.53	0.47 ± 0.14
198	280E,240S	2.07 ± 0.35	<0.38	<5.4	0.79 ± 0.69	0.77 ± 0.22
199	260E,240S	0.66 ± 0.24	<0.29	<4.2	1.02 ± 0.46	0.61 ± 0.21
200	240E,240S	0.50 ± 0.25	<0.31	<5.9	1.25 ± 0.50	0.53 ± 0.18
201	220E,240S	0.52 ± 0.26	<0.30	<5.2	1.23 ± 0.45	0.48 ± 0.16
202	200E,240S	0.51 ± 0.21	<0.29	<5.0	0.88 ± 0.38	0.22 ± 0.11
203	108E,240S	0.89 ± 0.26	<0.45	<4.1	0.93 ± 0.58	0.22 ± 0.11
204	160E,240S	0.85 ± 0.38	<0.44	13 ± 19	0.94 ± 0.68	0.89 ± 0.24
205	140E,240S	0.65 ± 0.34	<0.29	<6.2	2.20 ± 0.84	1.24 ± 0.22
206	120E,240S	0.61 ± 0.26	<0.30	<6.4	1.07 ± 0.57	0.63 ± 0.17
207	100E,240S	0.49 ± 0.28	<0.32	<6.0	0.71 ± 0.38	0.72 ± 0.19
208	80E,240S	0.89 ± 0.33	<0.28	<4.4	0.84 ± 0.34	0.77 ± 0.17
209	60E,240S	0.59 ± 0.28	<0.30	<6.2	1.13 ± 0.36	0.28 ± 0.15
210	40E,240S	0.75 ± 0.23	<0.39	<3.6	1.25 ± 0.51	0.38 ± 0.17
211	20E,240S	0.59 ± 0.25	<0.30	<6.1	0.83 ± 0.42	0.59 ± 0.18
212	0E,240S	0.56 ± 0.25	<0.30	<6.1	0.69 ± 0.43	0.59 ± 0.18
213	20W,240S	1.78 ± 0.36	<0.34	<5.8	0.73 ± 0.58	<0.05
214	40W,240S	1.55 ± 0.31	<0.30	<5.1	0.64 ± 0.50	<0.05
215	60W,240S	0.56 ± 0.26	<0.52	<5.5	0.93 ± 0.57	0.43 ± 0.15
216	280E,260S	1.86 ± 0.37	<0.39	<6.2	1.09 ± 0.52	0.68 ± 0.16
217	260E,260S	1.08 ± 0.34	<0.36	<4.7	0.91 ± 0.60	0.62 ± 0.15
218	240E,260S	0.61 ± 0.28	<0.28	<4.7	0.71 ± 0.39	0.38 ± 0.13
219	220E,260S	0.48 ± 0.20	<0.26	<3.7	0.69 ± 0.47	0.58 ± 0.15
220	200E,260S	0.81 ± 0.23	<0.26	12 ± 17	0.93 ± 0.31	0.52 ± 0.13
221	180E,260S	0.63 ± 0.30	<0.28	<6.1	0.94 ± 0.46	0.35 ± 0.13
222	160E,260S	0.67 ± 0.28	<0.30	<5.2	0.98 ± 0.46	0.89 ± 0.16
223	140E,260S	0.52 ± 0.26	<0.28	4.5 ± 17	0.80 ± 0.49	0.62 ± 0.15
224	120E,260S	0.55 ± 0.21	<0.28	<5.4	0.82 ± 0.49	0.41 ± 0.14
225	100E,260S	0.86 ± 0.24	<0.25	<4.8	0.92 ± 0.45	0.52 ± 0.15

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TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM GRID LINE INTERSECTIONS

Sample No.	Grid Location	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
226	80E,260S	1.19 ± 0.38	<0.32	<7.0	0.71 ± 0.46	0.82 ± 0.19
227	60E,260S	0.56 ± 0.22	<0.27	<4.7	1.23 ± 0.46	0.27 ± 0.11
228	40E,260S	0.63 ± 0.22	<0.25	<4.0	0.69 ± 0.37	0.14 ± 0.16
229	20E,260S	0.55 ± 0.22	<0.24	<5.5	1.04 ± 0.51	0.15 ± 0.12
230	0E,260S	0.69 ± 0.20	<0.26	<3.9	0.58 ± 0.41	0.70 ± 0.13
231	20W,260S	0.68 ± 0.21	0.56 ± 0.56	<3.5	0.53 ± 0.33	0.46 ± 0.13
232	40W,260S	0.60 ± 0.35	<0.28	<5.3	0.62 ± 0.55	0.73 ± 0.18
233	60W,260S	0.61 ± 0.20	<0.23	<2.6	0.81 ± 0.42	0.41 ± 0.11
234	280E,280S	1.61 ± 0.35	<0.35	<5.2	0.83 ± 0.50	0.81 ± 0.19
235	260E,280S	0.66 ± 0.22	<0.27	<3.7	0.98 ± 0.43	0.60 ± 0.15
236	240E,280S	0.78 ± 0.26	0.43 ± 0.70	<5.2	0.84 ± 0.41	0.49 ± 0.17
237	220E,280S	0.72 ± 0.26	<0.29	<3.7	0.98 ± 0.42	0.39 ± 0.14
238	200E,280S	0.57 ± 0.37	<0.30	<5.4	0.95 ± 0.60	0.67 ± 0.17
239	180E,280S	0.68 ± 0.22	<0.29	<4.1	1.31 ± 0.52	0.63 ± 0.14
240	160E,280S	0.53 ± 0.25	<0.25	<4.4	0.77 ± 0.52	0.44 ± 0.16
241	140E,280S	0.75 ± 0.21	0.74 ± 0.63	<0.17	0.97 ± 0.45	0.36 ± 0.15
242	120E,280S	0.56 ± 0.20	<0.27	<5.6	0.81 ± 0.44	0.43 ± 0.13
243	100E,280S	0.57 ± 0.20	<0.27	<4.8	0.82 ± 0.56	0.36 ± 0.12
244	80E,280S	0.58 ± 0.25	<0.30	14 ± 19	0.50 ± 0.47	0.78 ± 0.17
245	60E,280S	0.55 ± 0.22	<0.27	9.2 ± 13	0.76 ± 0.49	<0.04
246	40E,280S	0.54 ± 0.31	<0.26	<4.1	0.70 ± 0.46	0.52 ± 0.16
247	20E,280S	0.85 ± 0.23	<0.23	<2.5	0.18 ± 0.30	0.84 ± 0.14
248	0E,280S	0.59 ± 0.27	<0.58	<3.7	0.85 ± 0.46	0.44 ± 0.15
249	20W,280S	2.19 ± 0.44	<0.42	<7.2	0.90 ± 0.72	<0.06
250	40W,280S	0.79 ± 0.28	<0.27	<3.3	1.05 ± 0.38	0.56 ± 0.14
251	60W,280S	0.79 ± 0.21	<0.37	<4.3	1.20 ± 0.49	0.36 ± 0.16
None	280E,300S	---	---	---	---	---
252	260E,300S	0.56 ± 0.21	<0.2	8.4 ± 9.3	0.81 ± 0.37	0.28 ± 0.10
253	240E,300S	0.60 ± 0.24	<0.42	<4.0	0.77 ± 0.32	0.60 ± 0.13
254	220E,300S	0.71 ± 0.39	<0.29	<4.8	0.99 ± 0.42	1.05 ± 0.19
255	200E,300S	0.88 ± 0.25	<0.28	<4.3	0.78 ± 0.52	0.91 ± 0.18
256	180E,300S	0.98 ± 0.23	<0.29	<4.7	0.74 ± 0.45	0.27 ± 0.12
257	160E,300S	0.70 ± 0.21	<0.22	17 ± 22	0.63 ± 0.67	0.42 ± 0.16
258	140E,300S	1.01 ± 0.23	<0.27	<5.1	1.02 ± 0.57	0.56 ± 0.13
259	120E,300S	0.73 ± 0.28	<0.22	<3.4	0.74 ± 0.56	0.35 ± 0.11
260	100e,300S	0.78 ± 0.26	<0.28	<4.0	0.77 ± 0.48	0.30 ± 0.13
261	80E,300S	1.47 ± 0.30	<0.29	<5.0	0.96 ± 0.48	0.60 ± 0.15
262	60E,300S	0.78 ± 0.24	<0.26	<4.3	0.50 ± 0.37	0.27 ± 0.13
263	40E,300S	1.12 ± 0.25	<0.43	<5.6	0.90 ± 0.38	0.40 ± 0.15
264	20E,300S	0.39 ± 0.16	<0.15	<1.8	0.10 ± 0.18	0.38 ± 0.10
265	0E,300S	0.85 ± 0.26	<0.42	<4.5	0.97 ± 0.41	0.26 ± 0.13

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TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM GRID LINE INTERSECTIONS

Sample No.	Grid Location	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
266	20W,300S	0.63 ± 0.27	<0.29	<4.4	0.65 ± 0.48	0.59 ± 0.15
267	40W,300S	1.93 ± 0.39	<0.37	<6.3	0.79 ± 0.63	<0.06
268	60W,300S	1.08 ± 0.24	<0.27	<5.0	0.54 ± 0.39	0.49 ± 0.18
269	250E, 10S	0.81 ± 0.29	<0.30	<5.9	0.96 ± 0.57	0.60 ± 0.17
270	230E, 10S	0.85 ± 0.29	<0.30	<5.9	0.89 ± 0.49	0.64 ± 0.19
271	210E, 10S	1.02 ± 0.41	<0.39	<6.1	1.04 ± 0.63	0.67 ± 0.25
272	190E, 10S	0.81 ± 0.39	<0.39	<6.7	1.15 ± 0.65	0.57 ± 0.15
273	170E, 10S	0.72 ± 0.29	<0.30	<6.4	1.20 ± 0.51	0.52 ± 0.15
274	150E, 10S	0.75 ± 0.24	<0.31	<4.4	0.97 ± 0.44	0.41 ± 0.15
275	130E, 10S	0.61 ± 0.30	<0.32	<5.4	0.98 ± 0.72	0.72 ± 0.18
276	110E, 10S	0.81 ± 0.26	<0.33	<4.8	0.72 ± 0.46	0.47 ± 0.15
277	90E, 10S	0.87 ± 0.32	0.98 ± 0.76	<4.4	1.03 ± 0.44	0.78 ± 0.17
278	70E, 10S	0.53 ± 0.28	<0.31	<5.5	0.90 ± 0.37	0.67 ± 0.16
279	50E, 10S	0.75 ± 0.25	<0.30	<5.7	0.68 ± 0.32	0.60 ± 0.16
280	30E, 10S	0.94 ± 0.29	<0.33	<6.0	1.12 ± 0.51	0.85 ± 0.19
281	10E, 10S	0.55 ± 0.25	<0.30	<4.4	0.65 ± 0.72	0.54 ± 0.19

[a] Refer to Figure 2.
[b] Errors are 2σ based on counting statistics.
[c] No sample obtained due to presence of paved surfaces.

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TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM SELECTED LOCATIONS IDENTIFIED BY WALKOVER SCAN

Sample No. [a]	Grid Location	Radionuclide Concentrations (pCi/g)[b]				
		Ra-226	U-235	U-238	Th-232	Cs-137
B1	281E, 57S	14.0 ± 0.82[c]	3.90 ± 1.92	<10.4	0.81 ± 0.74	1.09 ± 0.22
B2	281E, 58S	30.1 ± 1.52	3.87 ± 0.27	46.0 ± 0.8	0.90 ± 1.07	1.40 ± 0.40
B3	280E,147S	10.4 ± 0.74	<0.68	<8.74	0.90 ± 0.62	3.68 ± 0.35
B4	278E,151S	16.8 ± 0.85	1.31 ± 1.42	<9.73	0.66 ± 0.80	2.87 ± 0.33
B5	279E,168S	17.1 ± 0.90	2.40 ± 1.56	<9.56	0.50 ± 0.95	1.48 ± 0.26
B6	281E,170S	8.15 ± 0.65	<0.59	<7.83	1.10 ± 0.67	2.42 ± 0.26
B7	282E,178S	14.3 ± 0.87	<0.78	<8.09	0.86 ± 0.79	1.37 ± 0.27
B8	281E,184S	9.55 ± 0.73	<0.65	<7.26	1.05 ± 0.84	2.33 ± 0.33
B9	280E,186S	17.9 ± 0.88	<0.80	<9.69	0.51 ± 0.76	1.24 ± 0.28
B10	281E,188S	---[e]	---	---	---	---
B11	280E,189S	40.0 ± 1.23	<1.00	<12.4	<0.46	3.23 ± 0.34
B12	280E,214S	---[f]	---	---	---	---
B13	280E,192S	---[g]	---	---	---	---
B14	280E,214S	14.2 ± 0.76	<0.70	<8.46	0.71 ± 0.64	1.48 ± 0.26
B15	281E,218S	16.1 ± 0.91	<1.36	<7.69	<0.34	1.20 ± 0.23
B16	281E,221S	13.4 ± 0.79	2.16 ± 1.39	<10.2	0.84 ± 0.73	1.74 ± 0.28
B17	278E,302S	22.8 ± 1.00	1.50 ± 1.44	<11.8	0.81 ± 0.93	1.52 ± 0.27
B18	156E,309S	6.37 ± 1.81	2.67 ± 2.62	<18.2	1.19 ± 1.11	1.77 ± 0.28
B19	38E,310S	22.1 ± 1.02	<0.97	<11.8	0.96 ± 0.91	1.03 ± 0.31

[a] Refer to Figure 3.
[b] Refer to Table 2 for direct radiation levels.
[c] Errors are 2σ based on counting statistics.
[d] Sample also contained 96.3 ± 2.7 pCi/g Pa-231 and other associated daughter products.
[e] No soil sample taken due to paved surface.
[f] Ra-226 level 0.38 μCi.
[g] Ra-226 level 0.39 μCi.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Sample No.	Grid Location[a]	Depth (m)	Radionuclide Concentrations (pCi/g)				
			U-238	Ra-226	U-235	Th-232	Cs-137
H1	156E,307S	Surface	<5.3	1.81 ± 0.36	<0.42	0.72 ± 0.51	<0.05
		0.5	<5.5	1.66 ± 0.33	<0.32	0.68 ± 0.54	<0.05
		1	<3.4	0.77 ± 0.23	<0.44	0.66 ± 0.51	<0.04
H2	38E,308S	Surface	<6.1	1.85 ± 0.37	<0.36	0.76 ± 0.60	<0.05
		0.5	<4.6	1.07 ± 0.37	<0.29	1.14 ± 0.46	<0.05
		1	<5.3	1.60 ± 0.32	<0.31	0.65 ± 0.52	<0.05
H3	83E,238S	Surface	<4.3	1.30 ± 0.26	<0.25	0.53 ± 0.42	<0.04
		0.5	<3.9	0.99 ± 0.27	<0.25	1.05 ± 0.48	0.22 ± 0.10
H4	106E,305S	Surface	<6.2	4.60 ± 0.49	0.71 ± 0.86	0.62 ± 0.46	0.94 ± 0.22
		0.5	<5.3	1.62 ± 0.33	<0.31	0.66 ± 0.53	<0.05
		1	<4.0	0.74 ± 0.33	<0.26	0.61 ± 0.44	<0.04
H5	113E,152S	Surface	<4.6	3.22 ± 0.36	<0.38	0.58 ± 0.42	<0.05
		0.5	<5.1	1.56 ± 0.31	<0.30	0.64 ± 0.51	<0.05
		1	<3.3	0.52 ± 0.81	<0.21	0.71 ± 0.31	0.06 ± 0.10
H6	200E,163S	Surface	<5.2	0.81 ± 0.16	<0.30	0.58 ± 0.42	<0.06
		0.5	<6.8	2.06 ± 0.41	<0.40	0.84 ± 0.67	<0.06
		1	<5.3	1.14 ± 0.25	<0.29	0.95 ± 0.56	<0.05
H7	226E,307S	Surface	<4.5	1.38 ± 0.28	<0.27	0.57 ± 0.45	<0.04
		0.5	<1.9	0.71 ± 0.21	<0.24	0.71 ± 0.50	<0.03
		1	<4.4	1.34 ± 0.27	<0.26	0.55 ± 0.44	<0.04
H8	280E, 10S	Surface	<6.6	4.98 ± 0.53	0.79 ± 0.99	1.37 ± 0.55	0.62 ± 0.19
		0.5	<5.8	1.75 ± 0.35	<0.34	0.72 ± 0.57	<0.05
		1	<3.8	1.44 ± 0.26	<0.25	0.89 ± 0.39	0.14 ± 0.10
H9	280E, 56S	Surface	<7.6	5.08 ± 0.51	<0.50	1.06 ± 0.59	0.70 ± 0.20
		0.5	<4.4	0.60 ± 0.26	<0.26	0.74 ± 0.42	<0.04
		1	<5.6	1.69 ± 0.34	<0.33	0.69 ± 0.55	<0.05
H10	280E,103S	Surface	<5.8	1.76 ± 0.35	<0.34	0.72 ± 0.57	<0.05
		0.5	<3.9	0.71 ± 0.25	<0.25	0.86 ± 0.61	<0.03
		1	<5.1	1.55 ± 0.31	<0.30	0.63 ± 0.50	<0.05
H11	280E,172S	Surface	<5.5	4.78 ± 0.51	<0.43	0.77 ± 0.62	0.52 ± 0.15
		0.5	<4.8	1.45 ± 0.29	<0.28	0.59 ± 0.47	<0.04
		1	<4.0	0.71 ± 0.28	<0.42	0.80 ± 0.55	<0.04

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TABLE 6, cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Sample No.	Grid Location	Depth (m)	Radionuclide Concentrations (pCi/g)				
			U-238	Ra-226	U-235	Th-232	Cs-137
H12	280E,226S	Surface	<5.3	1.62 ± 0.33	<0.31	0.66 ± 0.53	<0.05
		0.5	<3.3	0.54 ± 0.18	<0.43	0.77 ± 0.55	<0.04
		1	<6.2	1.87 ± 0.38	<0.36	0.77 ± 0.61	<0.05
H13	1E, 5S	Surface	<5.9	0.68 ± 0.31	<0.25	0.80 ± 0.73	<0.04
		0.5	<4.9	0.61 ± 0.22	<0.30	1.81 ± 0.60	<0.04
		1	<4.2	0.73 ± 0.21	<0.21	0.93 ± 0.43	<0.03
		2	<5.9	0.59 ± 0.19	<0.29	0.80 ± 0.44	0.68 ± 0.22
H14	9E,305S	Surface	<4.6	0.76 ± 0.32	<0.28	0.87 ± 0.53	<0.04
		0.5	<4.5	1.02 ± 0.26	<0.31	0.96 ± 0.51	<0.05
		1	6.9 ± 10	0.68 ± 0.28	<0.28	0.74 ± 0.63	0.11 ± 0.07
		2	<4.2	0.56 ± 0.30	<0.29	0.64 ± 0.45	<0.05
		3	<5.7	0.84 ± 0.21	<0.27	0.59 ± 0.47	<0.03
H15	53E, 80S	Surface	<5.9	0.65 ± 0.22	<0.27	0.95 ± 0.43	0.14 ± 0.43
		0.5	<4.5	0.63 ± 0.21	<0.27	0.71 ± 0.38	<0.03
		1	<4.0	0.67 ± 0.29	<0.51	0.63 ± 0.48	<0.05
		2	<6.2	0.67 ± 0.29	<0.28	0.74 ± 0.25	<0.04
		3	<4.2	0.48 ± 0.16	<0.22	0.85 ± 0.27	<0.02
H16	20E,194S	Surface	10 ± 21	5.50 ± 0.51	0.68 ± 0.85	0.74 ± 0.69	0.79 ± 0.18
		0.5	<5.8	0.57 ± 0.21	<0.26	0.77 ± 0.43	<0.03
		1	<5.7	0.55 ± 0.24	<0.24	0.81 ± 0.49	<0.04
		2	<3.9	0.62 ± 0.21	<0.23	0.70 ± 0.32	<0.03
		3	5.1 ± 8.0	0.46 ± 0.24	<0.19	0.97 ± 0.35	0.52 ± 0.12
H17	181E, 50S	Surface	<3.8	0.66 ± 0.22	<0.37	0.86 ± 0.52	0.10 ± 0.09
		0.5	<5.0	0.63 ± 0.22	<0.27	1.32 ± 0.72	<0.05
		1	<5.3	0.75 ± 0.28	<0.31	1.02 ± 0.49	<0.04
		2	<3.9	0.58 ± 0.30	0.44 ± 0.48	0.94 ± 0.41	<0.03
		3	<3.9	0.64 ± 0.20	<0.22	0.84 ± 0.58	<0.02
H18	215E,179E	Surface	<4.2	0.65 ± 0.31	<0.23	0.70 ± 0.50	0.11 ± 0.12
		0.5	<5.0	0.31 ± 0.23	<0.24	0.92 ± 0.44	0.08 ± 0.15
		1	<4.9	0.62 ± 0.23	<0.48	0.81 ± 0.43	<0.05
		2	<3.4	0.54 ± 0.22	<0.25	0.72 ± 0.47	<0.04
		3	4.5 ± 11	0.61 ± 0.22	<0.25	0.70 ± 0.40	0.20 ± 0.13
H19	275E, 14S	Surface	<5.2	1.55 ± 0.42	<0.67	0.75 ± 0.48	0.53 ± 0.17
		0.5	<4.5	0.59 ± 0.28	<0.27	0.94 ± 0.48	0.06 ± 0.09
		1	5.2 ± 12	0.80 ± 0.27	<0.24	1.00 ± 0.42	<0.04
		2	<4.2	0.61 ± 0.22	<0.22	0.89 ± 0.37	<0.03
		3	<3.6	0.58 ± 0.19	<0.21	0.72 ± 0.36	<0.03

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TABLE 6, cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Sample No.	Grid Location	Depth (m)	Radionuclide Concentration (pCi/g)				
			U-238	Ra-226	U-235	Th-232	Cs-137
H20	275E,305S	Surface	<5.3	4.29 ± 0.50	<0.44	1.10 ± 0.60	1.06 ± 0.19
		0.5	<3.6	0.71 ± 0.27	<0.24	1.04 ± 0.45	<0.04
		1	<5.1	0.56 ± 0.28	<0.28	0.66 ± 0.47	0.05 ± 0.07
		2	<4.6	0.79 ± 0.22	<0.41	0.68 ± 0.35	<0.03
		3	<4.1	0.52 ± 0.17	<0.21	0.68 ± 0.35	<0.03

[a] See Figure 4.

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TABLE 7

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

Sample No.	Sample Type	Grid Location	Radionuclide Concentrations (pCi/l)		
			Gross Alpha	Gross Beta	Ra-226
W1	Storm Drain	99E,241S	1.79 ± 1.36[a]	3.65 ± 1.98	---[b]
W2	Storm Drain	110E,150S	2.77 ± 1.60	4.56 ± 2.03	---
W3	Storm Drain	55E,260S	2.76 ± 1.51	3.80 ± 1.97	---
W4	Subsurface (H20)	275E,305S	28.4 ± 13.6	12.3 ± 13.1	0.05 ± 0.04
W5	Subsurface (H17)	181E, 50S	6.73 ± 2.28	3.96 ± 2.05	---
W6	Subsurface (H8)	275E, 14S	5.21 ± 2.02	2.73 ± 1.98	---

[a] Errors are 2σ based on counting statistics.
[b] Dash indicates analysis not performed.

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TABLE 8

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES
FROM STORM SEWERS

Sample No.	Grid Location[a]	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
SD2	110E,150S	0.35 ± 0.20[b]	<0.19	<2.9	0.42 ± 0.26	0.17 ± 0.07
SD3	55E,260S	0.49 ± 0.15	<0.20	<3.8	0.56 ± 0.32	0.26 ± 0.09

[a] Refer to Figure 5.
[b] Error is 2σ based on counting statistics.

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TABLE 9

DIRECT RADIATION MEASUREMENTS
IN THE SMALL BRICK BUILDING

Location[a]	Direct Probe Measurements[b]		
	Alpha	Beta-Gamma	
	dpm/100 cm^2	dpm/100 cm^2	μrad/h
1	45	1800	51
2	45	1300	38
3	<23	1700	49
4	<23	1500	43

[a] Refer to Figure 6.
[b] Gamma exposure levels ranged from 13-14 μR/h throughout the building.

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APPENDIX A

INSTRUMENTATION AND ANALYTICAL PROCEDURES

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APPENDIX A

Instrumentation and Analytical Procedures

Gamma Scintillation Measurements

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) crystals. Count rates were converted to exposure levels (μR/h) using factors determined by comparing the response of the scintillation detectors with that of a Reuter Stokes model RSS-111 pressurized ionization chamber at several locations on property L.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, scaler/ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates (μrad/h) were determined by comparison of the response of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes for a composite of soil samples from the site, which were high in Ra-226 content.

Borehole Logging

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe, connected to a Ludlum Model 2200 portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 mm x 7 mm holes evenly spaced around the region of the scintillation detector. The probe was lowered into each hole using a tripod holder with a small winch. Measurements were performed at 30-50 cm intervals in all holes. The logging data was used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-238, and Cs-137 there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

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Surface Contamination Measurements in Building

Measurements of surface beta-gamma contamination were performed using Eberline "Rascal," Model PRS-1, scaler/ratemeters with Model HP-260 thin-window, pancake G-M detectors. Alpha surface contamination was measured using Eberline "Rascal," Model PRS-1, scaler/ratemeters with Model AC3-7 ZnS (Ag) alpha scintillation probes. Count rates were converted to dpm/100 cm^2. Conversion included subtraction of background rates and applying appropriate factors for detector calibration and effective probe areas.

Soil and Sediment Sample Analysis

Soil and sediment samples were dried, mixed, and a portion placed in a 0.5-liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 400 to 600 g of soil. Net soil weights were determined and the samples counted using a 23% Ge(Li) detector (Princeton Gamma Tech) coupled to a Nuclear Data model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Ra-226 - 0.609 MeV from Bi-214 (secular equilibrium assumed)
U-235 - 0.143 MeV
U-238 - 1.001 MeV from Pa-234m (secular equilibrium assumed)
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)
Cs-137 - 0.662 MeV
Pa-231 - 0.283 MeV

Several samples were also analyzed for U-238 by neutron activation. Approximately 12-20 g of soil was irradiated for 30 minutes in a neutron flux of 10^8 n/cm^2/sec from a 25 mg Cf-252 spontaneous fission source. After a one minute wait time, the U-239 peak (74.6 KeV) was counted for 1000 seconds and the U-238 concentration calculated.

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration through 0.45 m membrane filters. The filtrate was acidified by addition of 20 ml of concentrated nitric acid. Fifty milliliters of each sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter.

Analysis for Ra-226 was performed using the standard technique EPA 600/4-75-008 (revised).

Calibration and Quality Assurance

With the exception of the exposure and dose rate conversion factors for portable survey gamma and beta-gamma meters, all survey and laboratory instruments were calibrated with NBS-traceable standards. The calibration procedures for these portable instruments are described above.

Quality control procedures on all instruments included daily background and check-source measurements to confirm lack of malfunctions and nonstatistical deviations in equipment. The ORAU laboratory participates in the EPA Quality Assurance Program.

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APPENDIX B

SUMMARY OF RADIATION GUIDELINES APPLICABLE TO OFF-SITE PROPERTIES AT THE NIAGARA FALLS STORAGE SITE

SUMMARY OF RADIATION GUIDELINES
APPLICABLE TO OFF-SITE PROPERTIES AT THE NIAGARA FALLS STORAGE SITE

Mode of Exposure	Exposure conditions	Guideline value	Guideline source
1. External gamma radiation	Continuous exposure to individual in general population (whole body)	60 μR/hr	Nuclear Regulatory Commission (NRC) Standards for Protection Against Radiation (10 CFR 20.105)
	Indoor gamma radiation (above background)	20 μR/h	EPA Standards for Uranium Mill Tailings (40 CFR 192)
2. Surface alpha contamination[a]	Ra-226 contamination fixed on surfaces	100 dpm/100 cm^2	NRC Guidelines for Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-product, Source, or Special Nuclear Material (Adapted from NRC Reg. Guide 1.86)
	Removable Ra-226	20 dpm/100 cm^2	
3. Surface beta contamination[a]	Removable beta-gamma	1000 dpm/100 cm^2	Same as number 2
4. Beta-gamma dose rate	Average dose rate on an area no greater than 1 m^2	0.2 mrad/h	Same as number 2
	Maximum dose rate in any 100 cm^2 area	1.0 mrad/h	Same as number 2
5. Exposure to radon	Maximum permissible concentration of Rn-220 in air in unrestricted areas	3.0 pCi/l	NRC 10 CFR 20.103, Appendix B, Table II
	Average annual radon daughter concentration (including background)	0.030 WL maximum 0.020 WL preferrable	EPA Standards for Mill Tailings

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SUMMARY OF RADIATION GUIDELINES
APPLICABLE TO OFF-SITE PROPERTIES AT THE NIAGARA FALLS STORAGE SITE, cont.

Mode of Exposure	Exposure conditions	Guideline value	Guideline source
6. Radionuclides in water	Maximum contaminant level for combined Ra-226 and Ra-228 in drinking water	5 pCi/l	EPA Interim Drinking Water Standards (40 CFR 141)
	Maximum permissible concentration of the following radionuclides in water for unrestricted area:		NRC (10 CFR 20.103 Appendix B, Table II)
	Ra-226	30 pCi/l	
	U-238	40,000 pCi/l	
	Th-230	2,000 pCi/l	
	Pb-210	100 pCi/l	
7. Radionuclides in soil	Concentration above background-averaged over an area of 100 m^2		
	Ra-226	5 pCi/g (surface) 15 pCi/g (subsurface)	EPA Standards for Uranium Mill Tailings
	U-238	40 pCi/g	Interim Soil Limits for D&D Projects, LA-UR-79-1865-Rev, J.W. Healy et al.
	Th-232	20 pCi/g	
	Sr-90	100 pCi/g	
	Cs-137	80 pCi/g	
	U-enriched in U-235	30 pCi/g	NRC Branch Technical Position Paper (Federal Register, October 23, 1981)

[a] Applicable to building and equipment surfaces only.

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APPENDIX C

REPORT OF GROUND-PENETRATING RADAR SURVEY
OF PROPERTIES L AND M
AT THE NIAGARA FALLS STORAGE SITE

DETECTION SCIENCES GROUP

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FINAL REPORT

GROUND-PENETRATING RADAR SURVEY
OF AREAS L AND M AT THE
FORMER LAKE ONTARIO ORDNANCE WORKS
LEWISTON, NEW YORK

RADARVISION

K-24794

DETECTION SCIENCES GROUP

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FINAL REPORT

GROUND-PENETRATING RADAR SURVEY OF AREAS L AND M AT THE FORMER LAKE ONTARIO ORDNANCE WORKS LEWISTON, NEW YORK

Prepared for

OAK RIDGE ASSOCIATED UNIVERSITIES, INC
Oak Ridge, Tennessee 37830

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INTRODUCTION AND SUMMARY

From August 9 to August 15, 1982, Detection Sciences Group performed a ground-penetrating radar survey at the former Lake Ontario Ordnance Works, Lewiston, New York. The survey covered selected portions of Area L and Area M in accordance with Oak Ridge Associated Universities, Inc. (ORAU) Purchase Order No. C-25303, Letter Release No. 2, dated July 28, 1982. The radar field work was performed under the direction of ORAU Team Leader Bernadette Rocco.

The purpose of the radar survey was to inspect the sites proposed for locating boreholes; verify the existence of buried utilities as shown on the site map; identify any buried pipes and utilities not shown on the site map; and, scan selected portions of Areas L and M for possible burial locations.

The pipe and utility locations were scaled from the site map (Drawing No. 100-17, supplied by ORAU). The radar charts were examined for signatures of these pipes and utilities. The results are tabulated in Tables I-I through I-VI, listing the presumed location, as scaled from the map; the type of pipe or utility; and, the grid location as shown by the radar.

In addition to the buried objects shown on the site map, various other buried objects were observed by the radar. The coordinates and depths of these unmapped buried objects are tabulated in Table II.

The locations proposed for the borings are tabulated in Table III, together with the reccommended locations.

Figure 1 shows the radar survey lines (heavy lines) superimposed on the survey grid lines (light lines) in Area L and Area M. The boring locations are also shown by the cross symbols (heavy lines).

Figure 2 shows an expanded-scale detail of all radar survey lines made between Ø South and 20 South along the north boundary of Area L and Area M. Two types of radar anomalies were observed in this zone: There was a "jittery" type of radar signature whose probable cause is electrically active materials in the ground. Possibly, the electrical activity could be due to induced currents in buried steel mesh, such as may have been used for reinforcing concrete. The geometry of the steel mesh may be such that it re-radiates energy back to the antenna, thus giving the "jittery" appearance to the data. The second type of anomaly is called a dark reflector. This is due to the dielectric constant of the ground being abnormally high. This can come from non-ionic liquid contaminants or the presence of a material in the ground whose dielectric constant is significantly higher than the surrounding earth. The coordinates of the radar anomalies mapped in Figure 2 are compiled in Table IV.

A bound set of radar graphic charts annotated to show the survey line number, line location and ground stations (grid co-ordinates), have been supplied under separate cover. The radar chart numbers are keyed to the sequence in which the data was taken, and are also keyed to the line numbers recorded in the Field Logs contained in the APPENDIX of this report.

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DESCRIPTION OF THE SURVEY

Where possible, the survey was conducted by towing the 120 MHz radar antenna with the survey van. All electrical support equipment and recording equipment are carried in the van, which also supplies the electrical power for the radar equipment. In locations where it was not possible to tow the radar antenna with the van, the survey lines were covered by hand-pulling the radar antenna, which has up to 150 meters of cable connecting it with the remainder of the radar controls and recording equipment.

Because much of the descriptive information concerning the survey procedure, methodology, and other factors common to all radar surveys have previously been covered in detail, it will not be repeated in this report. For additional information concerning the survey techniques, the details of the equipment, the principals of operation, and other background information, refer to **Detection Sciences Group**'s FINAL REPORT **for** AREA E' **and** AREA H', dated September 14, 1982.

RESULTS OF THE SURVEY

The results of the survey are discussed in the following paragraphs:

Buried Pipes

The radar results are in good agreement with the mapped locations of buried pipes according to Drawing No. 100-17. To obtain pipe locations a number of parallel lines were run from the boundaries of each site inward at increments of 20 meters. In those areas where complete transects were not possible due to severely disturbed ground surfaces or trenching, the lines were either broken into smaller segments or done by hand. When the correlation in buried objects is made between successive radar transect lines it is likely the buried object is a pipe. Table I-I through I-VI of the results lists the mapped location for each utility pipe vs. the actual observed location.

Unmapped Buried Objects

In addition to buried utility pipes, the ground-penetrating radar equipment also located a number of discrete buried objects not listed in Drawing No. 100-17. These objects have the same characteristics as those of a buried pipe, although the lack of successive repetition from one radar line to the next indicates that they are not necessarily buried utilities. Detection Sciences Group recognizes the existence of objects in these areas, but makes no determination as to the make-up of the objects. Table II of the results lists the locations of these discrete objects with the radar-located coordinates.

Borehole Locations

Detection Sciences Group was presented with a list of 14 Borehole locations to survey for possible relocation. All Boreholes were surveyed at the locations specified by O.R.A.U. with the exception of Borehole #14, whose location was moved 20 meters west for accessibility. The determination whether to relocate a hole or not was based on the observations of the adar charts generated on site. When it was determined there might be an object or foreign substance that could interfere with the drilling operation, the borehole was relocated to an area where no obstacle was observed by the radar. Each Borehole was surveyed with a cross-pattern extending 6 meters to the north, south, east and west. Table III of the results lists all O.R.A.U. borehole designations, and the radar-determined relocations (if required).

Buried Materials

O.R.A.U. voiced concern that there might be buried materials extending beyond a known burial area. The area of concern runs from 120 meters east to 440 meters east, and from 0 to 20 meters south. This area lies south of the north fence bordering sites L and M. As requested by O.R.A.U., the area was surveyed at 5 meter intervals. Preliminary inspection of all radar charts made in this area showed features such as reinforced concrete slabs and other evidence of former industrial use, but the charts did not show any obvious evidence of large concentrations of buried materials.

TABLE I-I

PIPE LOCATIONS WITHIN AREA L
SURVEYED WITH GROUND-PENETRATING RADAR

LINE 0 EAST

*Map Pipe Location		Type of Pipe		Radar Pipe Location
290m	South	6"	Storm Sewer	292.5m South
213m	South	4"	Storm Sewer	217.2m South
208.5m	South	2"	Steam	207.8m South
206.5m	South	12"	Storm Sewer	206.1m South
166m	South	8"	Storm Sewer	165.3m South
164.5m	South	8"	Fire Water	160.5m South
148m	South	1.25m	Steam	146.9m South
142m	South	2"	Drinking Water	142.8m South
124m	South	18"	Sanitary Sewer	123.2m South
		Line 240 East		
162m	South	10"	Fire Water	161m South
110m	South	8"	Fire Water	not observed
65m	South	2"	Drinking Water	not observed
		Line 260 East		
162m	South	10"	Fire Water	161m South
110m	South	8"	Fire Water	103.5m South
65m	South	2"	Drinking Water	not observed

*As scaled from map @ 200 ft./in.

TABLE I-II

PIPE LOCATIONS WITHIN AREA M
SURVEYED WITH GROUND-PENETRATING RADAR

LINE 300 EAST

*Map Pipe Location	Type of Pipe	Radar Pipe Location
289m South	4" Storm Sewer	290m South
273m South	4" Storm Sewer	274.8m South
257.5m South	4" Storm Sewer	259.7m South
242.5m South	4" Storm Sewer	243.9m South
227m South	4" Storm Sewer	228.4m South
211.5m South	4" Storm Sewer	213.67m South
196m South	4" Storm Sewer	198.7m South
180.5m South	4" Storm Sewer	183.45m South
165m South	4" Storm Sewer	167.7m South
149.5m South	4" Storm Sewer	152.9m South

Line 320 East

289m South	4" Storm Sewer	290m South
273m South	4" Storm Sewer	274.8m South
257.5m South	4" Storm Sewer	260m South
242.5m South	4" Storm Sewer	245.5m South
227m South	4" Storm Sewer	228.9m South
211.5m South	4" Storm Sewer	213.6m South
196m South	4" Storm Sewer	199.5m South
180.5m South	4" Storm Sewer	184.4m South
165m South	4" Storm Sewer	167.6m South
149.5m South	4" Storm Sewer	152.8m South
58m South	2" Drinking Water	76.2m South

*As scaled from map @ 200 ft./in.

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TABLE I-III

PIPE LOCATIONS WITHIN AREA M
SURVEYED WITH GROUND PENETRATING RADAR

LINE 420 EAST

*Map Pipe Location	Type of Pipe	Radar Pipe Location
287.5m South	4" Storm Sewer	290m South
271.5m South	4" Storm Sewer	275.1m South
255.5m South	4" Storm Sewer	259.2m South
240m South	4" Storm Sewer	244.6m South
225m South	4" Storm Sewer	228.9m South
209.5m South	4" Storm Sewer	213.75m South
194m South	4" Storm Sewer	198.9m South
178m South	4" Storm Sewer	183.8m South
163.5m South	4" Storm Sewer	168.2m South
148m South	4" Storm Sewer	152.8m South

Line 440 East

287.5m South	4" Storm Sewer	290m South
271.5m South	4" Storm Sewer	not observed
255.5m South	4" Storm Sewer	not observed
240m South	4" Storm Sewer	240m South
225m South	4" Storm Sewer	not observed
209.5m South	4" Storm Sewer	not observed
194m South	4" Storm Sewer	198.8m South
178m South	4" Storm Sewer	183.9m South
163.5m South	4" Storm Sewer	168.5m South
148m South	4" Storm Sewer	152.5m South

*As scaled from map @ 200 ft./in.

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TABLE I-IV

PIPE LOCATIONS WITHIN AREAS L AND M
SURVEYED WITH GROUND-PENETRATING RADAR

LINE 0 SOUTH

*Map Pipe Location	Type of Pipe	Radar Pipe Location
135m East	18" Sanitary Sewer	137m East
145m East	8" Drinking Water	not observed
160m East	24" RCP	164m East
205m East	4" Steam	203m East
275m East	10" Fire Water	274m East
215m East	4" Steam	311m East
370m East	30" Storm Sewer	370m East

Line 5 South

132.7m East	18" Sanitary Sewer	135m East
145m East	8" Drinking Water	not observed
160m East	24" RCP	removed
205m East	4" Steam	204m East
275m East	10" Fire Water	275m East
317.5m East	4" Steam	313m East
370m East	30" Storm Sewer	372m East

Line 10 South

130.5m East	18" Sanitary Sewer	134m East
145m East	8" Drinking Water	not observed
160m East	24" RCP	removed
205m East	4" Steam	not observed
275m East	10" Fire Water	275m East
320m East	4" Steam	317m East
370m East	30" Storm Sewer	372m East

*As scaled from map @ 200 ft./in.

TABLE I-V

PIPE LOCATIONS WITHIN AREAS L AND M
SURVEYED WITH GROUND-PENETRATING RADAR

LINE 15 SOUTH

*Map Pipe Location	Type of Pipe	Radar Pipe Location
128.25m East	18" Sanitary Sewer	132m East
145m East	8" Drinking Water	not observed
160m East	24" RCP	removed
205m East	4" Steam	not observed
275m East	10" Fire Water	274m East
322.5m East	4" Steam	325m East
370m East	30" Storm Sewer	374m East

Line 20 South

126m East	18" Sanitary Sewer	not observed
145m East	8" Drinking Water	150m East
160m East	24" RCP	removed
205m East	4" Steam	not observed
275m East	10" Fire Water	273m East
325m East	4" Steam	327m East
370m East	30" Storm Sewer	373m East

*As scaled from map @ 200 ft./in.

TABLE I-VI

PIPE LOCATIONS WITHIN AREAS L AND M
SURVEYED WITH GROUND-PENETRATING RADAR

LINE 260 SOUTH

*Map Pipe Location	Type of Pipe	Radar Pipe Location
51m East	4" Storm & 12" Storm	53.1m East
96.5m East	15" Storm Sewer	98.9m East
165m East	6" Storm Sewer	165.8m East
175m East	15" Storm Sewer	175.2m East
275m East	6" Storm Sewer	275.8m East
375m East	12" Storm Sewer	372.9m East

Line 280 South

8.5m East	6" Storm Sewer	10.6m East
28m East	8" Storm Sewer	30m East
97m East	15" Storm Sewer	98.24m East
178m East	6" Storm Sewer	178.5m East
375m East	12" Storm Sewer	373.1m East

*As scaled from map @ 200 ft./in.

TABLE II K-24794

COORDINATES OF UNMAPPED BURIED OBJECTS

South Coordinates	East Coordinates	Comments	Depth in Centimeters
150m	240m	Large pipe-like signature	100
132m	260m	Strong reflector	110
205m	260m	Small reflector	107
242m	260m	Small pipe-like signature	100
215m	260m	Small reflector	128
142m	300m	Strong pipe-like reflector	88
232.6m	320m	Strong deeper pipe-like	122
144.4m	320m	Small reflector	98
286.25m	420m	Large pipe-like signature	143
265m	420m	Small deeper reflector	143
251.1m	420m	Small reflector	110
145.4m	420m	Small reflector	85
0m	207m	Small strong reflector	82
0m	296m	Small strong reflector	116
0m	300m	Small reflector	98
0m	400m	Large strong reflector	82
0m	412m	Small reflector	104
0m	425m	Large reflector	101
5m	209m	Small strong reflector	82
5m	297m	Large pipe-like signature	101
5m	380m	Small strong reflector	85
5m	392m	Small pipe-like signature	101
5m	400m	Small reflector	82
5m	413m	Large strong reflector	82
5m	421m	Small reflector	101
10m	130m	Small strong reflector	88
10m	212m	Small reflector	107
10m	244m	Strong deeper reflector	140
10m	265m	Large reflector	104
10m	302m	Small reflector	113
10m	363m	Small strong reflector	98
10m	413m	Large reflector	104
15m	155m	Small reflector	98
15m	248m	Small pipe-like signature	98
15m	300m	Small reflector	98
15m	307m	Small reflector	101
15m	360m	Small strong reflector	116
20m	210m	Strong reflector	76
20m	295m	Small strong reflector	101
20m	345m	Small strong reflector	98
20m	353m	Small pipe-like signature	128
20m	357m	Small pipe-like signature	95
20m	418m	Small strong reflector	98
260m	240.7m	Small pipe-like signature	79
260m	423.7m	Small pipe-like signature	92
280m	45m	Strong reflector	98
280m	324.1m	Strong pipe-like signature	82
280m	427.9m	Strong Pipe-like signature	131

TABLE III

BORING LOCATIONS DETERMINED BY RADAR

Boring Number	Direction of Relocation	Proposed Location	Final Location
		AREA L	
1	Move 1m East	0E, 5S	1E, 5S
2	Move 4m East	5E, 305S	9E, 305S
3	Move 4m South	20E, 190S	20E, 194S
4	Move 3m East	50E, 80S	53E, 80S
5	Move 1m East	180E, 50S	181E, 50S
6	Move 1m North	215E, 180S	215E, 179S
7	Move 5m East	270E, 305S	275E, 305S
8	Move 4m South	275E, 10S	275E, 14S
		AREA M	
9	Move 4m North	295E, 300S	295E, 296S
10	Move 2m East	300E, 5S	302E, 5S
11	Move 3m South	355E, 200S	355E, 203S
12	---	390E, 90S	390E, 90S
13	---	445E, 295S	445E, 295S
14	Move 2m West	430E, 5S*	428E, 5S

*Survey Location moved 20 meters West for Accessibility.

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RESULTS OF THE SURVEY (Con't)

Radar Anomalies

All of the radar survey lines performed in Area L and Area M are shown in **Figure 1** (heavy lines). **Figure 2** shows the details of the radar survey lines between Ø South and 20 South at the northern boundary of Area L and Area M.

Two types of radar anomalies are observed in this area:

The "jittery" radar signatures, shown by the narrower dashed-line chart symbol, is very unusual. There are various possible explanations for such a signature, and we have systematically examined and discarded all but the most probable explanations.

Before describing the most probabale explanation, the discarded explanations should be discussed. First, it is possible that the "jittery" signature is caused by outside radio-frequency interference. CB radios, fm walkie-talkies, and short wave radios used in the vicinity of the radar system do cause interference with the system. (Our newly-developed radiation shield has now eliminated this problem.) Interference from these radios, as well as electrical interference from electric arcing (street cars, elevated trains, electric welders, etc.) appear as "white noise", much like the "snow" on a television screen. The jittery reflectors observed by the radar in Areas L and M have a much more coherent signature with distinct periodicity, and does not have the appearance of random noise.

Another possibility is malfunctioning of the radar equipment, such as a synchronizing circuit becoming bi-stable. Because the occurance of the jittery signature is relatively infrequent, it is unlikely that it would be due to a malfunction of the electronics. Even so, it is possible that there is an intermittant problem in the electronics. This does not seem likely, because the radar system has been used on a number of other surveys after surveying Area L and M with no reoccurrance of the jittery signature. In other words, if the jittery signature was due to an intermittant malfunction, then the problem has spontaneously dissappeared and has not reoccurred — a most unlikely situation.

Having ruled out both external and internal causes, we are left with the conclusion that the jittery signatures are real, and that they are in the ground. There are two possible explanations. First, is that steel reinforcing in a buried concrete slab is creating an electrical disturbance due to absorbing and re-radiating the radar energy. The periodicity of the jittery signature is consistent with the spacing between wires that would be found in a steel mesh.

Another possible explanation is the presence of a layer of coarse gravel, such as may be used for fill or for a foundation underlayer. The gravel size and the thickness of the gravel layer would have to be such that a resonance would occur with the radar radiation. In other words, if the thickness of the buried gravel layer were just right, it could act as a resonant cavity for the radar impulse (centered at a frequency of 120 MHz). We have occassionally observed such resonances, but never with the jittery, periodic signature.

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We cannot completely rule out the possibility that the cause is due to some type of active material that is outside of our experience. Again, however, we would fall back on the belief that if such a material were present, that the electrical activity or radiation would result in random noise being observed (such as with rf interference), and that it would not have a periodic appearance. Radar surveys made over burial sites of low-level radioactive material at a disposal site in Beatty, Neveda had normal radar characteristics, and showed no indication of the jittery signatures observed in Areas L and **M**. Thus, we again return to the most likely explanation of buried wire mesh.

The second type of radar anomaly is much more easily understood. The dark reflectors observed in Areas L and **M** are due to local concentrations of high-dielectric material. Non-ionic chemical contamination, such as organic solvents, petroleum products, and other non-ionic (non-electrically active) materials will give this signature. Perched water can also give such a signature, though it is generally an area of darker contrasts in the ground rather than dark reflectors.

It is reccommended that the composition of the dark reflecting material be determined by physical sampling (such as a core) and chemical analysis. In particular, we would reccommend that control samples be taken in adjacent areas not having the dark reflectors as well as the areas having the dark reflectors. For convenience, the grid co-ordinates of the radar anomalies have been tabulated in **Table IV.**

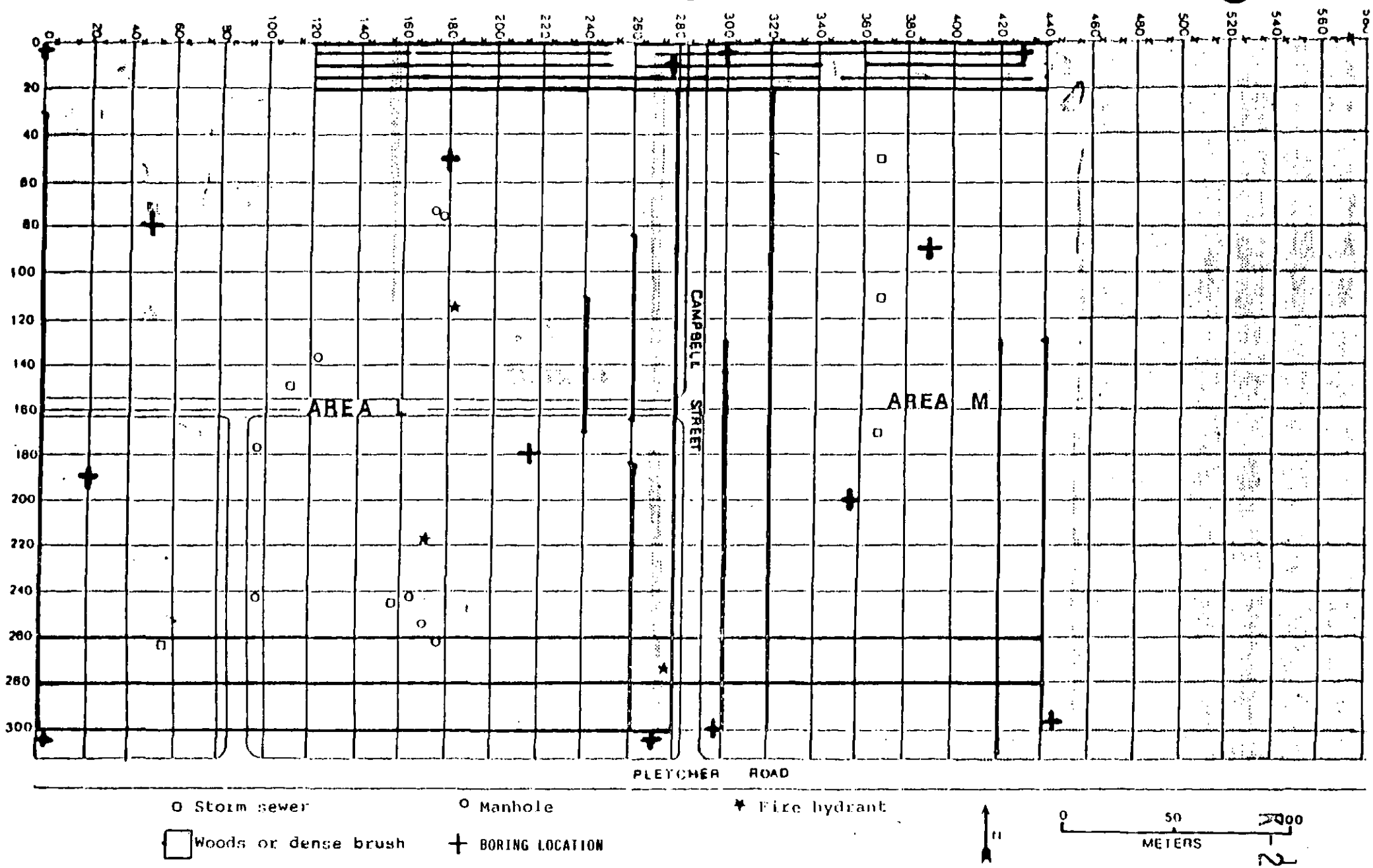
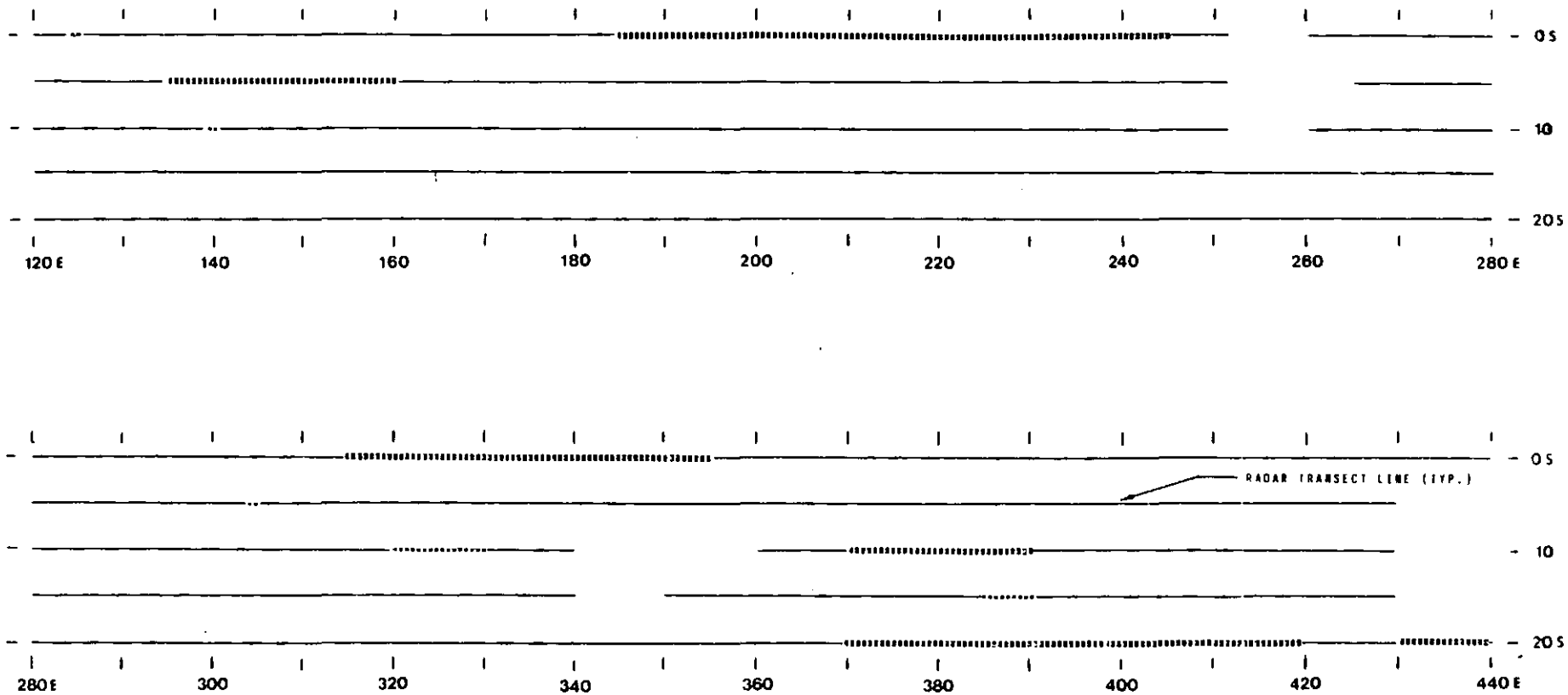


Figure 1. Area L and Area M, Showing Radar Survey Lines, Locations of Borings, the Grid System, and Major Surface Features.

R-24794



SCALE, METERS

0 10 20

Jittery Reflector

Dark Reflector (High Dielectric)

N

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Figure 2. Area L and Area M Radar Anomalies, 0 South to 20 South.

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TABLE IV

RADAR ANOMALIES IN AREAS L AND M

Chart Number	Radar Line	Location (Meters)	Depth (Cm.)	Comments
14	15S	113E	113	Jittery disturbance
15	10S	140E	152	Small, jittery disturbance
16	5S	134E to 160E	-	Change in character
17	ØS	125E	113	Jittery disturbance
18	20S	257E to 264E	98	Jittery disturbance
23	20S	370E to 420E	-	Sharp change in character
24	"	433E to 438E	-	Sharp change in character
25	15S	385E to 392E	-	Jittery character
27	10S	320E to 330E	-	Jittery character
28	10S	365E to 390E	-	Change in character
29	5S	305E	113	Small, jittery disturbance
30	ØS	317E to 355E	-	Change in character

APPENDIX

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RADARVISION

TAPE NO.: 8243 LOCATION: SCA CHEMICAL SVS. CO. CLIENT: ORAU

DATE: 8/9/82 LEWISTON NY SITES 2 & 4

RANGE ADJ	RANGE MULTIPLY			RANGE GAIN	FILTER			SENSITIVITY	SCAN SETTING						TAPE SPEED			TAPE CHANNEL			COMMENTS
	X1	X2	X4		H	M	L		51.2	25.6	12.8	6.4	3.2	SLOW	15	3 3/4	15/16	1	2	4	
350				9 1.5 0				250													J146-82

GRID NO.	GRID LINE	MARKER CODE	TAPE COUNT START	TAPE COUNT FINISH	FIRST MARK	LAST MARK	COMMENTS
1	280E	—	000	202	300 S	20 S	S → N 3' E OF LINE 1@10M
2	300S	2 #1	202	353	-10 E	280E	W → E 3' S OF LINE "
3	0E	3#1	353	502	300 S	30S	S → N 3' E OF LINE "

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FIELD LOGS

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(617) 369-7999

RADARVISION

TAPE NO.: 8243 LOCATION: SCA CHEMICAL SVS. CO. LEWISTON NY SITES L & M CLIENT: ORAU

DATE: 8/11/82

RANGE ADJ	RANGE MULTIPLY X1	X2	X4	RANGE GAIN	FILTER H	M	L	SENSITIVITY	SCAN SETTING 51.2	25.6	12.8	6.4	3.2	SLOW	TAPE SPEED 15	3 3/4	15/16	TAPE CHANNEL 1	2	4	COMMENTS
350				9.0				250													J146-82

GRID NO.	GRID LINE	MARKER CODE	TAPE COUNT START	TAPE COUNT FINISH	FIRST MARK	LAST MARK	COMMENTS
4	280S	4 # 1	502	655	-10E	440E	W → E 3'S OF LINE 1@10 UNSHIELDED
5	260S	5 # 1	655	775	-10E	440E	" " " "
6	440E	6 # 1	775	838	300S	130S	S → N 3'E OF LINE " "
7	420E	7 # 1	838	899	"	130S	" " " "
8	320E	8 # 1	899	982	"	20S	" " " " 2@TRUCK
9	300E	2 # 0	982	1033	"	130S	" " " "

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FIELD LOGS

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(617) 369-7999

RADARVISION

TAPE NO.: 8243 LOCATION: SCA CHEMICAL SVS. CO. LEWISTON NY SITES L & M CLIENT: ORAU

DATE: 8/12/82

RANGE ADJ	RANGE MULTIPLY X1	X2	X4	RANGE GAIN	FILTER H	M	L	SENSITIVITY	SCAN SETTING 51.2	25.6	12.8	6.4	3.2	SLOW	TAPE SPEED 15	3 3/4	15/16	TAPE CHANNEL 1	2	4	COMMENTS
350				9 12.5				250													J146-82

GRID NO.	GRID LINE	MARKER CODE	TAPE COUNT START	TAPE COUNT FINISH	FIRST MARK	LAST MARK	COMMENTS
10	260E	4#1	1034	1080	300 S	185 S	S → N 3' E OF LINE 1@10M
11	CONT. 260E	5#1	1080	1120	~165 S	83 S	" " "
12	240E	6#1	1120	1145	~168 S	112 S	" " "
13	20 S	7#1	1145	1202	120	240	W → E 3' S OF LINE 1@10M HAND
14	15 S	8#1	1202	1230	"	170	" " " "
15	10 S	2#1	1230	1258	"	160	" " " "
16	5 S	3#1	1258	1293	"	"	" " " "
17	0 S	4#1	1293	1330	"	170	" " " "
18	20 S	5#1	1330	1353	240	187	" " " VEHICLE
19	15 S	6#1	1353	1389	170	290	" " " ↓
20	10 S	7#1	1389	1424	160	252	" " "
21	5 S	8#1	1424	1457	163	252	" " "
22	Ø S	2#1	1457	1497	170	252	" " "

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FIELD LOGS

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(617) 369-7999

RADARVISION

TAPE NO.: 8243+8244 LOCATION: SCA CHEMICAL SYS. CO. LEWISTON NY CLIENT: ORAU
DATE: 8/14/82 SITES L & M

RANGE ADJ	RANGE MULTIPLY X1	X2	X4	RANGE GAIN	FILTER H	M	L	SENSITIVITY	SCAN SETTING 51.2	25.6	12.8	6.4	3.2	SLOW	TAPE SPEED 15	3 3/4	15/16	TAPE CHANNEL 1	2	4	COMMENTS
350				9 12.5 • 0				250													J146-82

GRID NO.	GRID LINE	MARKER CODE	TAPE COUNT START	TAPE COUNT FINISH	FIRST MARK	LAST MARK	COMMENTS
23	20S	3#1	1497	1576	280E	440E	W→E 3's OF LINE 1 @ 10 M
24	15S	4#1	000	93	"	340	NEW TAPE 8244 CH. 1
25	15S	5#1	93	180	350	433	" " "
26	10S	6#1	180	217	250	300	" " "
27	10S	7#1	217	309	250	340	" RESTART " "
28	10S	8#1	309	364	360	430+	" "
29	5S	2#1	364	468	270	430	" " "
30	Ø S	3#1	468	570	260	440	" " "
31	#1	4#1	570		+4	0	N→S 1@ 2M 2 @ INTERSECT
32	"	5#1		605	-6	+4	W→E " "
33	#2	6#1	605		+6	-6	N→S " "
34	"	7#1		628	-6	+6	W→E " "
35	#3	8#1	628		+6	-6	N→S " "
36	"	2#1		653	-6	+6	W→E " "

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FIELD LOGS

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(617) 369-7999

RADARVISION

TAPE NO.: 8244 LOCATION: SCA CHEMICAL SVS. CO. CLIENT: ORAU
DATE: 8/14/82 LEWISTON NY
SITES L&M

RANGE ADJ	RANGE MULTIPLY X1	X2	X4	RANGE GAIN	FILTER H	M	L	SENSITIVITY	SCAN SETTING 51.2	25.6	12.8	6.4	3.2	SLOW	TAPE SPEED 15	3 3/4	15/16	TAPE CHANNEL 1	2	4	COMMENTS
350				12.5 / 0				250													J146-82

GRID NO.	GRID LINE	MARKER CODE	TAPE COUNT START	TAPE COUNT FINISH	FIRST MARK	LAST MARK	COMMENTS
37	#6	3#1	653		+6	-6	N → S 1 @ 2M 2 @ INTERSECT
38	"	4#1		683	-6	+6	W → E " "
39	#4	5#1	683		+6	-6	N → S " "
40	"	6#1		707	-6	+6	W → E " "
41	#5	7#1	707		+6	-6	N → S " "
42	"	8#1		732	-6	+6	W → E " "
43	#7	2#1	732		+6	+6	N → S " "
44	"	3#1		752	-6	+6	W → E " "
45	#8	4#1	752		+6	-6	N → S " "
46	"	5#1		771	-6	+6	W → E " "
47	#9	6#1	771		+6	-6	N → S " "
48	"	7#1		791	-6	+6	W → E " "
49	#10	8#1	791		+6	-6	N → S " "
50	"	2#1		810	-6	+6	W → E " "

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FIELD LOGS

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(617) 369-7999

RADARVISION

TAPE NO.: 8244 LOCATION: SCA CHEMICAL SVS. CO. LEWISTON NY SITES L & M CLIENT: ORAU
DATE: 8/14/82

RANGE ADJ	RANGE MULTIPLY X1	X2	X4	RANGE GAIN	FILTER H	M	L	SENSITIVITY	SCAN SETTING 51.2	25.6	12.8	6.4	3.2	SLOW	TAPE SPEED 15	3 3/4	15/16	TAPE CHANNEL 1	2	4	COMMENTS
350				9.0 12.5				250													J146-82

GRID NO.	GRID LINE	MARKER CODE	TAPE COUNT START	TAPE COUNT FINISH	FIRST MARK	LAST MARK	COMMENTS
51	#11	3 #1	810		+6	-6	N→S 1 @ 2M 2 @ INTERSECTION
52	"	4 #1		832	-6	+6	W→E " "
53	#12	5 #1	832		+6	-6	N→S " "
54	"	6 #1		854	-6	+6	W→E " "
55	#13	7 #1	854		+6	-6	N→S " "
56	"	8 #1		887	-6	+6	W→E " "
57	#14	2 #1	887		+6	-6	N→S " "
58	"	3 #1		912	-6	+6	W→E " "

FIELD LOGS

K-24794

APPENDIX D

EVALUATION OF RADIATION EXPOSURES
ON OFF-SITE PROPERTY L
AT THE NIAGARA FALLS STORAGE SITE
LEWISTON, NEW YORK

K-24794

Appendix D

Evaluation of Radiation Exposures
on Off-Site Property L
at the Niagara Falls Storage Site
Lewiston, New York

INTRODUCTION

The U.S. Department of Energy has completed a radiological survey and determined that portions of the Department of Labor property, Lewiston, New York, are contaminated with low-level radioactive residues resulting from previous uses of this property. This property is part of the former Lake Ontario Ordnance Works (now know as the Niagara Falls Storage Site) where radioactive wastes from Manhattan Engineer District and Atomic Energy Commission operations were handled and stored. These wastes were primarily residues from uranium processing operations. However, they also included contaminated rubble and scrap from decommissioned facilities, biological and miscellaneous wastes from the University of Rochester, and low-level fission product waste from contaminated-liquid evaporators at the Knolls Atomic Power Laboratory (KAPL) in Schenectady, New York. Receipt of additional wastes was discontinued at the site in 1954. Although some storage of radioactive materials on a portion of the site continues under the control of the Department of Energy, work involving handling of radioactive waste has not been performed on the off-site properties for approximately 25 years.

In 1954 a preliminary cleanup of the site was performed by Hooker Chemical Company. Approximately 1298 acres of the original 1511 acre site were then declared excess and eventually sold by the General Services Administration to various private, commercial, and governmental agencies. The Department of Labor is the current owner of a 29.5 acre tract, identified as off-site property L. This property is not occupied or in use.

This property was surveyed by Oak Ridge Associated Universities, Oak Ridge, Tennessee, during August and September 1982, and found to contain isolated areas of radioactive contamination. The survey indicated

radionuclides from the naturally occurring uranium and actinium decay series and small quantities of Cs-137.

Cesium-137 is a man-made radionuclide created through the fission process such as in a nuclear reactor. Cesium-137 has a half-life* of approximately 30 years and emits both beta and gamma radiation. The naturally occurring decay series, known as the uranium and actinium series, are believed to have been created when the earth was formed, and they are still present today because of their very long half-lives. These series are presented in Tables D-1 and D-2.

As a radionuclide decays it changes into another substance. In the case of U-238, for example, the decay produces Th-234. Thorium-234 is called the "daughter" of U-238, U-238 is the "parent" of Th-234. In turn, Th-234 is the "parent" of Pa-234. Radioactive decay started by U-238 or U-235 continues as shown in the tables until a stable nuclide is formed.

The radionuclides in these decay series are present in small quantities throughout the environment. Concentrations of them normally occur in soil, air, water, food, etc., and are referred to as background concentrations. Radiation exposures resulting from this environmental radioactivity are referred to as background exposures. These background exposures are not caused by any human activity, and to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposure daily.

The use of radioactive materials for scientific, industrial, or medical purposes may cause radiation exposures above the background level to be received by workers in the industry, and to a lesser extent, by members of the general public. Scientifically based guidelines have been developed to place an upper limit on these additional exposures. Limits established for exposures to the general public are much lower than the limits established for workers in the nuclear industry.

---

* *The half-life is the time required for half of the atoms of a radioactive substance to disintegrate ("decay" or transform).*

RADIATION LEVELS ON PROPERTY L

The survey identified elevated levels of direct radiation and contamination of the soil above the normal background levels. The major radionuclide noted in these soils is Ra-226. Increased levels of radioactivity resulting from contaminated residues on this property can cause an increased radiation exposures to persons. The exposure comes from two primary sources or pathways: direct radiation emitted by the radionuclides in the residue or soil and inhalation of suspended airborne particulates and radon gas and its daughter products.* Additional exposures may also be received through ingestion of contaminated food or water. In Table D-3 the exposure levels associated with this property are summarized and compared with the guidelines and background radiation levels.

External Radiation Exposure Levels

As Tables D-1 and D-2 indicate, several members of the naturally occurring decay series emit gamma radiation as does Cs-137. (Gamma rays are penetrating radiation like x-rays.) Contaminated areas can, therefore, be sources of external gamma radiation exposures.

The National Council on Radiation Protection and Measurements has recommended a maximum annual whole-body exposure of 500,000 microroentgens** per year to an individual exposed in the general population. This is equivalent to a continuous level of approximately 57 microroentgens per hour. The maximum surface contact exposure level noted on this property was 79 microroentgens per hour. This level was noted only at contact with several small areas of contaminated surface soil. The average exposure rate of 13 microroentens per hour at about 3 feet above the surface is a better estimate of the average exposure an individual might receive. For comparison, the average background level in the Lewiston area is about 8 microroentgens per hour, and continuous exposure at this level would produce an annual exposure of about 69,800 microroentgens. Also, a

---

* *Radon-222 is a gas that results from the decay of radium-226, a member of the naturally occurring uranium series (see Table D-1).*

** *The Roentgen is the unit of exposure to X- or gamma radiation. A microroentgen is one-millionth of a Roentgen.*

typical chest x-ray (according to data from the Department of Health and Human Services) might yield an exposure of about 27,000 microroentgens.

The soil is contaminated with radium and lesser levels of uranium and cesium which emit beta and gamma radiations. Nuclear Regulatory Commission (NRC) guidelines for decommissioning former nuclear facilities require that the dose rate (from beta and gamma radiation) measured at a distance of one centimeter above the surface does not exceed 1.0 millirad* per hour and 0.2 millirad per hour average. The maximum dose rate measured at this site was 30 millirad per hour and the average was 0.046 millirad per hour. Although the maximum level exceeds NRC guideline, the primary concern of this guideline is exposure of skin surface. The thickness of ordinary shoe soles is adequate to protect the skin of feet from beta radiation. In most cases, exposures are negligible at a distance of 1 ft. away from the surface and areas of body skin are adequately protected from these exposures if they remain away from these surfaces. Beta radiation from surface residues are therefore not a significant factor in evaluating the potential health effects at this site.

Exposure From Inhalation of Airborne Radioactive Particulates

A very small amount of the radioactive contamination on this property may become airborne by resuspension of particulates from the surface layer of soil. The actual fraction of material that becomes resuspended is dependent on a number of factors including surface conditions (i.e. damp, dry, covered by ground vegetation, etc.), particle sizes, activities on the site which disturb the surface soil, and micrometeorological conditions (e.g. surface wind speed and direction). Determining average conditions of airborne radionuclides requires air sampling over an extended time period and was beyond the scope of the ORAU survey. However, an estimate of the potential airborne concentrations can be made based on the average concentration of radioactive material in the surface soil and using standard computation procedures of the Nuclear Regulatory Commission.

---

* *The rad is the unit of beta-gamma dose. A millirad is one-thousandth of a rad.*

Areas of significantly higher surface contamination levels are isolated and small (usually less than 6 inches in diameter). The average surface soil concentrations for property L are therefore best approximated by the samples collected at the grid line intersections. Radium-226 is the major radionuclide of concern on this site and the average concentration in surface soil is 0.80 picocuries* per gram or about 0.10 picocuries per gram above the level normally present in surface soils in the Lewiston area. The resulting concentration of resuspended Ra-226, based on a resuspension factor of 5×10^{-9} per meter, would be about 8×10^{-17} microcuries per cubic centimeters of air. For comparison, the Nuclear Regulatory Commission's guideline level for continuous exposure of the general public is 2×10^{-12} microcuries per cubic centimeter. The estimated concentration of airborne Ra-226 is almost a factor of 25,000 less than the guidance level and would therefore not result in a significant increase in radiation exposure to individuals on this property.

Exposure from Inhalation of Radon in Air

The deposits of radium-bearing residues in soil may be indirect sources of radiation exposure on site. As shown in Table D-1, Ra-226 changes to Rn-222 as a result of radioactive decay. Radon-222 is an inert gas which can emanate from the ground and with its daughter products result in lung exposures. Radon levels in the vicinity of the NFSS are continuously monitored by Department of Energy contractors. Sampling near property L indicated an average radon concentration of approximately 0.88 picocuries per liter of air during 1982**. The guideline for continuous exposure of the general public is 3 picocuries per liter. For comparison the average area background level during 1979 and 1980 was 0.23 picocuries per liter. Exposure to such radon concentrations would result in an annual lung dose of approximately 108 millirem above the normal background level.

---

* *The curie is the unit indicating the quantity of a radioactive substance. A picocurie is one-millionth-millionth of a curie.*

Other Exposure Considerations

Loose radioactive contamination can result in exposure through ingestion (eating or drinking) of contaminated foodstuffs. This site is not used for raising crops and average radionuclide concentrations in the ground water at this site are within the EPA drinking water limits. These pathways would not, therefore, result in significant exposures.

ESTIMATES OF HEALTH EFFECTS

The primary health effect associated with radiation exposure is an increased risk of cancer. In general, the risk is assumed to increase as the total dose of radiation increases. Total dose is dependent not only on exposure rate and concentration levels on the property, but also on the nature and duration of the exposure. In addition, a given individual's increased risk is dependent upon many factors including the individual's age at onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other hazardous agents, and the individual's family medical history. Because of these variables, large uncertainties would exist in any estimates of the number of increased cancers in a relatively small exposed population such as might be the situation on this site. Estimates of the increased risks have been calculated and are given in Table D-4. Assumptions made in performing these calculations are:

1. The levels reported in Table D-3 are representative of the conditions and will not change during the year or from year to year.

2. Average exposure levels in Table D-3 are representative of the averages to which an individual working on the property might be exposed.

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3. An individual would spend a working lifetime, i.e. 40 hours per week, 50 weeks per year, for 45 years (age 20 to 65) on the site.

4. Background exposure rates to individuals while not on the property will be 8 microroentgens per hour from external gamma radiation.

The risk estimates are based on the 1980 National Academy of Sciences report, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," and the 1977 report by the United States Scientific Committee on Effects of Atomic Radiation. The lifetime risk estimate used to calculate the values in Table D-4 is 100 cancer deaths per million persons exposed per rem of radiation exposure. It is believed by many radiation biologists that with low dose rates such as those encountered at this property, the actual risks of cancer are much less than 100 per million persons per rem, zero note being excluded.

The estimated Ra-226 air concentrations are a very small fraction of the guidance level and exposures and risk from this pathway would be negligible. In addition, exposures and risk from the pathways of ingestion of crops grown on contaminated soils and water containing radionuclides from the soil are also considered negligible, based on the low-levels and the intended use of this property. Exposures and risk are therefore limited to two pathways -- direct exposure to gamma radiation and inhalation of radon.

The estimated increased risk due to cancer from exposure to the average radiation and radon levels on property L, for a working lifetime is 0.531 per 1000 deaths. This can be compared with the average lifetime risks of cancer in Niagara County of 218 per 1000 deaths based on 1977 crude death rate statistics for this same year. The average lifetime risks of cancer in the State of New York and the United States are 216 per 1000 deaths and 203 per 1000 deaths respectively. An individual working under the assumed conditions will therefore be subject to an increased risk of dying from cancer of 0.0531 percent or an increase in total risk from 21.8 to 21.8531 percent when compared to the average risk in Niagara County.

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This may also be expressed as a percent increase in overall risk of getting a fatal cancer of 0.24 percent - a negligible increase.

SUMMARY

In summary, portions of NFSS off-site property L, now belonging to the Department of Labor, are contaminated with low-level residues containing Cs-137 and naturally occurring radionuclides. The level of Ra-226 contamination in the surface soil in some small isolated areas of the property exceeds the present criterion for release of this property for unrestricted use. Although this contamination is capable of producing slight radiation exposures to persons on this property under current conditions of property use, these exposures are well within the scientifically-based guidelines and risks to such persons are negligible.

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TABLE D-1

URANIUM DECAY SERIES

Parent	Half-Life	Major Decay Products	Daughter
Uranium-238	4.5 billion years	alpha	Thorium-234
Thorium-234	24 days	beta, gamma	Protactinium-234
Protactinium-234	1.2 minutes	beta, gamma	Uranium-234
Uranium-234	250,000 years	alpha	Thorium-230
Thorium-230	80,000 years	alpha	Radium-226
Radium-226	1,600 years	alpha	Radon-222
Radon-222	3.8 days	alpha	Polonium-218
Polonium-218	3 minutes	alpha	Lead-214
Lead-214	27 minutes	beta, gamma	Bismuth-214
Bismuth-214	20 minutes	beta, gamma	Polonium-214
Polonium-214	.0002 seconds	alpha	Lead-210
Lead-210	22 years	beta	Bismuth-210
Bismuth-210	5 days	beta	Polonium-210
Polonium-210	140 days	alpha	Lead-206
Lead-206	stable	none	none

TABLE D-2

ACTINIUM DECAY SERIES

Parent	Half-Life	Decay Products	Daughter
Uranium-235	710 million years	alpha	Thorium-231
Thorium-231	25.5 hours	beta	Protactinium-231
Protactinium-231	32,000 years	alpha	Actinium-227
Actinium-227	21.6 years	beta, gamma	Thorium-227
Thorium-227	18.2 days	alpha	Radium-223
Radium-223	11.4 days	alpha	Radon-219
Radon-219	4.0 seconds	alpha	Polonium-215
Polonium-215	.0018 seconds	alpha	Lead-211
Lead-211	36.1 minutes	beta, gamma	Bismuth-211
Bismuth-211	2.15 minutes	alpha	Thallium-207
Thallium-207	4.79 minutes	beta	Lead-207

TABLE D-3

SUMMARY OF EXPOSURE LEVELS ON PROPERTY L
LEWISTON, NEW YORK

Exposure Source	Levels on Site		Background Levels	Guidelines for General Public	Guidelines for Radiation Workers
	Average	Maximum			
Gamma Radiation from Cesium-137 and uranium and actinium decay	13 μR/h[a]	79 μR/h	8 μR/h	0.5 rem[b] per year for individual, equivalent to 250 μR/h above natural background for 40 h/wk and continuous exposure.	5 rems per year
Radionuclides (Radium-226) in air	8×10^{-17} μCi/cc[c]	---	unknown	2×10^{-12} μCi/cc for continuous (168 h/wk) exposure	5×10^{-11} μCi/cc for 40 h/wk exposure
Radon in air	0.88 pCi/l	---	0.23 pCi/l 1979 & 1980 avg.)	3 pCi/l	30 pCi/l for 40 h/wk exposure
Radionuclides (gross alpha concentration) in Ground Water	13 pCi/l	28 pCi/l	Appr. 0.8 pCi/l	15 pCi/l, EPA Standard for Public Drinking Water Systems	400 pCi/l
Radionuclides in Soil:					
Radium-126	0.80 pCi/g	40 pCi/g	Appr. 0.7 pCi/g	EPA Mill Tailings (Criteria is 5 pCi/g above background averaged over 100 m2 of surface soil.)	none
Cesium-137	0.5 pCi/g	3.7 pCi/g	Appr. 0.5 pCi/g	80 pCi/g above background (Criteria developed by Los Alamos sci. Lab. for cleanup at sites contaminated by fission product residues.	none

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TABLE D-3, cont.

SUMMARY OF EXPOSURE LEVELS ON PROPERTY L
LEWISTON, NEW YORK

Exposure Source	Levels on Site		Background Levels	Guidelines for General Public	Guidelines for Radiation Workers
	Average	Maximum			
Uranium-238	5.05 pCi/g	46.0 pCi/g	Appr. 3.3 pCi/g	40 pCi/g Interim Soil Limits for D & D Projects, LA-UR-79-1865-Rev, J.W. Healy, et al.	none
Uranium-235	0.32 pCi/g	3.90 pCi/g	Appr. 0.2 pCi/g	30 pCi/g (U enriched in U-235) NRC Branch Technical Paper (Federal Register, October 23, 1981)	

[a] The Roentgen (R) is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microroentgen (μR) is one millionth of a Roentgen.

[b] The rem is the unit of ionizing radiation that produces the same biological damage in man as an absorbed dose of 1 roentgen of high voltage x-ray. A roentgen of gamma exposure to a man is equivalent to one rem.

[c] The microcurie (μCi) and picocurie (pCi) are units which are defined for expressing the amount of radioactivity present in a substance. 1 μCi = 10^{-6} Ci, 1 pCi = 10^{-12} Ci.

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TABLE D-4

SUMMARY OF WORKING LIFETIME RADIATION
EXPOSURES AND ESTIMATES OF ASSOCIATED CANCER RISK
FOR PROPERTY L, LEWISTON, NY

Source of Exposure	Working Lifetime Dose Equivalent Corrected for Background	Increased Risk Due to All Cancers
External gamma radiation	0.13 rems	0.013 per 1000[a]
Inhalation of resuspended particulates	negligible	0
Inhalation of radon	5.18 rems	0.518 per 1000[a]
Ingestion of food and water contaminated by radioactive materials on-site	negligible	0
TOTAL	5.31 rems	0.531 per 1000[b]

[a] Using the risk coefficient of 100 cancer deaths/10^6 person rem. This is approximately a mean value from BEIR-III (1980) and UNSCEAR (1977).

[b] The average lifetime risk of death due to cancer in the United States is 203 per 1000 (20.3 percent); in Niagara County the average lifetime risk is 218 per 1000 (21.8 percent).