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Projects

U.S. Department
of Energy

COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY R

NIAGARA FALLS STORAGE SITE

LEWISTON, NEW YORK

J. D. BERGER

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

FINAL REPORT

February 1984

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LEWISTON, NEW YORK

Prepared for

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

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COMPREHENSIVE RADIOLOGICAL SURVEY

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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.[1]

Niagara Mohawk Power Corporation is the current owner of a tract from the NFSS, identified as off-site property R (see Figure 1). A radiological survey of that tract, conducted July-September 1983, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property R. The property is rectangular (about 190 m x 120 m) and occupies approximately 2.3 hectares. It is bounded on the south by Pletcher Road. Drainage ditches are located along both the eastern and western boundaries. Power transmission lines cross the property in a north/south direction and a small paved road provides access to these power lines. The property is otherwise unused and contains no structures. The land is level and is overgrown with brush and trees.

Radiological History

There is no evidence of contaminated waste burial or storage on property R; however, slightly elevated radiation levels have been detected along Pletcher Road and the northern site boundary.[1-3] Leakage or spillage of small amounts of contaminated residues from waste transport vehicles may have resulted in the elevated levels on Pletcher Road. Shine from residue materials, located on the nearby NFSS, has been suggested as the source of elevated radiation levels on the northern portion of the property.

SURVEY PROCEDURES

The comprehensive survey of off-site property R was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during the period of July-September, 1983. The survey was in accordance with a plan dated March 18, 1983, approved by the Department of Energy's Office of Nuclear Energy. 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 on property R. Radiological information collected included:

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

Procedures

1. Brush and weeds were cleared as needed to provide access for gridding and surveying and a 20 m system was established. These operations were performed by McIntosh and McIntosh of Lockport, NY, under subcontract. The grid system is shown on Figure 3.

2. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at 20 m grid intervals. Measurements were performed using portable gamma NaI(Tl) scintillation survey meters. Conversion of these measurements to exposure rates in microroentgens per hour (μR/h) was in accordance with cross calibration with a pressurized ionization chamber.

3. Beta-gamma dose rate measurements were performed 1 cm above the surface at 20 m grid intervals. These measurements were conducted using thin-window (<7 mg/cm^2) G-M detectors and portable scaler/ratemeters. Measurements were also obtained with the detector shielded to evaluate contributions of nonpenetrating beta and low-energy gamma radiations. Meter readings were converted to dose rate in microrads per hour (μrad/h) based on cross calibration with a thin-window ionization chamber.

4. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at 20 m grid intervals.

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

6. At locations of elevated surface radiation levels (see Figure 4), gamma exposure rates at 1 m above the surface and beta-gamma dose rates at 1 cm above the surface were also measured. Surface soil

samples were obtained from these locations and, following sampling, the surface exposure levels were remeasured to evaluate the effectiveness of shallow sampling on removal of the radiation source.

7. Detection Sciences Group of Carlisle, MA, performed ground-penetrating radar surveys at locations of proposed subsurface investigations to identify the presence of underground piping or utilities which would preclude borehole drilling.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Three boreholes were drilled by Site Engineers, Inc., of Cherry Hill, NJ, using a truck mounted 20 cm diameter hollow-stem auger. The locations of these boreholes are shown on Figure 5.

   A gamma scan of the boreholes was performed to identify elevated radiation levels, which would indicate subsurface residues. Radiation profiles in the boreholes were determined by measuring gamma radiation at 15-30 cm intervals between the surface and the hole bottom. A collimated gamma scintillation detector and portable scaler were used for these measurements.

   A sample of the ground water was collected from one of the boreholes using a hand bailer. Soil samples of approximately 1 kg each were collected from various depths in the holes by scraping the sides of each borehole with a specially constructed sampling tool.

9. Sediment samples (1 kg) were collected from two locations in the ditch on the site's west perimeter (see Figure 6).

10. Twenty soil samples and seven water samples were collected from the Lewiston area (but not on the NFSS or associated off-site properties) to provide baseline concentrations of radionuclides

for comparison purposes. Direct background radiation levels were measured at locations where baseline soil samples were collected. The locations of the baseline samples and background measurements are shown on Figure 7.

Sample Analyses and Interpretation of Results

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

Additional information concerning analytical equipment and procedures is contained in Appendix A.

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

RESULTS

Background Levels and Baseline Concentrations

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

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

Direct Radiation Levels

Direct radiation levels, measured at 20 m grid intervals, are presented in Table 2. The gamma exposure rates at 1 m above the surface ranged from 7 to 11 μR/h (average 8 μR/h). At surface contact, the exposure rates ranged from 6 to 17 μR/h (average 9 μR/h). Beta-gamma dose rates ranged from 8 to 51 μrad/h (average 22 μrad/h). 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. Levels were generally higher along the shoulder of Pletcher Road (grid lines 302-304S).

The walkover survey identified four small isolated areas with elevated surface radiation levels. These locations are indicated on Figure 4 and direct radiation levels at these locations are presented in Table 3. Contact gamma exposure rates ranged from 16 to 29 μR/h. Gamma exposure rates at 1 m above the surface and beta-gamma dose rates ranged from 12 to 14 μR/h and 20 to 56 μrad/h respectively. Sampling at these locations had no significant effect on the direct radiation levels, suggesting that any contamination at these points is diffused rather than in small discrete deposits.

Radionuclide Concentrations in Surface Soil

Table 4 lists the concentrations of radionuclides measured in surface soil from 20 m grid intervals. These samples contained Ra-226 concentrations ranging from <0.14 to 17.3 pCi/g. The highest level was in the sample from grid point 303S,80W, along the shoulder of Pletcher Road. Other samples from the shoulder of the road also contained elevated Ra-226 levels. Concentrations of U-235 and U-238 were not significantly different from those in baseline samples. The Cs-137 levels in samples from 159S,60W and 302S,100W were 6.45 and 3.46 pCi/g, respectively. Other samples contained baseline levels of that radionuclide.

Samples from locations of elevated contact radiation levels ranged from 6.55 to 29.9 pCi/g of Ra-226 (see Table 5). The maximum level was in sample B4 from grid location 304S,73W at the shoulder of Pletcher Road. These samples did not contain significant concentrations of other radionuclides.

Borehole Gamma Logging Measurements

The results of gamma scintillation measurements performed in boreholes indicated no subsurface contamination. Gamma logging data were not used to quantify radionuclide concentrations in the subsurface soil because of the varying ratios of Ra-226, U-235, U-238, and Cs-137 occurring in soils from this site.

Radionuclide Concentrations in Subsurface Soil

Table 6 presents the radionuclide concentrations measured in soil samples from three boreholes, located to provide a representative coverage of the property. These soil samples had radionuclide concentrations either in the range of baseline samples or less than the minimum detectable activity.

Radionuclide Concentrations in Water

No surface water sources were available on the property at the time of the survey. Water was obtained from one borehole and contained concentrations of 15.4 pCi/l gross alpha and 8.10 pCi/l gross beta (see Table 7). This sample also contained 0.38 pCi/l of Ra-226.

Radionuclide Concentrations in Storm Drainage Ditch Sediments

Concentrations in sediment samples, collected from the drainage ditch along the western property boundary, are presented in Table 8. These samples did not contain radionuclide levels significantly different from the levels in baseline soil.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

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 R are less than 20 μR/h above the background level. The average level of 8 μR/h is well below the 60 μR/h criteria for open land areas.

Surface soil samples, collected along the shoulder of Pletcher Road and at several locations of elevated direct radiation levels, exceed 5 pCi/g of Ra-226. These areas are indicated on Figure 8. The area along Pletcher Road is a narrow strip, 1-2 m wide, between grid points 70W and 180W. Other locations of Ra-226 surface soil contamination are isolated from each other and the concentrations averaged over 100 m^2 would be below the 5 pCi/g level. Direct measurements and sampling indicate that the contamination is limited to the surface soil. The gross alpha concentration of 15.4 pCi/l in water from one borehole exceeded the EPA Interim Drinking Water Standard of 15 pCi/l for gross alpha. The Ra-226 concentration was 0.38 pCi/l - well below the EPA Standard. It should be noted that the EPA Standards are used here for comparison purposes only and are not applicable to this site because the water does not actually represent a source of drinking water.

Sediment samples from property ditches did not contain radionuclide levels differing from baseline levels.

SUMMARY

A comprehensive survey of off-site property R at the Niagara Falls Storage Site was conducted during July-September, 1983. The survey included surface radiation scans, measurements of direct radiation levels, and analyses of radionuclide concentrations in surface and subsurface soil samples and in subsurface water. Analyses of sediment samples were also performed.

The results of the survey indicate a narrow strip of Ra-226 contaminated surface soil (0-15 cm deep) along the shoulder of Pletcher

Road. This area could be brought into compliance with the criteria by removal of approximately 30 m^3 of soil. Locations of soil areas where radionuclide concentrations exceed criteria levels are shown on Figure 8.

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.

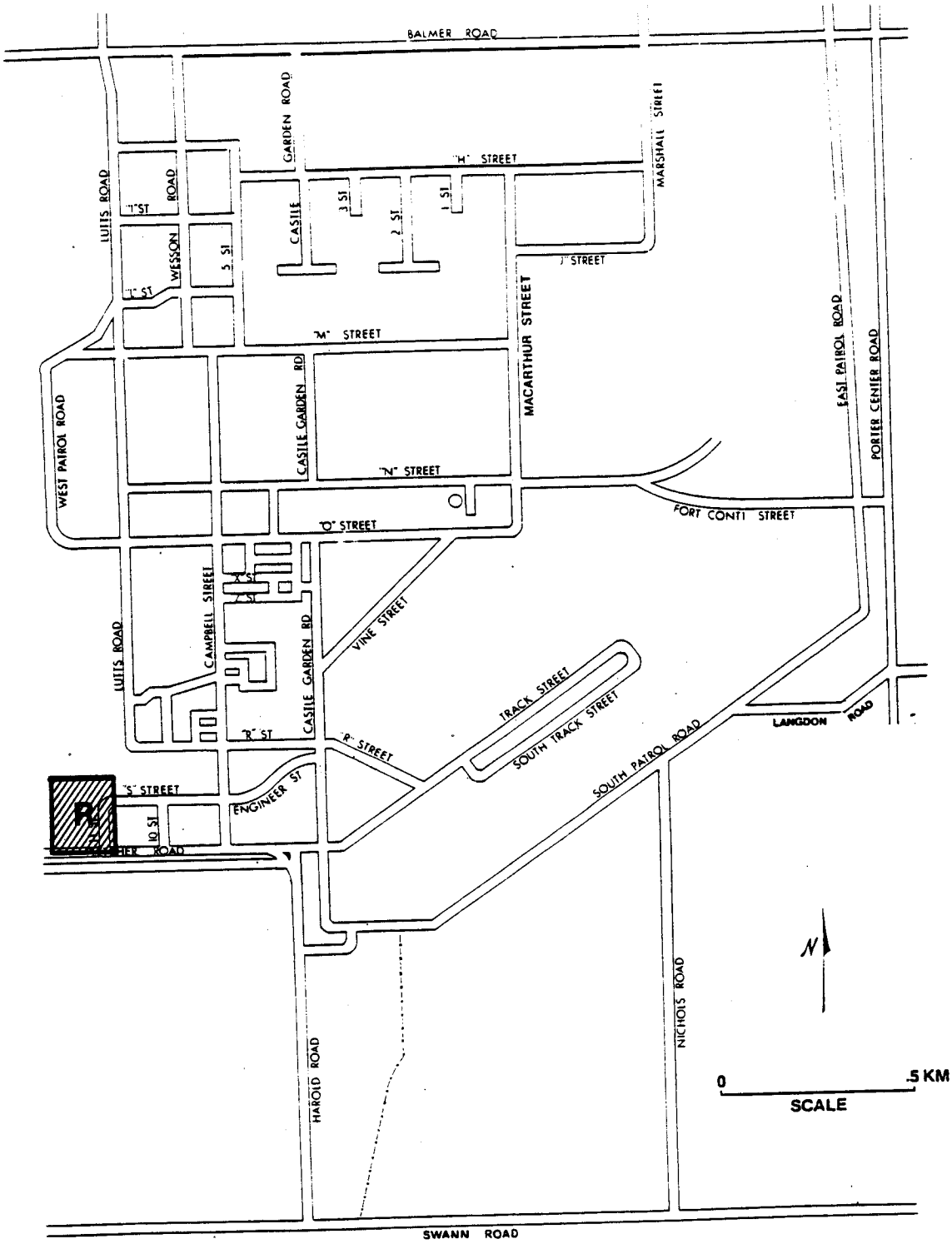

FIGURE 1. Map of the Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property R.

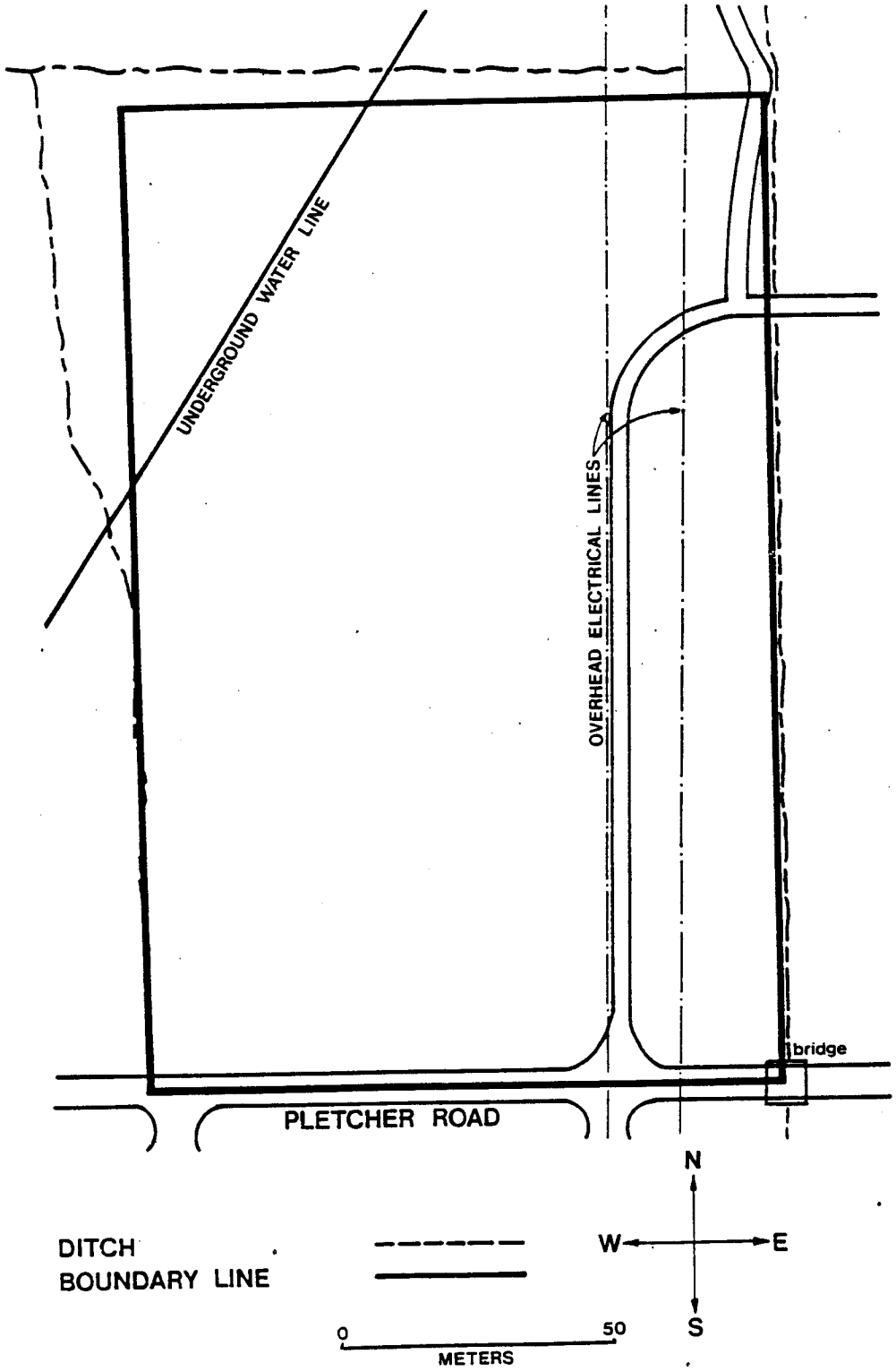

FIGURE 2. Plan View of NFSS Off-Site Property R Indicating Prominent Surface Features.

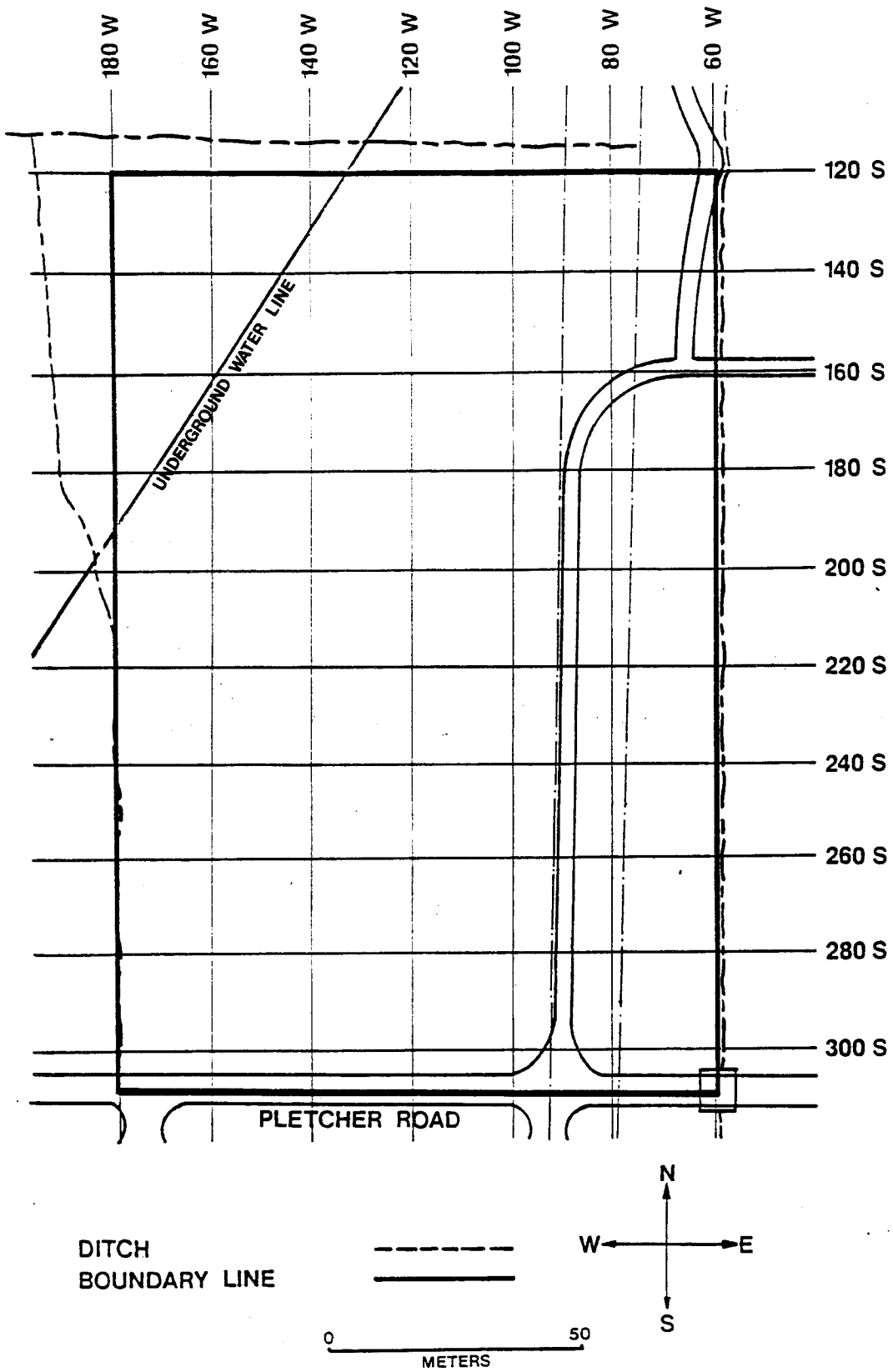

FIGURE 3. Plan View of NFSS Off-Site Property R Indicating the Grid System Established for Survey Reference.

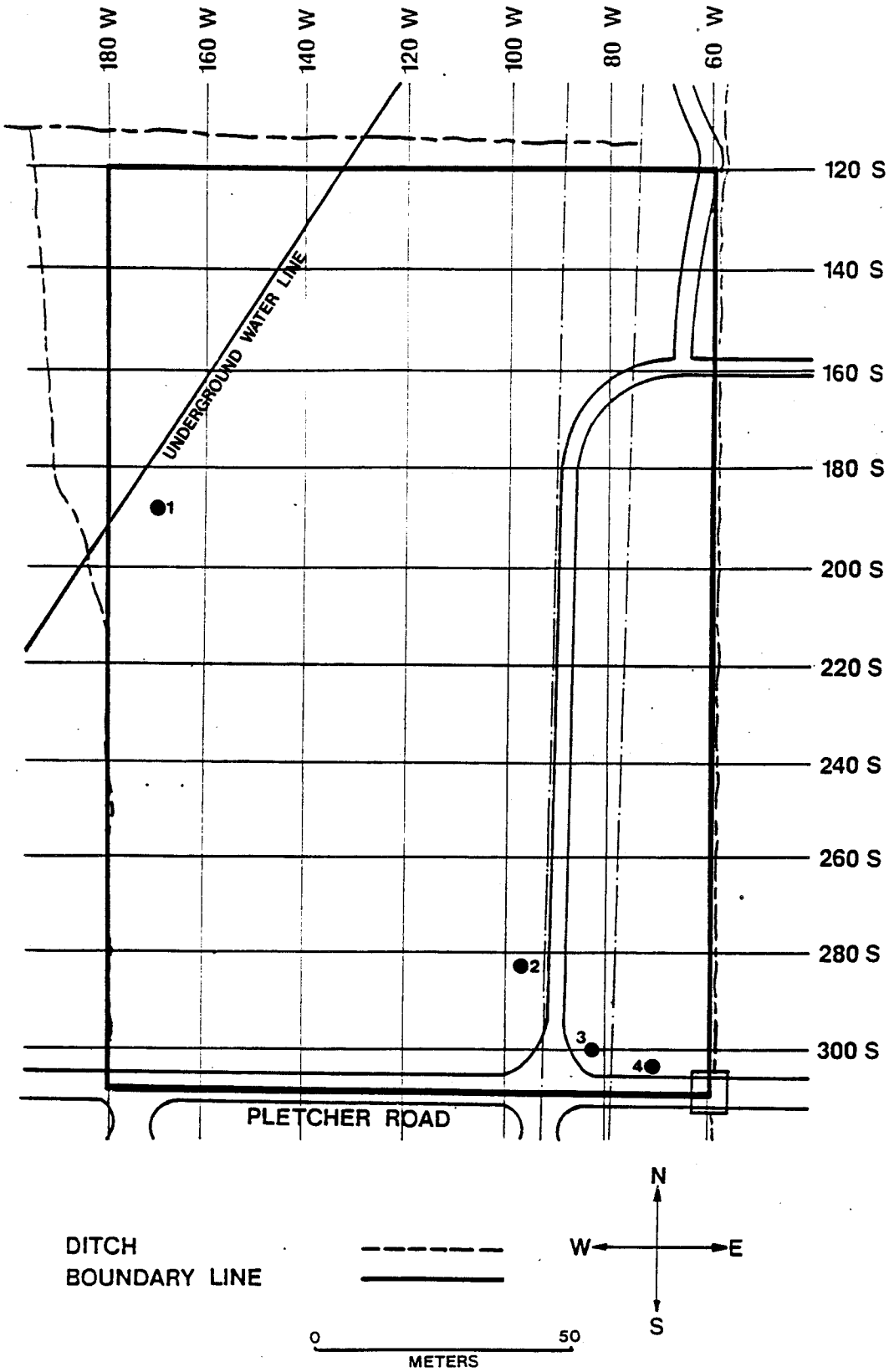

FIGURE 4. Locations of Areas of Elevated Direct Radiation.

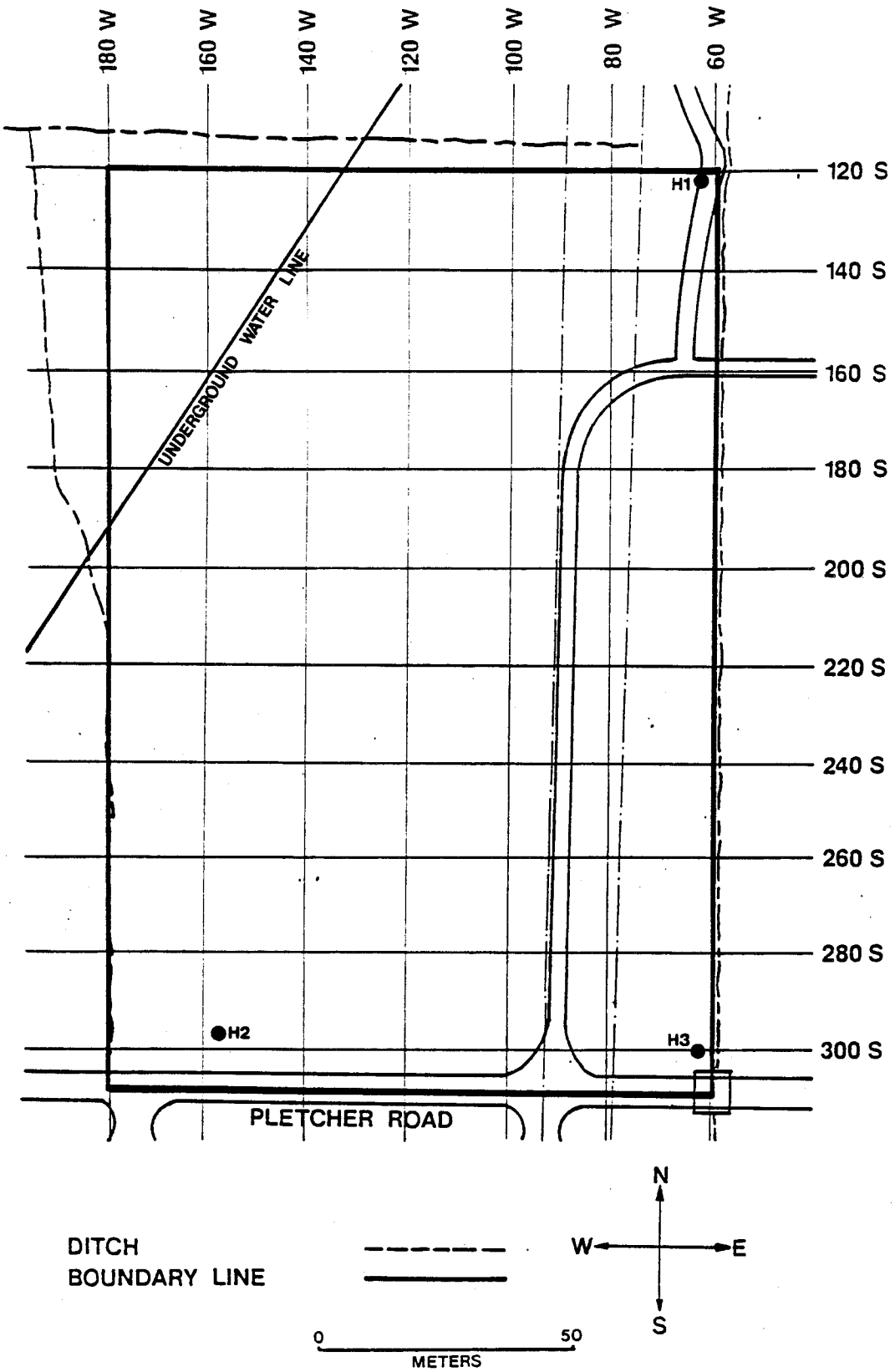

FIGURE 5. Locations of Boreholes for Subsurface Investigations.

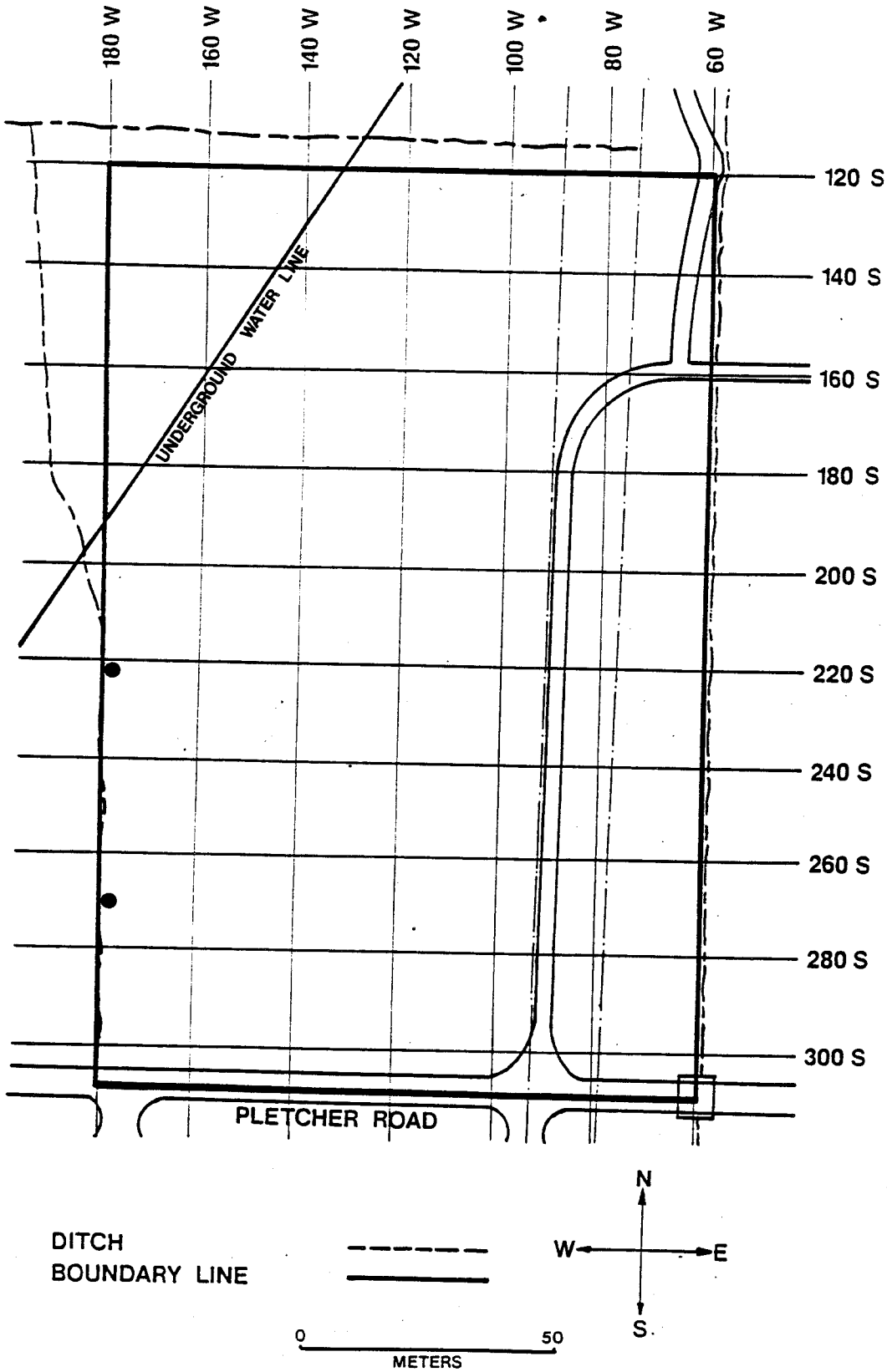

FIGURE 6. Locations of Ditch Sediment Samples.

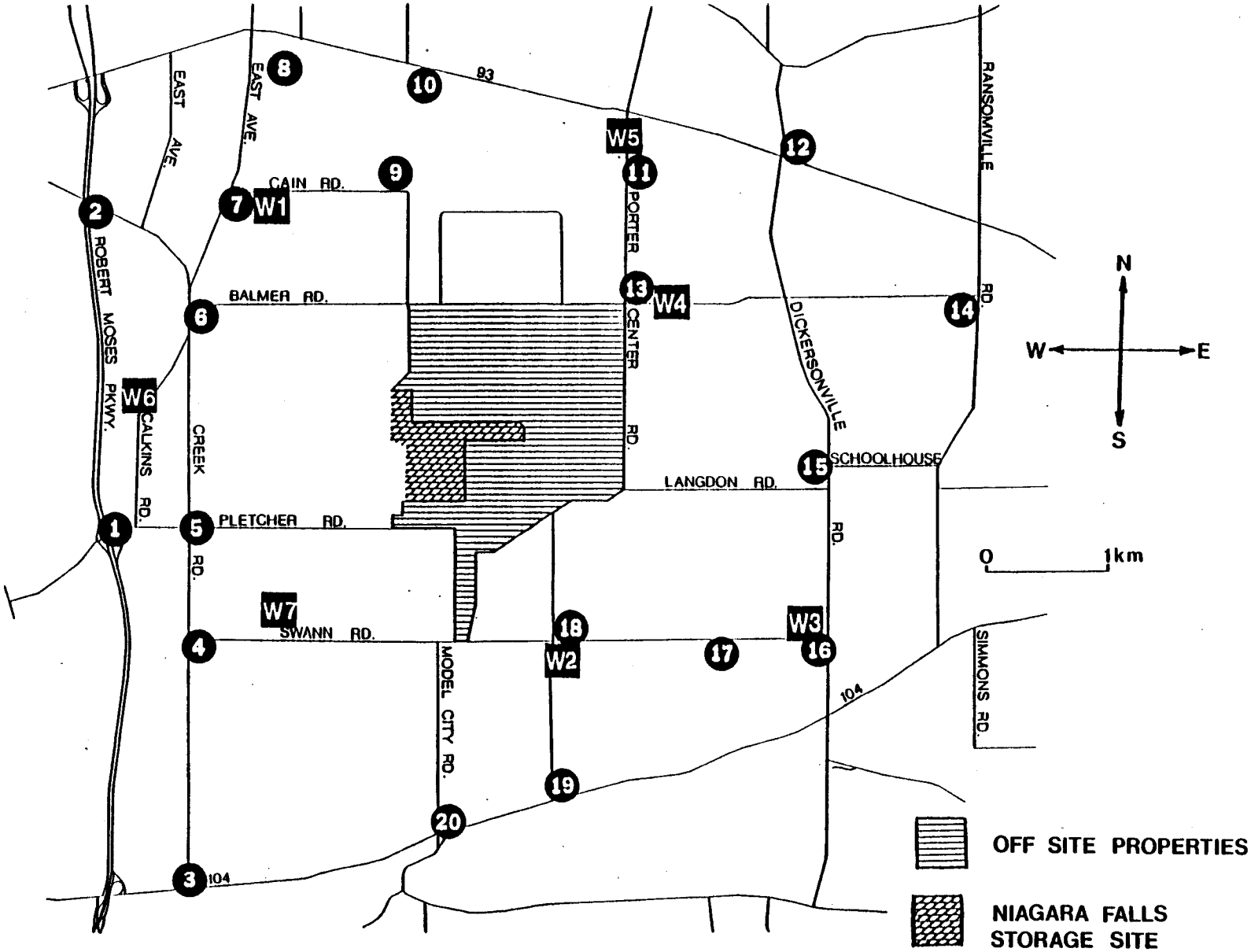

FIGURE 7. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples)

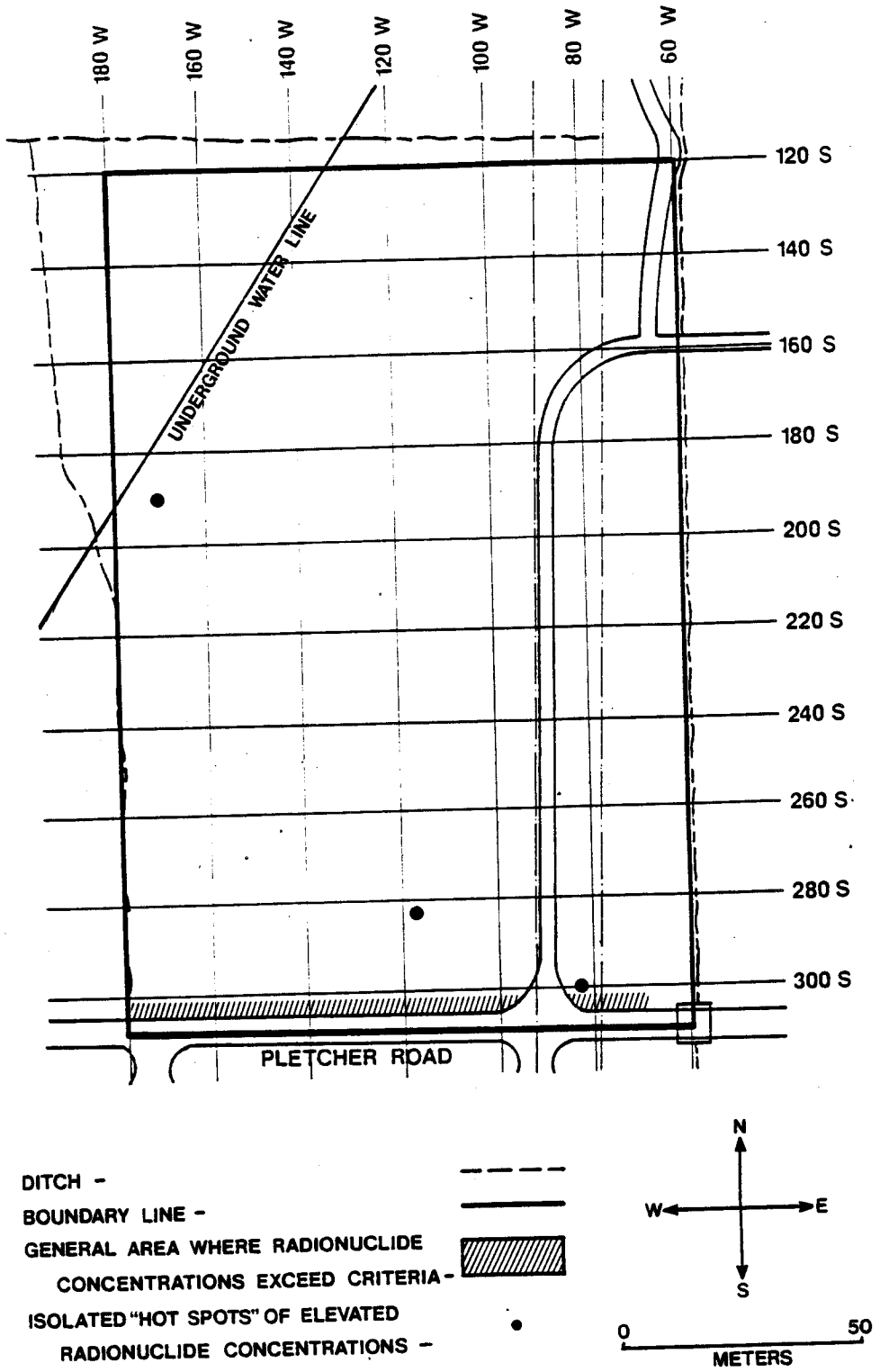

FIGURE 8. Map of NFSS Off-Site Property R Indicating Areas Where Radionuclide Concentrations in Soil Exceed Criteria Levels.

TABLE 1-A

BACKGROUND EXPOSURE RATES
AND
RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES

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

[a] Refer to Figure 7.
[b] Measured at 1 m above the surface.
[c] Errors are 2σ based on counting statistics.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

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

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

TABLE 2

DIRECT RADIATION LEVELS MEASURED
AT 20 M GRID INTERVALS

Grid Location S	Grid Location W	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
120	60	9	9	47
120	80	9	9	22
120	100	9	9	10
120	120	8	9	20
120	140	8	8	41
120	160	8	8	23
120	180	8	9	20
140	60	8	8	16
140	80	8	9	13
140	100	8	8	8
140	120	9	9	12
140	140	9	9	14
140	160	8	9	36
140	180	8	8	32
160	60	7	6	14
160	80	7	7	12
160	100	8	9	19
160	120	9	9	9
160	140	8	9	21
160	160	8	9	22
160	180	8	8	10
180	60	8	9	20
180	80	8	8	8
180	100	8	9	23
180	120	9	9	37
180	140	8	8	26
180	160	8	8	23
180	180	8	9	9
200	60	8	8	11
200	80	8	8	8
200	100	8	8	16
200	120	9	9	22
200	140	8	8	22
200	160	8	9	20
200	180	8	8	10

TABLE 2, cont.

DIRECT RADIATION LEVELS MEASURED
AT 20 M GRID INTERVALS

Grid Location S	Grid Location W	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
220	60	8	8	27
220	80	8	10	23
220	100	8	8	20
220	120	7	7	17
220	140	7	8	22
220	160	7	7	13
220	180	8	8	11
240	60	9	9	32
240	80	8	9	13
240	100	8	7	27
240	120	7	8	18
240	140	7	7	17
240	160	7	8	27
240	180	7	8	8
260	60	8	9	23
260	80	8	8	26
260	100	7	7	46
260	120	8	8	22
260	140	8	8	21
260	160	7	7	20
260	180	7	8	8
280	60	9	8	26
280	80	9	8	44
280	100	7	7	25
280	120	7	8	19
280	140	8	10	21
280	160	8	9	21
280	180	7	7	23
300	60	9	9	29
300	80	9	9	25
300	100	9	11	38
300	120	9	9	31
300	140	9	9	31
300	160	8	9	30
300	180	8	9	25

TABLE 2, cont.

DIRECT RADIATION LEVELS MEASURED
AT 20 M GRID INTERVALS

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 1 cm Above the Surface (μrad/h)
S	W			
304	60	9	10	15
304	80	9	8	12
304	100	8	7	8
304	120	11	12	21
304	140	10	12	51
304	160	10	13	32
304	180	10	17	34

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS IDENTIFIED BY THE WALKOVER SURFACE SCAN

Location	Grid Location[a]		Exposure Rates (μR/h)		Surface Dose Rate (μrad/h)	Sample No.[b]	Contact Exposure Rate After Sample Removal (μR/h)
	S	W	Contact	1 m Above Surface			
1	187	171	29	14	--[c]	B1	29
2	281	97	16	12	20	B2	14
3	300	83	16	12	56	B3	14
4	304	73	21	12	47	B4	20

a Refer to Figure 4.
b Radionuclide analyses of samples are presented in Table 5.
c Dash indicates measurement or sampling not performed.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)			
S	W	Ra-226	U-235	U-238	Cs-137
120	60	0.91 ± 0.25[a]	<0.18	1.28 ± 0.91	0.64 ± 0.14
120	80	0.61 ± 0.30	<0.24	2.61 ± 2.06	0.58 ± 0.12
120	100	1.01 ± 0.39	<0.34	4.73 ± 2.07	0.72 ± 0.15
120	120	1.13 ± 0.31	0.60 ± 0.62	3.26 ± 1.90	0.80 ± 0.16
120	140	1.08 ± 0.32	<0.25	<0.92	0.54 ± 0.17
120	160	0.84 ± 0.27	<0.20	1.67 ± 0.62	0.82 ± 0.16
120	180	1.22 ± 0.32	<0.40	4.35 ± 2.36	1.19 ± 0.22
140	60	1.03 ± 0.25	<0.19	0.71 ± 0.72	0.54 ± 0.10
140	80	1.33 ± 0.31	<0.39	0.94 ± 3.72	0.84 ± 0.17
140	100	0.85 ± 0.20	<0.22	1.57 ± 1.93	0.63 ± 0.15
140	120	0.98 ± 0.32	0.34 ± 0.50	3.37 ± 0.84	1.11 ± 0.17
140	140	<0.16	<0.22	4.56 ± 2.63	0.07 ± 0.05
140	160	1.04 ± 0.29	<0.23	1.50 ± 0.67	0.93 ± 0.18
140	180	0.39 ± 0.19	<0.46	4.03 ± 5.06	0.68 ± 0.21
159	60	1.44 ± 0.31	<0.47	1.86 ± 2.51	6.45 ± 0.38
160	81	1.04 ± 0.21	<0.15	<0.33	1.23 ± 0.26
160	100	1.17 ± 0.32	<0.39	4.15 ± 2.22	1.05 ± 0.20
160	120	0.90 ± 0.33	<0.24	2.93 ± 1.20	0.72 ± 0.14
160	140	0.71 ± 0.29	<0.28	1.87 ± 1.78	0.36 ± 0.19
160	160	1.38 ± 0.35	<0.39	1.69 ± 3.96	0.82 ± 0.18
160	180	1.49 ± 0.31	<0.29	5.23 ± 1.70	0.61 ± 0.13
180	60	0.84 ± 0.28	<0.29	1.15 ± 1.76	0.27 ± 0.11
180	80	1.34 ± 0.33	<0.33	<1.08	1.01 ± 0.16
180	100	0.89 ± 0.26	<0.28	1.68 ± 0.91	0.72 ± 0.10
180	120	1.01 ± 0.21	<0.30	<0.97	0.71 ± 0.12
180	140	1.15 ± 0.23	<0.23	<0.74	0.59 ± 0.11
180	160	0.93 ± 0.24	<0.31	1.76 ± 2.57	0.53 ± 0.18
180	180	0.95 ± 0.24	<0.35	<1.08	0.99 ± 0.16
200	60	0.69 ± 0.18	<0.13	0.21 ± 0.28	0.40 ± 0.09
200	80	0.98 ± 0.27	<0.18	0.98 ± 0.98	0.30 ± 0.10
200	100	0.98 ± 0.24	<0.28	0.78 ± 1.47	0.75 ± 0.13
200	120	1.17 ± 0.26	<0.30	2.02 ± 1.95	0.73 ± 0.13
200	140	1.13 ± 0.22	<0.33	2.83 ± 1.37	0.57 ± 0.15
200	160	1.09 ± 0.29	<0.28	<0.95	0.48 ± 0.15
200	180	0.71 ± 0.25	<0.19	0.73 ± 1.14	1.03 ± 0.20

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)			
S	W	Ra-226	U-235	U-238	Cs-137
220	60	0.20 ± 0.21	<0.24	<0.77	0.16 ± 0.08
220	80	1.02 ± 0.24	<0.31	<1.01	0.27 ± 0.10
220	100	1.42 ± 0.27	<0.30	1.86 ± 2.53	0.82 ± 0.14
220	120	0.75 ± 0.29	<0.23	2.96 ± 1.16	0.56 ± 0.11
220	140	0.59 ± 0.18	<0.16	<0.54	0.59 ± 0.11
220	160	0.65 ± 0.23	<0.13	0.19 ± 0.62	0.66 ± 0.10
220	180	0.73 ± 0.28	<0.22	1.09 ± 0.86	1.53 ± 0.21
240	60	0.99 ± 0.23	<0.21	1.76 ± 0.56	0.64 ± 0.16
240	80	0.85 ± 0.24	<0.21	1.71 ± 1.43	0.36 ± 0.12
240	100	<0.19	<0.14	0.66 ± 0.75	0.63 ± 0.11
240	120	0.76 ± 0.23	<0.27	<0.77	0.56 ± 0.11
240	140	0.18 ± 0.23	<0.14	1.24 ± 0.64	<0.06
240	160	0.83 ± 0.24	<0.16	0.88 ± 0.47	0.39 ± 0.08
240	180	0.65 ± 0.23	<0.15	0.68 ± 0.64	0.41 ± 0.10
260	60	0.95 ± 0.29	<0.19	0.84 ± 0.54	<0.09
260	80	1.03 ± 0.31	<0.22	1.71 ± 1.63	0.52 ± 0.13
260	100	0.73 ± 0.19	<0.15	0.57 ± 1.47	0.24 ± 0.07
260	120	1.06 ± 0.28	0.20 ± 0.55	<0.39	0.37 ± 0.16
260	140	<0.14	<0.23	<0.71	<0.06
260	160	0.74 ± 0.20	<0.24	<0.74	0.59 ± 0.12
260	180	0.64 ± 0.24	<0.14	1.06 ± 0.50	0.57 ± 0.12
280	60	1.16 ± 0.30	<0.30	2.72 ± 1.11	0.45 ± 0.10
280	80	2.43 ± 0.35	<0.22	2.41 ± 1.10	0.52 ± 0.12
280	100	0.73 ± 0.14	<0.20	2.22 ± 1.20	0.49 ± 0.10
280	120	0.60 ± 0.14	<0.23	<0.68	0.50 ± 0.09
280	140	0.83 ± 0.18	<0.15	0.63 ± 0.69	0.56 ± 0.09
280	160	<0.16	<0.20	<0.61	0.04 ± 0.04
280	180	0.86 ± 0.21	<0.21	4.02 ± 0.93	0.67 ± 0.14
300	60	1.43 ± 0.46	<0.34	<1.08	<0.07
300	80	1.76 ± 0.31	<0.35	<1.04	0.48 ± 0.11
300	100	2.65 ± 0.36	<0.19	1.75 ± 0.74	0.35 ± 0.08
300	120	<0.26	<0.30	<1.00	0.24 ± 0.12
300	140	1.98 ± 0.48	<0.37	<1.09	0.71 ± 0.17
300	160	1.75 ± 0.29	<0.20	1.36 ± 0.53	0.69 ± 0.14
300	180	1.79 ± 0.30	<0.32	2.30 ± 1.80	0.65 ± 0.15

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)			
S	W	Ra-226	U-235	U-238	Cs-137
304	60	1.90 ± 0.39	<0.21	<0.50	0.33 ± 0.12
303	80	17.3 ± 0.8	<0.56	<1.56	0.38 ± 0.12
302	100	15.9 ± 0.8	1.76 ± 1.13	<1.95	3.46 ± 0.27
303	120	8.73 ± 0.58	<0.29	<0.55	1.14 ± 0.14
304	140	5.68 ± 0.55	0.74 ± 0.78	<1.16	1.10 ± 0.17
302	160	7.98 ± 0.55	1.10 ± 0.80	<1.40	1.26 ± 0.17
304	180	6.29 ± 0.49	<0.48	<1.34	1.87 ± 0.19

[a] Errors are 2σ based on counting statistics.

TABLE 5

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

Sample No.[a]	Grid Location S	Grid Location W	Radionuclide Concentrations (pCi/g)[c] Ra-226	U-235	U-238	Cs-137
B1	187	171	25.1 ± 1.2[b]	2.16 ± 1.56	4.94 ± 3.84	0.28 ± 0.12
B2	281	97	6.55 ± 0.49	0.57 ± 0.71	4.16 ± 0.76	0.82 ± 0.11
B3	300	83	20.7 ± 0.9	0.88 ± 0.78	<0.68	1.58 ± 0.17
B4	304	73	29.9 ± 1.2	<0.97	<2.62	1.49 ± 0.18

[a] Refer to Figure 4.
[b] Errors are 2σ based on counting statistics.
[c] Refer to Table 3 for direct radiation levels.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.[a]	Grid Location		Depth (m)	Radionuclide Concentrations (pCi/g)			
	S	W		Ra-226	U-235	U-238	Cs-137
H1	120	62	Surface	1.30 ± 0.28[b]	<0.32	1.56 ± 2.72	<0.05
			0.5	1.26 ± 0.29	<0.35	<1.11	<0.05
			1.5	1.09 ± 0.22	<0.30	1.78 ± 1.69	<0.04
H2	296	156	Surface	1.03 ± 0.30	<0.33	3.68 ± 1.91	0.54 ± 0.12
			0.5	0.76 ± 0.19	<0.17	0.50 ± 0.57	<0.04
			1.5	0.87 ± 0.26	<0.29	1.80 ± 1.74	<0.04
H3	300	61	Surface	1.15 ± 0.40	<0.19	0.71 ± 0.82	0.64 ± 0.13
			0.5	0.81 ± 0.25	<0.30	1.83 ± 1.60	<0.04
			1.5	0.66 ± 0.20	<0.14	0.69 ± 0.62	<0.03

[a] Refer to Figure 5.
[b] Errors are 2σ based on counting statistics.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE WATER SAMPLE

Sample Identification	Sample Type	Grid Location		Radionuclide Concentrations (pCi/l)		
		S	W	Gross Alpha	Gross Beta	Ra-226
W1	Subsurface (Borehole H3)[a]	300	61	15.4 ± 3.1[b]	8.10 ± 2.09	0.38 ± 0.19

[a] Refer to Figure 5.
[b] Errors are 2σ based on counting statistics.

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES FROM DRAINAGE DITCHES

Grid Location[a]		Radionuclide Concentrations (pCi/g)			
S	W	Ra-226	U-235	U-238	Cs-137
224	179	0.92 ± 0.27[b]	0.28 ± 0.52	1.74 ± 0.63	0.62 ± 0.16
270	179	1.30 ± 0.33	<0.39	3.89 ± 2.20	1.62 ± 0.19

[a] Refer to Figure 6.
[b] Errors are 2σ based on counting statistics.

REFERENCES

1. E.A. Vierzba and A. Wallo, Background Report and Resurvey Recommendations for the Atomic Energy Commission Portion of the Lake Ontario Ordnance Works, Aerospace Corp., November 1982.

2. Oak Ridge Operations, U.S. Atomic Energy Commission, Radiation Survey and Decontamination Report of the Lake Ontario Ordnance Works Site, Oak Ridge, TN, January 1973.

3. T.E. Myrick, et al., Preliminary Results of the Ground-Level Gamma-Ray Scan Survey of the Former Lake Ontario Ordnance Works Site - Draft Report, ORNL, Oak Ridge, TN, 1981.

APPENDIX A

INSTRUMENTATION AND ANALYTICAL PROCEDURES

APPENDIX A

Instrumentation and Analytical Procedures

Gamma Scintillation Measurement

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) scintillation crystals. Count rates were converted to exposure levels (μR/h) using factors determined by comparing the response of the scintillation detector with that of a Reuter Stokes model RSS-111 pressurized ionization chamber at locations on the Niagara Falls Storage Site and off-site properties.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, portable scaler/ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates (μrad/h) were determined by comparison with the response of a Victoreen Model 440 ionization chamber survey meter.

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 cm x 7 mm holes evenly spaced around the region of the scintillation crystal. The probe was lowered into each hole using a tripod holder with a small winch. Measurements were performed at 15-30 cm intervals in all holes. The logging data were used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-235, U-238, and Cs-137 there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

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 600 to 800 g of soil. Net soil weights were determined and the samples counted using intrinsic germanium and Ge(Li) detectors 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 (corrected for equilibrium conditions)
U-235 - 0.143 MeV
U-238 - 0.094 MeV from Th-234 (secular equilibrium assumed)
Cs-137 - 0.662 MeV

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 10 ml of concentrated nitric acid. A known volume 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 (rev).

Calibration and Quality Assurance

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

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

APPENDIX B

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

U. S. DEPARTMENT OF ENERGY

RESIDUAL CONTAMINATION AND WASTE CONTROL CRITERIA
FOR
FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM (FUSRAP)
AND
REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM (SFMP) SITES

Presented here are the residual contamination cleanup and waste control criteria of general applicability to the FUSRAP project and remote SFMP sites[1/].

With the exception of limits for radium-226, the soil residual contamination criteria were developed on the basis of limiting maximum individual radiation exposure to DOE limits specified in DOE Order 5480.1A exclusive of exposure from natural background radiation or medical procedures. The aggregate of the contribution from all major pathways, based on scenarios for permanent intrusion, e.g., establishing residences on the site, has been assumed. In most circumstances, the probability is low that such an intrusion will occur. Also, conservative assumptions were used in deriving these criteria to ensure that a particular dose limit would not be exceeded. Use of these criteria is additionally conservative because the pathways considered in the derivation of the criteria assume all water intake and most food intake is from the site. Also, the sites often have limited agricultural capability and the contamination is generally not homogeneous. The combined effect of these factors is such that the probable radiation exposure to the average population on, or in the vicinity of, FUSRAP sites decontaminated to these criteria limits will not be appreciably different from that normally received from natural background radiation.

The residual contamination criteria for surface contamination of structures were developed from a proposed ANSI standard[2/] modified as appropriate to be consistent with DOE Order 5480.1A and the specific needs of FUSRAP for cost-effective, workable guidelines which provide an adequate safety margin. The waste control criteria are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR 192.

1/ A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE R&D or production area. Remote sites are more likely to be released to the public or excessed to other government agencies after decontamination than are sites located with major R&D or production areas.

2/ ANSI N13.12 (proposed) -- an adaptation to be applied, as appropriate.

A. RESIDUAL CONTAMINATION CRITERIA FOR FORMERLY UTILIZED SITES AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

The following criteria represent the maximum residual contamination limits for unrestricted use of land and structures contaminated with radionuclides related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. It is the policy of DOE to decontaminate sites to contamination levels at or below the limits and in a manner consistent with DOE's as-low-as-is-reasonably-achievable (ALARA) policy. Residual contamination limits for other nuclides will be developed when required using the same methodology[1/] as was used for those represented here.

1. Soil (Land) Criteria (Maximum Limits for Unrestricted Use)

Radionuclide	Soil Criteria[2/,3/,4/] (pCi/g above background)
U-Natural[5/]	75
U-238[6/]	150
U-234[6/]	150
Th-230[7/]	15
Ra-226	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over 15 cm thick soil layers more than 15 cm below the surface and less than 1.5m below the surface.
U-235[6/]	140
Pa-231	40
Ac-227	190
Th-232	15
Am-241	20
Pu-241[8/]	800
Pu-238, 239, 240	100
Cs-137	80
Sr-90	100
H-3 (pCi/ml soil moisture)	5,200

1/ Described in ORO-831 and ORO-832.

2/ In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1. There are two special cases for which this rule must be modified:

(a) If Ra-226 is present, then the fraction for Ra-226 should not be included in the sum if the Ra-226 concentration is less than or equal to the Th-230 concentration. If the Ra-226 concentration exceeds the Th-230 concentration, then the sum shall be evaluated by replacing the Ra-226 concentration by the difference between the Ra-226 and Th-230 concentrations.

(b) If Ac-227 is present, then the same rule given in (a) for Ra-226 relative to Th-230 applies for Ac-227 relative to Pa-231.

3/ Except for Ra-226, these criteria represent unrestricted-use residual concentrations above background averaged across any 15 cm thick layer to any depth and over any contiguous 100 m^2 surface area. The same conditions prevail for Ra-226 except for soil layers beneath 1.5 m; beneath 1.5 m, the allowable Ra-226 concentration may be affected by site-specific conditions and must be evaluated accordingly.

4/ Localized concentrations in excess of these limits are allowable provided that the average over 100 m^2 is not exceeded.

5/ A curie of natural uranium means the sum of 3.7×10^{10} disintegrations per second (dis/s) from U-238 plus 3.7×10^{10} dis/s from U-234 plus 1.7×10^{5} dis/s from U-235. One curie of natural uranium is equivalent to 3,000 kilograms or 6,600 pounds of natural uranium.

6/ Assumes no other uranium isotopes are present.

7/ The Th-230 guideline is 15 pCi/g to account for ingrowth of Ra-226 as Th-230 decays. Ra-226 is a limiting radionuclide because its decay product is Rn-222 gas.

8/ The Pu-241 criterion was derived from the Am-241 concentration.

2. Structure Criteria (Maximum Limits for Unrestricted Use)

a. Indoor Radon Decay Products

A structure located on private property and intended for unrestricted use shall be subject to remedial action as necessary to ensure the annual average concentration of radon decay products is less than 0.03 WL within the structure.

b. Indoor Gamma Radiation

The indoor gamma radiation after decontamination shall not exceed 20 microroentgen per hour (20 μR/h) above background.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides	Allowable Surface Residual Contamination[1/] (dpm/100 cm^2) Total	Removable
Group 1:	100	20
Radionuclides for which the uncontrolled area concentration guide in air above background[2/] is 2×10^{-13} Ci/m^3 or less or for which the uncontrolled area concentration guide in water above background[2/] is 2×10^{-7} Ci/m^3 or less; includes Pa-231, Th-228, Th-230, Ac-227, Ra-226, Ra-228, and Pb-210.		
Group 2:	1,000	200
Radionuclides not in Group 1 for which the uncontrolled area concentration guide in air above background[2/] is 1×10^{-12} Ci/m^3 or less or for which the uncontrolled area concentration guide in water above background[2/] is 1×10^{-6} Ci/m^3 or less; includes U-232, U-238, Th-232, Ra-223, and Po-210.		
Group 3:	5,000	1,000
Those radionuclides not in Group 1 or Group 2; includes U-234, U-235, and Ra-224 and all other beta-gamma emitters.		

1/ The levels may be averaged over 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value; dpm = disintegrations per minute. In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1.

2/ Given in Attachment 1 to Chapter XI, Table II, DOE Order 5480.1A.

B. CONTROL OF RADIOACTIVE WASTES AND RESIDUES FROM FUSRAP AND REMOTE SFMP SITES

Specified here are the control requirements (criteria) for radioactive wastes and residues related to the nuclear fuel cycle at FUSRAP and remote SFMP sites.

1. Interim Storage

All operational and control requirements specified in the following DOE Orders shall apply:

a. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations.

b. 5480.2, Hazardous and Radioactive Mixed Waste Management.

c. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities.

d. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements.

e. 5484.2, Unusual Occurrence Reporting System.

f. Control and stabilization features will be designed to ensure, to the extent reasonably achievable, an effective life of 50 years, and in any case, at least 25 years.

g. Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not (1) exceed 100 pCi/l at any given point, or an average concentration of 30 pCi/l for the facility site, or (2) exceed an average Rn-222 concentration at or above any location outside the facility site of 3.0 pCi/l (above background).

h. For water protection, use existing state and federal standards; apply site-specific measures where needed.

2. Long-Term Management

a. All operational requirements specified for Interim Storage Facilities (B.1) will apply.

b. Control and stabilization features will be designed to ensure to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years. Other disposal site design features shall conform with 40 CFR Part 192 performance guidelines/requirements.

c. Rn-222 emanation to the atmosphere from facility surfaces or opening shall not (1) exceed an average release rate of 20 $pCi/m^2/s$, or (2) increase the annual average Rn-222 concentration at or above any location outside the facility site by more than 0.5 pCi/l.

d. For water protection, use existing state and federal standards; apply site-specific measures where needed.

e. Prior to placement of any potentially biodegradable contaminated wastes in a Long-Term Management Facility, such wastes will be properly conditioned to (1) ensure that the generation and escape of biogenic gases will not cause the criteria in paragraph 2.c. to be exceeded, and (2) ensure that biodegradation within the facility will not result in premature structural failure not in accordance with the criteria in paragraph 2.b.. If biodegradable wastes are conditioned by incineration, incineration operations will be carried out in compliance with all applicable federal, state, and local air emission standards and requirements, including any standards for radionuclides established pursuant to 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS).

C. EXCEPTIONS

1. Procedure -- Analysis of site-specific conditions.

2. Applicability -- Where health and safety would be endangered, or where cost clearly outweighs benefits.

D. CRITERIA SOURCE

Criteria	Source
Residual Contamination Criteria[1/]	
Soil Criteria	DOE Order 5480.1A, 40 CFR Part 192[2/]
Structure Criteria	40 CFR Part 192, proposed ANSI N13.12.
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	40 CFR Part 192

Exceptions

Procedure	40 CFR Part 192
Applicability	40 CFR Part 192

1/ The bases of the residual contamination criteria are developed in ORO-831 as supplemented and ORO-832.

2/ Based on limiting the concentration of radon-222 decay products to 0.03 WL within structures.