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COMPREHENSIVE RADILOGICAL SURVEY

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

Prepared for

U.S. Department of Energy  
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B.F. Rocco

Project Staff

J.D. Berger	R.C. Gentry
A.J. Boerner	W.C. Helton
W.D. Carden*	C.M. Plott
L.W. Cole	T.J. Sowell
R.D. Condra	G.F. Weaver
G.R. Foltz	

Prepared by

Radiological Site Assessment Program  
Manpower Education, Research, and Training Division  
Oak Ridge Associated Universities  
Oak Ridge, Tennessee 37830

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\*Industrial Safety and Applied Health Physics Division, Oak Ridge National  
Laboratory

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## COMPREHENSIVE RADIOLOGICAL SURVEY

### OFF-SITE PROPERTY Q 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 site were declared surplus. This property was eventually sold by the General Services Administration to various private, commercial, and governmental agencies.<sup>1</sup>

The Town of Lewiston is the current owner of a tract identified as off-site property Q (see Figure 1). A radiological survey of that tract, conducted in October and November 1982, is the subject of this report.

#### SITE DESCRIPTION

Figure 2 is a plan view of property Q. The property is generally L-shaped and occupies approximately 36 hectares. It is bounded on the south and west by Swann Road and Harold Road, respectively. The northern boundary is a fence dividing Town of Lewiston property and that owned by the Department of Labor. South Patrol Road forms the northeast boundary of the property. The remainder of the eastern boundary is not marked by any existing landmarks. Several recently constructed buildings occupy the extreme southern end of the property. A large metal structure serves as

the Highway Vehicle Maintenance Garage and offices occupy an adjacent small brick building. Salt, sand, and gravel for road maintenance and various pieces of heavy equipment and materials are stored in a fenced yard behind the buildings. No additional structures are on the site; the foundations of a warehouse remain along an abandoned railroad track, which traverses the property in a north-south direction. There are several roads on the site; however, they are not in routine use and access to them is blocked by fences or piles of earth. The northern portion of the property has been used by the Town of Lewiston as a sanitary landfill. There are numerous piles of construction scrap and rubbish on the central portion of property. A number of drainage ditches criss-cross the property. Some areas of the site are wooded or overgrown with dense brush and tall weeds.

#### Radiological History

Although there is no history of burials or processing of radioactive wastes on property Q, uranium metal was identified in soil samples previously collected from the site.<sup>2,3</sup> Three warehouses were located on this property during AEC/MED operations; they have since been demolished or destroyed by fire. There is no indication that these buildings were used for radioactive waste storage. In previous surveys, areas along the railroad tracks exhibited gamma activities above 20  $\mu\text{R}/\text{h}$ , possibly due to natural radioactivity in the track bed.<sup>1</sup> Several other areas that underwent decontamination efforts in 1972 had exposure levels up to 50  $\mu\text{R}/\text{h}$ .<sup>1</sup>

#### SURVEY PROCEDURES

The comprehensive survey of NFSS off-site property Q was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during the period of October 11-November 3, 1982. The survey was in accordance with a plan dated September 27, 1982, approved by the Department of Energy's Office of Operational Safety. The objective and procedures from that plan are presented in this section.

### Objective

The objective of the survey was to provide a comprehensive assessment of the radiological conditions and associated potential health effects, if any, on property Q. 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, and
4. concentrations of radionuclides in surface and ground water.

### Procedures

#### 1. Site Preparation

- a. Brush and weeds were cleared as needed to provide access for gridding and surveying. This operation was performed under subcontract 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 Figures 3 and 4. Some small areas and grid line intersections were inaccessible due to the presence of debris, heavy equipment, and large piles of sand and gravel.
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 ( $\mu\text{R}/\text{h}$ ) 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 ( $7 \text{ mg/cm}^2$ ) C-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 ( $\mu\text{rad/h}$ ) 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 every other accessible grid line intersection. In the yard behind the maintenance garage, surface soil samples were collected at each accessible grid line intersection.
5. Walkover surface scans were conducted at 5-10 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.
6. At 22 of the locations of elevated surface radiation levels, surface gamma exposure rates, and beta-gamma dose rates at 1 cm above the surface were 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. Locations where these additional measurements and samples were obtained are indicated on Figures 3 and 4.
7. Detection Sciences Group of Carlisle, MA, performed ground penetrating radar surveys at locations of proposed subsurface investigations. The purpose of these radar scans was to identify the presence of underground piping or utilities which would preclude borehole drilling. Ground radar scans were also

conducted in the vicinity of the warehouse foundation, where elevated direct radiation levels were noted to identify subsurface objects or anomalies which might be indicative of buried materials.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Fourteen 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 Figures 5 and 6.

The boreholes were gamma scanned over their entire length for the presence of subsurface residues. Radiation profiles in the boreholes were 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) and at locations of elevated readings identified by the borehole scan. 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 deep boreholes, as available. 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. Surface water samples of 3.5 liters were collected at three locations from on-site ditches (Figure 7).
10. A walkover gamma scintillation scan and five direct beta-gamma and alpha measurements were performed in the metal maintenance garage on the property (see Figure 8).

11. Twenty soil samples and seven water samples were collected from the Lewiston area (but not on 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 were collected. The locations of the baseline samples and background measurements are shown on Figure 9.

#### 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. Radium-226 analysis was performed on water samples exceeding the EPA drinking water standards for gross alpha 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 9) in the vicinity of the Niagara Falls Storage Site, are presented in Table 1-A. Exposure rates ranged from 6.8 to 8.8  $\mu\text{R/h}$  (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,

\* The less than symbol indicates that the concentration measured was less than the minimum detectable detection limit of the monitor.

<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 soil.

Radiactivity levels in baseline water samples are presented in Table I-B. The gross alpha and gross beta concentration 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 5.4 to 22  $\mu$ R/h (average 11). At surface contact the exposure rates ranged from 4.7 to 22  $\mu$ R/h (average 11). Beta-gamma dose rates at 1 cm above the surface ranged from 15 to 75  $\mu$ rad/h (average 44). 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 nonpenetrating beta or low-energy photon radiations.

The walkover survey identified one area of general surface contamination between grid lines 769S, 809S and 168E, 173E in front of an old warehouse foundation. Exposure rates in contact with this area ranged up to 130  $\mu$ R/h. Several smaller areas with elevated surface radiation levels were also located on property Q and are indicated on Figures 10 and 11. Contact exposure rates ranged up to 280  $\mu$ R/h in these areas. Direct contact radiation levels at the 22 locations selected for further investigation ranged from 22 to 280  $\mu$ R/h (see Table 3). Contact beta-gamma dose rates ranged from 89 to 1056  $\mu$ rad/h.

At most locations, contact exposure rates were not reduced by soil sampling; exposure rates actually increased following sampling at many of the locations. The contact exposure rate after sampling at 796S, 170E (Location 5 Figure 3) was 430  $\mu$ R/h; this was the highest gamma level

measured on this property. These results indicate that the contamination extends greater than 15 cm below the surface and/or is diffused rather than in discrete particles.

#### 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 Q. The samples from grid line intersections (Table 4) contained Ra-226 concentrations ranging from <0.13 to 8.27 pCi/g. The highest level was in sample 322 from grid location 860S, 280E. Other samples had Ra-226 concentrations in the same range as baseline levels. Concentrations of U-235, U-238, and Cs-137 were not significantly different from those in baseline samples.

Eighteen of the twenty-two soil samples, collected from locations of elevated contact radiation levels (refer to Table 5), contained Ra-226 concentrations above those in baseline samples. The highest Ra-226 concentration (1020 pCi/g) was in sample B20 (grid point 1087S, 217E). This location is along the abandoned railroad track. Radium-226 concentrations of samples (B3-B7) collected within the generally contaminated area near the old warehouse foundation ranged from 1.44 to 51.9 pCi/g. Samples B5 and B7 from this area contained the highest U-238 concentrations of 36.6 and 22.1 pCi/g respectively. Two samples, B10 and B17, had Th-232 levels of 13.0 and 8.71 pCi/g. Cesium-137 concentrations were slightly elevated in most of these samples; the maximum level of 7.11 pCi/g was noted in sample B19 (grid point 1107S, 216E).

#### Ground Penetrating Radar Findings

The subcontractor's report, summarizing the ground penetrating radar survey results for property Q, is provided as Appendix C. (This report also includes the findings on property N/N' South, since the two properties were surveyed simultaneously.) In the area between 760S and 840S and 160E and 180E, radar signatures indicative of non-ionic liquids were present. These anomalies are most likely due to the presence of petroleum solvent or

oils that do not readily disperse in the ground. There is no evidence of buried residues in this area. Pipes and other subsurface interferences were detected at several locations, necessitating slight relocations of 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. As evidenced by soil sample analyses, the gamma count rates determined by the borehole measurements were reliable indicators of elevated subsurface radionuclide levels. However, the gamma logging data were not useful in quantifying the radionuclide concentrations in the subsurface soil, because of the varying ratios of Ra-226, 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 locations of the fourteen boreholes (H1-H14), selected 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 H15-H24 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. Only one subsurface sample, from the 1.0 m depth in borehole H23, had an elevated Ra-226 concentration (2.25 pCi/g). None of the subsurface samples contained elevated concentrations of U-238, U-235, Cs-137, or other gamma emitting radionuclides.

#### Radionuclide Concentrations in Water

The results of water sample analyses are presented in Table 7. It should be noted that all water samples contained high concentrations of

dissolved solids which resulted in residues, adversely affecting the measurement sensitivities and errors for the gross alpha and gross beta procedure. All surface water samples had concentrations within the EPA Interim Drinking Water Standards of 15 pCi/l gross alpha and 50 pCi/l gross beta.

Water was obtained from twelve of the deep and two of the shallow boreholes on this property. Samples W8, W15, and W17 had gross alpha levels slightly above the EPA drinking water criteria of 15 pCi/l. In cases where gross alpha activity exceeds the 15 pCi/l limit, further analysis of the water for radium content will determine compliance. These samples were subsequently analyzed for Ra-226 and Ra-228 and found to have concentrations of these radionuclides well below the EPA guidance level of 5 pCi/l combined Ra-226 and Ra-228.

#### Direct Radiation Levels Inside the Maintenance Building

Direct alpha and beta-gamma levels measured at five random locations in the building are presented in Table 8. All alpha levels were <23 dpm/100 cm<sup>2</sup>. Beta-gamma levels and the associated dose rates ranged from 900-1400 dpm/100 cm<sup>2</sup> and 25-39  $\mu$ rad/h, respectively.

The walkover survey did not detect any areas of elevated gamma exposure rates. Gamma exposure rates ranged from 4.4 to 6.0  $\mu$ R/h throughout the building. 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 Q are less than 20  $\mu$ R/h above the background level. The average level of 11  $\mu$ R/h is well below the 60  $\mu$ R/h criteria established by the Nuclear Regulatory Commission for open land areas.

Surface soil samples collected at isolated locations of elevated direct radiation levels exceed 5 pCi/g of Ra-226. The contaminated residues are mainly in a 40 m x 5 m strip between grid lines 769S, 809S, 168E, and 173E an area of approximately 200 m<sup>2</sup> (Figure 12). The average Ra-226 soil concentration based on five samples taken in the area is 16.3 pCi/g and exceeds the 5 pCi/g criteria limit averaged over 100 m<sup>2</sup>. The average U-238 concentration of the five samples is 16.5 pCi/g. Another area that slightly exceeds the 5 pCi/g criteria is located in the grassy area in front of the town of Lewiston maintenance garage, between grid lines 1460S, 1455S, and 91E, 105E - an area of 70 m<sup>2</sup> (Figure 13). The average Ra-226 soil concentration, based on four samples taken in this area is 7.63 pCi/g. The other locations of Ra-226 surface soil contamination are isolated and the concentrations averaged over 100 m<sup>2</sup> would be below the 5 pCi/g level. None of the samples contained other radionuclides exceeding the cleanup criteria.

Borehole sampling indicates 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 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. Surface contamination levels within the Maintenance Garage are below the NRC guidelines for release for unrestricted use.

An evaluation of the potential health effects associated with radiation levels and residual contamination on property Q 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 Q at the Niagara Falls Storage Site was conducted during October and November 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 on the property. The major contaminant is Ra-226; although, several areas of uranium and thorium contamination were 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 in two areas on the property. One area, between grid lines 769S, 809S, and 168E, 173E, could be brought into compliance with the criteria by removal of approximately 50 to 100 m<sup>3</sup> soil. Only 20 to 35 m<sup>3</sup> of soil would have to be removed to bring the area in front of the maintenance garage into compliance. 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.

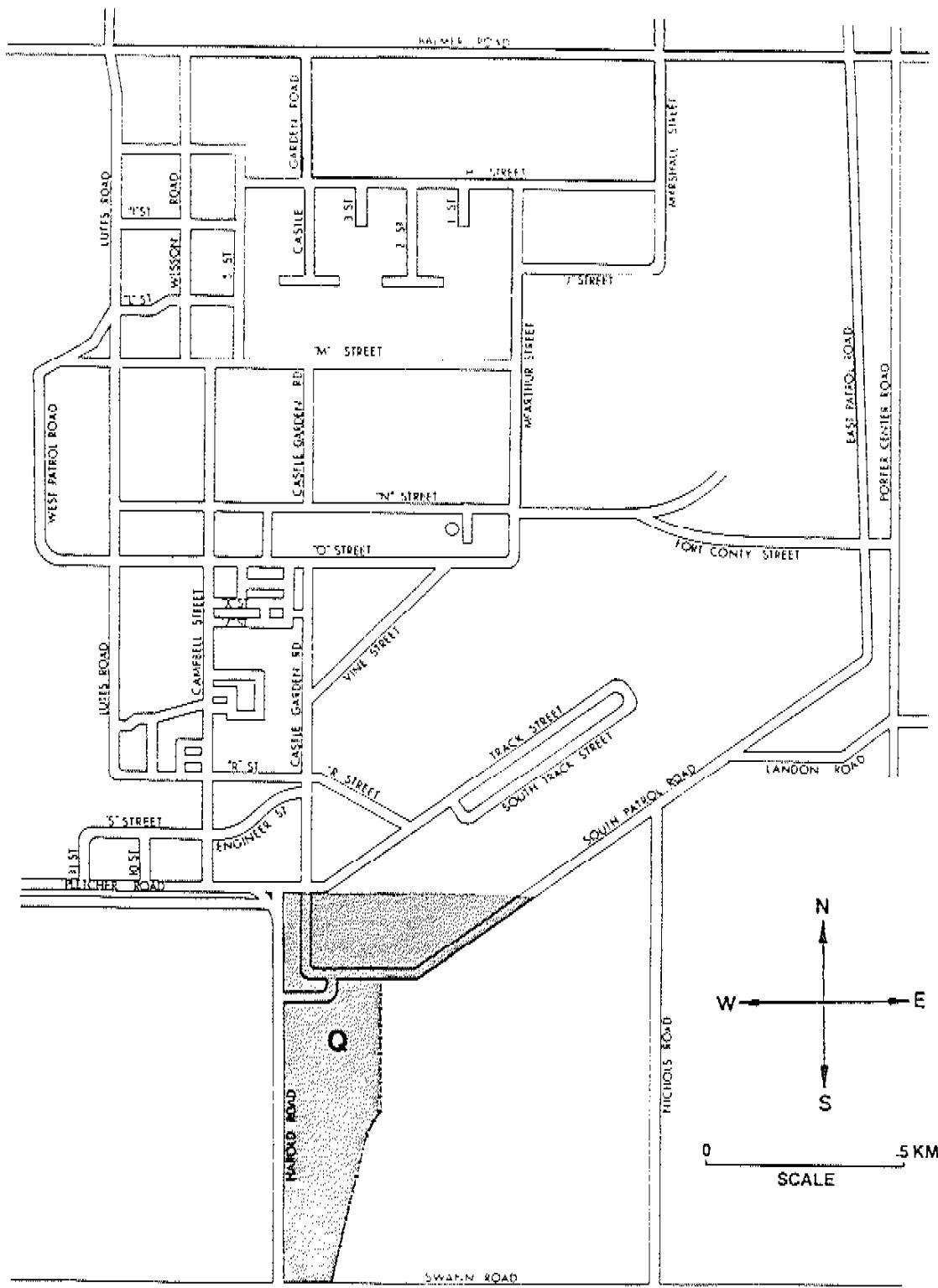


FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property Q.

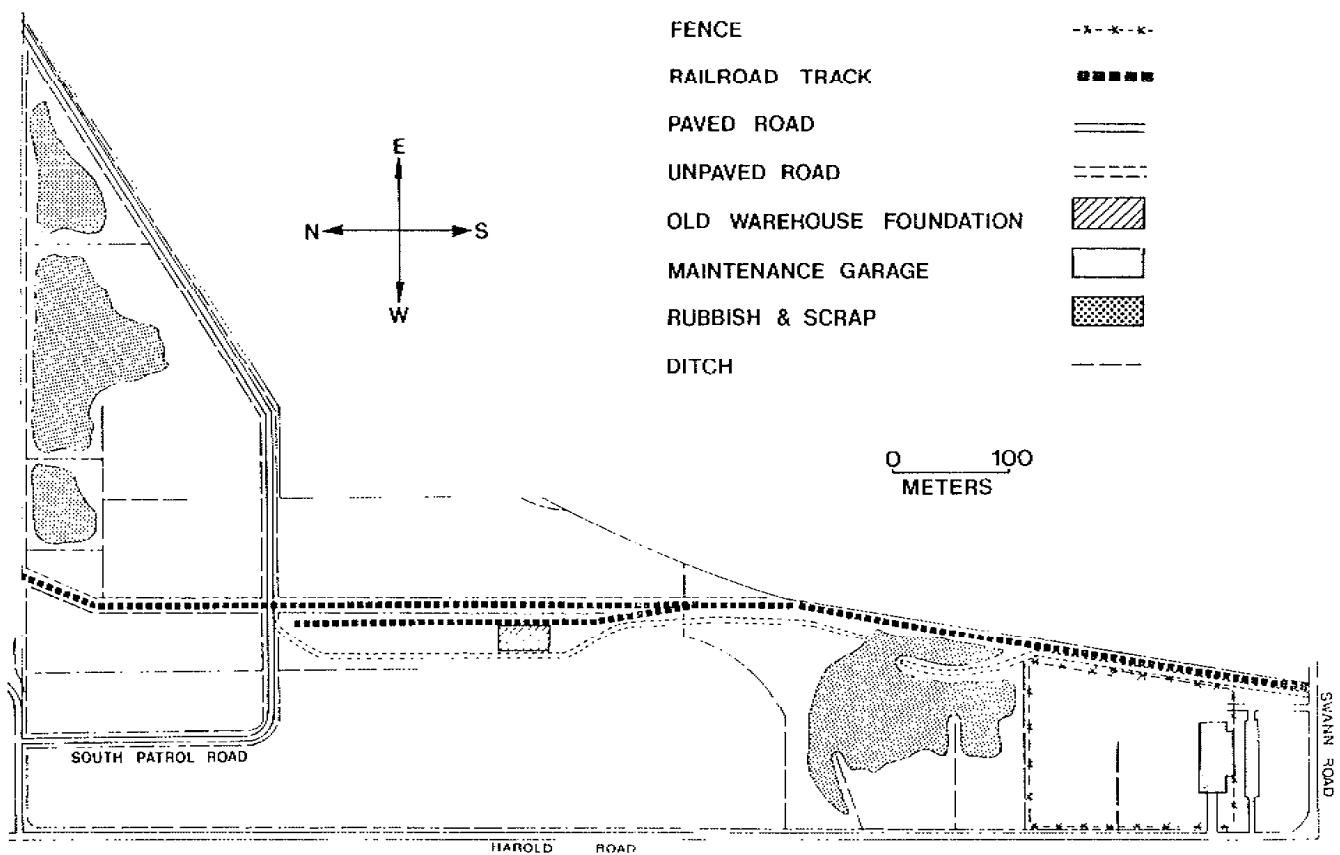


FIGURE 2. Plan View of Niagara Falls Storage Site Off-Site Property Q, Indicating Prominent Surface Features.

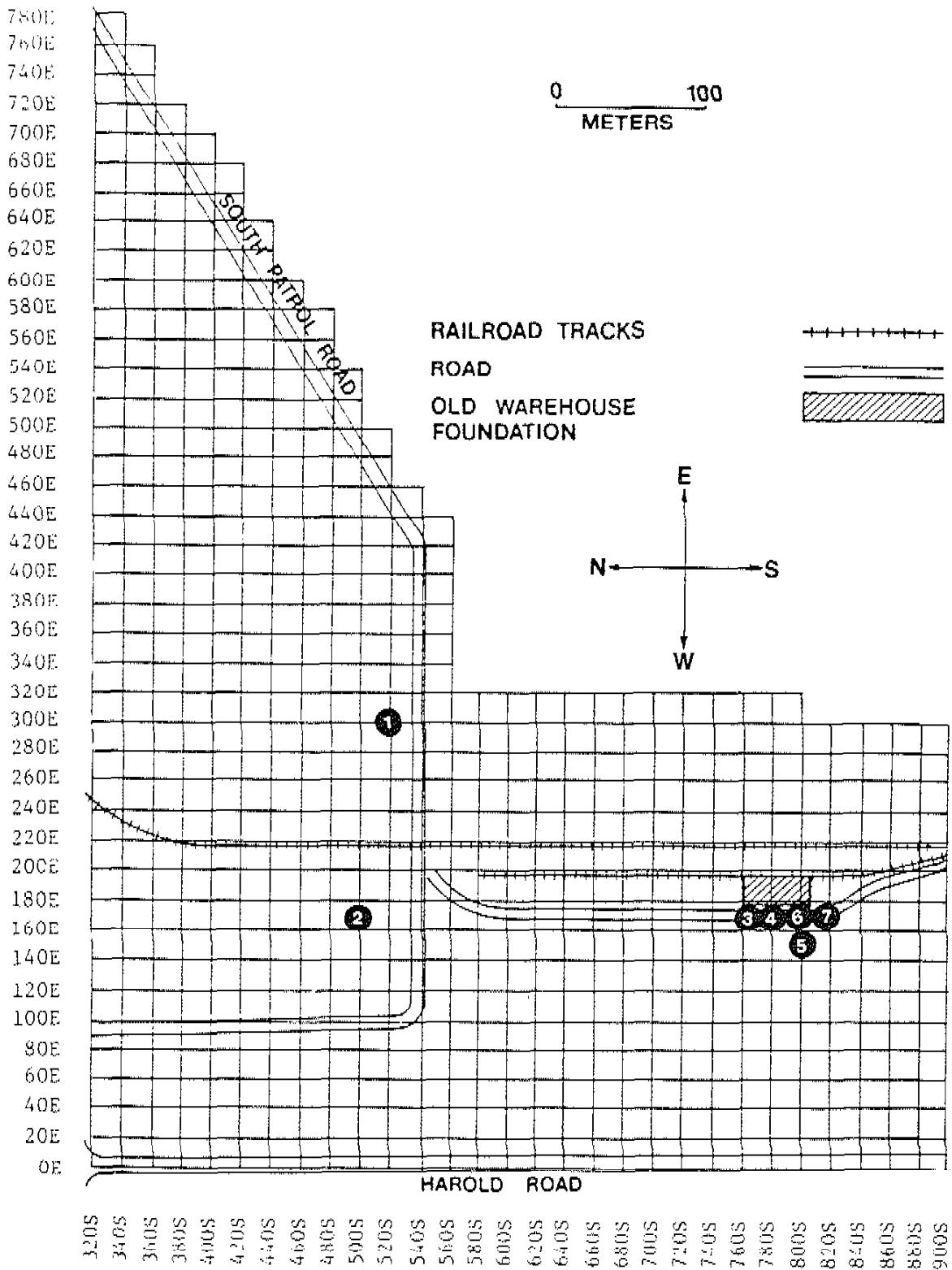


FIGURE 3. Map of the Northern Portion of Property Q indicating the Grid System and Areas of Elevated Direct Radiation Levels.

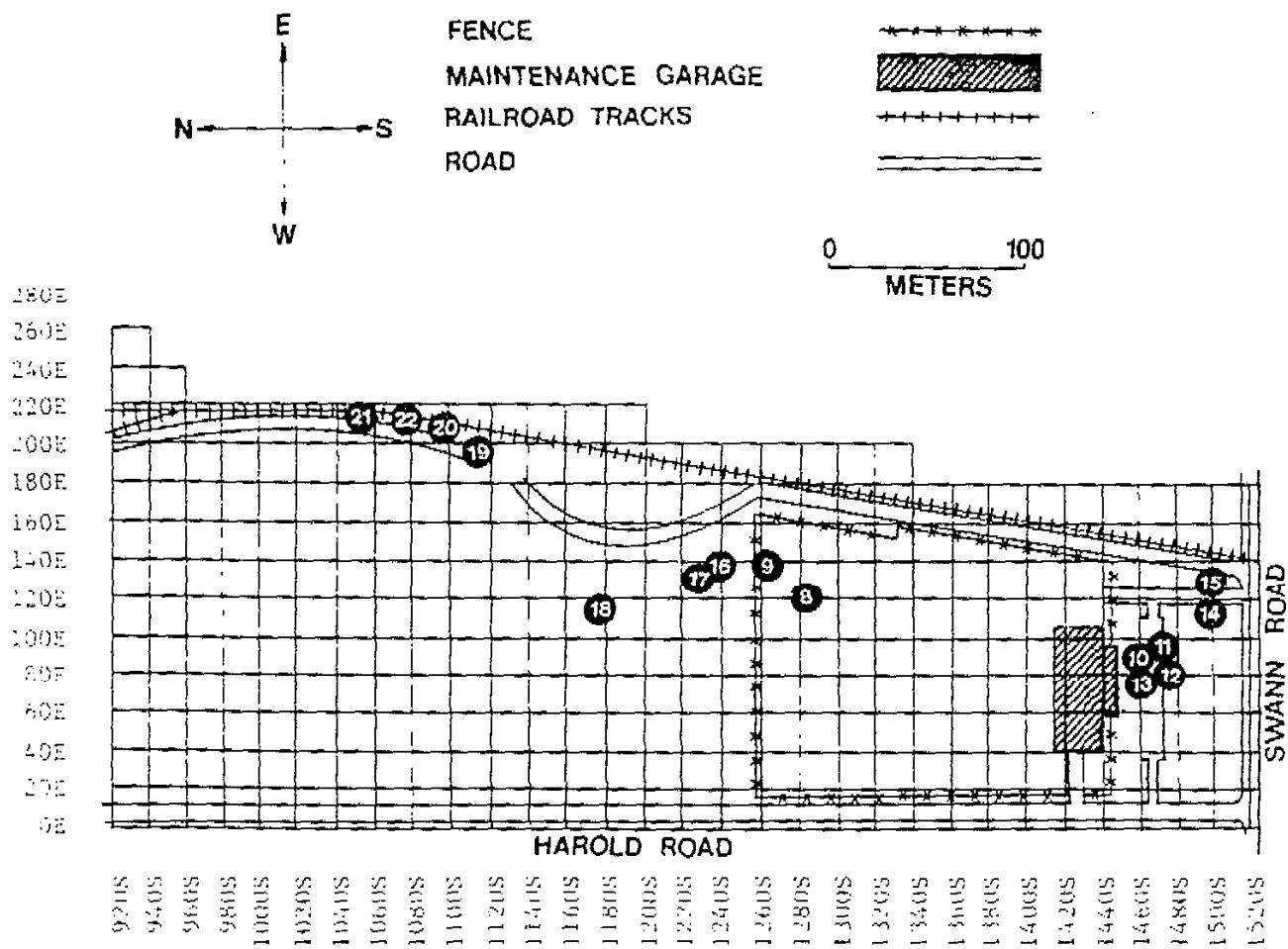


FIGURE 4. Map of the Southern Portion of Property Q Indicating the Grid System and Areas of Elevated Direct Radiation Levels.

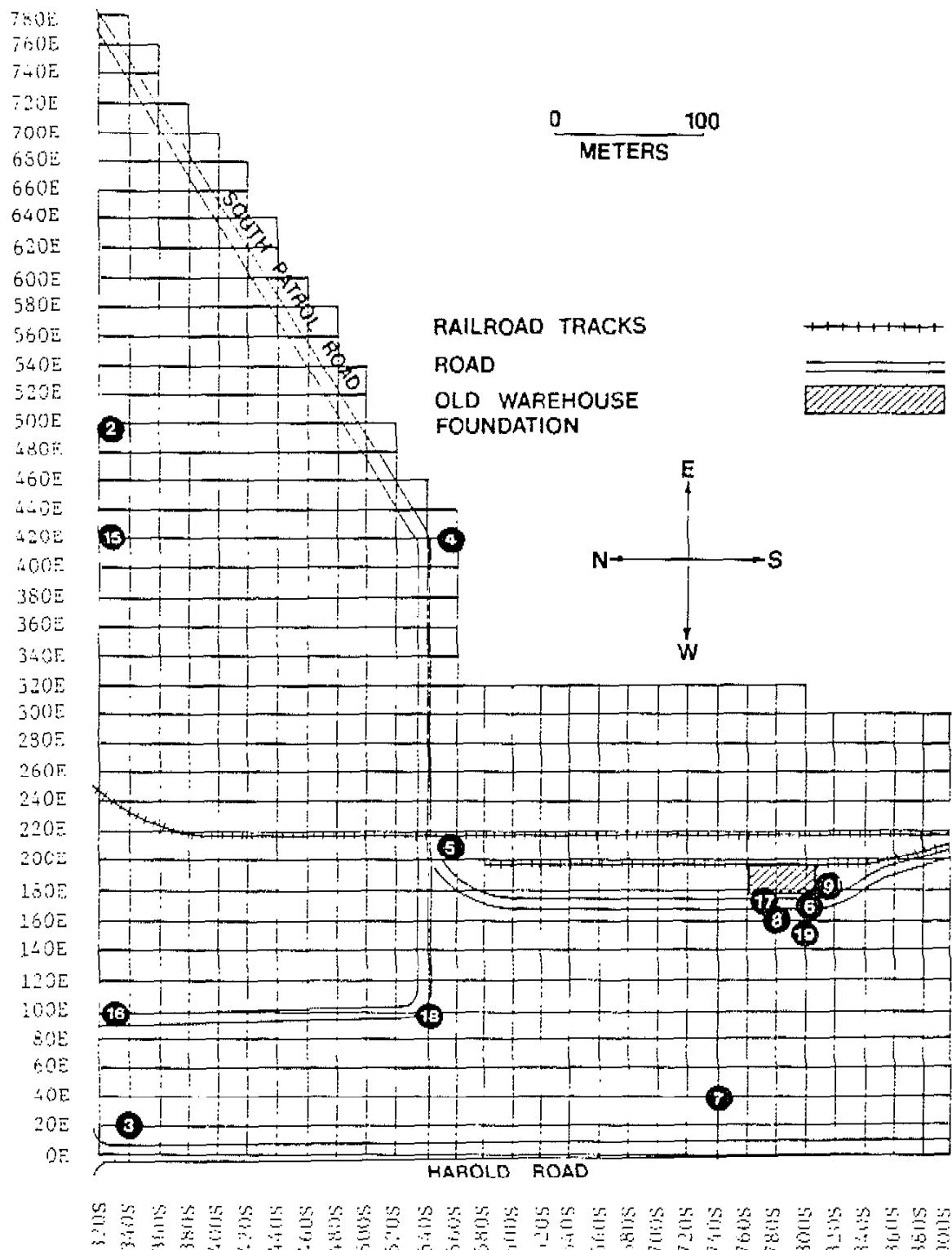


FIGURE 5. Borehole Locations on the Northern Portion of Property O.

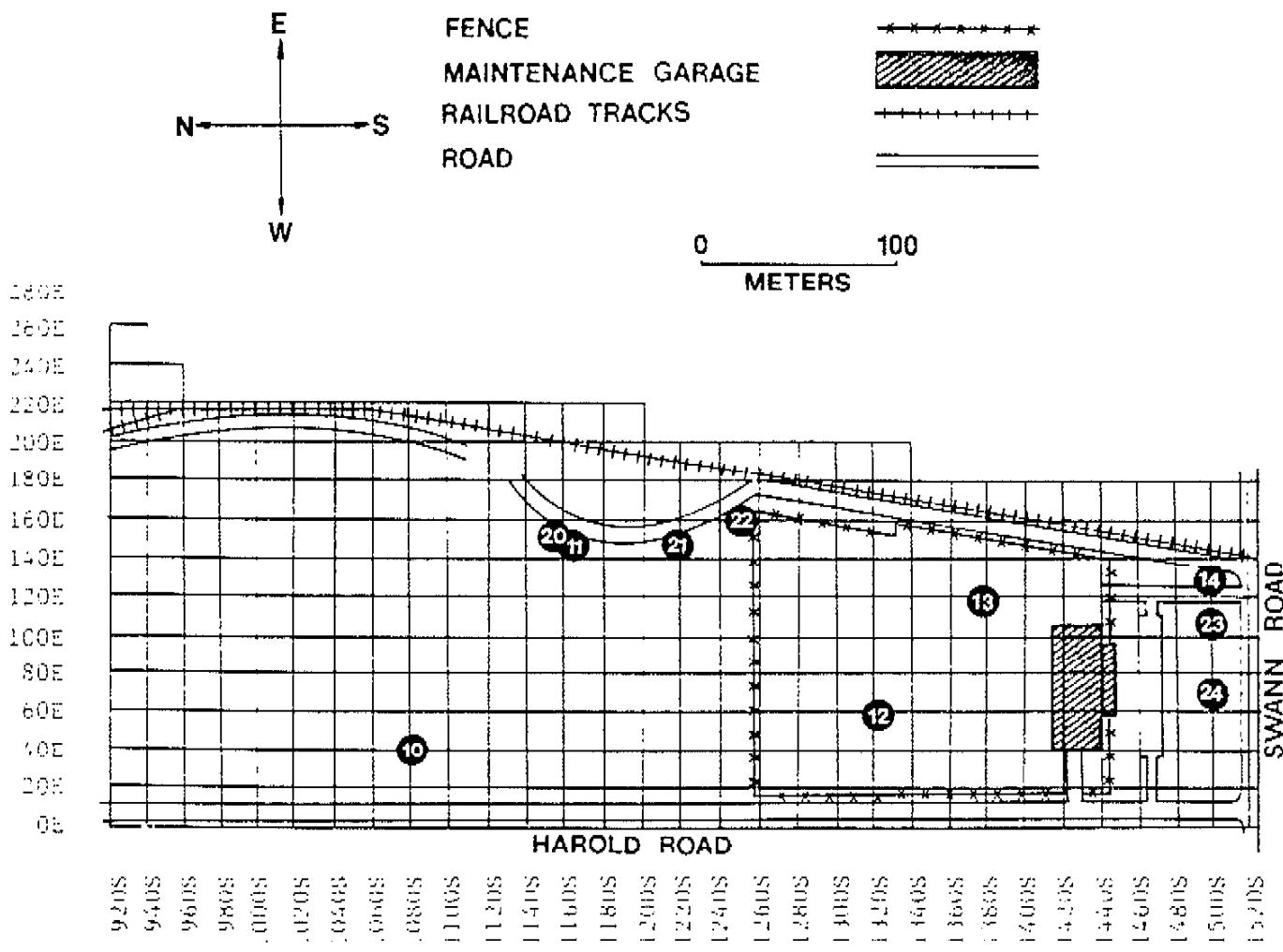


FIGURE 6. Borehole Locations on the Southern Portion of Property Q.

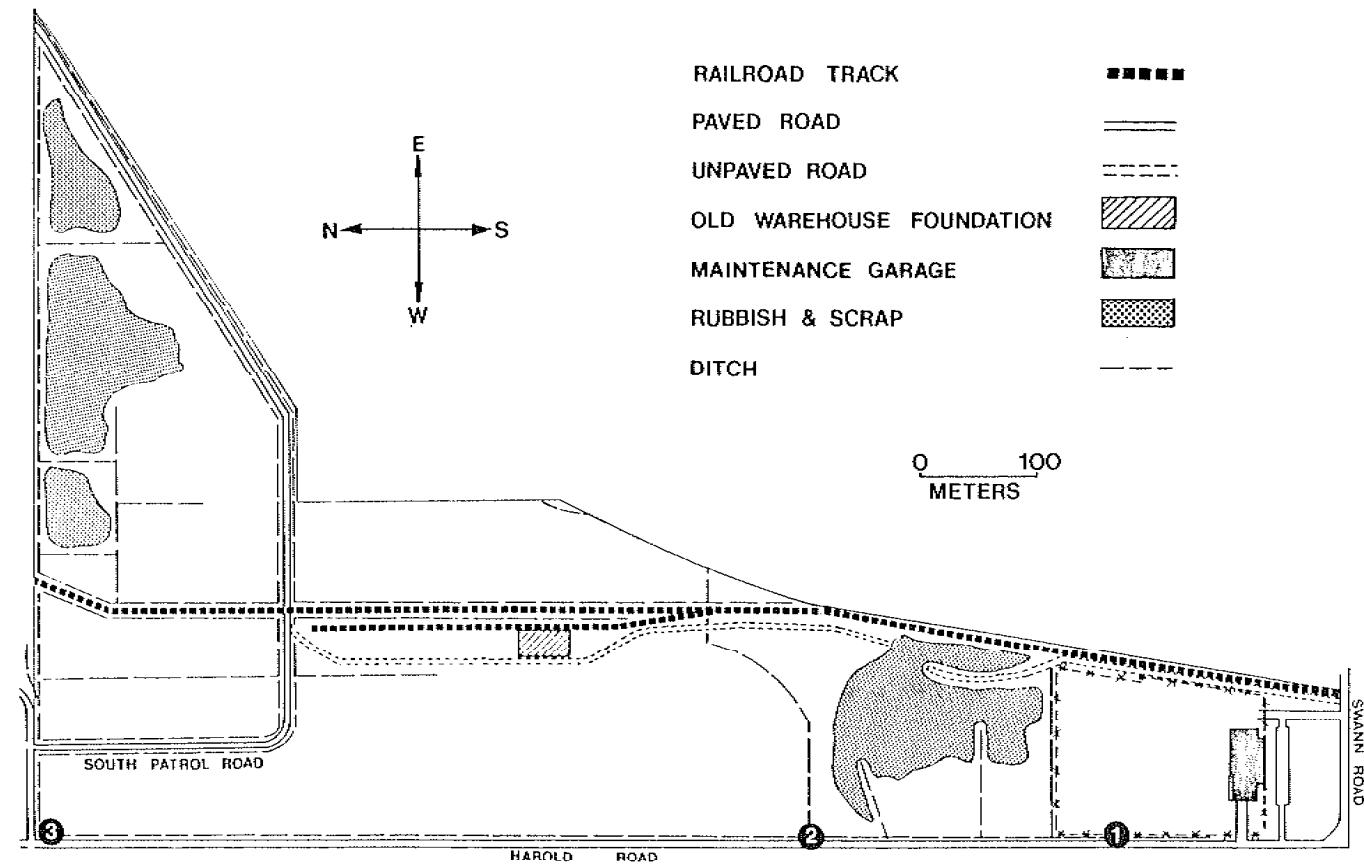


FIGURE 7. Locations of Surface Water Samples Collected on Property Q.

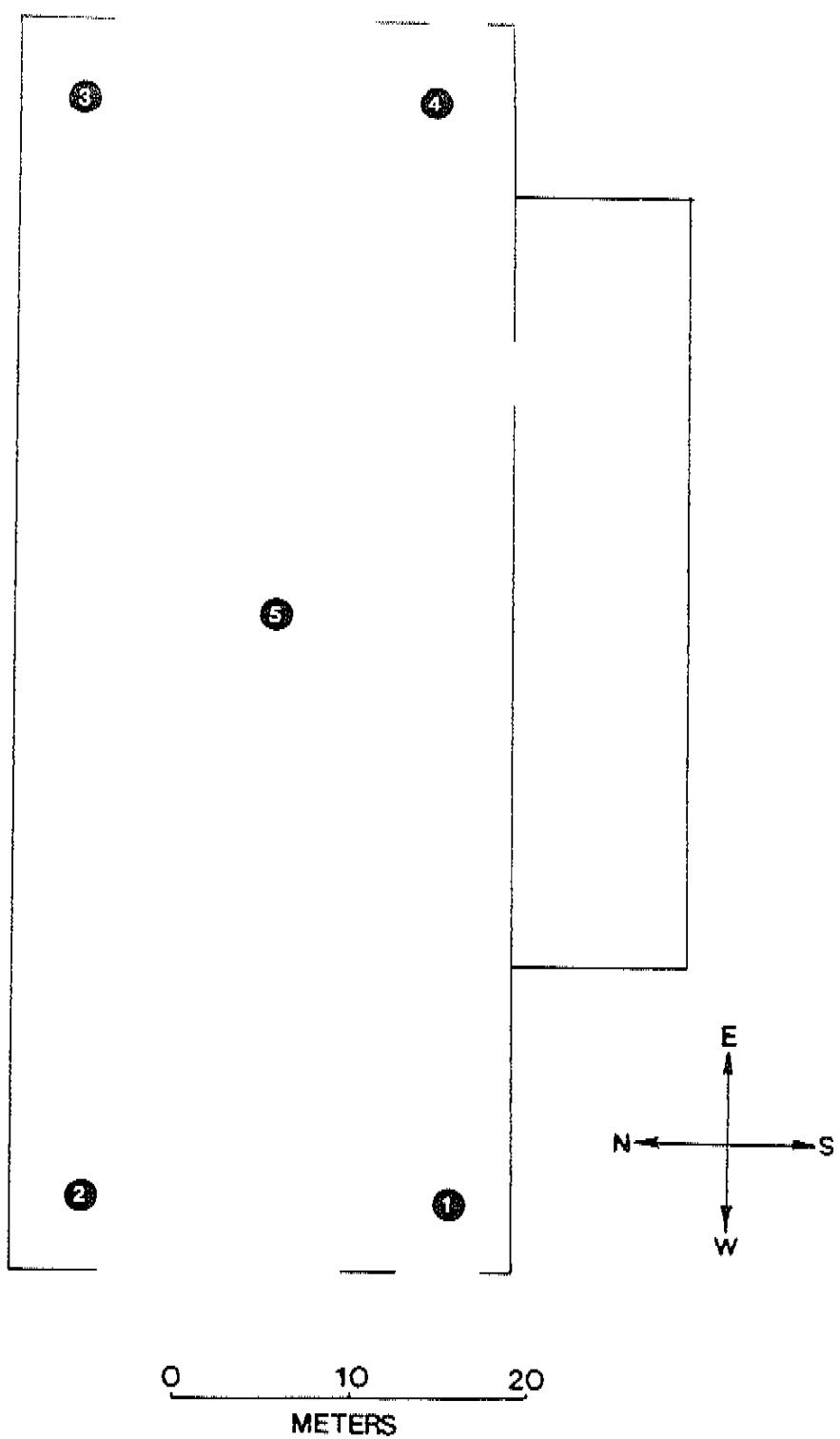


FIGURE 8. Locations of Direct Radiation Measurements in the Maintenance Building on Property Q.

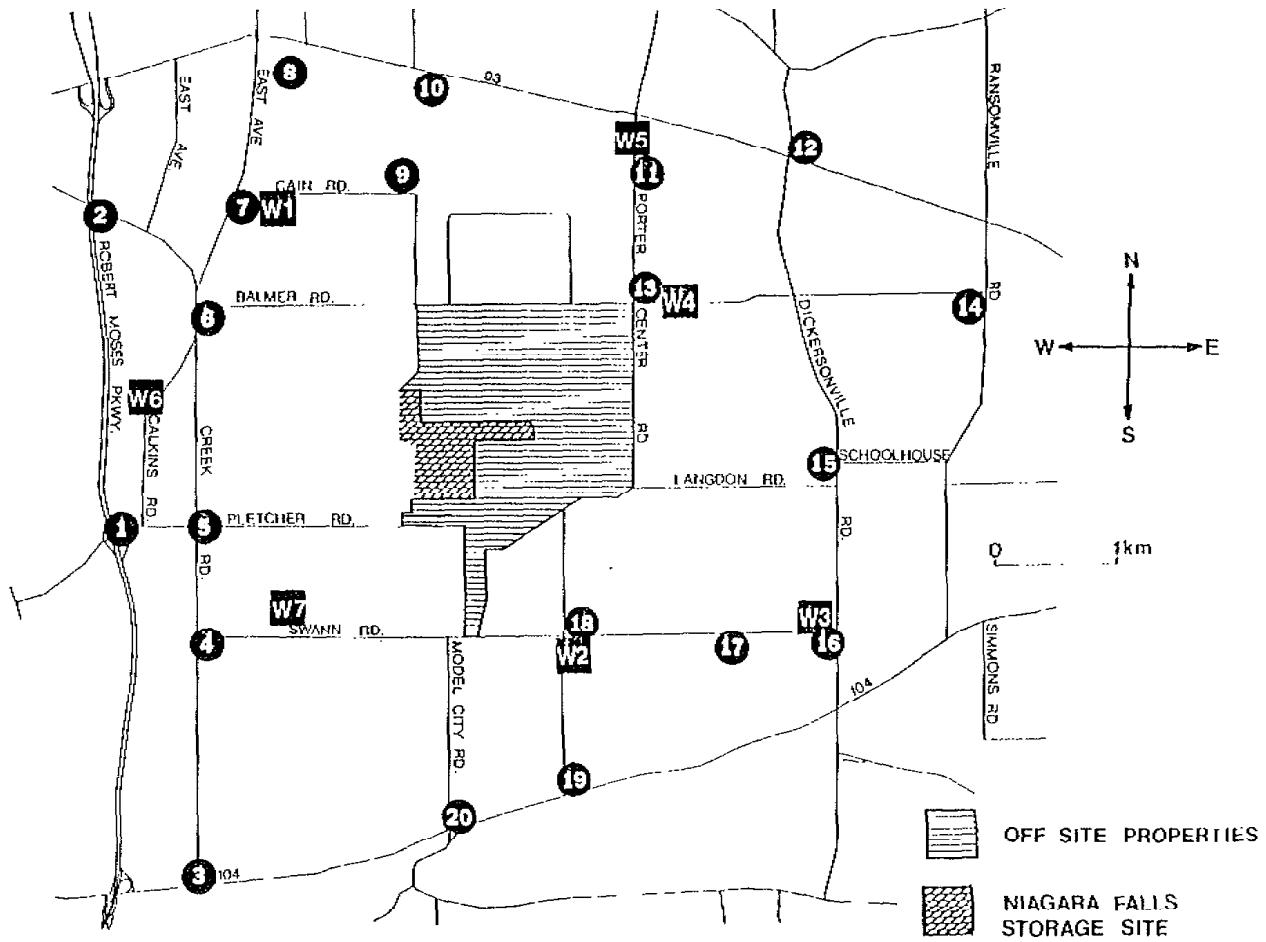


FIGURE 9. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples.

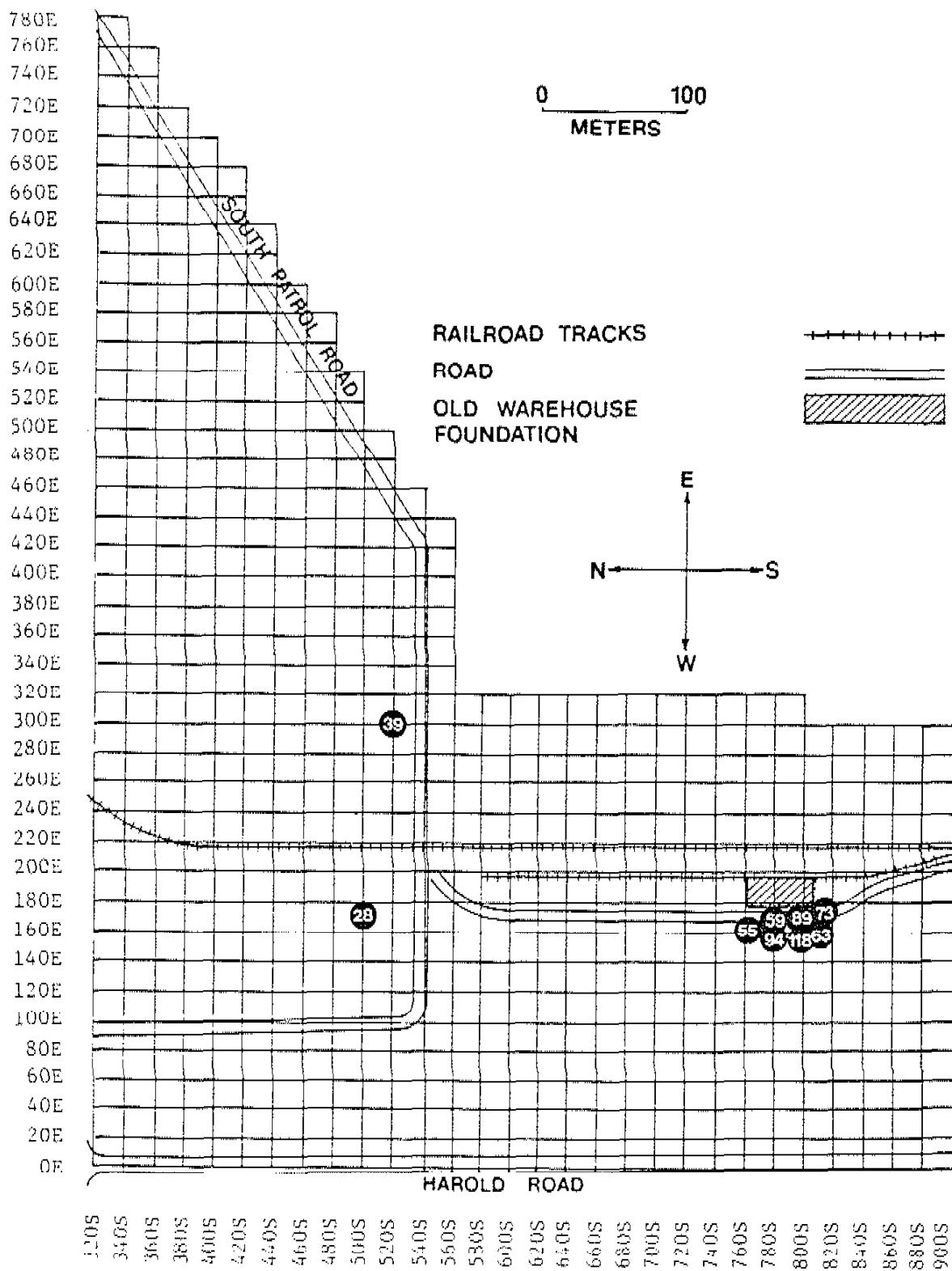


FIGURE 10. Locations and Levels ( $\mu\text{R/h}$ ) of Elevated Contact Radiation on the Northern Portion of Property Q.

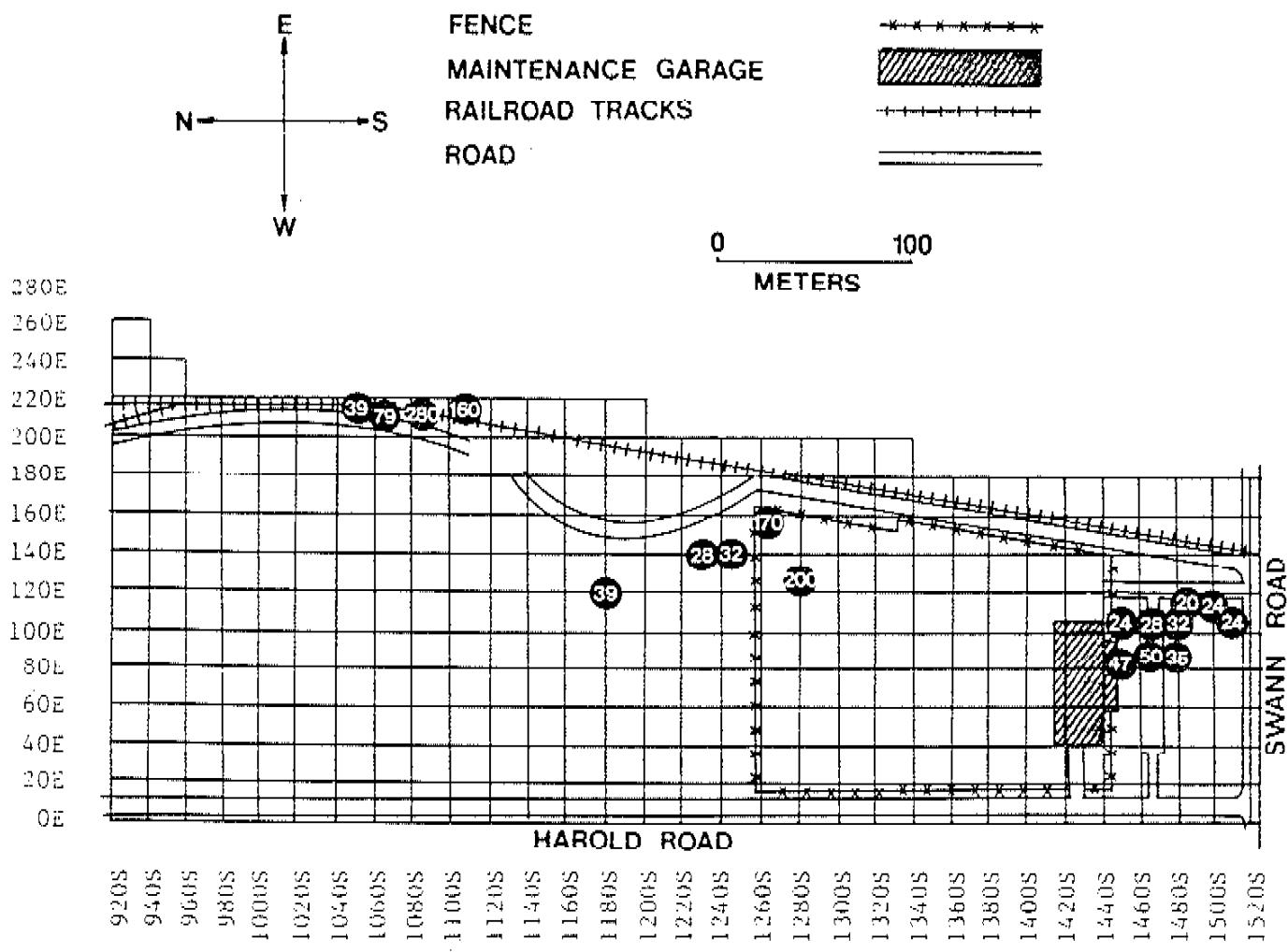


FIGURE 11. Locations and Levels ( $\mu\text{R}/\text{h}$ ) of Elevated Contact Radiation on the Southern Portion of Property Q.

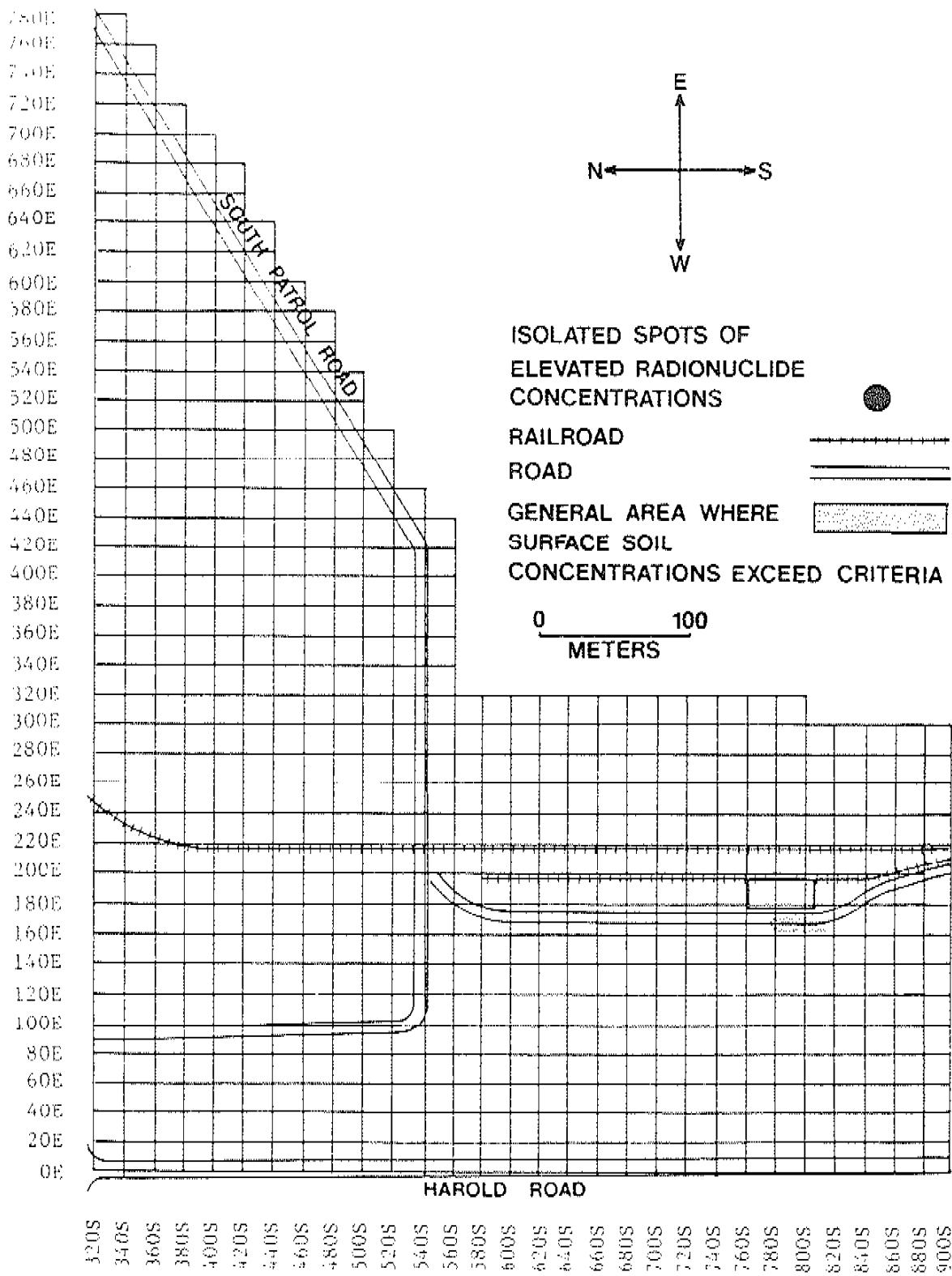


FIGURE 12. Map of NFSS Off-Site Property Q (Northern Portion)  
Indicating the Area Where Radionuclide Concentrations  
in Soil Exceed Criteria.

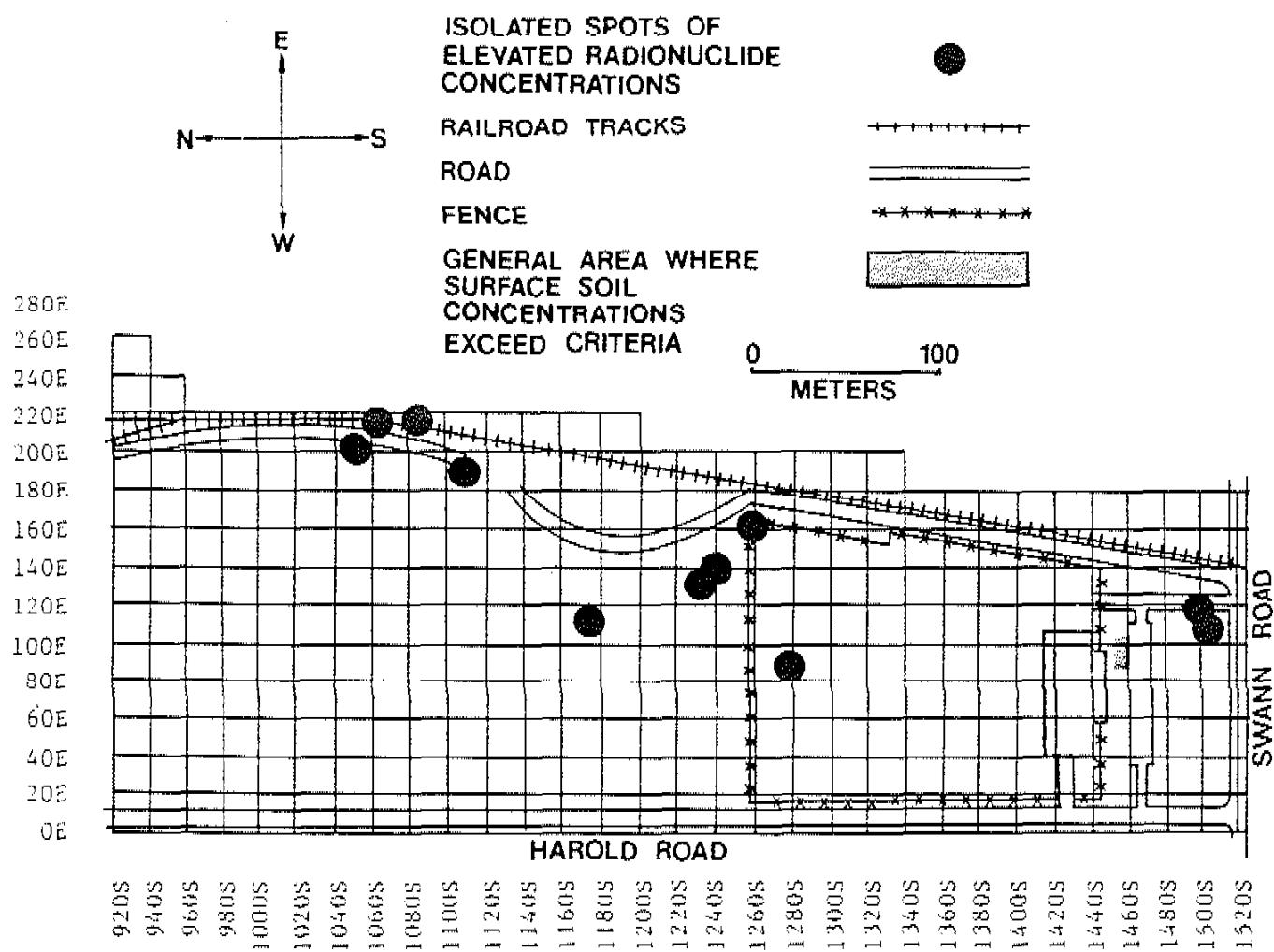


FIGURE 13. Map of NFSS Off-Site Property Q (Southern Portion) Indicating the Area Where Radionuclide Concentrations in Soil Exceed Criteria.

TABLE 1-A  
 BACKGROUND EXPOSURE RATES  
 AND  
 RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES

Location <sup>a</sup>	Exposure Rate <sup>b</sup> ( $\mu\text{R}/\text{h}$ )	Radionuclide Concentrations ( $\text{pCi/g}$ )				
		Ra-226	U-235	U-238	Th-232	Cs-137
1	6.8	0.74 $\pm$ 0.16 <sup>c</sup>	<0.19	<2.89	0.70 $\pm$ 0.46	0.29 $\pm$ 0.05
2	6.8	0.75 $\pm$ 0.19	<0.19	<3.35	0.86 $\pm$ 0.24	0.24 $\pm$ 0.05
3	8.3	0.71 $\pm$ 0.18	0.46 $\pm$ 0.41	<3.72	0.88 $\pm$ 0.33	0.34 $\pm$ 0.09
4	7.9	0.67 $\pm$ 0.18	<0.22	<4.10	1.18 $\pm$ 0.35	0.12 $\pm$ 0.07
5	7.3	0.70 $\pm$ 0.16	<0.17	<3.34	0.68 $\pm$ 0.24	0.35 $\pm$ 0.08
6	7.7	0.50 $\pm$ 0.15	<0.16	<2.33	0.52 $\pm$ 0.35	0.17 $\pm$ 0.09
7	7.7	0.63 $\pm$ 0.13	<0.17	<2.73	0.83 $\pm$ 0.24	0.35 $\pm$ 0.08
8	7.6	0.59 $\pm$ 0.12	<0.14	<2.20	0.54 $\pm$ 0.23	<0.02
9	7.1	0.63 $\pm$ 0.20	<0.23	<4.16	0.83 $\pm$ 0.35	0.69 $\pm$ 0.11
10	7.1	0.70 $\pm$ 0.16	<0.19	<2.98	0.59 $\pm$ 0.25	0.69 $\pm$ 0.10
11	6.7	<0.09	<0.19	<2.83	0.49 $\pm$ 0.31	0.48 $\pm$ 0.14
12	7.1	0.48 $\pm$ 0.13	<0.16	<2.84	0.65 $\pm$ 0.36	0.68 $\pm$ 0.10
13	6.7	0.57 $\pm$ 0.14	<0.17	<2.36	0.49 $\pm$ 0.26	0.41 $\pm$ 0.08
14	6.8	0.68 $\pm$ 0.17	<0.19	<3.24	0.67 $\pm$ 0.25	0.70 $\pm$ 0.10
15	8.2	0.65 $\pm$ 0.14	<0.17	<3.20	0.72 $\pm$ 0.35	0.23 $\pm$ 0.08
16	7.4	0.91 $\pm$ 0.17	<0.71	<3.58	0.83 $\pm$ 0.26	0.61 $\pm$ 0.09
17	7.0	0.48 $\pm$ 0.14	<0.16	<2.73	0.32 $\pm$ 0.22	0.38 $\pm$ 0.08
18	7.7	0.73 $\pm$ 0.16	<0.18	6.26 $\pm$ 9.23	1.01 $\pm$ 0.54	0.32 $\pm$ 0.12
19	8.8	1.22 $\pm$ 0.22	<0.23	<3.79	1.08 $\pm$ 0.49	1.05 $\pm$ 0.13
20	8.6	0.83 $\pm$ 0.17	<0.21	<3.59	0.84 $\pm$ 0.29	0.08 $\pm$ 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

<sup>a</sup> Refer to Figure 9.

<sup>b</sup> Measured at 1 m above the surface.

<sup>c</sup> Errors are 2 $\sigma$  based on counting statistics.

TABLE 1-B  
RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

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

<sup>a</sup> Refer to Figure 9.

<sup>b</sup> Errors are  $2\sigma$  based on counting statistics.

TABLE 2  
DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
320S, 0E	10	10	28
320S, 20E	11	11	31
320S, 40E	10	10	20
320S, 60E	10	10	29
320S, 80E	11	11	32
320S, 100E	9.8	8.7	48
320S, 120E	11	11	42
320S, 140E	12	12	52
320S, 160E	13	13	42
320S, 180E	12	15	54
320S, 200E	14	16	57
320S, 220E	13	15	45
320S, 240E	13	15	31
320S, 260E	13	13	45
320S, 280E	14	15	55
320S, 300E	13	15	66
320S, 320E	13	12	38
320S, 340E	11	11	35
320S, 360E	11	10	17
320S, 380E	11	10	28
320S, 400E	11	11	43
320S, 420E	11	11	34
320S, 440E	11	11	35
320S, 460E	11	11	37
320S, 480E	11	11	22
320S, 500E	11	11	58
320S, 520E	11	11	31
320S, 540E	12	12	37
320S, 560E	12	12	51
320S, 580E	12	12	31
320S, 600E	11	11	45
320S, 620E	11	11	42
320S, 640E	11	12	31
320S, 660E	11	11	37
320S, 680E	11	12	35
320S, 700E	11	12	43
320S, 720E	11	11	26
320S, 740E	11	11	37
320S, 760E	11	11	31
320S, 780E	10	11	29

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
340S, 0E	12	12	34
340S, 20E	11	12	48
340S, 40E	11	12	35
340S, 60E	12	12	49
340S, 80E	11	12	49
340S, 100E	11	11	42
340S, 120E	11	11	32
340S, 140E	12	12	28
340S, 160E	12	12	25
340S, 180E	11	12	35
340S, 200E	11	12	43
340S, 220E	12	12	46
340S, 240E	13	13	43
340S, 260E	12	12	48
340S, 280E	12	12	28
340S, 300E	12	12	37
340S, 320E	12	12	38
340S, 340E	12	12	45
340S, 360E	11	11	26
340S, 380E	11	12	25
340S, 400E	11	12	25
340S, 420E	12	12	25
340S, 440E	12	12	38
340S, 460E	12	12	49
340S, 480E	11	11	34
340S, 500E	9.8	9.8	18
340S, 520E	10	10	20
340S, 540E	11	11	34
340S, 560E	11	12	42
340S, 580E	11	12	34
340S, 600E	11	12	29
340S, 620E	11	11	37
340S, 640E	12	12	35
340S, 660E	11	11	38
340S, 680E	12	12	40
340S, 700E	11	11	35
340S, 720E	11	11	23
340S, 740E	11	11	29
340S, 760E	10	10	31
340S, 780E	10	10	38

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)
360S, 0E	12	12	46
360S, 20E	12	12	35
360S, 40E	12	13	32
360S, 60E	12	12	22
360S, 80E	12	12	28
360S, 100E	11	11	29
360S, 120E	11	12	35
360S, 140E	11	11	34
360S, 160E	12	12	22
360S, 180E	11	11	28
360S, 200E	11	11	42
360S, 220E	12	12	22
360S, 240E	12	12	29
360S, 260E	12	13	20
360S, 280E	12	12	46
360S, 300E	12	13	43
360S, 320E	11	11	31
360S, 340E	11	11	48
360S, 360E	11	11	42
360S, 380E	12	12	34
360S, 400E	11	12	31
360S, 420E	11	12	60
360S, 440E	12	12	40
360S, 460E	12	12	23
360S, 480E	12	12	49
360S, 500E	11	11	42
360S, 520E	12	12	23
360S, 540E	11	12	55
360S, 560E	11	12	38
360S, 580E	11	11	35
360S, 600E	11	12	38
360S, 620E	11	11	34
360S, 640E	11	11	31
360S, 660E	12	12	28
360S, 680E	11	11	42
360S, 700E	11	12	35
360S, 720E	11	12	46
360S, 740E	11	11	46
380S, 0E	10	10	35
380S, 20E	11	11	37

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
380S, 40E	11	12	35
380S, 60E	11	12	34
380S, 80E	11	11	40
380S, 100E	11	11	38
380S, 120E	12	12	30
380S, 140E	11	11	29
380S, 160E	12	12	54
380S, 180E	11	11	35
380S, 200E	12	12	40
380S, 220E	13	16	57
380S, 240E	12	12	35
380S, 260E	12	13	37
380S, 280E	11	12	58
380S, 300E	12	11	29
380S, 320E	12	11	34
380S, 340E	11	11	26
380S, 360E	10	10	35
380S, 380E	11	11	29
380S, 400E	11	11	38
380S, 420E	11	12	17
380S, 440E	11	12	37
380S, 460E	12	12	31
380S, 480E	12	12	32
380S, 500E	12	12	34
380S, 520E	12	12	54
380S, 540E	11	12	32
380S, 560E	11	12	40
380S, 580E	11	12	28
380S, 600E	12	12	38
380S, 620E	12	11	23
380S, 640E	11	11	35
380S, 660E	11	11	37
380S, 680E	11	11	46
380S, 700E	8.7	8.7	45
400S, 0E	10	8.7	28
400S, 20E	11	11	37
400S, 40E	11	12	31
400S, 60E	12	12	46
400S, 80E	11	12	28
400S, 100E	12	12	46

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)
400S, 120E	12	12	49
400S, 140E	11	11	46
400S, 160E	12	12	37
400S, 180E	12	12	42
400S, 200E	11	12	57
400S, 220E	12	12	42
400S, 240E	11	11	29
400S, 260E	12	12	32
400S, 280E	12	12	32
400S, 300E	12	12	35
400S, 320E	12	12	38
400S, 340E	11	11	40
400S, 360E	12	12	34
400S, 380E	12	12	38
400S, 400E	12	12	34
400S, 420E	12	12	42
400S, 440E	11	12	29
400S, 460E	11	12	29
400S, 480E	12	11	46
400S, 500E	12	12	38
400S, 520E	12	12	28
400S, 540E	11	12	32
400S, 560E	11	11	37
400S, 580E	11	11	29
400S, 600E	12	12	40
400S, 620E	10	10	37
400S, 640E	11	11	29
400S, 660E	11	12	35
400S, 680E	11	11	37
420S, 0E	9.8	9.8	29
420S, 20E	11	11	45
420S, 40E	11	11	46
420S, 60E	11	11	23
420S, 80E	11	10	43
420S, 100E	12	12	51
420S, 120E	11	11	46
420S, 140E	12	12	43
420S, 160E	12	12	54
420S, 180E	12	12	37
420S, 200E	12	12	35

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
420S, 220E	12	12	40
420S, 240E	11	11	34
420S, 260E	11	12	43
420S, 280E	12	12	22
420S, 300E	11	11	34
420S, 320E	11	12	43
420S, 340E	12	12	38
420S, 360E	11	12	35
420S, 380E	11	12	45
420S, 400E	11	12	38
420S, 420E	12	12	45
420S, 440E	12	12	48
420S, 460E	12	12	31
420S, 480E	11	11	34
420S, 500E	11	11	51
420S, 520E	11	12	43
420S, 540E	12	12	43
420S, 560E	11	11	32
420S, 580E	11	11	31
420S, 600E	11	11	29
420S, 620E	11	11	32
420S, 640E	11	11	25
440S, 0E	9.5	8.7	28
440S, 20E	11	12	46
440S, 40E	11	12	35
440S, 60E	11	11	46
440S, 80E	11	11	38
440S, 100E	11	11	41
440S, 120E	11	11	35
440S, 140E	12	12	34
440S, 160E	12	12	42
440S, 180E	12	12	34
440S, 200E	12	12	37
440S, 220E	12	12	45
440S, 240E	12	12	45
440S, 260E	11	11	42
440S, 280E	11	11	43
440S, 300E	11	11	46
440S, 320E	12	12	37
440S, 340E	11	12	38

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
440S, 360E	11	12	45
440S, 380E	11	11	40
440S, 400E	12	12	45
440S, 420E	12	12	32
440S, 440E	11	11	34
440S, 460E	11	11	45
440S, 480E	11	11	29
440S, 500E	11	11	43
440S, 520E	11	11	28
440S, 540E	11	12	32
440S, 560E	12	12	25
440S, 580E	11	11	34
440S, 600E	9.8	8.0	37
440S, 620E	11	11	46
460S, 0E	10	9.8	35
460S, 20E	11	12	43
460S, 40E	11	11	49
460S, 60E	11	11	32
460S, 80E	11	11	42
460S, 100E	11	11	58
460S, 120E	11	11	34
460S, 140E	12	12	51
460S, 160E	12	12	31
460S, 180E	11	11	31
460S, 200E	11	12	31
460S, 220E	12	12	40
460S, 240E	11	11	37
460S, 260E	12	12	25
460S, 280E	11	11	34
460S, 300E	10	11	34
460S, 320E	11	12	35
460S, 340E	12	12	35
460S, 360E	11	12	17
460S, 380E	11	12	31
460S, 400E	11	12	29
460S, 420E	11	12	31
460S, 440E	11	12	31
460S, 460E	11	11	38
460S, 480E	12	12	40
460S, 500E	11	11	42

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid location	Gamma Exposure Rates at 1 m Above the Surface (. $\mu$ R/h)	Gamma Exposure Rates at the Surface (. $\mu$ R/h)	Beta-Gamma Dose Rates at the Surface (.rad/h)
460S, 520E	11	11	38
460S, 540E	10	11	40
460S, 560E	11	11	32
480S, 0E	10	8.7	45
480S, 20E	11	11	35
480S, 40E	11	12	37
480S, 60E	11	11	42
480S, 80E	12	12	29
480S, 100E	11	11	23
480S, 120E	12	11	48
480S, 140E	11	11	31
480S, 160E	12	12	40
480S, 180E	12	12	38
480S, 200E	12	12	38
480S, 220E	13	13	31
480S, 240E	11	12	17
480S, 260E	11	11	52
480S, 280E	11	11	37
480S, 300E	11	11	45
480S, 320E	11	12	31
480S, 340E	11	11	35
480S, 360E	12	12	28
480S, 380E	11	11	55
480S, 400E	11	12	38
480S, 420E	11	11	45
480S, 440E	11	11	43
480S, 460E	11	11	29
480S, 480E	10	10	20
480S, 500E	11	11	43
480S, 520E	11	11	26
500S, 0E	9.8	9.8	23
500S, 20E	11	11	45
500S, 40E	11	11	18
500S, 60E	11	11	38
500S, 80E	12	12	32
500S, 100E	11	11	40
500S, 120E	11	11	35
500S, 140E	12	12	34
500S, 160E	11	12	26

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\text{mrad/h}$ )
500S, 180E	11	12	38
500S, 200E	11	11	45
500S, 220E	12	12	46
500S, 240E	12	11	18
500S, 260E	10	11	38
500S, 280E	11	11	32
500S, 300E	11	11	48
500S, 320E	12	12	32
500S, 340E	11	11	26
500S, 360E	12	12	46
500S, 380E	12	12	23
500S, 400E	12	12	34
500S, 420E	11	11	34
500S, 440E	11	11	34
500S, 460E	11	11	25
500S, 480E	11	11	42
520S, 0E	8.7	8.4	23
520S, 20E	11	11	49
520S, 40E	11	11	46
520S, 60E	11	11	28
520S, 80E	11	11	31
520S, 100E	11	11	45
520S, 120E	11	12	51
520S, 140E	11	11	40
520S, 160E	11	13	45
520S, 180E	11	11	35
520S, 200E	12	13	42
520S, 220E	13	13	48
520S, 240E	11	12	45
520S, 260E	11	11	35
520S, 280E	11	12	46
520S, 300E	22	22	40
520S, 320E	12	12	37
520S, 340E	11	12	28
520S, 360E	12	12	49
520S, 380E	11	12	45
520S, 400E	11	11	28
520S, 420E	11	10	25
520S, 440E	11	11	45
520S, 460E	11	12	49

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (uR/h)	Gamma Exposure Rates at the Surface (uR/h)	Beta-Gamma Dose Rates at the Surface (.rad/h)
540S, 0E	9.5	8.4	32
540S, 20E	11	12	34
540S, 40E	11	11	37
540S, 60E	11	11	38
540S, 80E	10	10	31
540S, 100E	11	11	38
540S, 120E	11	11	38
540S, 140E	11	11	26
540S, 160E	11	12	32
540S, 180E	11	12	49
540S, 200E	12	11	35
540S, 220E	12	12	42
540S, 240E	11	11	45
540S, 260E	11	11	34
540S, 280E	11	11	45
540S, 300E	11	12	30
540S, 320E	12	12	35
540S, 340E	11	11	26
540S, 360E	11	11	34
540S, 380E	11	12	26
540S, 400E	11	11	23
540S, 420E	11	11	32
540S, 440E	10	9.8	25
540S, 460E	10	11	42
560S, 0E	9.8	9.5	32
560S, 20E	11	11	32
560S, 40E	11	12	48
560S, 60E	10	10	25
560S, 80E	11	10	37
560S, 100E	11	11	29
560S, 120E	10	11	32
560S, 140E	11	11	49
560S, 160E	11	12	46
560S, 180E	11	11	37
560S, 200E	10	10	29
560S, 220E	12	14	42
560S, 240E	11	11	34
560S, 260E	11	11	45
560S, 280E	11	11	42

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
560S, 300E	11	12	35
560S, 320E	11	11	49
560S, 340E	11	11	52
560S, 360E	12	12	46
560S, 380E	11	11	35
560S, 400E	11	11	45
560S, 420E	11	11	26
580S, 0E	9.8	8.7	25
580S, 20E	11	11	49
580S, 40E	10	11	34
580S, 60E	12	12	22
580S, 80E	11	12	40
580S, 100E	11	11	28
580S, 120E	11	11	31
580S, 140E	11	11	37
580S, 160E	11	12	48
580S, 180E	11	11	45
580S, 200E	11	11	32
580S, 220E	14	13	34
580S, 240E	11	12	40
580S, 260E	11	11	43
580S, 280E	11	12	40
580S, 300E	11	12	26
580S, 320E	11	11	34
600S, 0E	8.0	8.7	31
600S, 20E	10	11	28
600S, 40E	11	11	38
600S, 60E	10	11	32
600S, 80E	11	11	38
600S, 100E	11	11	28
600S, 120E	12	11	32
600S, 140E	11	11	42
600S, 160E	11	12	37
600S, 180E	11	11	34
600S, 200E	12	11	45
600S, 220E	13	12	54
600S, 240S	11	12	32
600S, 260S	11	11	37
600S, 280S	11	12	34

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
600S, 300E	11	12	40
600S, 320E	11	11	55
620S, 0E	9.8	8.7	31
620S, 20E	11	11	25
620S, 40E	11	11	22
620S, 60E	11	11	29
620S, 80E	11	11	32
620S, 100E	11	11	26
620S, 120E	11	11	35
620S, 140E	12	12	28
620S, 160E	12	12	38
620S, 200E	12	12	31
620S, 220E	14	13	45
620S, 240E	11	11	51
620S, 260E	11	11	34
620S, 280E	11	11	43
620S, 300E	12	12	49
620S, 320E	12	12	42
640S, 0E	10	10	52
640S, 20E	10	11	28
640S, 40E	11	11	31
640S, 60E	11	11	37
640S, 80E	11	11	48
640S, 100E	11	11	29
640S, 120E	11	12	34
640S, 140E	11	11	37
640S, 160E	12	11	28
640S, 180E	11	11	34
640S, 200E	12	12	32
640S, 220E	12	12	37
640S, 240E	11	11	31
640S, 260E	11	11	42
640S, 280E	11	11	38
640S, 300E	12	12	48
640S, 320E	12	12	40
660S, 0E	10	11	42
660S, 20E	10	10	46
660S, 40E	11	11	31

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
660S, 60E	10	11	34
660S, 80E	11	11	38
660S, 100E	11	11	29
660S, 120E	11	11	35
660S, 140E	11	11	31
660S, 160E	11	12	49
660S, 180E	11	12	40
660S, 200E	12	12	32
660S, 220E	11	11	26
660S, 240E	11	11	29
660S, 260E	11	11	34
660S, 280E	11	11	38
660S, 300E	11	11	31
660S, 320E	11	11	35
680S, 0E	10	10	32
680S, 20E	11	11	29
680S, 40E	11	11	35
680S, 60E	11	11	37
680S, 80E	11	11	35
680S, 100E	11	11	40
680S, 120E	11	11	40
680S, 140E	10	11	32
680S, 160E	11	11	37
680S, 180E	11	11	34
680S, 200E	11	11	37
680S, 220E	12	12	32
680S, 240E	12	12	37
680S, 260E	11	12	31
680S, 280E	11	11	35
680S, 300E	11	11	43
680S, 320E	11	11	29
700S, 0E	8.7	8.7	22
700S, 20E	11	11	28
700S, 40E	11	10	25
700S, 60E	11	11	35
700S, 80E	11	11	32
700S, 100E	11	11	38
700S, 120E	11	11	32
700S, 140E	11	11	40

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R}/\text{h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R}/\text{h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad}/\text{h}$ )
700S,160E	11	11	34
700S,180E	11	11	31
700S,200E	12	12	43
700S,220E	13	13	52
700S,240E	12	12	42
700S,260E	12	12	35
700S,280E	11	11	29
700S,300E	11	11	32
700S,320E	11	11	28
720S, 0E	9.9	10	40
720S, 20E	8.4	9.8	38
720S, 40E	10	11	32
720S, 60E	11	11	46
720S, 80E	11	11	37
720S,100E	11	11	42
720S,120E	11	11	31
720S,140E	10	11	32
720S,160E	11	11	29
720S,180E	12	11	42
720S,200E	12	12	31
720S,220E	12	12	32
720S,240E	11	11	31
720S,260E	11	11	40
720S,280E	11	11	37
720S,300E	11	11	32
720S,320E	11	11	28
740S, 0E	8.0	8.4	42
740S, 20E	11	11	29
740S, 40E	11	11	32
740S, 60E	12	12	38
740S, 80E	13	13	49
740S,100E	13	13	42
740S,120E	13	15	43
740S,140E	11	12	35
740S,160E	11	11	31
740S,180E	11	11	35
740S,200E	11	11	37
740S,220E	12	12	48
740S,240E	12	12	40

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (uR/h)	Gamma Exposure Rates at the Surface (uR/h)	Beta-Gamma Dose Rates at the Surface (urad/h)
740S, 260E	11	11	34
740S, 280E	11	11	31
740S, 300E	11	11	28
740S, 320E	11	11	35
760S, 0E	10	11	31
760S, 20E	11	11	34
760S, 40E	11	11	34
760S, 60E	11	11	34
760S, 80E	11	11	31
760S, 100E	11	11	32
760S, 120E	11	11	28
760S, 140E	11	11	31
760S, 160E	11	11	35
760S, 180E	11	11	40
760S, 200E	12	12	46
760S, 220E	12	13	42
760S, 240E	10	10	43
760S, 260E	11	11	37
760S, 280E	11	11	35
760S, 300E	10	10	28
760S, 320E	11	11	31
780S, 0E	10	11	28
780S, 20E	12	11	23
780S, 40E	11	11	23
780S, 60E	10	12	42
780S, 80E	11	11	54
780S, 100E	11	11	37
780S, 120E	11	12	35
780S, 140E	11	12	35
780S, 160E	11	11	28
780S, 180E	11	12	26
780S, 200E	13	17	46
780S, 220E	12	13	32
780S, 240E	11	11	46
780S, 260E	11	11	45
780S, 280E	11	12	35
780S, 300E,	12	11	37

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
800S, 0E	9.8	9.8	32
800S, 20E	11	11	26
800S, 40E	11	11	34
800S, 60E	11	12	35
800S, 80E	11	11	35
800S, 100E	11	11	31
800S, 120E	11	12	28
800S, 140E	11	11	34
800S, 160E	11	11	31
800S, 180E	12	11	32
800S, 200E	14	15	63
800S, 220E	14	15	55
800S, 240E	11	12	42
800S, 260E	11	11	34
800S, 280E	10	11	32
800S, 300E	11	12	46
820S, 0E	10	11	32
820S, 20E	11	11	40
820S, 40E	11	11	35
820S, 60E	11	11	45
820S, 80E	11	11	35
820S, 100E	11	11	38
820S, 120E	11	11	34
820S, 140E	11	12	46
820S, 160E	11	10	35
820S, 180E	11	11	23
820S, 200E	14	16	51
820S, 220E	13	14	60
820S, 240E	11	11	34
820S, 260E	11	12	54
820S, 280E	11	12	54
820S, 300E	11	11	40
840S, 0E	9.8	10	26
840S, 20E	11	11	29
840S, 40E	11	11	26
840S, 60E	11	11	34
840S, 80E	11	11	26
840S, 100E	11	11	32
840S, 120E	11	11	28

TABLE 2, cont.  
DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R}/\text{h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R}/\text{h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad}/\text{h}$ )
840S, 140E	11	12	57
840S, 160E	11	11	40
840S, 180E	11	11	42
840S, 200E	15	16	51
840S, 220E	13	13	65
840S, 240E	11	11	35
840S, 260E	10	11	45
840S, 280E	11	11	42
840S, 300E	11	11	34
860S, 0E	10	11	26
860S, 20E	11	11	43
860S, 40E	11	11	48
860S, 60E	11	11	38
860S, 80E	11	11	37
860S, 100E	11	11	28
860S, 120E	11	11	34
860S, 140E	11	12	32
860S, 160E	11	12	15
860S, 180E	11	11	42
860S, 200E	11	10	18
860S, 220E	13	13	38
860S, 240E	11	12	51
860S, 260E	11	11	56
860S, 280E	11	11	38
860S, 300E	11	11	26
880S, 0E	9.9	11	40
880S, 20E	11	11	43
880S, 40E	11	11	48
880S, 60E	11	11	38
880S, 80E	11	11	37
880S, 100E	11	11	28
880S, 120E	11	11	34
880S, 140E	11	12	32
880S, 160E	11	12	15
880S, 180E	12	12	42
880S, 200E	11	11	18
880S, 220E	13	13	38
880S, 240E	11	12	51
880S, 260E	11	11	57

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
880S, 280E	11	11	38
880S, 300E	11	11	26
900S, 0E	11	11	38
900S, 20E	11	11	32
900S, 40E	11	11	45
900S, 60E	11	11	22
900S, 80E	11	11	42
900S, 100E	11	11	37
900S, 120E	11	11	28
900S, 140E	11	12	32
900S, 160E	11	11	28
900S, 180E	11	12	31
900S, 200E	11	11	45
900S, 220E	13	13	60
900S, 240E	11	11	48
900S, 260E	11	11	29
900S, 280E	11	11	60
900S, 300E	11	11	34
920S, 0E	11	11	42
920S, 20E	11	11	21
920S, 40E	10	10	23
920S, 60E	11	11	34
920S, 80E	11	11	40
920S, 100E	11	12	46
920S, 120E	11	11	28
920S, 140E	11	11	35
920S, 160E	11	11	34
920S, 180E	11	11	25
920S, 200E	11	11	43
920S, 220E	14	14	34
920S, 240E	11	11	38
920S, 260E	10	11	49
920S, 280E	10	11	42
940S, 0E	10	11	29
940S, 20E	11	11	43
940S, 40E	11	11	51
940S, 60E	11	11	35
940S, 80E	11	11	18

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)
940S, 100E	12	12	37
940S, 120E	11	11	32
940S, 140E	11	11	46
940S, 160E	11	12	29
940S, 180E	11	12	38
940S, 200E	11	12	35
940S, 220E	13	15	60
940S, 240E	11	11	37
940S, 260E	12	12	45
960S, 0E	9.8	8.7	20
960S, 20E	11	11	48
960S, 40E	11	11	45
960S, 60E	11	11	49
960S, 80E	11	12	48
960S, 100E	11	11	35
960S, 120E	11	11	29
960S, 140E	11	11	29
960S, 160E	11	11	28
960S, 180E	11	12	29
960S, 200E	11	11	31
960S, 220E	14	17	75
960S, 240E	11	11	45
960S, 260E	11	12	28
980S, 0E	8.7	8.4	20
980S, 20E	11	12	40
980S, 40E	11	12	35
980S, 60E	11	12	42
980S, 80E	11	12	23
980S, 100E	11	11	37
980S, 120E	11	11	49
980S, 140E	11	11	48
980S, 160E	11	12	38
980S, 180E	12	12	62
980S, 200E	12	13	40
980S, 220E	12	13	46
1000S, 0E	8.7	8.0	28
1000S, 20E	11	11	38
1000S, 40E	11	11	43

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
1000S, 60E	11	11	49
1000S, 80E	11	11	37
1000S, 100E	11	11	34
1000S, 120E	11	11	34
1000S, 140E	11	11	52
1000S, 160E	11	11	22
1000S, 180E	12	13	46
1000S, 200E	11	11	37
1020S, 0E	8.7	8.0	37
1020S, 20E	11	12	34
1020S, 40E	11	11	48
1020S, 60E	12	12	54
1020S, 80E	11	11	23
1020S, 100E	11	11	38
1020S, 120E	11	11	35
1020S, 140E	11	12	15
1020S, 160E	12	12	51
1020S, 180E	11	11	37
1020S, 200E	11	12	34
1040S, 0E	9.8	8.0	38
1040S, 20E	11	11	35
1040S, 40E	10	11	31
1040S, 60E	11	11	29
1040S, 80E	11	12	32
1040S, 100E	11	11	37
1040S, 120E	11	11	38
1040S, 140E	12	12	32
1040S, 160E	12	11	31
1040S, 180E	11	11	49
1040S, 200E	11	12	31
1060S, 0E	9.9	8.7	31
1060S, 20E	10	11	52
1060S, 40E	11	11	20
1060S, 60E	11	12	42
1060S, 80E	10	10	32
1060S, 100E	10	9.9	37
1060S, 120E	11	12	38
1060S, 140E	11	11	32

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
1060S, 160E	11	12	54
1060S, 180E	12	13	46
1060S, 200E	12	11	42
1080S, 0E	9.5	9.5	43
1080S, 20E	11	11	52
1080S, 40E	11	11	42
1080S, 60E	12	11	51
1080S, 80E	12	12	35
1080S, 100E	11	11	23
1080S, 120E	11	12	46
1080S, 140E	12	11	37
1080S, 160E	12	12	43
1080S, 180E	12	12	55
1080S, 200E	11	11	38
1100S, 0E	9.8	8.4	37
1100S, 20E	10	10	48
1100S, 40E	11	11	40
1100S, 60E	10	11	54
1100S, 80E	10	11	48
1100S, 100E	11	11	54
1100S, 120E	11	11	68
1100S, 140E	11	11	40
1100S, 160E	11	12	48
1100S, 180E	11	12	38
1100S, 200E	12	12	52
1120S, 0E	8.1	8.0	28
1120S, 20E	11	12	32
1120S, 40E	11	11	45
1120S, 60E	11	11	37
1120S, 80E	11	11	37
1120S, 100E	11	11	52
1120S, 120E	11	11	38
1120S, 140E	11	11	38
1120S, 160E	10	11	38
1120S, 180E	11	11	54
1120S, 200E	12	13	42

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)
1140S, 0E	8.4	8.4	31
1140S, 20E	11	11	34
1140S, 40E	11	11	23
1140S, 60E	11	11	37
1140S, 80E	10	11	38
1140S, 100E	11	11	31
1140S, 120E	10	11	23
1140S, 140E	11	11	46
1140S, 160E	9.8	9.8	37
1140S, 180E	10	11	40
1160S, 0E	9.8	8.0	23
1160S, 20E	11	11	35
1160S, 40E	11	11	29
1160S, 60E	11	11	43
1160S, 80E	11	11	42
1160S, 100E	11	11	38
1160S, 120E	10	11	48
1160S, 140E	10	10	40
1160S, 160E	10	10	31
1160S, 180E	11	11	32
1180S, 0E	9.5	8.1	25
1180S, 20E	10	11	37
1180S, 40E	11	11	31
1180S, 60E	11	11	34
1180S, 80E	11	11	42
1180S, 100E	11	11	35
1180S, 120E	11	11	34
1180S, 140E	12	12	43
1180S, 160E	10	10	26
1200S, 0E	9.8	8.1	26
1200S, 20E	12	12	45
1200S, 40E	11	11	37
1200S, 60E	10	11	31
1200S, 80E	11	11	34
1200S, 100E	9.9	9.9	46
1200S, 120E	11	11	32
1200S, 140E	11	11	35
1200S, 160E	9.5	9.8	34

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
1220S, 0E	9.5	9.5	38
1220S, 20E	9.8	9.5	37
1220S, 40E	9.8	9.8	29
1220S, 60E	11	11	46
1220S, 80E	10	11	37
1220S, 100E	10	10	32
1220S, 120E	11	11	48
1220S, 140E	10	10	28
1220S, 160E	8.4	7.0	38
1240S, 0E	9.9	8.4	25
1240S, 20E	9.8	10	35
1240S, 40E	11	11	29
1240S, 60E	10	10	28
1240S, 80E	10	11	49
1240S, 100E	10	10	31
1240S, 120E	10	10	40
1240S, 140E	11	11	34
1240S, 160E	10	10	46
1260S, 0E	10	9.9	25
1260S, 20E	11	10	69
1260S, 40E	11	11	35
1260S, 60E	11	11	28
1260S, 80E	6.4	6.7	28
1260S, 100E	9.8	9.5	20
1260S, 120E	10	11	55
1260S, 140E	11	12	69
1260S, 160E	10	11	48
1260S, 180E	10	10	38
1280S, 0E	8.7	8.4	29
1280S, 20E	10	10	31
1280S, 40E	11	10	37
1280S, 60E	6.4	4.7	34
1280S, 80E	5.7	5.4	29
1280S, 100E	--a	--	--
1280S, 120E	11	11	40
1280S, 140E	11	12	43
1280S, 160E	11	11	51
1280S, 180E	12	12	57

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
1300S, 0E	9.5	8.1	35
1300S, 20E	11	11	63
1300S, 40E	11	10	40
1300S, 60E	8.0	9.8	37
1300S, 80E	5.4	5.7	28
1300S, 100E	-- <sup>a</sup>	--	--
1300S, 120E	-- <sup>a</sup>	--	--
1300S, 140E	-- <sup>a</sup>	--	--
1300S, 160E	12	14	49
1300S, 180E	12	13	58
1320S, 0E	9.8	10	17
1320S, 20E	11	11	52
1320S, 40E	10	11	68
1320S, 60E	10	10	52
1320S, 80E	6.0	5.4	37
1320S, 100E	-- <sup>a</sup>	--	--
1320S, 120E	-- <sup>a</sup>	--	--
1320S, 140E	-- <sup>a</sup>	--	--
1320S, 160E	12	13	54
1320S, 180E	12	13	62
1340S, 0E	9.8	9.8	32
1340S, 20E	10	11	38
1340S, 40E	10	10	35
1340S, 60E	9.9	10	29
1340S, 80E	6.0	6.0	26
1340S, 100E	-- <sup>a</sup>	--	--
1340S, 120E	-- <sup>a</sup>	--	--
1340S, 140E	-- <sup>a</sup>	--	--
1340S, 160E	11	10	58
1340S, 180E	11	13	69
1360S, 0E	8.0	8.0	22
1360S, 20E	10	11	46
1360S, 40E	11	11	40
1360S, 60E	10	11	34
1360S, 80E	10	11	37
1360S, 100E	10	11	45
1360S, 120E	11	11	49

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
1360S, 140E	10	9.9	34
1360S, 160E	11	11	40
1360S, 180E	12	12	34
1380S, 0E	9.8	9.8	26
1380S, 20E	11	11	42
1380S, 40E	10	11	63
1380S, 60E	10	10	42
1380S, 80E	10	11	37
1380S, 100E	12	12	66
1380S, 120E	10	11	31
1380S, 140E	9.8	10	42
1380S, 160E	12	11	62
1380S, 180E	12	13	75
1400S, 0E	9.8	8.0	28
1400S, 20E	11	11	72
1400S, 40E	9.8	9.8	31
1400S, 60E	10	11	57
1400S, 80E	11	12	58
1400S, 100E	9.8	10	45
1400S, 120E	6.7	7.4	38
1400S, 140E	6.7	6.7	31
1400S, 160E	12	11	65
1400S, 180E	11	11	48
1420S, 0E	8.7	8.0	22
1420S, 20E	8.0	10	48
1420S, 40E	8.4	11	45
1420S, 60E	-- <sup>b</sup>	--	--
1420S, 80E	-- <sup>b</sup>	--	--
1420S, 100E	7.4	8.0	42
1420S, 120E	7.4	8.0	42
1420S, 140E	6.0	6.7	38
1420S, 160E	12	13	69
1420S, 180E	11	12	57
1440S, 0E	8.7	8.4	31
1440S, 20E	10	11	49
1440S, 40E	11	11	51
1440S, 60E	10	12	63

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
1440S, 80E	-- <sup>b</sup>	--	--
1440S, 100E	9.8	9.5	37
1440S, 120E	6.7	6.0	25
1440S, 140E	6.7	6.7	43
1440S, 160E	11	12	34
1440S, 180E	11	11	48
1460S, 0E	8.0	8.7	32
1460S, 20E	10	11	52
1460S, 40E	6.7	6.7	26
1460S, 60E	7.4	7.4	55
1460S, 80E	6.7	7.4	55
1460S, 100E	13	14	57
1460S, 120E	6.7	7.0	29
1460S, 140E	8.7	9.8	42
1460S, 160E	12	10	45
1460S, 180E	11	11	46
1480S, 0E	8.0	8.0	34
1480S, 20E	11	11	42
1480S, 40E	11	11	52
1480S, 60E	11	11	52
1480S, 80E	12	12	55
1480S, 100E	12	12	35
1480S, 120E	7.4	7.7	40
1480S, 140E	11	11	60
1480S, 160E	11	10	46
1480S, 180E	11	10	45
1500S, 0E	8.0	8.4	23
1500S, 20E	10	10	38
1500S, 40E	11	10	62
1500S, 60E	11	11	42
1500S, 80E	12	11	52
1500S, 100E	12	12	32
1500S, 120E	9.5	8.7	25
1500S, 140E	8.4	8.0	32
1500S, 160E	11	10	55
1500S, 180E	10	10	35

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT GRID LINE INTERSECTIONS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at the Surface ( $\mu\text{rad/h}$ )
1520S, 0E	8.4	8.4	34
1520S, 20E	7.4	7.0	28
1520S, 40E	7.4	7.0	25
1520S, 60E	8.7	7.7	31
1520S, 80E	8.0	7.4	26
1520S, 100E	8.7	8.4	49
1520S, 120E	8.0	7.4	42
1520S, 140E	7.4	7.0	31
1520S, 160E	11	10	37
1520S, 180E	10	10	40

<sup>a</sup> Measurements not taken due to presence of gravel piles.<sup>b</sup> Measurements not taken due to presence of the Maintenance Building.

TABLE 3  
DIRECT RADIATION LEVELS AT SELECTED LOCATIONS  
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Location <sup>a</sup>	Grid Point	Exposure Rate (.R/h)		Surface Dose Rate (.rad/h)	Soil Sample <sup>b</sup>
		at Contact Before Sampling	After Sampling		
1	514S,300E	39	30	195	B1
2	500S,176E	28	30	131	B2
3	111S,170E	55	98	150	B3
4	782S,169E	79	200	282	B4
5	796S,170E	130	430	490	B5
6	799S,173E	94	200	564	B6
7	809S,172E	67	120	244	B7
8	1280S,126E	200	410	618	B8
9	1260S,158E	170	55	808	B9
10	1460S, 91E	55	120	207	B10
11	1471S, 97E	35	59	149	B11
12	1458S, 91E	45	94	167	B12
13	1455S,105E	26	53	130	B13
14	1506S,111E	24	43	89	B14
15	1488S,118E	22	41	112	B15
16	1239S,138E	32	41	147	B16
17	1233S,137E	28	37	140	B17
18	1175S,114E	39	28	182	B18
19	1107S,216E	160	280	571	B19
20	1087S,217E	280	43	1056	B20
21	1054S,209E	39	35	234	B21
22	1062S,216E	79	120	288	B22

<sup>a</sup> Refer to Figures 3 and 4.

<sup>b</sup> Soil concentrations are presented in Table 5.

TABLE 4  
RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci/g}$ ) <sup>a</sup>			
		Ra-226	U-235	U-238	Cs-137
1	3205, 20E	0.98 ± 0.24 <sup>b</sup>	<0.24	<3.48	0.16 ± 0.12
2	3215, 60E	1.03 ± 0.24	<0.24	<3.78	0.75 ± 0.14
3	3235, 140E	0.72 ± 0.26	<0.24	<3.19	0.29 ± 0.16
4	3205, 140E	1.10 ± 0.26	<0.24	<6.42	1.41 ± 0.20
5	3205, 160E	0.83 ± 0.22	<0.24	<4.30	0.35 ± 0.10
6	3205, 220E	2.30 ± 0.42	<0.24	<7.65	0.96 ± 0.22
7	3205, 260E	0.43 ± 0.24	<0.24	6.16 ± 11.12	0.39 ± 0.12
8	3205, 300E	1.17 ± 0.26	<0.24	<4.34	0.49 ± 0.12
9	3205, 340E	<0.17	<0.24	<4.55	0.46 ± 0.16
10	3205, 380E	0.59 ± 0.20	<0.24	<4.56	0.59 ± 0.12
11	3205, 420E	0.50 ± 0.16	<0.24	<3.42	0.55 ± 0.14
12	3205, 460E	0.58 ± 0.22	<0.24	<3.55	0.31 ± 0.10
13	3205, 500E	0.57 ± 0.22	<0.24	<2.56	0.60 ± 0.12
14	3205, 540E	0.61 ± 0.18	<0.24	7.04 ± 10.24	0.64 ± 0.12
15	3205, 580E	0.43 ± 0.28	<0.24	4.90 ± 8.80	0.64 ± 0.12
16	3205, 620E	0.37 ± 0.16	<0.24	<3.67	0.64 ± 0.12
17	3205, 660E	0.54 ± 0.22	<0.24	<3.91	0.42 ± 0.10
18	3205, 700E	0.51 ± 0.26	<0.24	<5.17	0.84 ± 0.10
19	3205, 740E	0.54 ± 0.22	<0.24	<3.21	0.46 ± 0.12
20	3205, 780E	0.54 ± 0.26	<0.24	<4.04	0.68 ± 0.14
21	3405, 40E	0.43 ± 0.22	<0.24	<4.64	0.50 ± 0.14
22	3405, 80E	0.44 ± 0.20	<0.24	<4.10	0.64 ± 0.16
23	3405, 120E	0.67 ± 0.32	<0.24	<4.13	0.54 ± 0.16
24	3405, 160E	0.53 ± 0.20	0.61 ± 0.60	<3.47	0.46 ± 0.14
25	3405, 200E	0.39 ± 0.20	<0.24	<3.69	0.55 ± 0.14
26	3405, 240E	0.51 ± 0.18	<0.24	<4.40	0.31 ± 0.14
27	3405, 280E	0.60 ± 0.22	<0.24	<3.28	<0.03
28	3405, 320E	0.52 ± 0.22	<0.24	<4.19	<0.04
29	3405, 360E	0.89 ± 0.32	<0.24	<4.30	0.26 ± 0.10
30	3405, 400E	0.41 ± 0.20	<0.24	<5.75	0.12 ± 0.12
31	3405, 440E	0.54 ± 0.20	<0.24	<3.38	0.10 ± 0.08
32	3405, 480E	0.59 ± 0.28	<0.24	<2.75	0.09 ± 0.10
33	3405, 520E	0.75 ± 0.22	<0.24	<3.83	0.08 ± 0.10
34	3405, 560E	0.67 ± 0.24	<0.24	<4.17	0.11 ± 0.10
35	3405, 600E	0.47 ± 0.32	<0.24	<3.81	0.68 ± 0.14
36	3405, 640E	0.51 ± 0.30	<0.24	<5.11	0.17 ± 0.10
37	3405, 680E	0.76 ± 0.22	<0.24	<4.07	<0.03
38	3405, 720E	0.48 ± 0.26	<0.24	<4.30	0.16 ± 0.12

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci/g}$ )			
		Ra-226	U-235	U-238	Cs-137
59	340S, 760E	0.53 ± 0.20	<0.23	<3.95	0.25 ± 0.10
60	360S, 20E	0.51 ± 0.22	<0.26	<4.41	0.28 ± 0.10
61	360S, 60E	0.59 ± 0.26	<0.26	<3.56	0.30 ± 0.12
62	360S, 100E	0.68 ± 0.24	<0.24	<4.52	<0.04
63	360S, 140E	0.40 ± 0.18	<0.24	<3.49	0.42 ± 0.14
64	360S, 180E	0.36 ± 0.20	<0.24	<3.11	0.47 ± 0.12
65	360S, 220E	0.51 ± 0.20	<0.25	<3.87	0.62 ± 0.16
66	360S, 260E	0.33 ± 0.16	<0.24	<4.23	0.05 ± 0.03
67	360S, 300E	0.75 ± 0.24	<0.24	<4.36	<0.05
68	360S, 340E	0.56 ± 0.20	<0.27	<5.18	<0.04
69	360S, 380E	0.37 ± 0.22	<0.20	<4.42	<0.03
70	360S, 420E	0.59 ± 0.20	<0.24	<4.67	<0.04
71	360S, 460E	0.65 ± 0.20	<0.26	<3.16	<0.04
72	360S, 500E	0.69 ± 0.24	<0.24	<3.91	0.05 ± 0.06
73	360S, 540E	0.71 ± 0.26	<0.28	<3.18	0.14 ± 0.12
74	360S, 580E	0.41 ± 0.18	<0.24	<3.30	0.11 ± 0.08
75	360S, 620E	<0.13	<0.22	<3.30	0.60 ± 0.12
76	360S, 660E	0.33 ± 0.26	<0.23	<3.94	0.92 ± 0.14
77	360S, 700E	0.53 ± 0.22	<0.24	<3.51	<0.03
78	360S, 740E	0.52 ± 0.24	<0.24	<3.51	0.19 ± 0.10
79	380S, 40E	0.71 ± 0.30	<0.33	<3.07	0.72 ± 0.16
80	380S, 80E	0.63 ± 0.20	<0.24	<4.20	0.63 ± 0.12
81	380S, 120E	0.36 ± 0.24	<0.12	<5.14	1.04 ± 0.26
82	380S, 160E	0.87 ± 0.26	0.33 ± 0.6?	<4.52	1.22 ± 0.22
83	380S, 200E	0.50 ± 0.28	<0.22	<3.90	0.54 ± 0.16
84	380S, 240E	0.45 ± 0.20	<0.24	<4.66	0.38 ± 0.14
85	380S, 280E	0.58 ± 0.24	<0.27	<4.80	<0.05
86	380S, 320E	0.37 ± 0.30	<0.24	<4.18	0.10 ± 0.10
87	380S, 360E	0.63 ± 0.32	<0.24	<4.89	0.20 ± 0.16
88	380S, 400E	0.51 ± 0.24	<0.24	<4.70	<0.04
89	380S, 440E	0.70 ± 0.24	<0.24	<4.61	<0.04
90	380S, 480E	0.43 ± 0.22	<0.24	<3.18	0.06 ± 0.03
91	380S, 520E	0.51 ± 0.20	<0.25	<3.86	0.35 ± 0.10
92	380S, 560E	0.53 ± 0.22	<0.27	<3.01	<0.04
93	380S, 600E	0.73 ± 0.24	<0.28	<3.49	0.18 ± 0.12
94	380S, 640E	0.59 ± 0.20	<0.25	<3.59	0.24 ± 0.10
95	380S, 680E	0.62 ± 0.22	<0.24	<5.27	0.37 ± 0.14
96	380S, 720E	0.22 ± 0.20	<0.24	<4.04	0.18 ± 0.12

TABLE 4, cont.

 RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
 FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations (pCi/g)			
		Ra-226	U-235	U-238	Cs-137
77	400S, 20E	0.66 ± 0.24	0.29 ± 0.61	<4.50	0.55 ± 0.14
78	400S, 60E	1.24 ± 0.32	<0.30	<3.15	0.53 ± 0.10
79	400S, 140E	0.63 ± 0.24	<0.24	<3.77	0.76 ± 0.17
80	400S, 140E	0.41 ± 0.18	0.32 ± 0.46	<4.48	0.30 ± 0.14
81	400S, 180E	0.45 ± 0.24	<0.24	<6.03	0.78 ± 0.26
82	400S, 220E	0.39 ± 0.22	<0.26	<4.71	0.40 ± 0.14
83	400S, 260E	0.40 ± 0.24	<0.24	<4.66	0.50 ± 0.16
84	400S, 300E	0.60 ± 0.22	<0.24	<4.48	0.15 ± 0.14
85	400S, 340E	0.49 ± 0.26	<0.24	<4.81	0.41 ± 0.12
86	400S, 380E	0.45 ± 0.20	<0.24	<4.00	<0.06
87	400S, 420E	0.40 ± 0.16	<0.24	<4.67	0.34 ± 0.10
88	400S, 460E	0.70 ± 0.16	<0.21	<3.86	0.04 ± 0.10
89	400S, 500E	0.55 ± 0.10	<0.24	<4.06	<0.03
90	400S, 540E	0.38 ± 0.24	<0.24	<3.79	0.24 ± 0.14
91	400S, 580E	0.74 ± 0.18	<0.24	<4.10	0.14 ± 0.06
92	400S, 620E	0.54 ± 0.16	<0.15	<3.32	0.32 ± 0.10
93	400S, 660E	0.49 ± 0.18	<0.24	<3.59	0.49 ± 0.12
94	420S, 40E	0.52 ± 0.22	<0.24	<4.16	0.41 ± 0.12
95	420S, 80E	0.48 ± 0.22	<0.23	<4.77	0.53 ± 0.12
96	420S, 120E	0.58 ± 0.20	<0.24	<4.30	0.35 ± 0.12
97	420S, 160E	0.61 ± 0.30	<0.24	<5.28	2.00 ± 0.26
98	420S, 200E	0.65 ± 0.24	<0.23	<4.16	0.21 ± 0.12
99	420S, 240E	0.45 ± 0.20	<0.24	5.76 ± 12.76	0.49 ± 0.12
100	420S, 280E	0.55 ± 0.22	<0.25	<4.80	0.71 ± 0.16
101	420S, 320E	0.52 ± 0.18	<0.24	<4.61	0.71 ± 0.12
102	420S, 360E	0.49 ± 0.18	<0.24	<4.61	0.43 ± 0.12
103	420S, 400E	0.39 ± 0.18	<0.24	<3.33	0.04 ± 0.06
104	420S, 440E	0.44 ± 0.18	<0.22	<4.14	0.07 ± 0.10
105	420S, 480E	0.66 ± 0.26	0.54 ± 0.63	<5.16	0.10 ± 0.06
106	420S, 520E	0.70 ± 0.20	<0.23	<3.09	<0.03
107	420S, 560E	0.60 ± 0.20	<0.20	<4.34	<0.05
108	420S, 600E	0.58 ± 0.24	<0.23	<4.65	0.35 ± 0.12
109	420S, 640E	0.52 ± 0.20	<0.24	<3.85	0.71 ± 0.16
110	440S, 20E	0.48 ± 0.18	<0.24	5.75 ± 11.72	0.34 ± 0.12
111	440S, 60E	0.65 ± 0.20	<0.24	<4.37	0.39 ± 0.10
112	440S, 100E	0.54 ± 0.20	<0.25	<4.92	0.40 ± 0.12
113	440S, 140E	0.72 ± 0.22	<0.24	<4.74	0.40 ± 0.12
114	440S, 180E	0.57 ± 0.22	<0.27	<5.01	0.80 ± 0.18

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci/g}$ )			
		Ra-226	U-235	U-238	Cs-137
115	440S,220E	0.59 $\pm$ 0.24	<0.24	<3.77	0.08 $\pm$ 0.08
116	440S,260E	0.58 $\pm$ 0.20	<0.24	<5.33	0.64 $\pm$ 0.12
117	440S,300E	0.41 $\pm$ 0.24	<0.24	<3.76	0.38 $\pm$ 0.16
118	440S,340E	0.48 $\pm$ 0.30	<0.24	<5.15	0.91 $\pm$ 0.18
119	440S,380E	0.42 $\pm$ 0.20	<0.24	<3.67	0.46 $\pm$ 0.12
120	440S,420E	0.49 $\pm$ 0.20	<0.24	<3.85	0.16 $\pm$ 0.08
121	440S,460E	0.52 $\pm$ 0.18	<0.24	<3.46	0.21 $\pm$ 0.10
122	440S,500E	0.50 $\pm$ 0.20	<0.13	4.82 $\pm$ 10.84	0.09 $\pm$ 0.10
123	440S,540E	0.66 $\pm$ 0.20	<0.24	<4.41	0.06 $\pm$ 0.02
124	440S,580E	0.58 $\pm$ 0.24	<0.22	<3.27	0.12 $\pm$ 0.08
125	440S,620E	0.26 $\pm$ 0.28	<0.24	<5.07	0.29 $\pm$ 0.06
126	460S,40E	0.51 $\pm$ 0.20	<0.24	<3.03	0.39 $\pm$ 0.20
127	460S,80E	0.34 $\pm$ 0.26	0.17 $\pm$ 0.50	6.88 $\pm$ 6.44	0.60 $\pm$ 0.14
128	460S,120E	0.42 $\pm$ 0.24	<0.24	<4.59	0.48 $\pm$ 0.12
129	460S,160E	0.53 $\pm$ 0.32	<0.24	<4.95	1.75 $\pm$ 0.20
130	460S,200E	0.67 $\pm$ 0.28	<0.24	<3.54	0.62 $\pm$ 0.16
131	460S,240E	0.37 $\pm$ 0.24	<0.24	<2.59	0.48 $\pm$ 0.14
132	460S,280E	0.74 $\pm$ 0.20	<0.24	<3.23	0.86 $\pm$ 0.14
133	460S,320E	0.31 $\pm$ 0.20	<0.24	<4.44	0.45 $\pm$ 0.12
134	460S,360E	0.57 $\pm$ 0.20	<0.24	<3.77	0.70 $\pm$ 0.14
135	460S,400E	0.55 $\pm$ 0.24	<0.24	<4.86	<0.04
136	460S,440E	0.57 $\pm$ 0.20	<0.24	<4.28	0.42 $\pm$ 0.12
137	460S,480E	0.64 $\pm$ 0.20	<0.24	<3.93	<0.03
138	460S,520E	0.65 $\pm$ 0.20	<0.24	10.8 $\pm$ 9.62	0.09 $\pm$ 0.10
139	460S,560E	0.67 $\pm$ 0.20	<0.24	<4.73	0.79 $\pm$ 0.14
140	460S,60E	0.50 $\pm$ 0.22	<0.24	6.34 $\pm$ 13.34	0.48 $\pm$ 0.12
141	460S,640E	0.45 $\pm$ 0.28	<0.24	<1.50	0.62 $\pm$ 0.14
142	480S,100E	0.30 $\pm$ 0.18	<0.24	<4.84	0.67 $\pm$ 0.18
143	480S,140E	0.55 $\pm$ 0.26	<0.24	<4.57	0.32 $\pm$ 0.12
144	480S,180E	0.21 $\pm$ 0.20	<0.24	<4.49	0.54 $\pm$ 0.14
145	480S,220E	0.77 $\pm$ 0.22	<0.24	<4.54	0.26 $\pm$ 0.10
146	480S,260E	0.44 $\pm$ 0.16	<0.24	<4.36	0.83 $\pm$ 0.16
147	480S,300E	0.60 $\pm$ 0.18	0.37 $\pm$ 0.48	<4.28	1.06 $\pm$ 0.18
148	480S,340E	0.56 $\pm$ 0.30	<0.24	<4.82	1.06 $\pm$ 0.18
149	480S,380E	0.31 $\pm$ 0.24	<0.24	<6.62	0.94 $\pm$ 0.16
150	480S,420E	0.51 $\pm$ 0.22	<0.24	<4.89	0.09 $\pm$ 0.08
151	480S,460E	0.60 $\pm$ 0.20	<0.24	<4.06	<0.04
152	480S,500E	0.43 $\pm$ 0.22	<0.24	<4.23	0.21 $\pm$ 0.08

TABLE 4, cont.

**RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS**

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci/g}$ )			
		Ra-226	V-235	U-238	Cs-137
153	500S, 540E	0.59 $\pm$ 0.18	<0.24	<4.06	0.16 $\pm$ 0.10
154	500S, 40E	0.47 $\pm$ 0.18	0.31 $\pm$ 0.44	<1.62	0.54 $\pm$ 0.16
155	500S, 80E	0.44 $\pm$ 0.22	<0.24	<3.71	0.54 $\pm$ 0.14
156	500S, 120E	0.32 $\pm$ 0.24	<0.24	<6.22	0.98 $\pm$ 0.18
157	500S, 160E	0.65 $\pm$ 0.34	<0.32	<4.52	0.48 $\pm$ 0.18
158	500S, 200E	0.05 $\pm$ 0.20	<0.24	<3.42	0.55 $\pm$ 0.14
159	500S, 240E	0.68 $\pm$ 0.20	<0.24	<4.99	0.53 $\pm$ 0.14
160	500S, 280E	0.58 $\pm$ 0.22	0.26 $\pm$ 0.66	<3.10	0.53 $\pm$ 0.14
161	500S, 320E	0.68 $\pm$ 0.24	<0.24	<4.22	0.69 $\pm$ 0.14
162	500S, 360E	0.46 $\pm$ 0.26	0.68 $\pm$ 0.54	<5.13	0.88 $\pm$ 0.16
163	500S, 400E	0.40 $\pm$ 0.34	<0.24	<3.59	1.45 $\pm$ 0.20
164	500S, 440E	0.44 $\pm$ 0.18	<0.25	<5.15	0.32 $\pm$ 0.16
165	500S, 480E	0.61 $\pm$ 0.20	<0.24	<4.68	<0.64
166	500S, 520E	0.50 $\pm$ 0.22	0.79 $\pm$ 0.52	<4.08	0.50 $\pm$ 0.14
167	520S, 20E	0.49 $\pm$ 0.18	<0.24	<5.63	0.58 $\pm$ 0.12
168	520S, 60E	0.45 $\pm$ 0.18	<0.24	<4.57	0.53 $\pm$ 0.12
169	520S, 100E	1.04 $\pm$ 0.26	<0.25	<4.46	0.78 $\pm$ 0.16
170	520S, 140E	0.49 $\pm$ 0.18	<0.24	<4.47	0.59 $\pm$ 0.14
171	520S, 180E	0.45 $\pm$ 0.26	<0.24	<5.63	0.74 $\pm$ 0.16
172	520S, 220E	<0.13	<0.24	<3.16	0.08 $\pm$ 0.10
173	520S, 260E	0.51 $\pm$ 0.22	<0.23	<3.45	0.45 $\pm$ 0.12
174	520S, 300E	0.42 $\pm$ 0.24	<0.24	<2.59	0.41 $\pm$ 0.10
175	520S, 340E	0.47 $\pm$ 0.20	<0.24	<4.14	0.31 $\pm$ 0.12
176	520S, 380E	0.65 $\pm$ 0.22	<0.24	<5.04	0.73 $\pm$ 0.14
177	520S, 420E	0.43 $\pm$ 0.20	<0.24	<3.78	0.26 $\pm$ 0.14
178	520S, 460E	0.63 $\pm$ 0.22	<0.24	<4.93	0.81 $\pm$ 0.14
179	540S, 40E	0.30 $\pm$ 0.18	<0.24	<2.80	0.40 $\pm$ 0.12
180	540S, 80E	0.60 $\pm$ 0.22	<0.24	<4.71	0.77 $\pm$ 0.14
181	540S, 120E	0.62 $\pm$ 0.30	<0.24	5.27 $\pm$ 9.74	0.43 $\pm$ 0.16
182	540S, 160E	0.37 $\pm$ 0.16	<0.24	<3.64	0.46 $\pm$ 0.12
183	540S, 200E	0.59 $\pm$ 0.22	<0.24	<4.56	1.60 $\pm$ 0.20
184	540S, 240E	0.51 $\pm$ 0.24	<0.24	<2.57	0.25 $\pm$ 0.10
185	540S, 280E	0.72 $\pm$ 0.22	<0.24	4.88 $\pm$ 9.14	0.48 $\pm$ 0.10
186	540S, 320E	0.47 $\pm$ 0.16	<0.24	<3.58	<0.93
187	540S, 360E	0.46 $\pm$ 0.20	<0.24	<3.49	0.43 $\pm$ 0.12
188	540S, 400E	0.46 $\pm$ 0.20	<0.22	<3.35	0.54 $\pm$ 0.14
189	540S, 440E	0.44 $\pm$ 0.20	<0.24	<3.92	0.13 $\pm$ 0.10
190	540S, 480E	0.64 $\pm$ 0.18	<0.24	3.95 $\pm$ 16.18	0.50 $\pm$ 0.12
191	540S, 520E	0.66 $\pm$ 0.20	<0.24	<5.40	0.45 $\pm$ 0.12

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci}/\text{g}$ )			
		Ra-226	U-235	U-238	U-232
192	540S, 400E	0.49 ± 0.18	<0.24	<3.26	0.21 ± 0.08
193	540S, 440E	0.37 ± 0.18	<0.18	<3.46	0.60 ± 0.10
194	560S, 20E	0.59 ± 0.20	<0.24	<7.81	0.62 ± 0.12
195	560S, 60E	0.45 ± 0.18	<0.24	<3.76	0.11 ± 0.08
196	560S, 100E	0.63 ± 0.15	<0.24	<3.73	0.51 ± 0.12
197	560S, 140E	0.52 ± 0.20	<0.24	<4.28	0.70 ± 0.14
198	560S, 160E	0.56 ± 0.20	<0.24	<3.67	0.46 ± 0.18
199	560S, 220E	0.43 ± 0.18	<0.24	<4.02	1.02 ± 0.16
200	560S, 260E	0.13 ± 0.18	<0.24	<3.26	0.46 ± 0.14
201	560S, 300E	0.66 ± 0.18	<0.24	<4.06	0.36 ± 0.14
202	560S, 140L	0.43 ± 0.22	<0.24	5.78 ± 12.66	0.12 ± 0.10
203	560S, 380E	0.53 ± 0.16	<0.24	<4.27	0.25 ± 0.08
204	560S, 420E	0.55 ± 0.18	<0.21	<4.63	0.23 ± 0.08
205	580S, 40E	0.31 ± 0.16	<0.24	<3.60	0.86 ± 0.14
206	580S, 80E	0.54 ± 0.20	<0.24	<3.78	0.47 ± 0.12
207	580S, 120E	0.50 ± 0.22	<0.24	<4.68	0.60 ± 0.12
208	580S, 160E	0.53 ± 0.26	<0.24	<5.74	3.74 ± 0.30
209	580S, 200E	0.51 ± 0.20	<0.24	<3.02	1.79 ± 0.22
210	580S, 240E	0.60 ± 0.26	<0.24	<4.32	0.66 ± 0.14
211	580S, 280E	0.68 ± 0.24	<0.24	<5.06	1.12 ± 0.18
212	580S, 320E	0.65 ± 0.16	<0.24	<4.54	0.56 ± 0.14
213	600S, 20E	0.53 ± 0.16	<0.24	<4.11	0.54 ± 0.12
214	600S, 60E	0.34 ± 0.18	<0.24	<6.10	0.34 ± 0.14
215	600S, 100E	0.38 ± 0.16	<0.24	<3.07	0.46 ± 0.14
216	600S, 140E	0.52 ± 0.24	<0.24	7.81 ± 11.04	0.53 ± 0.14
217	600S, 180E	0.54 ± 0.24	<0.24	<3.38	0.51 ± 0.14
218	600S, 220E	0.41 ± 0.16	<0.24	<2.97	0.42 ± 0.10
219	600S, 260E	0.40 ± 0.16	<0.24	<3.10	0.39 ± 0.12
220	600S, 300E	0.41 ± 0.18	<0.24	5.55 ± 7.68	0.15 ± 0.05
221	620S, 40E	0.44 ± 0.20	<0.24	<4.10	0.36 ± 0.12
222	620S, 80E	0.48 ± 0.14	<0.24	<3.07	0.20 ± 0.06
223	620S, 120E	0.24 ± 0.16	<0.24	<4.23	0.19 ± 0.05
224	620S, 160E	0.47 ± 0.16	<0.24	<4.61	0.31 ± 0.04
225	620S, 200E	0.40 ± 0.16	<0.24	7.30 ± 8.54	0.31 ± 0.10
226	620S, 240E	0.46 ± 0.16	<0.24	<4.01	0.36 ± 0.12
227	620S, 280E	0.39 ± 0.21	<0.24	<2.38	0.47 ± 0.12
228	620S, 320E	0.49 ± 0.22	<0.24	<3.82	0.42 ± 0.12
229	640S, 20E	0.44 ± 0.20	<0.20	<2.65	0.34 ± 0.10
230	640S, 60E	0.29 ± 0.14	<0.24	<3.26	0.31 ± 0.12

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci/g}$ )			
		Ra-226	U-235	U-238	Cs-137
231	640S,100E	0.41 ± 0.22	<0.24	<1.24	0.24 ± 0.12
232	640S,140E	0.44 ± 0.18	<0.24	8.20 ± 7.52	0.77 ± 0.14
233	640S,180E	0.71 ± 0.24	<0.24	<3.02	0.25 ± 0.10
234	640S,220E	0.55 ± 0.18	<0.24	<1.52	0.45 ± 0.10
235	640S,260E	0.79 ± 0.20	<0.24	<3.48	0.47 ± 0.14
236	640S,300E	0.40 ± 0.18	<0.24	<4.22	0.13 ± 0.10
237	660S, 40E	0.40 ± 0.12	<0.24	<4.14	0.42 ± 0.12
238	660S, 80E	0.36 ± 0.14	<0.24	<2.77	0.50 ± 0.12
239	660S,120E	1.35 ± 0.22	<0.24	<4.13	0.51 ± 0.12
240	660S,160E	0.63 ± 0.16	<0.24	7.04 ± 6.12	0.47 ± 0.12
241	660S,200E	0.50 ± 0.16	<0.24	<3.16	0.22 ± 0.05
242	660S,240E	0.29 ± 0.22	<0.24	<3.61	0.46 ± 0.12
243	660S,280E	0.42 ± 0.22	<0.24	<3.04	0.43 ± 0.12
244	660S,320E	0.36 ± 0.16	<0.24	<3.35	0.59 ± 0.12
245	680S, 20E	0.45 ± 0.16	<0.24	<1.67	0.39 ± 0.12
246	680S, 60E	0.40 ± 0.14	<0.24	<3.19	0.56 ± 0.10
247	680S,100E	0.36 ± 0.16	<0.20	<3.14	0.45 ± 0.12
248	680S,140E	0.49 ± 0.16	<0.24	<3.61	<0.03
249	680S,180E	0.46 ± 0.12	0.42 ± 0.36	<3.29	0.18 ± 0.10
250	680S,220E	0.39 ± 0.18	<0.24	<3.90	0.33 ± 0.10
251	680S,260E	0.49 ± 0.16	<0.22	<2.96	0.46 ± 0.16
252	680S,300E	0.30 ± 0.20	<0.24	6.90 ± 8.84	0.47 ± 0.12
253	700S, 40E	0.15 ± 0.16	<0.24	<2.28	1.24 ± 0.16
254	700S, 80E	0.28 ± 0.14	<0.24	<3.04	0.16 ± 0.05
255	700S,120E	0.40 ± 0.20	<0.24	<3.08	0.55 ± 0.12
256	700S,160E	0.53 ± 0.22	<0.24	<5.40	0.78 ± 0.12
257	700S,200E	0.48 ± 0.16	<0.24	<4.18	0.23 ± 0.05
258	700S,240E	0.36 ± 0.16	<0.24	<1.87	0.63 ± 0.12
259	700S,280E	0.41 ± 0.18	<0.24	<1.05	0.22 ± 0.10
260	700S,320E	0.31 ± 0.16	<0.24	<3.92	0.80 ± 0.16
261	720S, 20E	0.18 ± 0.12	<0.14	<3.24	0.33 ± 0.10
262	720S, 60E	0.41 ± 0.16	<0.15	<3.81	0.67 ± 0.12
263	720S,100E	0.43 ± 0.20	<0.24	14.8 ± 13.28	0.41 ± 0.12
264	720S,140E	0.30 ± 0.16	<0.24	<2.79	0.49 ± 0.10
265	720S,180E	0.72 ± 0.22	<0.24	<1.87	0.70 ± 0.14
266	720S,220E	0.55 ± 0.20	<0.24	<4.17	0.15 ± 0.17
267	720S,260E	0.44 ± 0.16	<0.24	<4.49	0.56 ± 0.14
268	720S,300E	0.49 ± 0.18	<0.24	<1.69	0.67 ± 0.12
269	740S, 40E	0.43 ± 0.20	<0.22	<3.37	0.74 ± 0.10
270	740S, 80E	0.35 ± 0.18	<0.24	<2.97	0.47 ± 0.14
271	740S,120E	0.44 ± 0.20	0.18 ± 0.50	<4.42	0.24 ± 0.10
272	740S,160E	0.43 ± 0.16	<0.24	<2.64	0.16 ± 0.08
273	740S,200E	0.37 ± 0.28	<0.24	<4.06	0.37 ± 0.12

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations (pCi/g)			
		Ra-226	U-235	U-238	Cs-137
274	740S, 240E	0.38 ± 0.18	<0.24	<3.61	0.62 ± 0.12
275	740S, 280E	0.48 ± 0.16	<0.24	<4.35	0.46 ± 0.10
276	740S, 320E	0.24 ± 0.32	<0.24	5.29 ± 6.14	0.39 ± 0.12
277	760S, 24E	0.37 ± 0.16	<0.24	<2.46	0.23 ± 0.08
278	760S, 60E	0.66 ± 0.16	<0.24	<3.59	0.43 ± 0.10
279	760S, 100E	0.39 ± 0.15	<0.24	<4.05	0.51 ± 0.12
280	760S, 140E	0.55 ± 0.08	<0.17	1.95 ± 4.64	0.09 ± 0.04
281	760S, 160E	0.52 ± 0.14	<0.24	<4.66	1.15 ± 0.09
282	760S, 180E	0.97 ± 0.18	<0.24	<3.07	0.59 ± 0.12
283	760S, 220E	0.23 ± 0.28	<0.24	5.14 ± 8.16	0.61 ± 0.14
284	760S, 260E	0.40 ± 0.22	<0.24	4.96 ± 8.96	0.43 ± 0.12
285	760S, 300E	0.55 ± 0.22	<0.24	<3.81	0.39 ± 0.12
286	780S, 40E	0.48 ± 0.18	<0.24	<3.72	0.39 ± 0.10
287	780S, 80E	0.43 ± 0.24	<0.24	<3.55	0.10 ± 0.08
288	780S, 120E	0.41 ± 0.18	<0.22	<3.45	0.26 ± 0.08
289	780S, 160E	0.71 ± 0.22	<0.24	<2.71	0.19 ± 0.14
290	780S, 200E	1.09 ± 0.22	<0.24	<4.73	0.27 ± 0.08
291	780S, 240E	0.50 ± 0.16	<0.24	<2.97	0.15 ± 0.10
292	780S, 280E	0.53 ± 0.18	<0.24	<3.19	0.11 ± 0.10
293	800S, 20E	0.45 ± 0.16	<0.24	<3.71	0.41 ± 0.10
294	800S, 60E	0.42 ± 0.18	0.27 ± 0.59	<3.86	0.38 ± 0.10
295	800S, 100E	0.55 ± 0.18	<0.24	<3.99	0.65 ± 0.14
296	800S, 140E	0.34 ± 0.18	0.39 ± 0.44	<3.16	0.31 ± 0.08
297	800S, 180E	0.48 ± 0.20	0.42 ± 0.50	<4.15	0.48 ± 0.17
298	800S, 220E	0.54 ± 0.18	<0.24	<3.93	0.77 ± 0.14
299	800S, 260E	0.62 ± 0.16	<0.24	<3.77	<0.14
300	800S, 300E	0.45 ± 0.20	<0.24	<3.95	0.19 ± 0.10
301	820S, 40E	0.43 ± 0.20	<0.24	<3.41	0.10 ± 0.10
302	820S, 80E	0.49 ± 0.20	<0.24	<4.10	0.11 ± 0.08
303	820S, 120E	0.42 ± 0.16	<0.24	<3.77	0.26 ± 0.10
304	820S, 160E	0.52 ± 0.28	<0.24	<3.37	0.23 ± 0.10
305	820S, 200E	0.68 ± 0.24	<0.24	<4.41	0.97 ± 0.14
306	820S, 240E	0.59 ± 0.16	<0.24	<3.91	0.15 ± 0.10
307	820S, 280E	0.60 ± 0.20	<0.24	<3.63	0.13 ± 0.12
308	840S, 20E	0.40 ± 0.16	<0.24	5.09 ± 7.44	0.31 ± 0.10
309	840S, 60E	<0.12	<0.24	<3.74	0.21 ± 0.14
310	840S, 100E	0.48 ± 0.18	<0.24	<3.11	0.30 ± 0.14
311	840S, 140E	0.38 ± 0.20	<0.24	<4.26	0.63 ± 0.12
312	840S, 180E	0.58 ± 0.18	<0.24	4.89 ± 8.36	0.28 ± 0.10

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci/g}$ )			
		Ra-226	U-235	U-238	Cs-137
311	840S, 220E	0.76 ± 0.20	<0.24	<3.50	0.33 ± 0.10
314	840S, 260E	0.45 ± 0.16	<0.24	<4.17	0.34 ± 0.12
315	840S, 300E	0.31 ± 0.18	<0.24	<3.44	0.31 ± 0.14
316	860S, 40E	0.43 ± 0.22	<0.24	<3.20	0.27 ± 0.12
317	860S, 80E	0.52 ± 0.18	0.46 ± 0.71	<4.84	0.33 ± 0.10
318	860S, 120E	0.40 ± 0.22	<0.24	6.34 ± 6.38	0.30 ± 0.12
319	860S, 160E	0.53 ± 0.20	<0.24	<3.71	0.33 ± 0.10
320	860S, 200E	0.41 ± 0.20	<0.24	<3.79	0.36 ± 0.10
321	860S, 240E	0.50 ± 0.20	<0.24	<4.00	0.05 ± 0.08
322	860S, 280E	8.27 ± 0.62	<0.24	<6.41	0.36 ± 0.26
323	880S, 20E	0.40 ± 0.20	<0.24	5.57 ± 12.24	0.26 ± 0.10
324	880S, 60E	0.37 ± 0.22	<0.24	<2.82	0.35 ± 0.12
325	880S, 100E	0.81 ± 0.28	<0.24	<5.42	0.15 ± 0.12
326	880S, 140E	0.50 ± 0.24	<0.24	<3.84	0.37 ± 0.14
327	880S, 180E	0.44 ± 0.20	0.43 ± 0.50	<3.67	0.42 ± 0.12
328	880S, 220E	0.62 ± 0.20	<0.24	<3.68	0.50 ± 0.14
329	880S, 260E	0.39 ± 0.16	<0.24	<3.41	0.33 ± 0.10
330	880S, 300E	0.81 ± 0.24	<0.21	<3.30	0.23 ± 0.12
331	900S, 40E	0.30 ± 0.20	<0.24	<4.91	0.39 ± 0.12
332	900S, 80E	0.34 ± 0.22	<0.24	<4.14	0.40 ± 0.14
333	900S, 120E	0.68 ± 0.22	<0.24	<4.75	0.15 ± 0.10
334	900S, 160E	0.65 ± 0.20	<0.24	<4.33	0.15 ± 0.10
335	900S, 200E	0.38 ± 0.16	<0.24	<3.90	0.29 ± 0.08
336	900S, 240E	0.36 ± 0.20	<0.24	<5.47	0.17 ± 0.12
337	900S, 280E	0.52 ± 0.20	<0.24	<3.98	0.09 ± 0.10
338	920S, 20E	0.58 ± 0.20	<0.24	<3.58	0.24 ± 0.16
339	920S, 60E	0.43 ± 0.18	<0.24	<3.80	0.22 ± 0.08
340	920S, 100E	0.39 ± 0.28	<0.24	7.55 ± 7.84	0.45 ± 0.12
341	920S, 140E	0.56 ± 0.18	<0.24	<3.64	0.19 ± 0.10
342	920S, 180E	0.39 ± 0.26	<0.24	<3.74	0.53 ± 0.12
343	920S, 220E	0.40 ± 0.16	<0.24	<3.68	0.08 ± 0.06
344	920S, 260E	0.42 ± 0.20	<0.24	<3.73	0.37 ± 0.12
345	940S, 40E	0.43 ± 0.18	0.45 ± 0.56	<3.75	<0.07
346	940S, 80E	0.38 ± 0.20	<0.24	6.75 ± 8.78	0.33 ± 0.12
347	940S, 120E	0.52 ± 0.22	<0.24	<3.25	0.41 ± 0.12
348	940S, 160E	0.56 ± 0.18	<0.24	<2.95	0.21 ± 0.09
349	940S, 200E	0.58 ± 0.72	0.36 ± 0.66	<3.65	0.28 ± 0.10
350	940S, 240E	0.45 ± 0.22	<0.24	<3.42	0.12 ± 0.10
351	960S, 20E	0.71 ± 0.26	<0.24	<4.47	0.33 ± 0.12

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations (pCi/g)			
		Rb-226	U-235	U-238	Cs-137
352	980S, 60E	0.48 ± 0.24	<0.24	<4.56	0.34 ± 0.12
353	980S, 160E	0.50 ± 0.18	<0.24	<1.96	0.29 ± 0.16
354	980S, 140E	0.40 ± 0.20	<0.24	<3.30	0.20 ± 0.12
355	980S, 180E	0.70 ± 0.77	<0.24	<3.91	0.57 ± 0.14
356	980S, 220E	0.53 ± 0.18	<0.24	<4.26	0.56 ± 0.12
357	980S, 260E	0.43 ± 0.22	<0.24	<3.13	0.16 ± 0.14
358	980S, 40E	0.50 ± 0.24	<0.24	<4.60	0.23 ± 0.12
359	980S, 80E	0.61 ± 0.20	<0.24	<4.59	0.35 ± 0.18
360	980S, 120E	0.34 ± 0.28	<0.24	<4.11	0.19 ± 0.10
361	980S, 160E	0.49 ± 0.18	<0.24	<4.05	0.37 ± 0.12
362	980S, 200E	1.46 ± 0.24	<0.24	<2.74	0.42 ± 0.16
363	1000S, 20E	0.53 ± 0.24	<0.24	<3.73	0.20 ± 0.14
364	1000S, 60E	0.52 ± 0.18	<0.24	<3.91	0.45 ± 0.12
365	1000S, 100E	0.43 ± 0.18	<0.24	<3.70	0.31 ± 0.12
366	1000S, 140E	0.59 ± 0.20	<0.24	<3.91	0.29 ± 0.10
367	1000S, 180E	1.63 ± 0.26	<0.24	<2.67	0.44 ± 0.12
368	1020S, 40E	0.36 ± 0.28	<0.22	<2.98	0.29 ± 0.10
369	1020S, 80E	0.51 ± 0.18	0.41 ± 0.50	<4.69	0.36 ± 0.12
370	1020S, 120E	0.58 ± 0.22	<0.24	<3.41	0.55 ± 0.16
371	1020S, 160E	0.61 ± 0.22	<0.24	<5.18	0.70 ± 0.15
372	1020S, 200E	0.69 ± 0.22	<0.24	<2.66	1.57 ± 0.12
373	1040S, 20E	0.57 ± 0.20	<0.24	<5.20	0.52 ± 0.12
374	1040S, 60E	0.33 ± 0.20	<0.24	<3.61	0.61 ± 0.20
375	1040S, 100E	0.61 ± 0.18	<0.24	<4.65	0.56 ± 0.12
376	1040S, 140E	0.54 ± 0.20	<0.24	<5.20	0.57 ± 0.14
377	1040S, 180E	0.50 ± 0.20	<0.24	8.99 ± 10.36	0.68 ± 0.14
378	1050S, 40E	0.58 ± 0.22	<0.24	<5.48	0.57 ± 0.17
379	1050S, 80E	0.52 ± 0.20	<0.24	<2.98	0.20 ± 0.10
380	1050S, 120E	0.38 ± 0.14	<0.24	<3.24	0.53 ± 0.10
381	1050S, 160E	0.61 ± 0.20	<0.24	<1.07	0.14 ± 0.12
382	1050S, 200E	1.32 ± 0.26	<0.24	<3.90	0.73 ± 0.10
383	1050S, 240E	0.53 ± 0.24	<0.24	<3.16	0.63 ± 0.12
384	1060S, 60E	0.58 ± 0.22	<0.24	<3.66	0.49 ± 0.14
385	1060S, 100E	0.54 ± 0.20	0.51 ± 0.20	<4.42	0.39 ± 0.12
386	1050S, 140E	0.46 ± 0.22	<0.24	<4.02	0.14 ± 0.14
387	1020S, 160E	0.74 ± 0.24	<0.24	<4.51	0.76 ± 0.16
388	1100S, 40E	0.47 ± 0.18	<0.21	<2.57	0.34 ± 0.10
389	1100S, 80E	0.36 ± 0.16	<0.24	<4.26	0.14 ± 0.12
390	1100S, 120E	0.71 ± 0.22	<0.24	<3.89	0.40 ± 0.14

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations (pCi/g)			
		Ra-226	U-235	C-238	Gs-137
391	1100S, 160E	0.56 ± 0.20	<0.24	<5.17	0.06 ± 0.12
392	1120S, 20E	0.70 ± 0.30	<0.24	<3.79	0.94 ± 0.16
393	1120S, 60E	0.53 ± 0.22	<0.24	<4.05	0.56 ± 0.14
394	1120S, 100E	0.43 ± 0.20	<0.24	<5.24	0.53 ± 0.12
395	1120S, 140E	0.58 ± 0.22	<0.24	<3.87	0.39 ± 0.12
396	1120S, 180E	0.78 ± 0.12	<0.24	<4.97	0.78 ± 0.14
397	1140S, 40E	0.65 ± 0.20	<0.24	<3.82	0.47 ± 0.12
398	1140S, 80E	0.37 ± 0.20	<0.24	<4.33	0.69 ± 0.14
399	1140S, 120E	0.61 ± 0.22	<0.24	<2.82	0.12 ± 0.10
400	1140S, 160E	0.94 ± 0.20	0.44 ± 0.42	<4.71	<0.05
401	1160S, 20E	0.55 ± 0.20	<0.24	<3.95	0.52 ± 0.12
402	1160S, 60E	0.54 ± 0.24	<0.21	<3.49	0.36 ± 0.12
403	1160S, 100E	0.39 ± 0.20	<0.24	<3.17	0.58 ± 0.12
404	1160S, 140E	0.55 ± 0.24	<0.24	<2.25	0.11 ± 0.10
405	1160S, 180E	0.54 ± 0.18	<0.24	<3.08	0.14 ± 0.08
406	1180S, 40E	0.58 ± 0.26	<0.24	<4.52	0.30 ± 0.12
407	1180S, 80E	0.69 ± 0.24	<0.24	<4.77	0.31 ± 0.10
408	1180S, 120E	0.41 ± 0.24	<0.22	4.54 ± 8.64	0.33 ± 0.10
409	1180S, 160E	0.42 ± 0.20	<0.24	<3.59	0.19 ± 0.12
410	1200S, 20E	0.74 ± 0.22	<0.24	<3.59	0.86 ± 0.14
411	1200S, 60E	0.51 ± 0.20	<0.24	<1.41	0.13 ± 0.08
412	1200S, 100E	0.64 ± 0.22	<0.24	<2.86	0.22 ± 0.10
413	1200S, 140E	0.61 ± 0.20	<0.24	<3.64	0.16 ± 0.08
414	1200S, 180E	0.47 ± 0.18	<0.24	<4.09	0.10 ± 0.10
415	1220S, 40E	0.45 ± 0.20	<0.24	<3.89	0.21 ± 0.08
416	1220S, 80E	0.64 ± 0.24	<0.24	<3.01	0.13 ± 0.12
417	1220S, 120E	1.14 ± 0.22	<0.24	<3.19	0.08 ± 0.08
418	1220S, 160E	0.46 ± 0.14	<0.74	<2.16	0.09 ± 0.05
419	1240S, 20E	0.44 ± 0.16	<0.24	<2.98	0.20 ± 0.10
420	1240S, 60E	0.62 ± 0.18	<0.24	<3.13	0.14 ± 0.10
421	1240S, 100E	0.59 ± 0.26	<0.24	<2.79	0.15 ± 0.12
422	1240S, 140E	0.53 ± 0.26	<0.22	<3.73	0.10 ± 0.05
423	1240S, 180E	0.58 ± 0.22	<0.23	2.20 ± 8.42	0.16 ± 0.16
424	1260S, 20E	0.69 ± 0.26	0.42 ± 0.58	6.44 ± 8.62	0.19 ± 0.12
425	1260S, 40E	0.43 ± 0.24	<0.24	<3.27	0.45 ± 0.16
426	1260S, 80E	0.71 ± 0.74	<0.24	<4.84	0.12 ± 0.10
426a	1260S, 80E	---	---	---	---
426c	1260S, 100E	---	---	---	---
427	1260S, 120E	0.38 ± 0.20	<0.24	<5.31	0.63 ± 0.14
428	1260S, 140E	0.36 ± 0.18	<0.24	<4.99	0.59 ± 0.14
429	1260S, 160E	0.47 ± 0.20	<0.24	<5.53	0.32 ± 0.14

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations (pCi/g)			
		Ra-226	U-235	U-238	Cs-137
430	1280S, 180E	1.51 ± 0.38	<0.24	<5.05	0.16 ± 0.10
431	1280S, 20E	0.65 ± 0.20	<0.24	<4.34	0.17 ± 0.08
432	1280S, 40E	0.53 ± 0.18	<0.24	<4.10	0.19 ± 0.12
433	1280S, 30E	0.43 ± 0.20	<0.24	8.92 ± 10.02	<0.03
None	1280S, 80E	---c	---	---	---
None	1280S, 100E	---c	---	---	---
434	1280S, 120E	0.44 ± 0.16	<0.24	<1.15	0.13 ± 0.08
435	1280S, 140E	0.76 ± 0.24	<0.24	<3.03	0.65 ± 0.14
436	1280S, 160E	0.67 ± 0.22	<0.24	<4.68	0.60 ± 0.14
437	1300S, 20E	0.40 ± 0.27	<0.24	<5.07	0.64 ± 0.14
438	1300S, 40E	0.51 ± 0.22	<0.24	<2.66	0.67 ± 0.16
439	1300S, 60E	0.67 ± 0.22	<0.24	<3.71	0.64 ± 0.10
None	1300S, 80E	---c	---	---	---
None	1300S, 100E	---c	---	---	---
440	1300S, 120E	1.91 ± 0.40	<0.24	<4.86	<0.05
None	1300S, 140E	---c	---	---	---
441	1310S, 160E	1.76 ± 0.34	<0.24	<6.71	0.09 ± 0.12
442	1320S, 20E	0.45 ± 0.20	<0.24	<2.84	0.48 ± 0.16
443	1320S, 40E	0.69 ± 0.22	<0.24	<5.23	0.42 ± 0.12
444	1320S, 60E	0.60 ± 0.20	<0.24	<4.64	0.31 ± 0.10
None	1320S, 80E	---c	---	---	---
None	1320S, 120E	---c	---	---	---
445	1320S, 140E	1.94 ± 0.36	<0.24	<5.45	<0.04
446	1320S, 160E	0.60 ± 0.26	<0.24	<1.51	0.92 ± 0.16
447	1340S, 20E	0.59 ± 0.26	<0.24	<4.38	0.63 ± 0.14
448	1340S, 40E	0.42 ± 0.22	<0.24	<4.07	0.34 ± 0.12
449	1340S, 58E	0.38 ± 0.18	<0.24	<3.45	0.03 ± 0.08
None	1340S, 80E	---c	---	---	---
None	1340S, 100E	---c	---	---	---
450	1340S, 120E	1.73 ± 0.32	<0.24	<3.88	<0.03
451	1340S, 140E	0.62 ± 0.22	<0.24	<3.71	0.16 ± 0.08
452	1340S, 160E	0.44 ± 0.20	<0.24	<3.59	0.05 ± 0.05
453	1360S, 20E	0.58 ± 0.20	<0.24	<3.05	0.12 ± 0.08
454	1360S, 40E	0.62 ± 0.22	<0.24	<3.71	0.16 ± 0.08
455	1360S, 60E	0.42 ± 0.18	<0.24	<2.77	0.46 ± 0.12
456	1360S, 80E	0.66 ± 0.16	<0.24	<3.62	0.12 ± 0.06
457	1360S, 100E	0.80 ± 0.26	<0.24	<2.82	0.22 ± 0.10
458	1360S, 120E	1.54 ± 0.30	<0.24	<4.14	0.11 ± 0.10
459	1360S, 140E	0.55 ± 0.20	<0.24	<4.60	0.35 ± 0.10
460	1360S, 160E	0.40 ± 0.16	<0.24	<3.59	<0.04
461	1380S, 20E	0.47 ± 0.20	<0.24	<4.92	0.14 ± 0.12
462	1380S, 40E	0.50 ± 0.22	<0.24	<4.23	0.17 ± 0.08

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci/g}$ )			
		Ra-226	U-235	U-238	Cs-137
453	1380S, 60E	0.51 ± 0.22	<0.24	<3.65	0.62 ± 0.12
464	1380S, 80E	0.53 ± 0.18	<0.24	<7.52	0.33 ± 0.10
465	1380S, 100E	0.75 ± 0.20	0.36 ± 0.48	<4.38	0.21 ± 0.17
466	1380S, 120E	0.28 ± 0.10	<0.24	<1.11	0.02 ± 0.06
467	1380S, 140E	1.06 ± 0.20	<0.24	<4.64	0.32 ± 0.14
468	1380S, 160E	0.42 ± 0.18	0.43 ± 0.60	<3.29	0.26 ± 0.10
469	1400S, 20E	0.56 ± 0.14	<0.24	<4.20	0.70 ± 0.10
470	1400S, 40E	0.48 ± 0.18	<0.22	<4.81	0.12 ± 0.08
471	1400S, 60E	0.47 ± 0.22	<0.24	<3.30	0.12 ± 0.08
472	1400S, 80E	0.58 ± 0.18	<0.24	<3.38	0.11 ± 0.08
473	1399S, 100E	0.47 ± 0.18	<0.24	<4.06	0.07 ± 0.08
None	1400S, 120E	---	---	---	---
None	1400S, 140E	---	---	---	---
None	1400S, 160E	---	---	---	---
474	1420S, 20E	0.31 ± 0.20	0.34 ± 0.54	<3.50	0.21 ± 0.10
475	1420S, 40E	0.67 ± 0.16	<0.24	<3.69	0.25 ± 0.10
None	1420S, 60E	---	---	---	---
None	1420S, 80E	---	---	---	---
None	1420S, 100E	---	---	---	---
None	1420S, 120E	---	---	---	---
476	1420S, 140E	0.56 ± 0.18	<0.24	<2.37	0.10 ± 0.05
477	1420S, 160E	1.16 ± 0.36	0.57 ± 0.87	<4.95	0.89 ± 0.18
478	1440S, 20E	1.76 ± 0.28	<0.24	<4.78	0.17 ± 0.10
479	1440S, 40E	0.49 ± 0.32	<0.24	<5.11	0.48 ± 0.14
480	1440S, 60E	0.51 ± 0.22	<0.24	<4.68	0.45 ± 0.12
None	1440S, 80E	---	---	---	---
481	1440S, 100E	0.59 ± 0.20	<0.24	<3.44	0.34 ± 0.10
482	1440S, 120E	0.72 ± 0.20	<0.24	<3.60	0.14 ± 0.10
483	1440S, 140E	0.19 ± 0.12	<0.13	2.56 ± 3.20	<0.01
None	1440S, 160E	---	---	---	---
484	1460S, 20E	0.53 ± 0.18	<0.24	<4.21	0.44 ± 0.12
485	1460S, 40E	0.39 ± 0.16	<0.24	<2.61	0.17 ± 0.06
None	1460S, 60E	---	---	---	---
None	1460S, 80E	---	---	---	---
486	1460S, 100E	0.62 ± 0.28	<0.24	<3.58	0.39 ± 0.12
487	1460S, 120E	0.65 ± 0.20	<0.24	<3.40	0.25 ± 0.08
488	1460S, 140E	0.40 ± 0.20	<0.24	<2.54	0.06 ± 0.06
489	1460S, 160E	0.52 ± 0.22	<0.24	<4.03	0.62 ± 0.12
490	1480S, 20E	0.62 ± 0.28	<0.24	<4.93	0.20 ± 0.12
491	1480S, 40E	0.54 ± 0.20	<0.24	<3.74	0.15 ± 0.08
492	1480S, 60E	0.59 ± 0.26	<0.24	<4.83	0.71 ± 0.14
493	1480S, 80E	0.60 ± 0.20	<0.24	<3.42	0.48 ± 0.12
494	1480S, 100E	1.05 ± 0.22	<0.24	<4.14	0.27 ± 0.08
495	1480S, 120E	0.64 ± 0.20	<0.24	<3.81	0.47 ± 0.16

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM GRID LINE INTERSECTIONS

Sample No.	Location	Radionuclide Concentrations ( $\mu\text{Ci}/\text{g}$ )			
		Ra-226	U-235	U-238	Cs-137
496	1480S, 140E	0.34 ± 0.16	<0.24	<2.94	0.33 ± 0.08
497	1500S, 20E	0.62 ± 0.24	<0.27	<2.61	0.06 ± 0.12
498	1500S, 40E	0.38 ± 0.16	<0.24	<3.71	0.09 ± 0.06
499	1500S, 60E	0.83 ± 0.28	<0.24	<5.00	0.15 ± 0.11
500	1500S, 80E	0.59 ± 0.18	<0.24	<3.22	0.16 ± 0.08
501	1500S, 100E	0.54 ± 0.28	<0.24	<4.57	0.42 ± 0.16
502	1500S, 120E	0.62 ± 0.30	<0.24	<4.03	0.23 ± 0.14

<sup>a</sup> Refer to Table 2 for direct radiation levels.<sup>b</sup> Errors are 2 $\sigma$  based on counting statistics.<sup>c</sup> No soil sample taken due to sand and gravel piles.<sup>d</sup> No sample taken due to paved surface.<sup>e</sup> No sample taken due to presence of maintenance building.

TABLE 5

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

Sample No. <sup>a</sup>	Location	Radiouclide Concentrations ( $\mu\text{Ci/g}$ ) <sup>b</sup>			
		Ra-226	U-235	U-238	Cs-137
B1	514S, 300E	$0.70 \pm 0.24^c$	<0.31	<1.07	$0.70 \pm 0.16$
B2	500S, 176E	<0.15	<0.31	<6.99	$1.31 \pm 0.22$
B3	771S, 170E	$51.9 \pm 1.3$	<0.31	$1.78 \pm 0.39$	$0.88 \pm 0.32$
B4	782S, 169E	$1.44 \pm 0.26$	$0.64 \pm 0.52$	$2.03 \pm 0.45$	$0.34 \pm 0.12$
B5	796S, 170E	$11.9 \pm 0.6$	$1.86 \pm 1.28$	$36.6 \pm 0.6$	$0.22 \pm 0.16$
B6	799S, 173E	$3.07 \pm 0.38$	<0.31	<5.67	$1.11 \pm 0.18$
B7	809S, 172E	$13.4 \pm 0.7$	$2.05 \pm 1.24$	$22.1 \pm 0.6$	$0.53 \pm 0.18$
B8	1209S, 126E	106	<0.31	$1.09 \pm 0.33$	$1.73 \pm 0.42$
B9	1260S, 158E	$92.6 \pm 2.3$	<0.31	$1.56 \pm 0.52$	$1.32 \pm 0.56$
B10 <sup>d</sup>	1460S, 91E	$31.9 \pm 1.2$	$1.86 \pm 2.06$	$18.3 \pm 0.4$	$0.75 \pm 0.32$
B11	1471S, 97E	$0.35 \pm 0.20$	<0.31	<3.85	$0.73 \pm 0.10$
B12	1458S, 91E	$8.12 \pm 0.64$	<0.31	$11.2 \pm 0.4$	<0.09
B13	1455S, 105E	$2.81 \pm 0.40$	<0.31	<5.77	$0.25 \pm 0.18$
B14	1506S, 111E	$7.79 \pm 0.20$	$0.97 \pm 1.18$	<1.22	$0.40 \pm 0.20$
B15	1488S, 118E	$2.79 \pm 0.42$	<0.31	<5.65	$0.36 \pm 0.20$
B16	1239S, 138E	$4.68 \pm 0.44$	$0.49 \pm 0.74$	<5.86	$0.27 \pm 0.12$
B17 <sup>e</sup>	1233S, 137E	$5.56 \pm 0.58$	<0.31	$8.99 \pm 0.53$	<0.08
B18	1175S, 114E	$2.65 \pm 0.14$	<0.31	<4.18	$0.14 \pm 0.10$
B19	1107S, 216E	$3.37 \pm 4.74$	<0.31	$0.50 \pm 0.55$	$7.11 \pm 1.04$
B20	1067S, 217E	1020	<0.31	$2.85 \pm 0.45$	<1.22
B21	1054S, 209E	$41.6 \pm 1.5$	<0.31	$1.39 \pm 0.33$	$1.18 \pm 0.22$
B22	1062S, 216E	209	<0.31	$1.34 \pm 0.48$	<0.53

<sup>a</sup> Refer to Figures 3 and 4.<sup>b</sup> Refer to Table 3 for direct radiation levels.<sup>c</sup> Errors are 2 $\sigma$  based on counting statistics.<sup>d</sup> Sample also contained  $13.0 \pm 1.54$  pCi/g Th-232.<sup>e</sup> Sample also contained  $8.71 \pm 1.32$  pCi/g Th-232.

TABLE 6  
RADIONUCLIDE CONCENTRATIONS IN BORHOLE SOIL SAMPLES

Borehole <sup>a</sup> No.	Location	Depth (m)	Radionuclide Concentrations ( $\mu\text{Ci}/\text{g}$ )			
			K-216	U-235	U-238	Cs-137
H1	319S, 778E	0.30	0.50 $\pm$ 0.14 <sup>b</sup>	<0.24	<2.82	<0.02
		2.70	0.56 $\pm$ 0.28	<0.24	<4.09	<0.02
H2	321S, 490E	0.30	0.43 $\pm$ 0.14	<0.24	<3.03	<0.02
		2.70	0.59 $\pm$ 0.16	<0.21	<3.95	<0.02
H3	334S, 18E	0.30	0.52 $\pm$ 0.20	<0.24	<3.59	<0.02
		2.50	0.50 $\pm$ 0.24	<0.24	<3.83	<0.03
H4	354S, 424E	0.30	0.77 $\pm$ 0.26	<0.24	<4.00	<0.03
		2.70	0.66 $\pm$ 0.20	<0.24	<3.36	<0.04
H5	356S, 703E	0.30	0.46 $\pm$ 0.22	<0.24	<2.62	<0.03
		2.70	0.44 $\pm$ 0.18	<0.24	<3.51	<0.03
H6	321S, 490E	0.30	0.43 $\pm$ 0.14	<0.24	<3.03	<0.02
		2.70	0.59 $\pm$ 0.16	<0.21	<3.95	<0.02
H7	716S, 17E	0.30	0.66 $\pm$ 0.28	<0.24	<3.90	<0.03
		2.70	0.65 $\pm$ 0.18	<0.24	<4.46	<0.03
H8	774S, 165E	0.30	0.87 $\pm$ 0.22	0.48 $\pm$ 0.49	<5.03	<0.04
		2.70	0.50 $\pm$ 0.24	<0.24	<3.26	<0.02
H9	815S, 177E	0.30	0.38 $\pm$ 0.20	<0.24	<2.32	<0.03
		2.70	0.52 $\pm$ 0.16	<0.24	<4.36	<0.04
H10	1080S, 28E	0.30	0.41 $\pm$ 0.22	<0.24	<3.84	<0.05
		2.40	0.49 $\pm$ 0.11	<0.24	<5.10	<0.03
H11	1167S, 159E	0.30	0.56 $\pm$ 0.20	<0.24	<4.19	<0.04
		2.40	0.69 $\pm$ 0.22	<0.24	<5.21	<0.04
H12	1375S, 60E	0.30	0.58 $\pm$ 0.18	<0.24	<3.55	0.41 $\pm$ 0.12
		2.40	0.69 $\pm$ 0.16	<0.24	<5.91	<0.07
H13	1380S, 120E	0.38	0.54 $\pm$ 0.18	<0.24	<3.43	0.32 $\pm$ 0.12
		1.95	0.49 $\pm$ 0.20	<0.24	<3.65	<0.02
H14	1503S, 420E	0.30	0.98 $\pm$ 0.24	<0.24	<4.05	<0.05
		2.40	0.56 $\pm$ 0.20	<0.24	<2.91	<0.03

TABLE 6, cont.

## RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole no.	Location	Depth (z)	Radionuclide Concentrations ( $\mu\text{Ci/g}$ )			
			Ra-226	U-235	U-238	Cs-137
H15	120S, 420E	0.30	0.46 $\pm$ 0.20	<0.24	<3.59	0.01 $\pm$ 0.02
		1.05	0.48 $\pm$ 0.18	<0.24	<3.62	0.04
H16	328S, 99E	0.30	1.38 $\pm$ 0.32	<0.24	<6.05	<0.04
		1.20	0.47 $\pm$ 0.24	<0.24	<3.88	<0.04
H17	272S, 127E	0.80	0.65 $\pm$ 0.18	<0.24	<6.92	0.14 $\pm$ 0.09
H18	544S, 103E	0.30	0.41 $\pm$ 0.16	<0.24	<4.15	0.01 $\pm$ 0.03
		1.35	0.39 $\pm$ 0.16	<0.22	<3.13	<0.03
H19	806S, 158E	0.70	0.64 $\pm$ 0.22	<0.24	<5.16	<0.04
H20	1160S, 160E	0.30	0.50 $\pm$ 0.18	<0.24	<3.43	<0.03
		0.90	0.53 $\pm$ 0.16	<0.20	<3.26	<0.02
H21	1221S, 152E	0.30	0.52 $\pm$ 0.20	<0.24	<4.28	0.35 $\pm$ 0.12
		0.90	0.53 $\pm$ 0.18	<0.22	<4.74	<0.03
H22	1245S, 160E	0.30	0.53 $\pm$ 0.16	0.33 $\pm$ 0.40	<3.03	0.07 $\pm$ 0.06
		1.20	0.76 $\pm$ 0.22	<0.24	<4.76	<0.03
H23	1501S, 106E	0.30	5.08 $\pm$ 0.44	<0.24	<6.95	0.22 $\pm$ 0.12
		1.00	2.25 $\pm$ 0.36	<0.24	<6.82	0.15 $\pm$ 0.14
H24	1495S, 70E	0.75	0.40 $\pm$ 0.22	<0.24	<2.59	0.31 $\pm$ 0.10

<sup>a</sup> Refer to Figures 5 and 6.<sup>b</sup> Errors are 2 $\sigma$  based on counting statistics.

TABLE 7  
RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

Sample No.	Sample Type	Grid <sup>a</sup> Location	Radionuclide Concentration (pCi/l)		
			Gross Alpha	Gross Beta	Ra-226
W1	Surface	1380S, 10E	<4.05	11.3 ± 6.2 <sup>b</sup>	---
W2	Surface	1080S, 10E	1.31 ± 1.62	2.60 ± 2.02	---
W3	Surface	340S, 10E	<0.52	7.90 ± 1.26	---
W4	Borehole (H1)	319S, 778E	8.53 ± 4.79	<5.42	---
W5	" (H2)	321S, 490E	<3.67	13.5 ± 5.9	---
W6	" (H3)	334S, 18E	2.99 ± 1.24	3.56 ± 1.99	---
W7	" (H4)	554S, 424E	6.10 ± 4.47	15.2 ± 4.6	---
W8	" (H5)	558S, 203E	17.4 ± 3.7	18.8 ± 3.3	0.05 ± 0.03
W9	" (H9)	815S, 17E	2.67 ± 1.52	6.83 ± 1.58	---
W10	" (H8)	774S, 165E	14.8 ± 3.6	17.7 ± 3.3	---
W11	" (H10)	1080S, 28E	13.1 ± 4.5	15.0 ± 4.3	---
W12	" (H11)	1167S, 159E	4.22 ± 1.16	5.81 ± 1.08	---
W13	" (H12)	1325S, 60E	3.14 ± 1.46	5.80 ± 1.53	---
W14	" (H13)	1380S, 120E	8.28 ± 2.49	14.5 ± 2.4	---
W15	" (H14)	1503S, 133E	15.4 ± 5.5	18.1 ± 5.1	0.08 ± 0.04
W16	" (H21)	1221S, 152E	3.23 ± 0.84	4.92 ± 0.82	---
W17	" (H22)	1245S, 160E	19.6 ± 9.4	15.1 ± 9.1	0.07 ± 0.04

<sup>a</sup> Refer to Figures 5, 6, and 7.

<sup>b</sup> Errors are 2σ based on counting statistics.

<sup>c</sup> Dashes indicate analysis not performed.

TABLE 8  
DIRECT RADIATION MEASUREMENTS  
IN THE MAINTENANCE BUILDING

Location <sup>a</sup>	Direct Probe Measurements <sup>b</sup>		
	Alpha dpm/100 cm <sup>2</sup>	Beta-Gamma dpm/100 cm <sup>2</sup>	μrad/h
1	<23	1400	39
2	<23	1200	34
3	<23	1300	36
4	<23	1200	34
5	<23	900	25

<sup>a</sup> Refer to Figure 8.

<sup>b</sup> Gamma exposure levels ranged from 4.4-6.0 μR/h throughout the building.

REFERENCES

1. Vierzba, E.A. and Wallo, A., A Background Report and Evaluation of Resurvey Requirements for the Former Atomic Energy Commission Portion of the Lake Ontario Ordnance Works, Aerospace Corp., November 1982.
2. Robinson, B.W., Second Report: Niagara Falls Site, December 24, 1970.
3. Robinson, B.W., Lake Ontario Ordnance Works Niagara Falls Site, January 15, 1971.

APPENDIX A  
INSTRUMENTATION AND ANALYTICAL PROCEDURES

## 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 ( $\mu\text{R}/\text{h}$ ) 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 Q.

#### 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 ( $\mu\text{rad}/\text{h}$ ) were determined by comparing the response of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes for soil samples which had elevated Ra-226 concentrations.

#### 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. The length of the hole was scanned and measurements were performed at intervals of 30-50 cm 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.

#### 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<sup>2</sup>. Conversion included subtraction of background rates and applying appropriate factors for detector efficiency and effective probe area.

#### 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 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-234 (secular equilibrium assumed)  
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)  
Cs-137 - 0.662 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<sup>2</sup>/sec from a 25 mg Cf-252 spontaneous fission source. After a two minute wait time, the U-239 peak (74.6 kev) was counted for 1000 seconds and the U-238 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 µm 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 determining the site specific 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.

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.

**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 R/hr	Nuclear Regulatory Commission (NRC) Standards for Protection Against Radiation (10 CFR 20.105)
	Indoor gamma radiation (above background)	20 R/h	EPA Standards for Uranium Mill Tailings (40 CFR 192)
2. Surface alpha contamination <sup>a</sup>	Ra-226 contamination fixed on surfaces	100 dpm/100 cm <sup>2</sup>	EBC 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 <sup>2</sup>	
3. Surface beta contamination <sup>a</sup>	Removable beta-gamma	1000 dpm/100 cm <sup>2</sup>	Same as number 2
4. Beta-gamma dose rate	Average dose rate on an area no greater than 1 m <sup>2</sup>	0.7 mrad/h	Same as number 2
	Maximum dose rate in any 100 cm <sup>2</sup> area	1.0 mrad/h	Same as number 2
5. Exposure to radon	Maximum permissible concentration of Ra-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 radon 0.020 WL preferable	EPA Standards for Mill Tailings

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

<b>Mode of Exposure</b>	<b>Exposure conditions</b>	<b>Guideline value</b>	<b>Guideline source</b>
<b>6. Radionuclides in water</b>	Gross Alpha Gross Beta Maximum contaminant level for combined Ra-226 and Ra-228 in drinking water	15 pCi/l 50 pCi/l 5 pCi/l	EPA Interim Drinking Water Standards (40 CFR 141)
	Maximum permissible concentra- tion of the following radionuclides in water for unrestricted areas:		HRC (10 CFR 20.103 Appendix B, Table II)
	Ra-226 U-238 Th-230 Pu-239	30 pCi/l 40,000 pCi/l 2,000 pCi/l 100 pCi/l	
<b>7. Radionuclides in soil</b>	Concentration above background-averaged over an area of 100 m <sup>2</sup>		
	Ra-226	5 pCi/g (surface) 15 pCi/g (subsurface)	EPA Standards for Uranium Mill Tailings
	U-238 Th-232 Sr-90 Cs-137	40 pCi/g 20 pCi/g 100 ,Ci/g 80 ,Ci/g	Interim Soil limits for PWR Projects, LAMP-IV Report, J.W. "Andy" et al.
	U-enriched in U-235	30 pCi/g	HRC French Technical Position Paper (Fodder) Register, October 21, 1981)

<sup>8</sup> Applicable to building and equipment surfaces only.

APPENDIX C

REPORT OF GROUND-PENETRATING RADAR SURVEY  
OF PROPERTY Q  
AT THE NIAGARA FALLS STORAGE SITE

DETECTION SCIENCES GROUP

FINAL REPORT  
GROUND-PENETRATING RADAR SURVEY  
OF AREAS Q AND N/N' AT THE  
FORMER LAKE ONTARIO ORDNANCE WORKS  
LEWISTON, NEW YORK

RADARVISION

# **DETECTION SCIENCES GROUP**

**496 HEALD ROAD    CARLISLE, MASSACHUSETTS 01741    (617)369-7999**

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## **FINAL REPORT**

### **GROUND-PENETRATING RADAR SURVEY OF AREAS Q AND N/N' 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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Purchase Order No. C-25303  
Letter Release No. 3  
Dated October 15, 1982

Report No. J147-82

December, 1982

# **RADARVISION**

DETECTION SCIENCES GROUP

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RADARVISION

**INTRODUCTION AND SUMMARY**

Starting on October 25, and continuing through November 1, 1982, Detection Sciences Group conducted a ground-penetrating radar survey of designated locations in Area Q and Areas N/N' at the former Lake Ontario Ordnance Works, Lewiston, New York. The radar survey was performed in accordance with Oak Ridge Associated Universities, Inc. Purchase Order No. C-25303, Letter Release No. 3, dated October 15, 1982, and per field instructions received from O.R.A.U. personnel.

The first area to be surveyed was a site in Area N at the southeast corner of "R" Street and Castle Garden Road. The radar survey zone was from 20S to 50S, extending from 140E to 185E. The radar anomalies and the radar survey lines are shown in Figure 1. The next task to be performed was the inspection of 24 boring sites located in Area Q. The boring locations and the co-ordinates of the borings that were relocated are given in Table 1. The third task was to run a series of survey lines between 760S and 840S, extending from 160E to 180E in Area Q. The results of the survey in this location are shown in Figure 2. The next task was to run six survey lines parallel to Track Street and South Track Street in Area N'. The radar survey lines and the radar anomalies are shown in Figure 3. The last task was to inspect the locations of 3 borings to be placed in the corners of the southwest triangle of Area N, bounded by Castle Garden Roac, "R" Street, and Track Street. These locations are tabulated in Table 2.

Out of the 24 boring locations surveyed in Area Q, 3 locations - Q1, Q4, and Q9 - were found to have underground pipes. These locations were moved 2 to 3 meters away from the pipes to avoid potential drilling problems. As a precautionary measure, 8 other boring locations in Area Q were moved 1 to 3 meters away from their original locations. In all cases, the relocated sites were chosen to be as near as possible to the original site chosen for the boring. Of the 3 boring sites in the southwest triangle of Area N, none had to be relocated.

Prior to the radar work, O.R.A.U. had placed pin flags at locations where monitoring instruments indicated activity. It was noted that the radar signatures obtained where there were clusters of pin flags were significantly different than the radar signatures observed over most of the surrounding area. Specifically, the radar signatures at the pin flag clusters tended to be much darker and more pronounced than the prevailing radar signatures of the overall site. The apparent correlation between the radar signatures and the pin flag clusters has been subdivided into two categories: those areas having very dark, strong signal returns, and those areas having moderately dark, strong returns. The difference between the two subdivisions is only a difference of degree. In general, this kind of radar signature is indicative of non-ionic liquids being present in the ground. Although water is itself a non-ionic liquid, the radar signatures are not typical for wet, saturated ground. More likely, the radar signatures are due to the presence of petroleum solvents or oils that do not readily disperse in the ground. Determination of the composition of the non-ionic liquids (including the possibility that it is perched water) would require physical samples to be taken from these locations, a task that is not part of the radar survey program.

**DESCRIPTION OF THE SURVEY**

The entire survey was conducted with the 120 MHz radar antenna. With the exception of the survey lines along Track Street and South Track Street, the survey was run with our antenna shield on the antenna to prevent any stray, above-ground reflections or electrical interference from obscuring the data.

The survey vehicle was used to tow the antenna on the long survey lines along Track Street and South Track Street. For the north-south survey lines between 760S and 840S in Area Q, we also utilized the vehicle to tow the antenna over the ground. All of the other survey work was performed by hand-pulling the 120 MHz antenna over the ground.

A significant gain was made in survey efficiency by using a labor-saving device consisting of a knotted rope 12 meters long. At the center of the rope was a loop through which a chaining pin or other pointed device could be inserted into the ground at the proposed location for a boring. The knots in the rope were spaced at 2 meter intervals, and were painted with high-visibility paint. Using this rope made it unnecessary to lay out a steel tape to measure and mark the 2 meter intervals used for ground locations in the vicinity of the proposed boring. Also, by leaving the center pin in place, the 12-meter rope was quickly rotated 90 degrees on the ground to mark off the orthogonal survey line crossing the proposed location of the boring. Using this technique, we were able to inspect more than twice as many boreholes in a single day as had previously been the case with manually laying out the 2-meter ground locations with a steel tape.

With the exception of using the antenna shield and the knotted marker rope, the survey methods were the same as have been described in previous reports.

**RADARVISION**

## RESULTS OF THE SURVEY

Area N.

The radar survey grid and the radar anomalies are plotted in Figure 1. Two types of anomalies appear in the radar records: very dark reflectors, which indicate high dielectric; and, medium reflectors which exhibit a moderately high dielectric. The reason for differentiating between the two types is to distinguish the degree to which the nominal dielectric constant of the ground appears to be modified by the presence of some modifying agent or agents.

The radar behavior in these dark-reflecting areas suggests the presence of non-ionic liquids in the ground. Water is one such non-ionic liquid, but the radar charts do not have the characteristics that are typical for wet, saturated ground. Rather, the radar charts are more typical of waste sites where there has been open dumping or spillage of petroleum-based solvents, oils, or other non-electrically active liquids. Depending on the type of soil, these non-water-soluble liquids tend not to disperse in the ground. What the radar observes is the modification of the dielectric constant of the ground, which becomes the criterion for judging the presence of non-ionic liquids. A more complete discussion of the radar properties of ionic and non-ionic liquid contaminants is given in the APPENDIX.

In the area between 26N and 39N, extending from 162E to 186E, the radar consistently shows dark reflectors. The visual appearance of the ground is also different in this area, being darker than the surrounding areas. The fact that the ground is dark is only a coincidence with the radar records being dark, but the observation of a visual contrast (whether darker or not) does appear to be correlated with the radar results. Similarly, the area at the western end of radar survey line 44N is also observed to be visually dark, again the darkness per se having no direct bearing on the radar signals also showing up dark. Our conclusion regarding this area is that the dark areas showing in the radar records indicate the presence of non-ionic liquids in the ground.

Borings - Area Q.

Table I lists the boring locations inspected in Area Q. At three locations, underground pipes were found at the proposed boring sites. These sites were relocated nearby, where no radar targets were observed in the ground. As a precautionary measure, eight other boring locations in Area Q were also moved 1 to 3 meters away from their proposed locations. The sequence of the Q-designations given to the boring locations is the chronological order in which the radar survey progressed, and is not derived from an O.R.A.U. numbering system.

Area Q.

and 840S

The location between 760S, bounded between 160E and 180E was surveyed according to the survey lines shown in Figure 2. Dark reflectors and some medium reflectors were found in the locations shown. This area is adjacent to a railroad siding, which suggests that the observed localized modifications of the radar properties of the ground may reflect this former use of the site.

# RADARVISION

Area N'.

The area scanned by the radar between Track Street and South Track Street is shown in **Figure 3**. This area is surprisingly free of any radar evidence of past usage, and shows mostly undisturbed ground free from any type of contaminants. A few, highly localized concentrations of dark and medium dark radar reflectors are observed, but do not appear to have any significance (in contrast to the dark reflectors extending over significant portions of the site surveyed in Area N).

Borings - Area N.

The locations of the three boring locations in Area N that were inspected by radar are listed in **Table II**. The three sites were all satisfactory, and none of the borings were relocated.

# RADARVISION

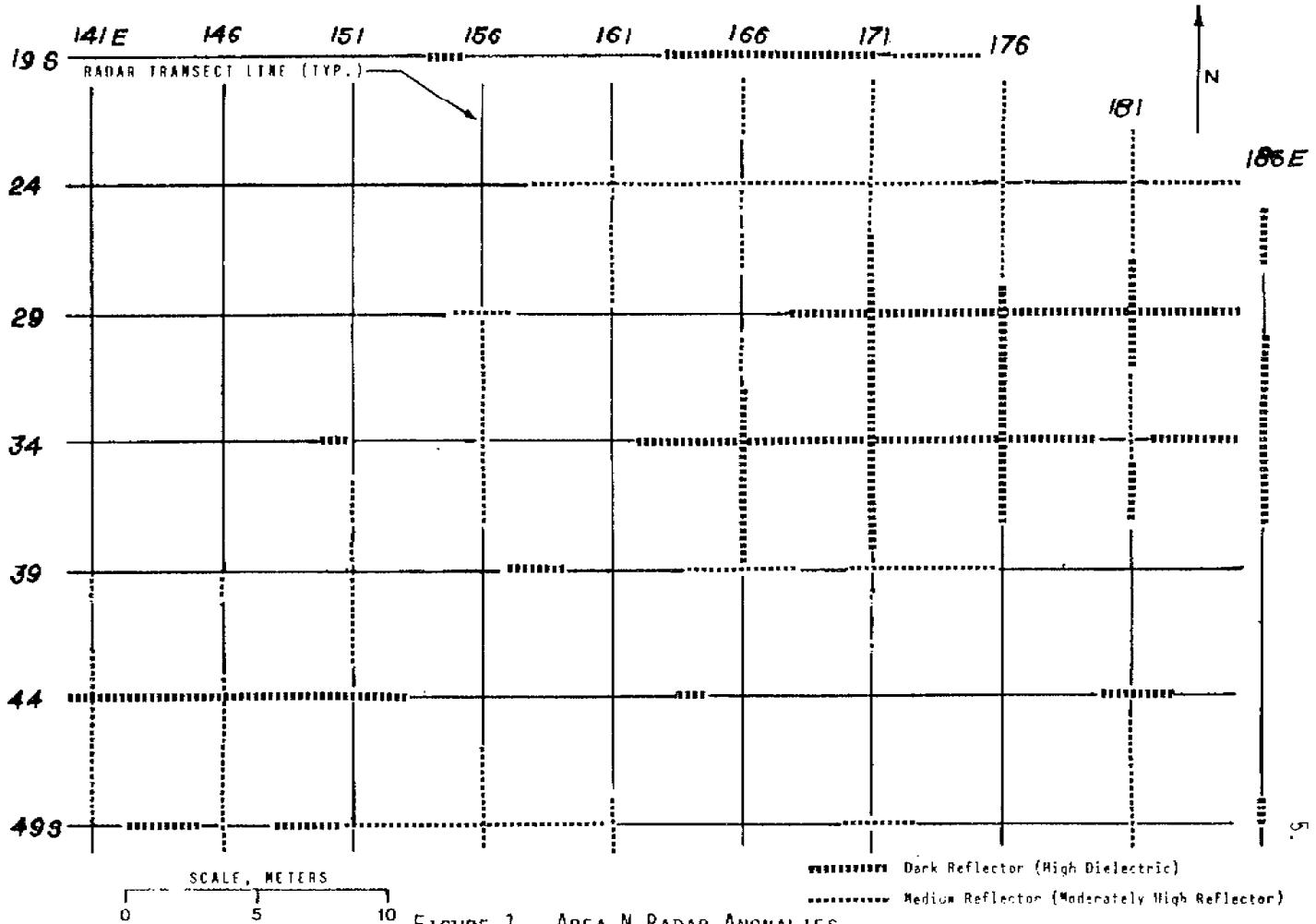


FIGURE 1. AREA N RADAR ANOMALIES

TABLE I  
BORING LOCATIONS DETERMINED BY RADAR

AREA Q

<u>Boring Number</u>	<u>Direction of Relocation</u>	<u>Proposed Location</u>	<u>Final Location</u>	<u>Notes</u>
Q1	Move 2m North	1502S, 103E	1500S, 103E	N-S Pipe @ 107.5E
Q2	-	1504S, 112E	1504S, 112E	
Q3	Move 2m West	1503S, 133E	1503S, 131E	
Q4	Move 2m North	1501S, 22E	1499S, 22E	E-W Pipe @ 1502E
Q5	Move 3m North	1507S, 25E	1504S, 25E	
Q6	-	1503S, 31E	1503S, 31E	
Q7	-	Storage Yard <sup>†</sup>	Storage Yard <sup>†</sup>	Gravel area
Q8	-	1340S, 48E	1340S, 48E	
Q9	Move 3m East	1266S, 176E	1266S, 179E	N-S Pipe @ 175E
Q10	-	1222S, 155E	1222S, 155E	
Q11	Move 2m South	1167S, 159E	1169S, 159E	
Q12	Move 1m West	1080S, 28E	1080S, 27E	
Q13	-	744S, 30E	744S, 30E	
Q14	Move 1m East	334S, 20E	334S, 21E	
Q15	-	569S, 200E	569S, 200E	
Q16	-	544S, 440E	44S, 440E	
Q17	-	320S, 526E	320S, 526E	
Q18	-	330S, 760E	330S, 760E	
Q19	-	805S, 175E	805S, 175E	Dark anomaly zone
Q20	Move 1m North	805S, 170E	804S, 170E	
Q21	-	805S, 165E	805S, 165E	
Q22	-	820S, 175E	820S, 175E	
Q23	Move 2m South	820S, 170E	822S, 170E	
Q24	Move 2m North	820S, 165E	818S, 165E	

<sup>†</sup>Town of Lewiston Public Works storage yard;  
26.2m south, 8.8m west of wooden light pole.

**RADARVISION**

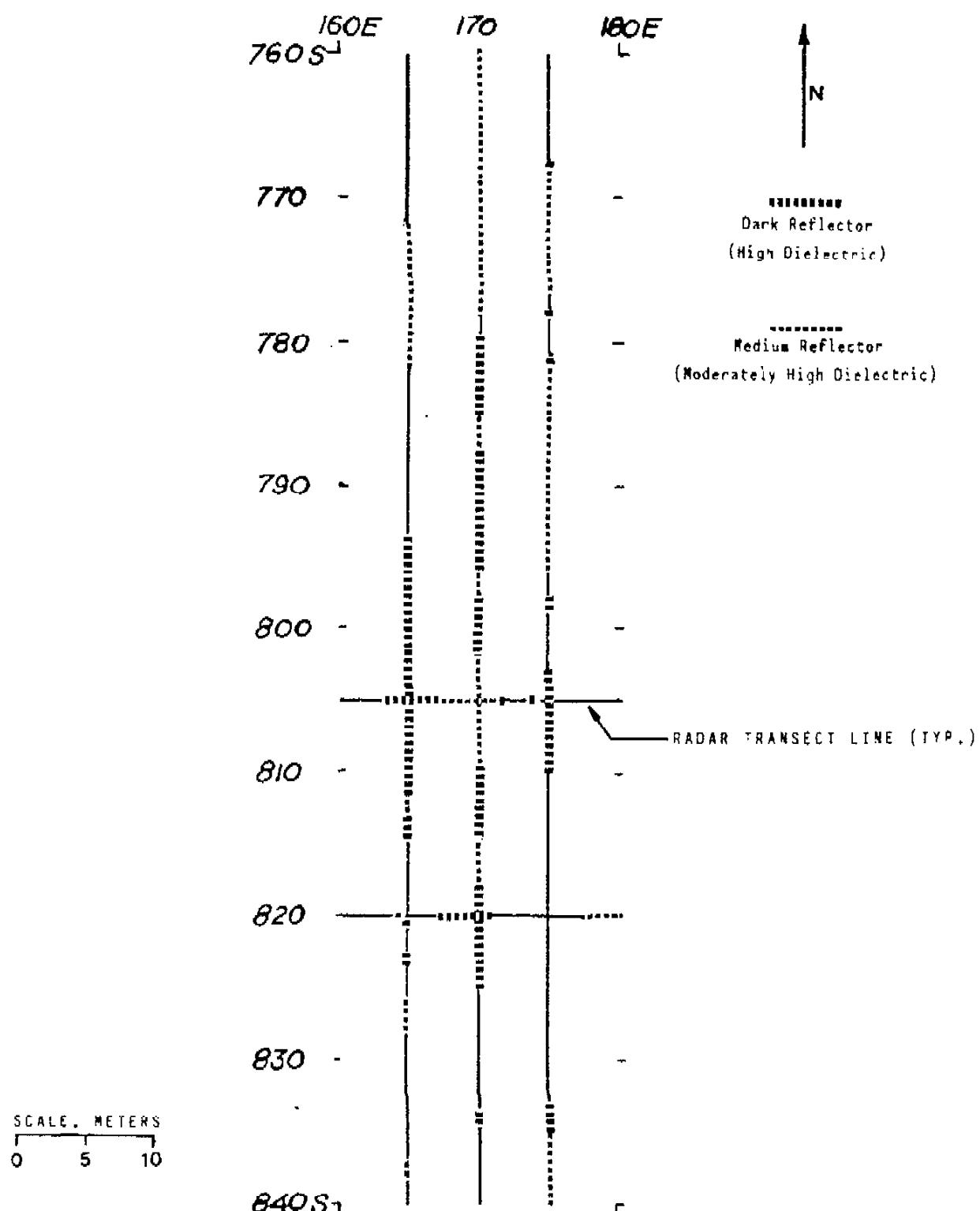


FIGURE 2. AREA Q RADAR ANOMALIES

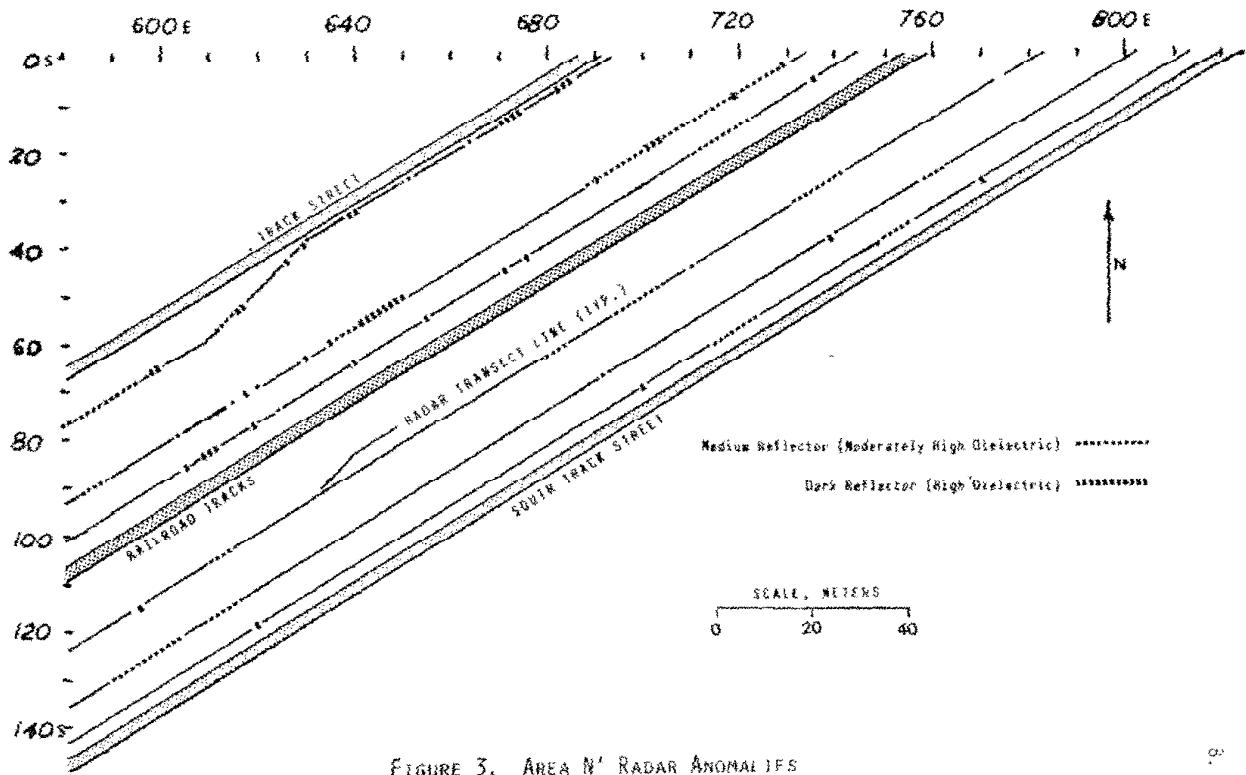


FIGURE 3. AREA N' RADAR ANOMALIES

TABLE II

## BORING LOCATIONS DETERMINED BY RADAR

AREA N

<u>Boring Number</u>	<u>Direction of Relocation</u>	<u>Proposed Location</u>	<u>Final Location</u>	<u>Notes</u>
N1	-	270S, 590E	270S, 590E	
N2	-	40S, 102E	40S, 102E	
N3	-	150S, 404E	150S, 404E	

**RADARVISION**

APPENDIX

Liquid Contaminants

Field Charts

RADARVISION

## LIQUID CONTAMINANTS

The presence of liquid contaminants in the ground creates distinct radar signatures according to the electrical properties of the liquid. Ionic liquids are electrically active due to the ions having electrical charge. Examples of ionic liquids are acids and salts. The presence of an ionic liquid in the ground lowers the electrical resistance of the ground, an effect that is observed by the radar system as a lighter-than-normal contrast.

Non-ionic liquids in the ground also modify the electrical characteristics of the ground, but in a different way: non-ionic liquids increase the dielectric constant of the ground, an effect that is observable by the radar system as a darker-than-normal contrast.

Fresh water is a special case of a non-ionic liquid. For reasons explained in the following paragraphs, water is usually distinguishable from other non-ionic liquids in the ground.

### Ionic Liquids

As the radar signal travels into the ground, the energy is attenuated in proportion to the electrical conductivity of the ground. Normally, the ground has relatively high resistivity (the inverse of conductivity). The presence of electrically-active liquids will lower the electrical resistivity of the ground, resulting in more rapid loss of the radar signal. This shows in the radar record as an area of lighter-than-normal contrast. Experience with the radar system allows us to make close estimates of the resistivity values. In effect, the radar can be used as an imaging resistivity meter because of its extreme sensitivity to this parameter. Vertical and horizontal boundaries which only show as broad trend lines with conventional resistivity probes become sharply delineated on the radar record, thus allowing the boundaries of a contamination zone to be established with high accuracy.

### Non-ionic Liquids

Non-ionic liquids such as petroleum-based solvents, oils, or other non-electrically active substances do not alter the electrical conductivity. Instead, non-ionic liquids tend to increase the dielectric constant of the ground. Higher dielectric values affect the coefficient of reflection according to the following equation:

$$r = \frac{\sqrt{\epsilon_1} - \sqrt{\epsilon_2}}{\sqrt{\epsilon_1} + \sqrt{\epsilon_2}}$$

where       $r$       = coefficient of reflection  
 $\epsilon_1$       = dielectric constant, layer 1  
 $\epsilon_2$       = dielectric constant, layer 2

## DETECTION SCIENCES GROUP

496 HEALD ROAD CARLISLE, MASSACHUSETTS 01741

(617)369-7999

## RADARVISION

TAPE NO. 8245  
DATE: 10/25/82LOCATION: LEWISTON NY  
AREA N'

CLIENT: ORAN

RANGE ADJ	RANGE MULTIPLY			RANGE GAIN	FILTER	SENSI- TIVITY	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
350				9 12.5 0		250														J147-82
GRID		MARKER CODE	TAPE COUNT			FIRST MARK	LAST MARK	COMMENTS												
			START	FINISH				DEATH 12 FT.												
1	141E	—	000	0057	20S	50S														TEST RUN DIRT PILES 40S TO 50S
2	141E	2#0	057	128	20S	50S														NOTE DIRT PILES
3	146E	3#0	128	196	20S	50S														DIRT PILES 40S TO 50S DITCH AT 36S
4	151E	4#0	196	285	20S	50S														DITCH AT 29S DIRT PILE AT 49-50S
5	156E	5#0	285	352	20S	50S														DIRT AT 60S DARK AREA AT 35S COINCIDES DITCH AT 25S WITH THE CLUSTER OF PIN PILES
6	161E	6#0	352	413	20S	50S														NO SURFACE EVIDENCE OF ANOMALIES
6	166E	6#0	413	469	20S	50S														NO SURFACE EVIDENCE OF ANOMALIES
8	171E	8#0	469	530	20S	50S														SURFACE TRASH EVIDENT IN DARK AREA 70-80S
9	176E	2#0	530	584	20S	50S				"	"	"								"
10	181E	3#0	584	638	20S	50S														START 22S
11	186E	4#0	638	689	25S	50S														SURFACE TRASH IN DARK AREA
12	191	5#0	689	746	175E	190E														START 175E DITCH 156E
13	245	6#0	746	807	185E	190E														DITCH 154E
14	295	7#0	807	869	185E	190E														HEAVY DADATT REFLECTOR AT PIN PILES

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**RADARVISION**TAPE NO.: **8245**  
DATE: **10/25/82**LOCATION: **LEWISTON, NY**  
**AREA N'**CLIENT: **ORAU**

RANGE ADJ	RANGE MULTIPLY			RANGE GAIN	FILTER			SENSI- TIVITY	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		
350				9	12	0		250												J147-82	
GRID		MARKER CODE		TAPE COUNT				FIRST MARK	LAST MARK	COMMENTS											
NO.	LINE	START	FINISH																		
15	343	840	869	924	185E	140E		SURFACE TRASH EVIDENT AT BEGINNING CLUSTER OF PIN CLIPS IN DIRT AREA 157E													
16	393	240	924	976	185E	140E															
17	443	340	976	1033	185E	140E		DIRTY PILE AT 145E - 140E													
18	493	440	1033	1089	185E	140E		DIRTY PILE AT END													
								1340S, 48E													

## DETECTION SCIENCES GROUP

496 HEALD ROAD CARLISLE, MASSACHUSETTS 01741  
(617)369-7999

## RADARVISION

TAPE NO.: 8245  
DATE: 10/26/82LOCATION: LEWISTON, NY  
AREA Q

CLIENT: ORAU

RANGE ADJ	RANGE MULTIPLY			RANGE GAIN		FILTER			SENSI- TIVITY	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				9.5	12 <sup>t</sup>	6														J1A7-82
GRID		MARKER CODE		TAPE COUNT				FIRST	LAST MARK		COMMENTS									SYSTEMATIC BOREHOLES
NO.	LINE	START	FINISH																	
19	As	3#0	1089	1130	-6M	+6M	N→S	1502S, 103E	/every 2m											
20	As	2#0	1130	1163	-6M	+6M	W→E	" "	Z @ BOREHOLE											
21	Bs	3#0	1163	1197	-6M	+6M	N→S	1504S, 112E												
22	Bs	4#0	1197	1229	-6M	+6M	W→E	" "												
23	Cs	5#0	1229	1261	-6M	+6M	N→S	1503S, 133E												
24	Cs	6#0	1261	1291	-6M	+6M	W→E	" "												
25	As	7#0	1291	1329	-6M	+6M	N→S	1501S, 22E												
26	As	8#0	1329	1359	-6M	+6M	W→E	" "												
27	8s	4#0	1359	1389	-6M	+6M	N→S	1507S, 25E												
28	Bs	2#0	1389	1420	-6M	+6M	W→E	" "												
29	Cs	3#0	1420	1455	-6M	+6M	N→S	1503S, 31E												
30	Cs	4#0	1455	1493	-6M	+6M	W→E	" "												
31	Q7	5#0	1493	1526	-6M	+6M	N→S	26.2 METERS S OF NODDY LIGHT	ANGLE											
32	Q7	6#0	1526		-6M	+6M	W→E	8.8	" N "											

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## RADARVISION

TAPE NO.: 8245  
DATE: 10/26/82LOCATION: LEWISTON, NY  
AREA Q

CLIENT: ORAU

RANGE ADJ	RANGE MULTIPLY			GAIN	FILTER			SENSI- TIVITY	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 1/2	1	2	4	
350				9 12. 0				250													J147-82
GRID		MARKER CODE			TAPE COUNT			FIRST MARK	LAST MARK	COMMENTS											
NO.	LINE				START	FINISH				SYSTEMATIC BOREHOLES											
33	Q8	7#0	1556	1585	-6M	+6M	N→S	Q8 @ 1340S, 48E													UNDISTURBED EARTH
34	Q8	8#0	1585	1612	-6M	+6M	W→E	Q8	"	"											BELOW FLOW ZONE
35	Q9	-	000	071	-6M	+6M	N→S	Q9 1266S, 176E @ 1267S													PIPE RUNS N-S
36	Q9	2#0	071	135	-6M	+6M	W→E	Q9	"	"											
37	Q10	3#0	135	250	-6M	+6M	N→S	Q10 1222S, 155E													
38	Q10	4#0	250	309	-6M	+6M	W→E	Q10	"	"											
39	Q11	5#0	309	368	-6M	+6M	N→S	Q11 1167S, 159E													
A0	Q11	6#0	368	424	-6M	+6M	W→E	Q11	"	"											
41	Q12	7#0	424	475	-6M	+6M	N→S	Q12 1080S, 28E													
42	Q12	8#0	475	525	-6M	+6M	W→E	Q12	"	"											
43	Q13	2#0	525	573	-6M	+6M	N→S	Q13 744S, 30E													
44	Q13	3#0	573	619	-6M	+6M	W→E	Q13	"	"											

PAGE 1 OF 8

## DETECTION SCIENCES GROUP

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## RADARVISION

TAPE NO.: 8245  
DATE: 10/26/82LOCATION: LEWISTON, NY  
AREA Q

CLIENT: ORAU

RANGE ADJ	RANGE MULTIPLY			RANGE GAIN		FILTER			SENSI- TIVITY	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	12	0	---	---	---	---	---	---	250	---	---	---	---	---	---	---	J147-82
GRID		MARKER CODE		TAPE COUNT				FIRST MARK	LAST MARK	COMMENTS											
NO.	LINE	START	FINISH																		
45	Q14	4#0	619	676	-6M	+6M	N→S	Q14	3345	20E											
46	Q14	5#0	676	724	-6M	+6M	W→E	Q14	"	"											
47	Q15	6#0	724	781	-6M	+6M	N→S	Q15	5695	200E											
48	Q15	7#0	781	827	-6M	+6M	W→E	Q15	"	"											
49	Q16	8#0	827	870	-6M	+6M	N→S	Q16	5445	440E											
50	Q16	3#0	870	908	-6M	+6M	W→E	Q16	"	"											
51	Q17	2#0	908	939	-4M	+6M	N→S	Q17	3205	526E											
52	Q17	3#0	939	969	-4M	+6M	W→E	Q17	"	"											BRUSH PILE AT BEGINNING
53	Q18	4#0	969	1005	-6M	+6M	N→S	Q18	3305	760E											
54	Q18	5#0	1005	1041	-6M	+6M	W→E	Q18	"	"											

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## DETECTION SCIENCES GROUP

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## RADARVISION

TAPE NO.: 8245  
DATE: 10/27/82

LOCATION: LEWISTON, NY  
AREA Q

CLIENT: DRAV

RANGE ADJ	RANGE MULTIPLY			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 1/2	0			250													J147-82
GRID		MARKER CODE	TAPE COUNT				FIRST MARK	LAST MARK	COMMENTS												
NO.	LINE		START	FINISH																	
55	805S	6#0	1041	1090	160E	180E			W-E 12.8 ips												
56	820S	7#0	1090	1135	160E	180E			W-E 12.8 ips												
57	165E	8#0	1135	1283	760S	840S			N-S 1 EVERY 5M; 2 AT BORINGS    15 ips												
58	175E	4#0	1283	1401	760S	840S			N-S " "												
59	170E	2#0	1401	1529	760S	840S			" " "												
									HOT SPOT CLUSTER @ 770S, 170E												
									" " " 780S -> 810S LINE 170E												
									CHANNEL 4												
									AREA N' TRACK ST.												
60	—	000	600	580#	820E	SW-E			3M NW OF RD E / MARK EVERY 10M												
61	2#1	600	985	"	"	"			14M NW OF RD E (AT ANGLE)												
62	3#1	985	1279	"	"				10M SE OF RD E												

PAGE 1 OF 0

## DETECTION SCIENCES GROUP

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## RADARVISION

TAPE NO.: 8246  
DATE: 10/29/82LOCATION: LEWISTON, NY  
AREA N'

CLIENT: ORAU

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	12			250													J1A7-82
GRID	MARKER CODE		TAPE COUNT			FIRST MARK	LAST MARK		COMMENTS												
NO. LINE			START	FINISH																	
63		2#0	1140	1340	580E	ON	SW -> NE GM NW OF R.R. & [MARK EVERY 10M]														
64		3#0	1340	1490	580E	ON	REPEAT #63 (WHEEL JAMMED) [ON ANGLE 60]														
							CHANNEL 4														
			-	000	090	580E	SW -> NE 12M NW OF R.R. & [ABORT]														
65		2#0	090	436	580E	HOME ON 120	" " " " " " "														
66		3#0	436	699	580E		SW -> NE 9M SE OF ROAD &, THEN DIAGONAL (605, 610E (ON SE SIDE)) TO 505, 620E TO 403, 630E, THEN PARALLEL TO ROAD, 2M SE OF ROAD &														
			:																		
				</td																	

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# RADARVISION

TAPE NO.: 8246  
DATE: 11/1/82

LOCATION: LEXINGTON NY,  
AREA N & N'

CLIENT: *seeu*

DATE 0 AC 0

FIELD LOGS

APPENDIX D

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

## Appendix D

### Evaluation of Radiation Exposures on Off-Site Property Q 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 Town of Lewiston 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 known 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 Town of Lewiston is the current owner of a 89-acre tract, identified as off-site property Q. The town's highway maintenance garage, several town offices, and a fenced yard for storing heavy equipment and sand and gravel occupy the extreme southern portion of the property.

This property was surveyed by Oak Ridge Associated Universities, Oak Ridge, Tennessee, during October and November 1982, and found to contain isolated areas of radioactive contamination. The survey indicated radionuclides from the naturally occurring uranium, thorium, 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, thorium, 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, D-2, and D-3.

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

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

with only one small area of contaminated surface soil. The average exposure rate of 11 microroentgens 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 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 1.1 millirad per hour and the average was 0.044 millirad per hour. Although the maximum level exceeds the 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,

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

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.

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 Q is 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 0.57 picocuries\* per gram - less than the background levels normally present in surface soils in the Lewiston area.

The resulting concentrations of resuspended Ra-226, based on a resuspension factor of  $5 \times 10^{-9}$  per meter, would be about  $6 \times 10^{-17}$  microcuries per cubic centimeters of air. For comparison the Nuclear Regulatory Commission guideline level for continuous exposure of the general public is  $2 \times 10^{-12}$  microcuries per cubic centimeter. The estimated concentration of airborne Ra-226 is more than a factor of 30,000 less than the guideline 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 with its daughter products and

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

result in lung exposures. Radon levels in the vicinity of the NFSS are continuously monitored by Department of Energy contractors. Sampling near property Q indicated an average radon concentration of approximately 0.2 picocuries per liter of air from May, 1978 to February, 1980.\* The guidelines for continuous exposure of the general public is 3 picocuries per liter. For comparison the average area background level during 1979 and 1980 was also 0.2 picocuries per liter.

#### 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 presented in Table D-5. Assumptions made in performing these calculations are:

1. The levels reported in Table D-4 are representative of the conditions and will not change during the year or from year to year.

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\*Data from National Lead Co. of Ohio, Review of Radon Monitoring at the Niagara Falls Storage Site, Cincinnati, OH, March 31, 1980.

2. Average exposure levels in Table D-4 are representative of the averages to which an individual working on the property might be exposed.
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 on 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-5 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 not being excluded.

Since the estimated Ra-226 air concentrations are a very small fraction of the guidance level and the Rn-222 air concentrations are essentially background, exposures and risk from the inhalation pathway would be negligible and were therefore not evaluated further. 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 the property. Exposures and risk are therefore limited to one pathway -- direct exposure to gamma radiation.

The estimated increased risk due to cancer from exposure to the average radiation levels on property Q, for a working lifetime is 0.027 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 0.0027 percent or an increase in total risk from 21.8 to 21.8027 percent when compared to the average risk in Niagara County. This may also be expressed as a percent increase in overall risk of getting a fatal cancer of 0.012 percent - a negligible increase.

#### SUMMARY

In summary portions of NFSS off-site property Q, now belonging to the Town of Lewiston, are contaminated with low-level residues containing 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.

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  
THORIUM DECAY SERIES

Parent	Half-Life	Major Decay Products	Daughter
Thorium-232	14 billion years	alpha	Radium-228
Radium-228	5.8 years	beta	Actinium-228
Actinium-228	6.13 hours	beta, gamma	Thorium-228
Thorium-228	1.91 years	alpha	Radium-224
Radium-224	3.64 days	alpha	Radon-220
Radon-220	55 seconds	alpha	Polonium-216
Polonium-216	0.15 seconds	alpha	Lead-2112
Lead-212	10.6 hours	beta, gamma	Bismuth-212
Bismuth-212	60.6 minutes	alpha (1/3)* beta (2/3)*	Thallium-208 Polonium-212
Thallium-208	3.1 minutes	beta, gamma	Lead-208
Polonium-212	0.0000003 seconds	alpha	Lead-208
Lead-208	stable	none	none

\* Two decay modes are possible for Bismuth-212.

TABLE D-3  
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-4  
SUMMARY OF EXPOSURE LEVELS ON PROPERTY Q  
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	11 $\mu\text{R/h}^a$	430 $\mu\text{R/h}$	8 $\mu\text{R/h}$	0.5 rem <sup>b</sup> per year for individual, equivalent to 250 $\mu\text{R/h}$ above natural background for 40 h/wk and continuous exposure.	5 rems per year
Radionuclides (Radium-226) in air	$6 \times 10^{-17}$ $\mu\text{Ci/cc}^c$	---	unknown	$2 \times 10^{-12}$ $\mu\text{Ci/cc}$ for continuous (168 h/wk) exposure	$5 \times 10^{-11}$ $\mu\text{Ci/cc}$ for 40 h/wk exposure
D-12 Radon in air	0.2 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	7.59 pCi/l	19.6 pCi/l	Appr. 0.8 pCi/l	15 pCi/l, EPA Standard for Public Drinking Water Systems	400 pCi/l
Radionuclides in Soil:					
Radium-226	0.57 pCi/g	1020 pCi/g	Appr. 0.7 pCi/g	EPA MLL Tailings (Criteria is 5 pCi/g above background averaged over 100 m <sup>2</sup> of surface soil.)	none
Cesium-137	0.47 pCi/g	7.1 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

TABLE D-4, cont.

SUMMARY OF EXPOSURE LEVELS ON PROPERTY Q  
LEWISTON, NEW YORK

Exposure Source	Levels on Site			Guidelines for General Public	Guidelines for Radiation Workers
	Average	Maximum	Background Levels		
Uranium-238	4.10 pCi/g	36.6 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	0.25 pCi/g	2.06 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 ( $\mu$ R) 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 ( $\mu$ Ci) and picocurie (pCi) are units which are defined for expressing the amount of radioactivity present in a substance.  $1 \mu\text{Ci} = 10^{-6} \text{ Ci}$ ,  $1 \text{ pCi} = 10^{-12} \text{ Ci}$ .

TABLE D-5

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

Source of Exposure	Working Lifetime Dose Equivalent Corrected for Background	Increased Risk Due to All Cancers
External gamma radiation	0.27 rems	0.027 per 1000 <sup>a</sup>
Inhalation of resuspended particulates	negligible	0
Inhalation of radon	negligible	0
Ingestion of food and water contaminated by radioactive materials on-site	negligible	0
TOTAL	0.27 rems	0.027 per 1000 <sup>b</sup>

<sup>a</sup> 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).

<sup>b</sup> 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).