FILE

Prepared by
Oak Ridge Associated
Universities

Prepared for
Division of
Remedial Action
Projects

U.S. Department
of Energy

COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY U

NIAGARA FALLS STORAGE SITE

LEWISTON, NEW YORK

A.J. BOERNER

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

FINAL REPORT

March 1984

COMPREHENSIVE RADIOLOGICAL SURVEY

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

Prepared for

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

A.J. Boerner

Project Staff

J.D. Berger
R.D. Condra
J.S. Epler*
P.W. Frame
W.O. Helton
J.A. Perry
W.L. Smith*
T.J. Sowell
L.B. Taus*
C.F. Weaver
B.S. Zacharek

Prepared by

Radiological Site Assessment Program
Manpower Education, Research, and Training Division
Oak Ridge, Associated Universities
Oak Ridge, Tennessee 37831-0117

FINAL REPORT

March 1984

This report is based on work performed under contract number DE-AC05-76OR00033 with the Department of Energy.

*Evaluation Research Corporation, Oak Ridge, Tennessee

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY U
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 (now known as the Niagara Falls Storage Site (NFSS) and associated 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]

Somerset Group, Inc., is the current owner of the tract identified as off-site property U (see Figure 1). A radiological survey of that tract, conducted in June-August 1983, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property U. The property is approximately 120 m long and 310 m wide and occupies a total area of 3.5 hectares. The site is bounded on the east, south, and west sides by security fences. "I" Street is located immediately outside the southern perimeter fenceline; "H" Street, Wesson Street, "5" Street, and several unnamed roads pass through the property. An out-of-service railroad track is located on the western portion of the site. There are several structures and a larger number of concrete foundations and slabs. The buildings are unoccupied (most are badly deteriorated and unuseable). The

Central Drainage Ditch passes along the western perimeter of the site. The land is maintained and essentially clear of brush and weeds.

Radiological History

There is no evidence of contaminated waste storage or burial on property U.[1] The 1971-72 AEC survey identified spotty contamination along "H" Street, east of Wesson Street, and near the intersection of "H" and "5" Streets.[2] The 1980 mobile scan by ORNL verified these findings.[3] It is possible that these elevated areas are due to natural radioactivity in the rock- and slag-like material used as fill and in the roadbeds and parking areas. Any contamination remaining from MED/AEC activities on this property would likely have been disturbed during construction of the Mathieson rocket fuel facility on this site. The Central Drainage Ditch and its easement were contaminated by run-off from residues on the Niagara Falls Storage Site and cleanup of this area is being conducted by Bechtel National, Inc.

SURVEY PROCEDURES

The comprehensive survey of NFSS off-site proeprty U was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during June-August 1983. The survey was in accordance with a plan dated March 18, 1983, approved by the Department of 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 and associated potential health effects, if any, on property U. Radiological information collected included:

1. direct radiation exposure rates and surface beta-gamma dose rates,
2. locations of elevated surface residues, and
3. concentrations of radionuclides in surface and subsurface soil.

The Central Drainage Ditch and its easement are being cleaned and surveyed by Bechtel National, Inc. and were therefore not included in this survey.

Procedures

1. A 20 m grid system was established by McIntosh and McIntosh of Lockport, NY, under subcontract. The grid system is shown on Figure 3.

2. Walkover surface scans were conducted over all accessible areas of the property. Traverses were at 2-3 m intervals on those areas that were relatively inaccessible and had no history of radioactive use. Scanning intervals were 1-2 m along all roads, in areas previously indentified as having elevated radiation levels; and in other areas where direct radiation measurements suggested possible contaminated residues. Portable gamma NaI (Tl) scintillation survey meters were used for the scans. Locations of elevated contact radiation levels were noted and surface exposure rates were measured at these locations.

3. Gamma exposure rate measurements were made at the surface 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.

4. Beta-gamma dose rate measurements were performed at 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 rates in microrads per hour (μrad/h) based on cross calibration with a thin-window ionization chamber.

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

6. At selected locations of elevated surface radiation levels beta-gamma surface dose rates and exposure rates at 1 m above the surface were also measured. Surface samples were obtained from these locations and, following sampling, the surface exposure levels were remeasured for comparison with presampling levels.

7. Detection Sciences Group of Carlisle, MA, performed ground penetrating radar surveys of property U at proposed borehole locations to assure that subsurface piping and utilities would not be damaged during drilling. In some cases, slight relocations of borehole locations were required.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Eleven 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 4.

   Gamma radiation scans were performed in the boreholes to identify the locations of elevated direct radiation levels which might 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.

   Soil samples of approximately 1 kg each were collected from various depths in the boreholes by scraping the sides of the hole with an ORAU designed sampling tool.

9. One water sample was collected from a storm drain (see Figure 5).

10. Walkover scans were performed in each structure on this site using NaI gamma scintillation detectors. Because of the dilapidated conditions of the buildings and the negative findings of the gamma scans, further interior survey measurements were not performed.

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 6.

Sample Analyses and Interpretation of Results

Soil samples were analyzed by gamma spectrometry. Radium 226 was the major radionuclide of concern, although spectra were reviewed for U-235, U-238, Th-232, Cs-137 and other gamma emitters. The water sample was analyzed for gross alpha and gross beta concentrations.

Additional information concerning analytical equipment and procedures is provided 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 6) 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 at these grid points ranged from 6 to 14 μR/h (average 9 μR/h). Surface contact gamma exposure rates and beta-gamma dose rates were 5 to 16 μR/h (average 9 μR/h) and 5 to 40 μrad/h (average 17 μrad/h), respectively. 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 small surface areas and isolated spots with elevated contact radiation levels. These locations are indicated in Figure 7, and associated radiation levels are presented in Table 3. Surface contact gamma exposure rates ranged from 12 to 440 μR/h; the maximum level was measured at grid point 536N, 172E. Exposure rates at 1 m above the surface at these locations ranged from 8 to 26 μR/h. Beta-gamma

dose rates ranged from 20-2070 μrad/h. The highest dose rate was at grid coordinate 455N, 48W. Sampling at some of the locations was effective in reducing the radiation levels; however, in many cases the level was not changed significantly or actually increased as a result of the sampling.

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 <0.20 to 9.39 pCi/g. The highest level was in the sample collected at grid point 440N, 80W; the sample from grid point 428N, 100E contained 9.14 pCi/g of the Ra-226. Although additional samples contained Ra-226 levels above the baseline range, only three samples exceeded 5 pCi/g. Concentrations of U-235, U-238, Th-232, and Cs-137 were not significantly different from those in baseline samples. No other gamma emitting radionuclides were noted in these samples.

Radionuclide concentrations in surface samples from locations of elevated contact radiation levels are presented in Table 5. With only a few exceptions, these samples contained Ra-226 concentrations exceeding baseline levels. The maximum was 894 pCi/g in sample B9 from near grid point 520N, 80E. Most of the samples also contained elevated levels of U-238 - frequently at approximately the same level as the Ra-226 concentration. Samples B11, B22, and B23 also contained high Th-232 levels. The highest Th-232 measured was 942 pCi/g in sample B23 from grid point 441N, 78W. Cs-137 concentrations were either in the range of baseline levels or below the detection sensitivity of the procedure.

Sampling indicated that the elevated surface radiation levels are primarily associated with areas of crushed-rock fill and paving base, or with individual pieces of rock- or slag-like material. Most of the samples of this material contain comparable levels of Ra-226 and U-238, suggesting natural origin and not attributed to MED/AEC activities on this property. The crushed rock is believed to be pseudowallastonite, a chemical processing slag, commonly used in the Niagara Falls area for fill and as a paving base. This material, which normally contains from 5 to 50 pCi/g of

U-238 and Ra-226, has been identifed on several other NFSS off-site properties. The material containing the high Th-232 levels is similar in composition to the rock from a parking lot on off-site property P. Several of the samples, notably B3, B4 (A and B), B5 (A and B), B13 and B19, contain levels of Ra-226 much higher than the U-238 levels; these samples are likely associated with previous MED/AEC activities. Similar material to this has also been identified on other off-site properties, e.g. property D.

Borehole Gamma-Logging Measurements

The results of gamma scintillation measurements in boreholes indicate that contamination is confined to the upper 15-30 cm of soil. As evidenced by sample analysis, the gamma count rates determined by the borehole measurements were reliable indicators of elevated subsurface radionuclide levels. However, the gamma logging data was not useful in quantifying radionuclide concentrations in the subsurface soil, because of the varying ratios of Ra-226, U-235, U-238, Th-232, and Cs-137 occurring in soils from this site.

Radionuclide Concentrations in Borehole Soil Samples

Table 6 presents the radionuclide concentrations measured in soil samples from boreholes. The four boreholes H1-H4, located to provide a representative coverage of the property, contained radionuclide concentrations in the range of baseline levels. Of boreholes H5-H11, drilled at locations identified by the walkover scan, only H5 and H7 contained elevated subsurface Ra-226 concentrations. Borehole H5 contained 21.9 pCi/g of Ra-226 at a depth of 0.15 m; borehole H7 contained Ra-226 and U-238 concentrations of 4.48 and 4.12 pCi/g, respectively at a depth of 0.15 m.

Radionuclide Concentrations in Water

Sample W1, collected from a storm drain (refer to Table 7) contained gross alpha and beta concentrations of <0.56 pCi/l and 33.9 pCi/l, respectively.

Building Surveys

Due to the dilapidated condition of the structures on this property, building surveys were limited to walkover surface gamma scans. No area of elevated direct radiation were noted.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of off-site properties at the Niagara Falls Storage Site are presented in Appendix B. Radiation levels and radionuclide concentrations, associated with small, isolated spots of surface or near-surface contamination, exceed these guidelines values. However, when considered in terms of potential exposures or averaged over larger surface areas, many of these levels and concentrations meet the cleanup criteria.

The maximum exposure rate of 440 μR/h, in contact with one of the isolated areas of surface contamination, exceeds the guideline of 60 μR/h for open land areas accessible by the general public. Exposure rates at 1 m above the surface ranged from 8–26 μR/h; these values are well within the 60 μR/h criterion.

Areas of surface contamination exceeding the criteria are summarized in Table 8 and shown on Figure 8. Most of these areas contained Ra-226 concentrations exceeding 5 pCi/g above background. Three of the samples had U-238 concentrations above 1572 pCi/g and seven samples contained Th-232 levels exceeding 15 pCi/g. Most of these areas are small and isolated, and concentrations would satisfy the criteria when averaged over an area of 100 m^2.

Only one small area, in the vicinity of 538N, 176E, contains subsurface Ra-226 exceeding 15 pCi/g. Based on sample analysis and direct measurements this material is between 15 and 30 cm deep.

Elevated radionuclide levels appear to be associated, in many areas, with a rock- or slag-like material commonly used as a fill and paving base. Radium, uranium, and thorium levels contained in this material do not result from previous government activities on this site. Several areas containing Ra-226 levels exceeding criteria do not have comparable levels of U-238 and are probably associated with MED/AEC operations. Removal of the remaining contamination of this type could be accomplished by removal of a relatively small quantity (estimated as less than 5 m^3) of material from the property.

Surface run-off water, collected from a storm drain, contained gross alpha and gross beta concentrations within the EPA Interim Drinking Water Standards of 15 and 50 pCi/l, respectively.

SUMMARY

A comprehensive survey of off-site property U at the Niagara Falls Storage Site was conducted during June-August 1983. The survey included: surface radiation scans, measurements of direct radiation levels, and analyses for radionuclide concentrations in soil and water samples. Ground penetrating radar was used to identify subsurface utilities which might preclude borehole drilling.

The results of the survey indicated small areas and isolated "hot spots" of Ra-226, and U-238 and Th-232 contamination, resulting in elevated radiation levels. The contamination is found principally in the form of crushed rock and a slag-like material, commonly used for fill and as a paving base in the Niagara Falls area. This contamination is not attributable to previous radioactive waste handling and storage activities on property U. There are several small areas of contamination, associated

with individual pieces of rock-like material. This material contains Ra-226 concentrations significantly higher than the materials described above and its presence is likely due to previous MED/AEC operations.

Although the contaminated residues on small portions of this property exceed the guidelines established for release of the site for unrestricted use by the general public, the contaminants do not pose potential health risks to the public or site workers. There is no evidence that migration of the radioactive materials is adversely affecting adjacent properties.

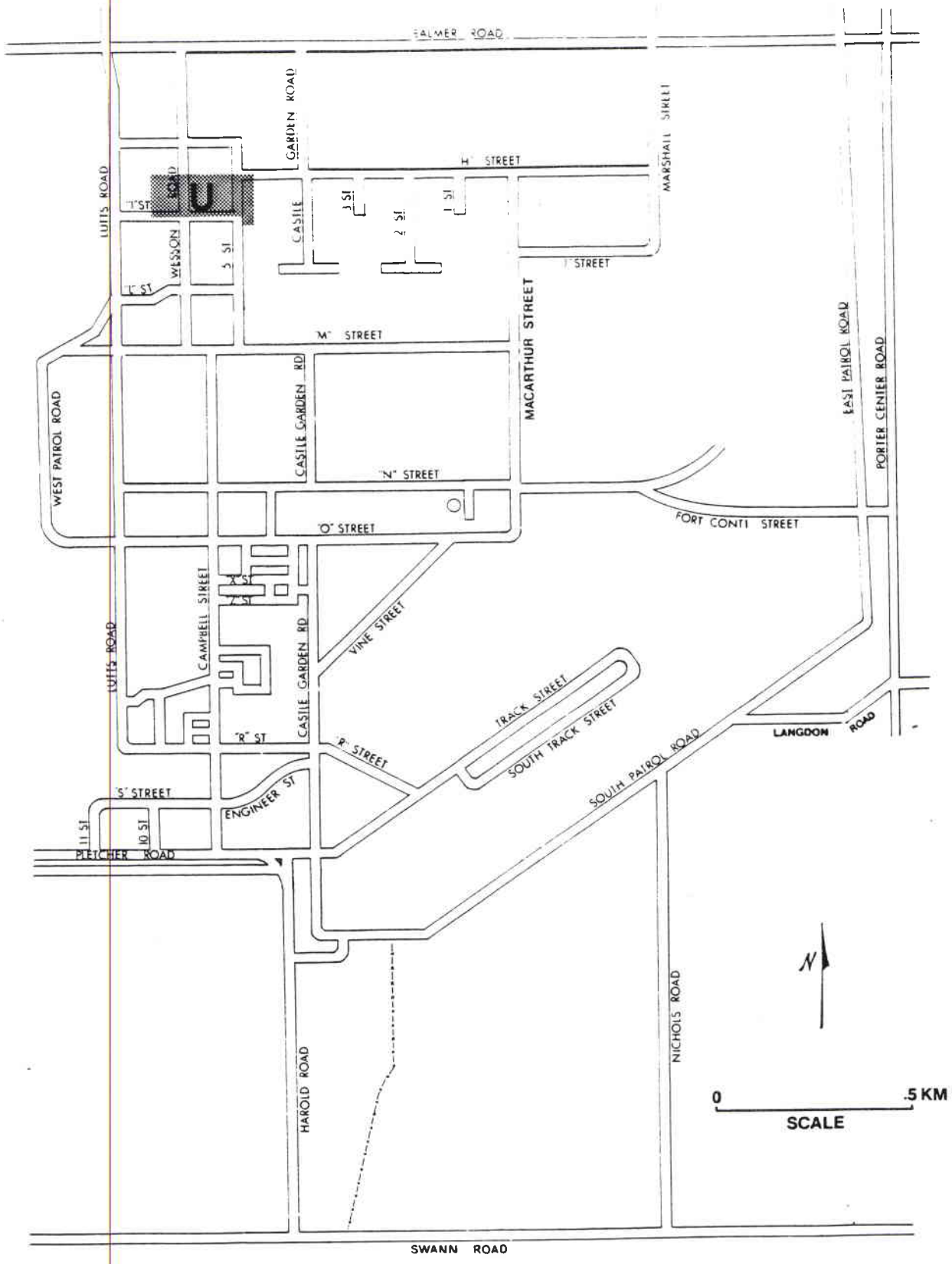

FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property U.

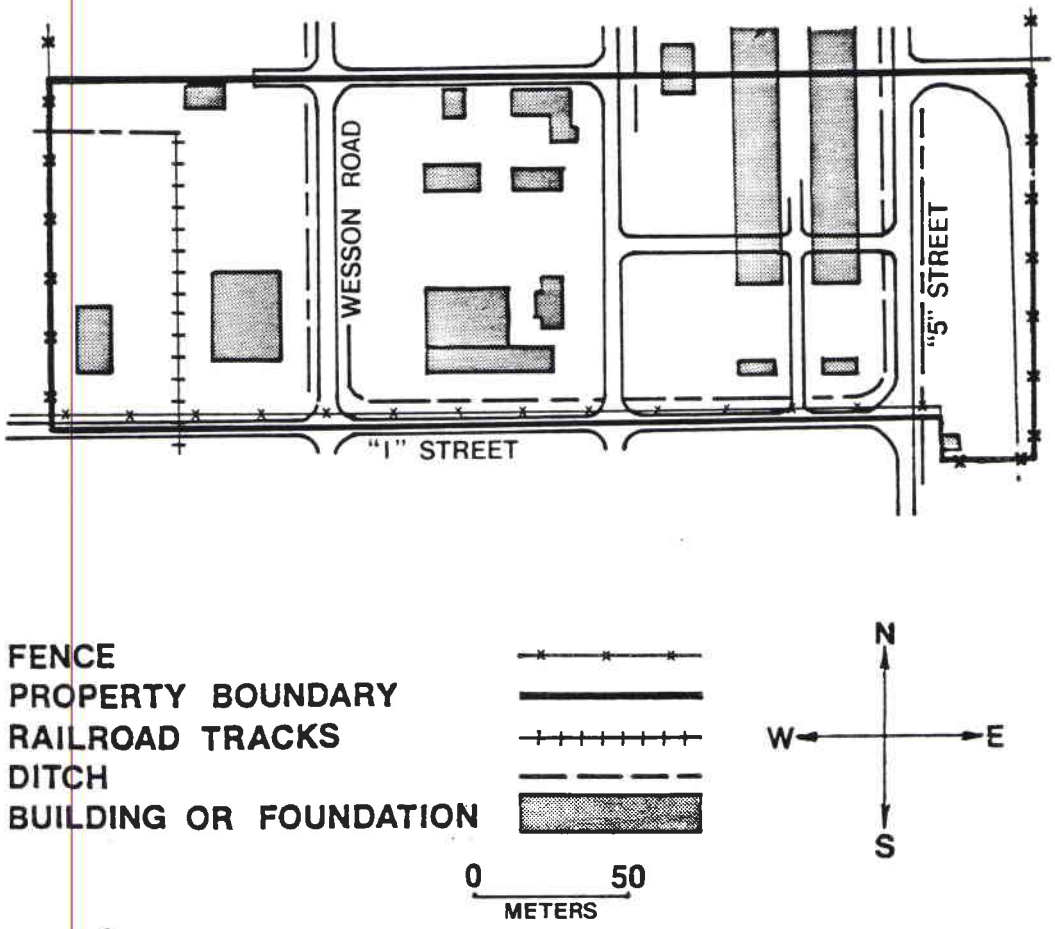

FIGURE 2. Plan View of NFSS Off-Site Property U Indicating Prominent Surface Features.

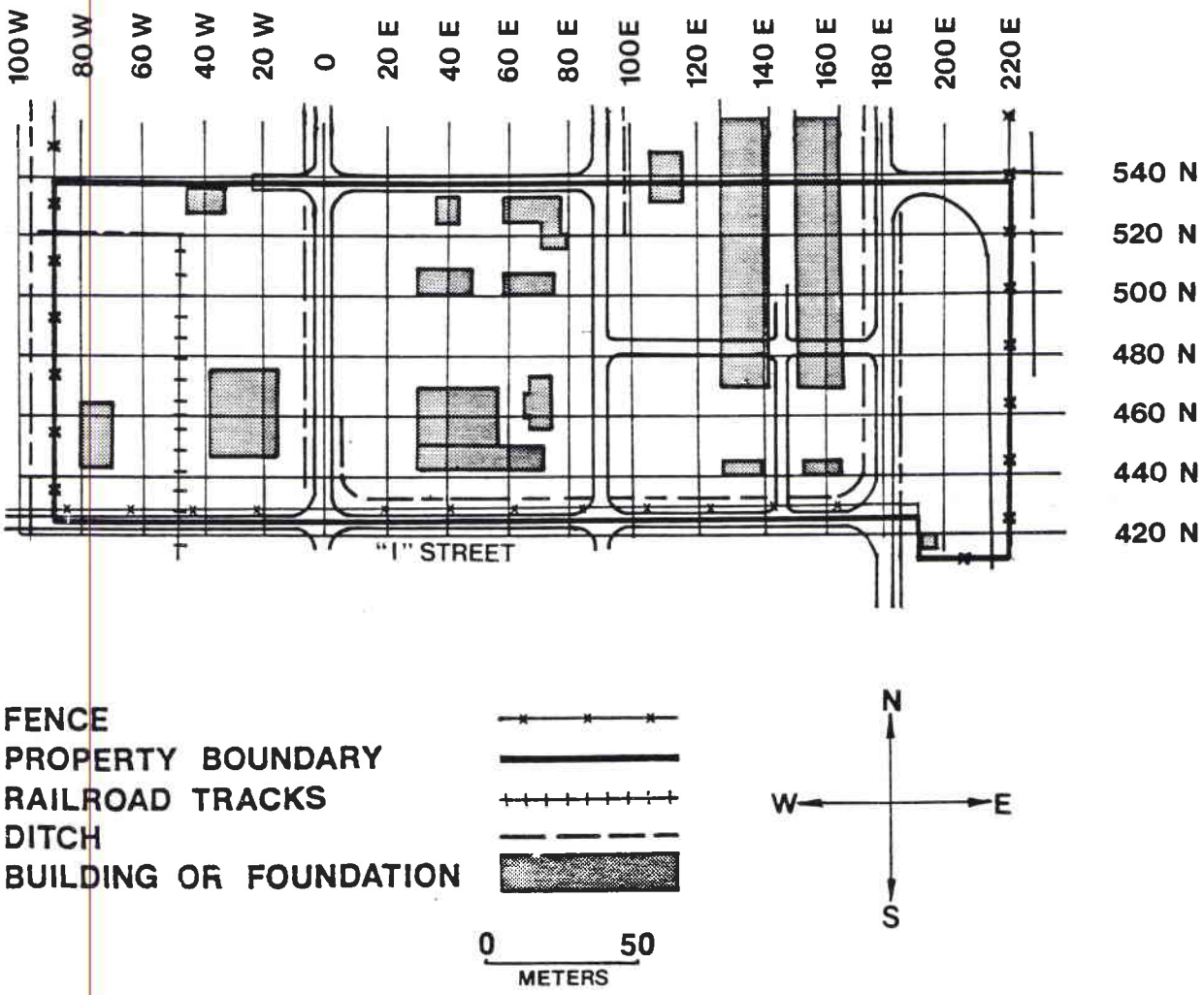

FIGURE 3. Plan View of NFSS Off-Site Property U Indicating the Grid System Established for Survey Reference.

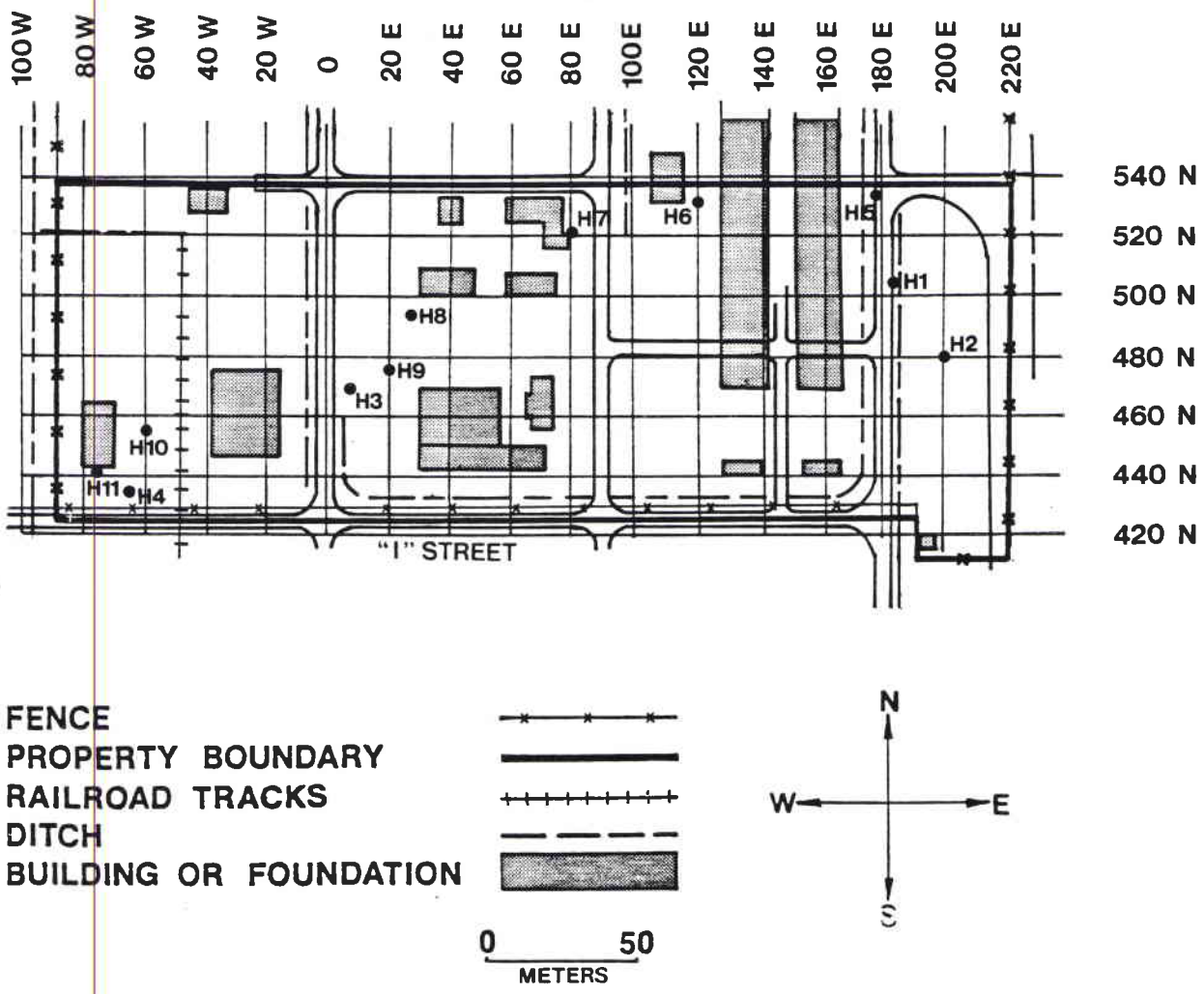

FIGURE 4. Locations of Boreholes for Subsurface Investigations.

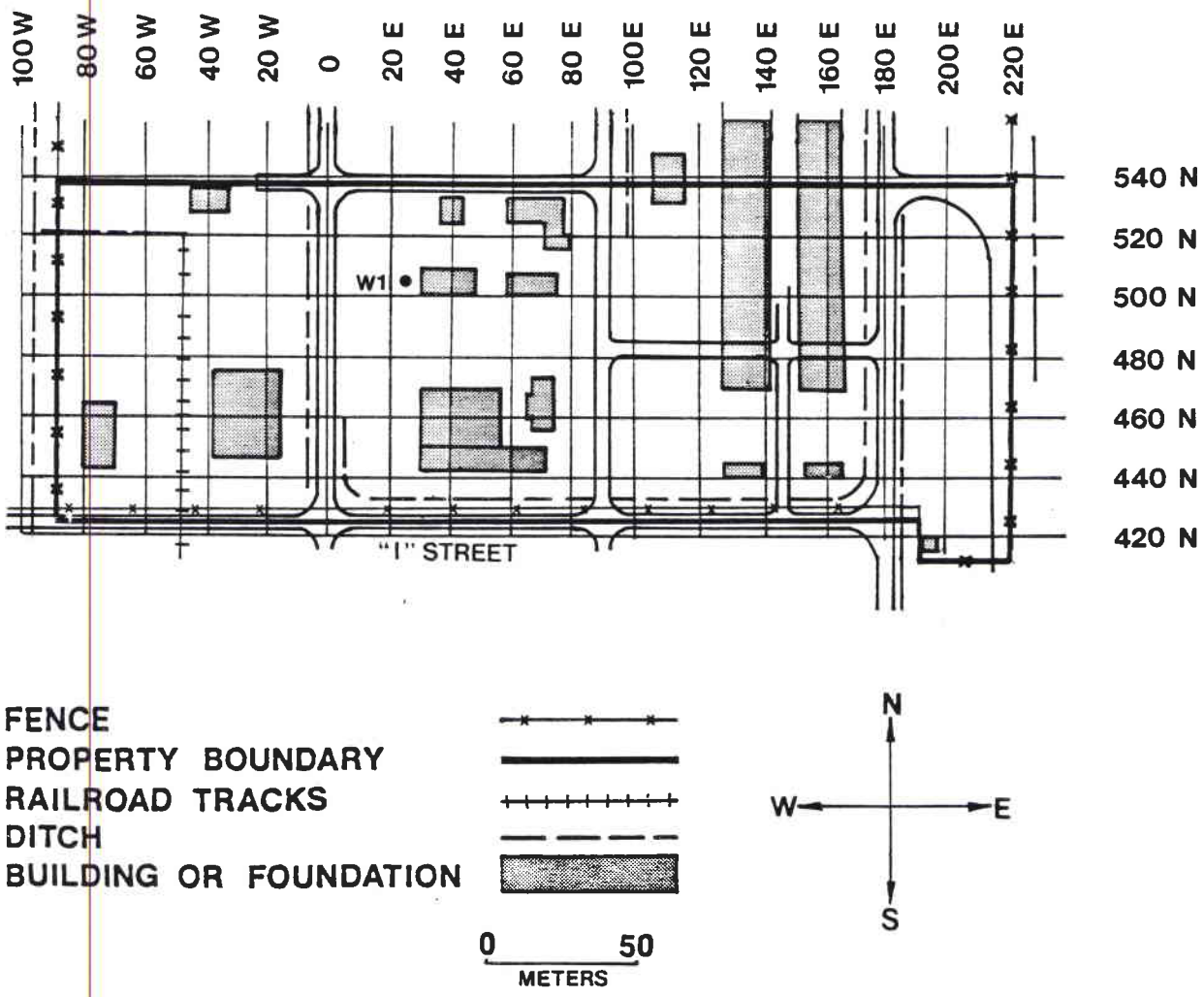

FIGURE 5. Location of a Water Sample from a Storm Drain.

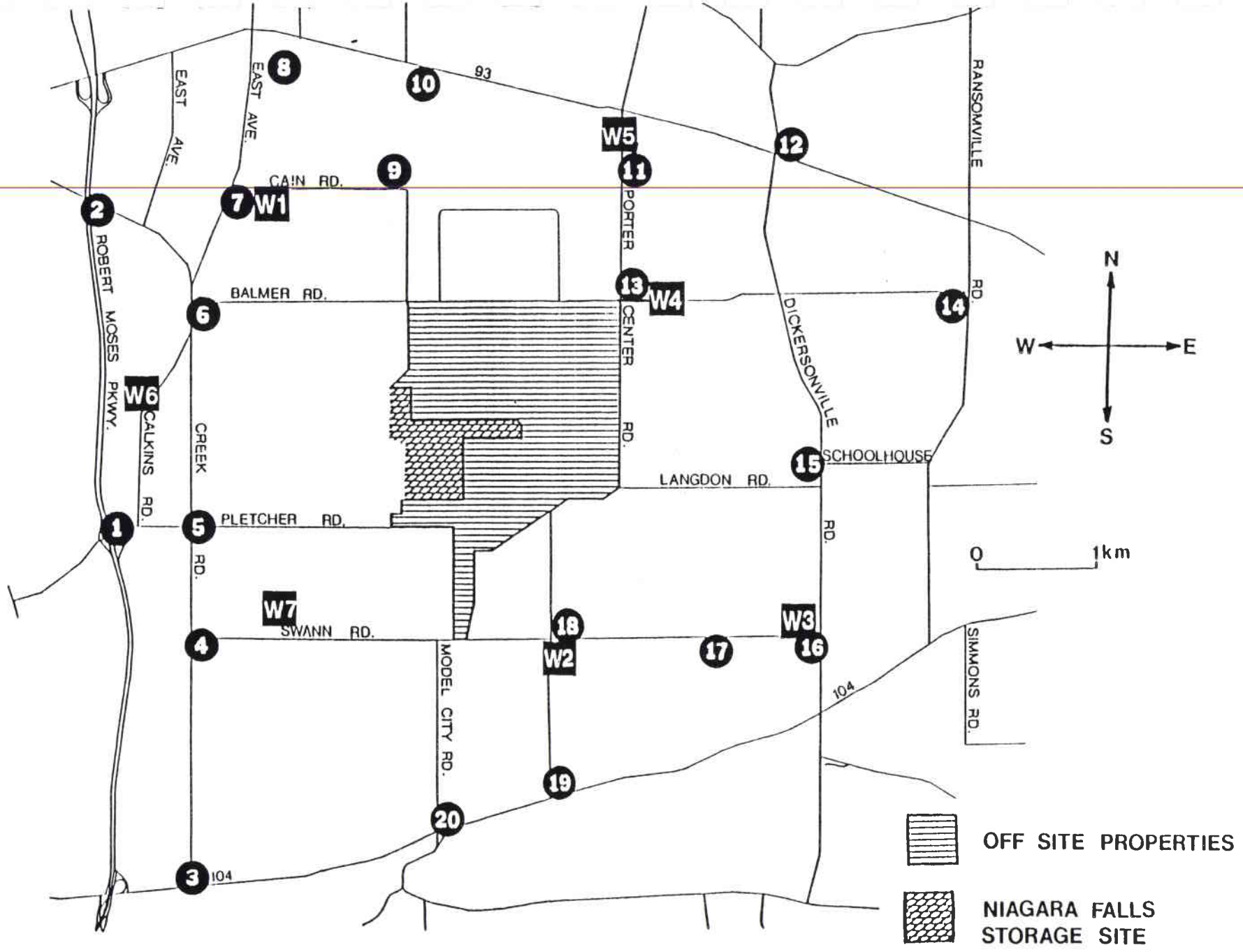

FIGURE 6. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples.)

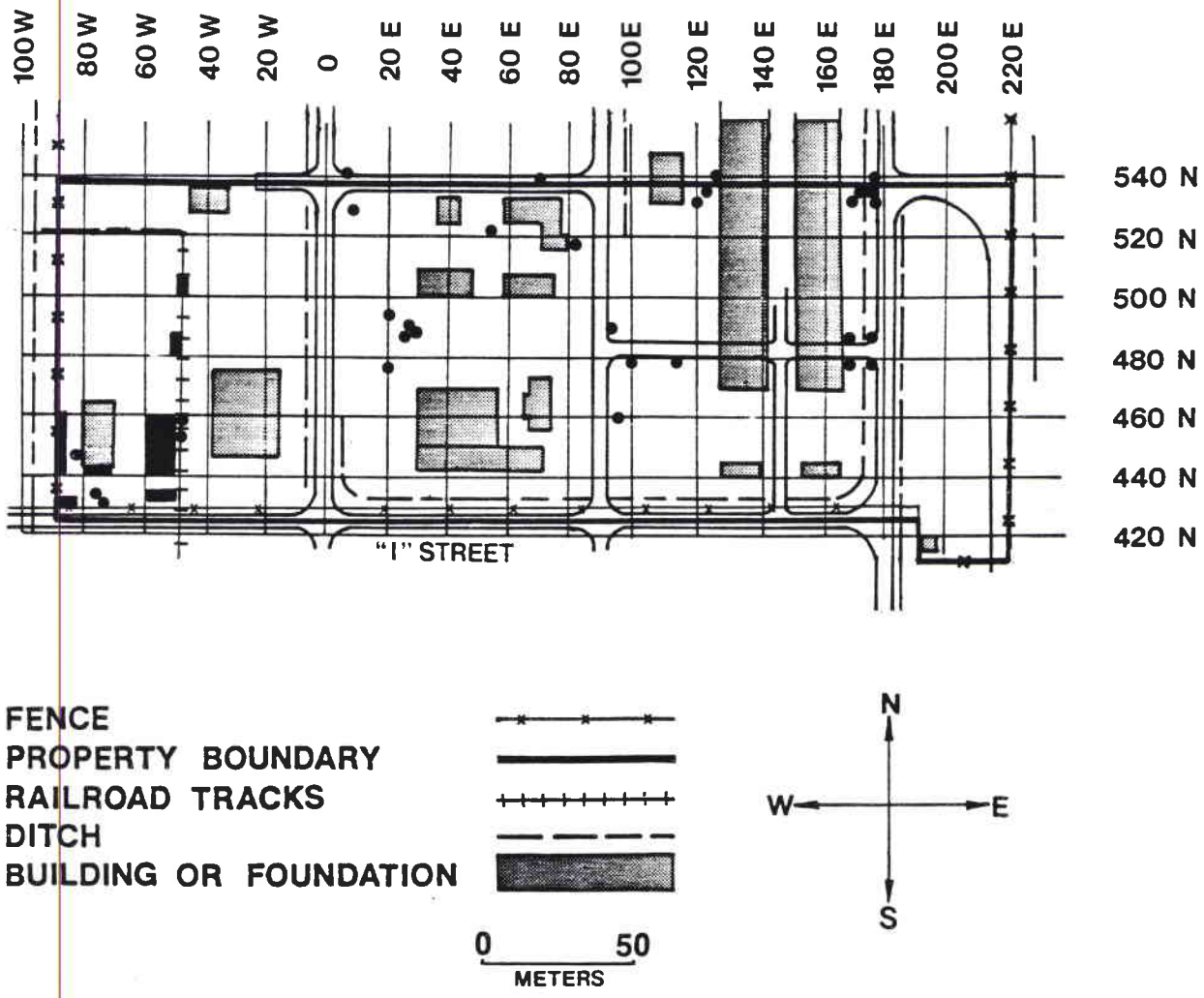

FIGURE 7. Locations (shaded) of Areas of Elevated Direct Radiation.

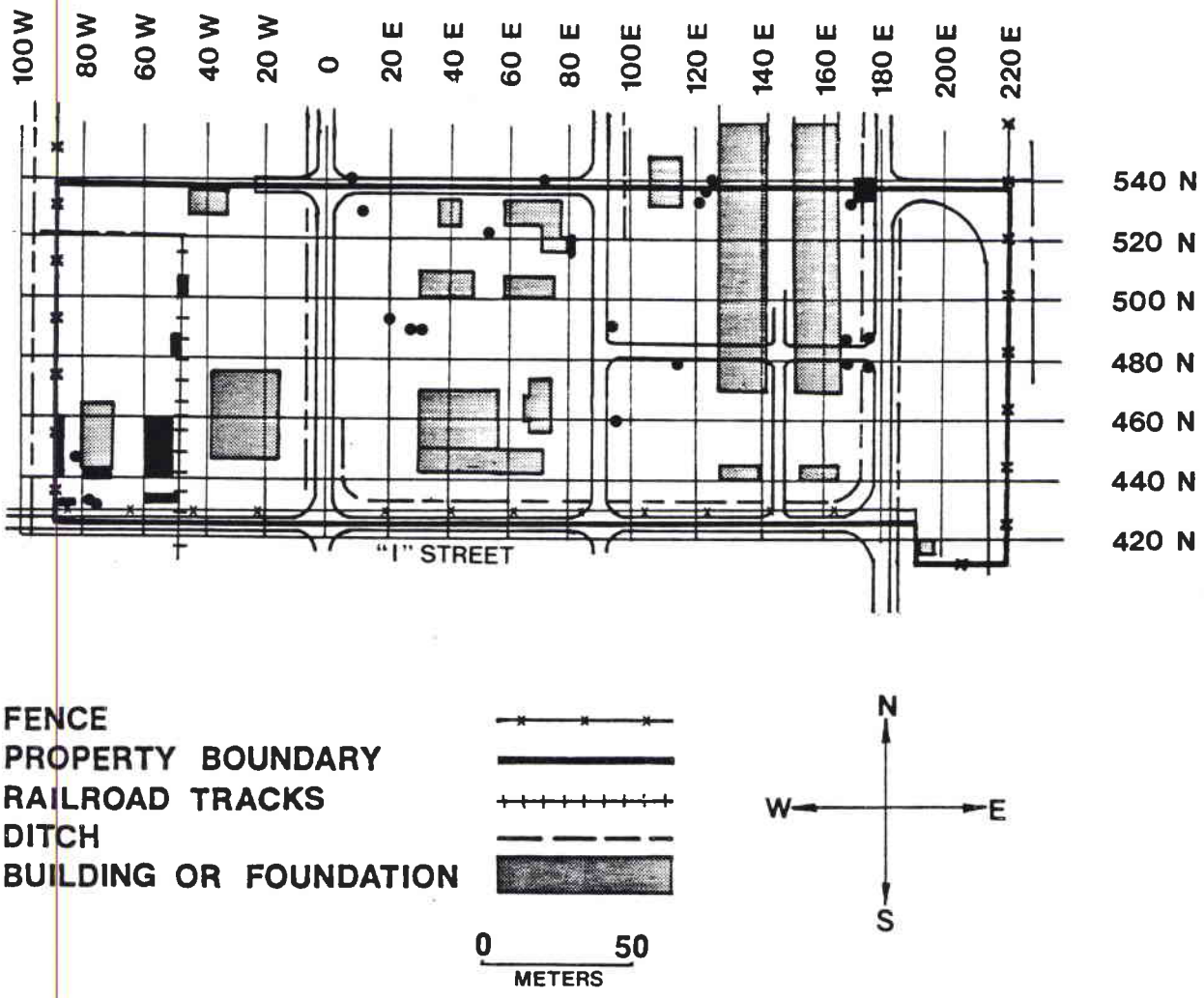

FIGURE 8. Map of NFSS Off-Site Property U Indicating Areas (shaded) Where Radionuclide Concentrations in Soil Exceed Criteria.

TABLE 1-A

BACKGROUND EXPOSURE RATES
AND
BASELINE RADIONUCLIDE CONCENTRATIONS IN SOIL

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

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

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 6.
[b] Errors are 2σ based on counting statistics.

TABLE 2

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)
540N	90W	9	10	24
540N	80W	9	10	27
540N	60W	8	8	19
540N	40W	7	7	20
540N	20W	6	6	7
540N	0E	8	10	17
540N	20E	6	8	22
540N	40E	10	10	17
540N	60E	11	11	14
540N	80E	9	11	27
540N	100E	7	6	8
540N	120E	10	10	10
540N	140E	a	a	a
540N	160E	a	a	a
540N	180E	11	9	14
540N	200E	11	11	18
540N	220E	9	9	22
520N	90W	10	9	12
520N	80W	9	9	9
520N	60W	9	9	18
520N	40W	8	8	8
520N	20W	8	8	18
520N	0E	9	10	27
520N	20E	8	7	16
520N	40E	7	8	9
520N	60E	7	7	7
520N	80E	14	16	20
520N	100E	8	8	9
520N	120E	6	7	7
520N	140E	a	a	a
520N	160E	a	a	a
520N	180E	7	7	7
520N	200E	8	8	19
520N	220E	7	8	12
500N	90W	9	8	24
500N	80W	9	9	14
500N	60W	9	10	24
500N	40W	8	8	11
500N	20W	8	8	21
500N	0E	9	9	23

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)
500N	20E	8	8	10
500N	40E	7	7	11
500N	56E	6	6	6
500N	80E	9	9	9
500N	100E	8	8	19
500N	120E	7	7	7
500N	140E	a	a	a
500N	160E	a	a	a
500N	180E	8	8	8
500N	200E	7	8	18
500N	220E	8	9	12
480N	90W	10	10	36
480N	80W	10	11	27
480N	60W	12	12	25
480N	40W	8	8	14
480N	20W	8	8	10
480N	0E	9	9	22
480N	20E	8	9	16
480N	40E	7	8	17
480N	60E	6	6	13
480N	80E	8	9	12
480N	100E	12	12	39
480N	120E	8	10	36
480N	140E	a	a	a
480N	160E	a	a	a
480N	180E	8	7	17
480N	200E	7	8	18
480N	220E	8	9	19
460N	90W	14	16	30
460N	80W	7	7	26
460N	60W	12	12	26
460N	40W	8	9	14
460N	20W	7	8	8
460N	0E	8	9	15
460N	20E	8	7	13
460N	40E	6	6	6
460N	60E	6	5	5
460N	80E	9	10	26
460N	100E	9	9	11
460N	120E	7	7	8

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)
460N	140E	7	7	24
460N	160E	7	7	--
460N	180E	8	8	21
460N	200E	8	8	9
460N	220E	8	9	9
440N	90W	11	11	25
440N	80W	14	14	25
440N	60W	11	11	14
440N	40W	8	8	8
440N	20W	8	8	27
440N	0E	8	9	25
440N	20E	8	8	8
440N	40E	7	7	10
440N	60E	7	7	7
440N	80E	9	13	40
440N	100E	9	9	22
440N	120E	8	8	24
440N	140E	a	a	a
440N	160E	a	a	a
440N	180E	8	8	8
440N	200E	8	8	18
440N	220E	9	8	8
420N	200E	8	8	8
420N	220E	8	8	14

[a] Grid point reading not taken due to presence of building.

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Location[a]		Exposure Rate (μR/h)		Surface Does Rate (μrad/h)	Sample Identification	Contact Exposure Rate After Sample Removal (μR/h)
		Contact	1 m Above Surface			
540N	8E	31	18	57	B1	39
540N	70E	38	21	41	B2	55
540N	126E	26	16	26	B3	23
539N	177E	95	26	130	B4 (A & B)	84
538N	176E	220	23	280	B5 (A & B)	130
537N	123E	200	----[b]	----	----	----
536N	172E	440	----	----	----	----
536N	176E	220	----	----	----	----
535N	120E	200	13	200	B6	84
534N	171E	110	10	110	c	12
529N	10E	31	16	31	B7	40
523N	54E	23	10	23	B8	40
515-520N	80-83E	14-29	----	----	----	----
520N	80E	170	----	----	B9	----
519N	80E	20	17	26	B10	18
515N	80E	27	----	----	----	----
502-506N	46-48W	25-29	----	----	----	----
505N	48W	48	8	390	B11	14
492N	20E	50	----	----	----	----
491N	24E	54	10	57	B12	16
491N	25E	59	----	----	----	----
490N	90E	22	----	----	----	----
489N	23E	50	10	110	B13	12
485N	174E	27	12	----	B14	16
484N	166E	22	----	----	----	----
481N	100E	22	13	22	B15	29

TABLE 3, cont.

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Location		Exposure Rate (μR/h)		Surface Does Rate (μrad/h)	Sample Identification	Contact Exposure Rate After Sample Removal (μR/h)
		Contact	1 m Above Surface			
480N	112E	26	14	63	B16	28
480N	167E	20	----	----	----	----
480N	175E	18	12	75	B17	18
480-488N	52-56W	17-20	----	----	----	----
482N	54W	29	10	29	B18	8
479N	20E	310	15	1350	B19	12
440-460N	90-92W	12-17	----	----	----	----
442N	90W	17	12	57	B20	14
440-460N	51-60W	17-110	----	----	----	----
460N	60W	110	----	----	----	----
460N	51W	42	25	98	----	42
455N	60W	84	13	1150	c	12
460N	94E	20	12	34	B21	21
458N	48W	39	----	----	----	----
455N	48W	68	12	2070	B22	11
444N	80W	22	----	----	----	----
440-443N	72-79W	15-34	----	----	----	----
441N	78W	34	20	120	B23	35
430N	75W	38	21	100	B24	50
430-433N	48-60W	29-40	----	----	----	----
430N	55W	40	22	40	B25	59
427-431N	83-88W	27-31	----	----	----	----
429N	74W	38	----	----	----	----

[a] Refer to Figure 7.
[b] Dash indicates measurement or sampling not performed.
[c] Source of elevated radiation level removed and disposed of at NFSS.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Cs-137	Th-232
540N	90W	1.46 ± 0.38[a]	<0.33	<1.01	0.57 ± 0.11	0.87 ± 0.39
540N	80W	1.23 ± 0.31	<0.30	1.24 ± 1.58	<0.06	1.24 ± 0.37
540N	60W	0.64 ± 0.30	0.36 ± 0.53	2.13 ± 0.86	0.18 ± 0.11	0.62 ± 0.33
540N	45W	0.76 ± 0.29	<0.25	2.10 ± 1.64	<0.05	0.89 ± 0.33
540N	20W	0.94 ± 0.29	<0.33	<0.97	1.26 ± 0.17	1.27 ± 0.42
537N	4W	1.08 ± 0.34	0.19 ± 0.68	<0.93	1.10 ± 0.17	0.61 ± 0.36
540N	20E	0.96 ± 0.28	<0.20	1.27 ± 1.67	0.72 ± 0.11	0.77 ± 0.31
540N	40E	1.34 ± 0.29	<0.29	2.93 ± 1.21	0.76 ± 0.14	0.82 ± 0.64
540N	60E	2.44 ± 0.34	<0.23	1.41 ± 1.47	0.34 ± 0.08	0.36 ± 0.68
541N	80E	2.15 ± 0.41	<0.26	2.43 ± 2.84	0.51 ± 0.13	0.68 ± 0.56
540N	100E	0.51 ± 0.18	<0.23	0.92 ± 1.36	0.53 ± 0.11	0.55 ± 0.28
540N	124E	1.54 ± 0.33	<0.26	<1.08	0.34 ± 0.17	1.44 ± 0.53
540N	140E	b	b	b	b	b
540N	160E	b	b	b	b	b
540N	174E	1.59 ± 0.35	<0.25	1.55 ± 2.93	1.23 ± 0.22	0.43 ± 0.45
542N	200E	0.91 ± 0.34	<0.24	2.84 ± 1.85	1.17 ± 0.19	0.97 ± 0.41
540N	220E	1.21 ± 0.25	<0.30	<0.93	<0.04	1.41 ± 0.38
520N	90W	1.86 ± 0.36	<0.27	1.39 ± 1.87	0.25 ± 0.12	0.89 ± 0.52
520N	80W	2.08 ± 0.33	<0.31	1.67 ± 1.52	0.19 ± 0.11	1.05 ± 0.43
520N	60W	0.91 ± 0.26	<0.21	<0.84	0.19 ± 0.08	0.36 ± 0.47
520N	40W	1.24 ± 0.40	<0.26	<0.84	0.51 ± 0.12	0.66 ± 0.56
520N	20W	0.75 ± 0.30	<0.21	1.33 ± 0.96	0.42 ± 0.17	0.80 ± 0.31
520N	3W	0.99 ± 0.36	<0.23	1.96 ± 2.09	0.64 ± 0.15	0.71 ± 0.42
520N	20E	0.49 ± 0.25	<0.19	0.97 ± 1.35	0.24 ± 0.08	0.45 ± 0.42
520N	40E	1.01 ± 0.26	<0.28	2.00 ± 1.07	0.41 ± 0.10	0.92 ± 0.40
520N	60E	0.50 ± 0.14	<0.14	0.78 ± 1.17	0.33 ± 0.75	0.22 ± 0.12
520N	80E	0.36 ± 0.18	<0.11	<0.44	0.12 ± 0.06	0.26 ± 0.28

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Cs-137	Th-232
520N	100E	0.90 ± 0.24	<0.30	1.11 ± 1.95	0.41 ± 0.11	0.87 ± 0.39
520N	120E	0.81 ± 0.31	<0.22	1.12 ± 2.13	0.53 ± 0.10	0.58 ± 0.23
520N	140E	b	b	b	b	b
520N	160E	b	b	b	b	b
520N	174E	1.10 ± 0.33	<0.28	2.66 ± 2.37	1.14 ± 0.25	0.50 ± 0.35
520N	200E	1.23 ± 0.26	<0.30	4.30 ± 1.92	1.17 ± 0.15	0.69 ± 0.28
520N	220E	0.56 ± 0.21	<0.16	1.45 ± 1.34	0.38 ± 0.10	0.71 ± 0.30
500N	90W	0.85 ± 0.24	<0.20	<0.82	0.30 ± 0.09	0.80 ± 0.32
500N	80W	0.78 ± 0.31	<0.21	3.65 ± 1.76	0.13 ± 0.08	0.70 ± 0.63
500N	60W	2.19 ± 0.53	<0.35	3.31 ± 2.52	0.26 ± 0.13	0.93 ± 0.42
500N	40W	0.63 ± 0.19	<0.20	0.87 ± 1.92	0.62 ± 0.13	0.53 ± 0.85
500N	20W	0.85 ± 0.39	<0.41	<1.29	0.69 ± 0.20	1.12 ± 0.45
500N	3W	1.25 ± 0.33	<0.22	<0.90	0.79 ± 0.16	0.31 ± 0.24
500N	20E	0.96 ± 0.28	<0.23	<0.81	0.21 ± 0.09	0.60 ± 0.26
500N	40E	0.90 ± 0.21	<0.31	<0.97	0.29 ± 0.13	1.12 ± 0.44
500N	59E	0.59 ± 0.19	<0.16	<0.67	0.47 ± 0.11	0.27 ± 0.21
500N	80E	0.90 ± 0.23	<0.21	<0.76	0.42 ± 0.11	0.91 ± 0.36
500N	100E	0.89 ± 0.24	<0.27	2.20 ± 1.30	<0.04	0.97 ± 0.29
500N	120E	0.55 ± 0.26	<0.22	<0.83	0.35 ± 0.09	0.82 ± 0.39
500N	140E	b	b	b	b	b
500N	160E	b	b	b	b	b
500N	177E	1.54 ± 0.40	<0.27	0.72 ± 1.88	0.75 ± 0.15	0.90 ± 0.45
500N	200E	<0.20	<0.34	2.28 ± 1.16	0.49 ± 0.12	1.24 ± 0.61
500N	220E	1.13 ± 0.41	<0.26	1.51 ± 2.08	0.05 ± 0.05	1.01 ± 0.49
480N	90W	2.08 ± 0.38	<0.27	1.98 ± 1.73	0.18 ± 0.09	1.24 ± 0.38
480N	80W	0.84 ± 0.28	<0.30	0.96 ± 2.09	0.07 ± 0.10	0.88 ± 0.26
480N	60W	0.94 ± 0.34	<0.23	2.32 ± 2.00	0.49 ± 0.15	0.71 ± 0.48

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Cs-137	Th-232
480N	40W	0.73 ± 0.35	<0.28	2.96 ± 1.29	0.44 ± 0.10	0.82 ± 0.43
480N	20W	0.45 ± 0.39	<0.21	<0.84	0.97 ± 0.20	0.39 ± 0.29
480N	3W	0.90 ± 0.28	<0.20	0.85 ± 1.52	1.16 ± 0.17	<0.20
480N	20E	0.93 ± 0.31	<0.23	<0.89	0.38 ± 0.14	0.80 ± 0.40
480N	40E	0.66 ± 0.26	<0.23	1.74 ± 1.68	0.13 ± 0.12	0.74 ± 0.52
480N	60E	0.55 ± 0.26	<0.14	<0.71	0.61 ± 0.14	<0.17
480N	80E	0.69 ± 0.23	<0.27	<1.00	0.39 ± 0.11	0.70 ± 0.31
480N	100E	2.23 ± 0.43	<0.29	3.11 ± 1.94	0.50 ± 0.20	0.75 ± 0.61
480N	120E	2.81 ± 0.45	1.11 ± 0.72	2.07 ± 2.36	0.86 ± 0.16	0.75 ± 0.48
480N	140E	b	b	b	b	b
480N	160E	b	b	b	b	b
480N	177E	0.75 ± 0.23	<0.31	1.10 ± 0.87	1.01 ± 0.17	0.41 ± 0.30
480N	200E	1.40 ± 0.34	<0.23	<0.82	0.48 ± 0.11	0.89 ± 0.40
480N	220E	1.06 ± 0.24	<0.21	1.35 ± 2.30	1.86 ± 0.19	0.55 ± 0.35
460N	90W	2.61 ± 0.44	<0.37	<1.15	0.28 ± 0.13	0.86 ± 0.45
460N	80W	0.81 ± 0.25	<0.21	<0.85	0.32 ± 0.10	0.83 ± 0.35
460N	60W	2.14 ± 0.45	<0.26	1.51 ± 2.71	0.21 ± 0.07	0.83 ± 0.39
460N	40W	0.80 ± 0.26	<0.21	<0.82	0.59 ± 0.13	0.63 ± 0.46
460N	20W	0.76 ± 0.23	<0.22	1.35 ± 1.93	0.52 ± 0.11	1.18 ± 0.33
460N	3W	0.76 ± 0.28	<0.19	<0.85	1.51 ± 0.19	0.41 ± 0.32
460N	20E	0.75 ± 0.24	<0.19	1.55 ± 2.14	0.62 ± 0.13	0.48 ± 0.37
460N	40E	0.60 ± 0.29	<0.19	<0.79	0.27 ± 0.12	0.46 ± 0.29
460N	60E	0.76 ± 0.24	<0.14	1.71 ± 0.96	1.15 ± 0.15	0.23 ± 0.17
460N	80E	1.15 ± 0.29	<0.24	<1.06	0.28 ± 0.09	1.09 ± 0.38
460N	100E	1.58 ± 0.39	<0.23	2.45 ± 3.40	1.16 ± 0.23	0.88 ± 0.52
460N	120E	0.84 ± 0.30	<0.25	<1.12	0.64 ± 0.20	0.56 ± 0.48
460N	140E	0.90 ± 0.54	<0.25	<0.95	1.41 ± 0.26	1.70 ± 0.68

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Cs-137	Th-232
460N	160E	1.05 ± 0.40	0.52 ± 0.63	2.15 ± 2.03	0.60 ± 0.21	0.75 ± 0.37
460N	177E	1.61 ± 0.40	<0.30	1.86 ± 2.56	0.61 ± 0.18	1.09 ± 0.51
460N	200E	1.56 ± 0.46	<0.25	2.50 ± 1.08	0.80 ± 0.18	1.02 ± 0.35
460N	220E	0.80 ± 0.31	<0.31	<0.94	0.90 ± 0.16	0.96 ± 0.40
440N	90W	2.75 ± 0.44	<0.29	1.03 ± 3.31	0.10 ± 0.07	1.09 ± 0.43
440N	80W	9.39 ± 0.81	0.52 ± 1.38	5.51 ± 4.65	0.69 ± 0.15	0.47 ± 0.76
440N	60W	1.40 ± 0.35	<0.26	<1.06	0.19 ± 0.14	1.07 ± 0.45
440N	40W	0.91 ± 0.19	<0.26	2.61 ± 1.44	0.46 ± 0.09	0.88 ± 0.36
440N	20W	0.65 ± 0.31	<0.25	1.46 ± 0.31	0.50 ± 0.17	1.19 ± 0.49
440N	3W	1.13 ± 0.28	<0.24	<1.00	0.57 ± 0.15	0.74 ± 0.33
440N	20E	0.85 ± 0.25	<0.33	1.20 ± 1.75	0.43 ± 0.11	1.45 ± 0.39
440N	40E	1.04 ± 0.35	<0.23	<0.78	0.55 ± 0.12	0.87 ± 0.31
440N	60E	0.93 ± 0.35	<0.24	2.19 ± 2.20	0.52 ± 0.15	0.66 ± 0.50
440N	80E	1.36 ± 0.29	<0.27	<0.94	0.49 ± 0.14	1.13 ± 0.38
440N	100E	1.05 ± 0.61	<0.27	<1.13	0.72 ± 0.19	1.02 ± 0.58
440N	120E	0.95 ± 0.63	<0.21	3.57 ± 3.59	0.53 ± 0.25	0.67 ± 0.83
440N	140E	b	b	b	b	b
440N	160E	b	b	b	b	b
440N	170E	1.04 ± 0.61	<0.23	1.57 ± 2.72	0.74 ± 0.33	0.74 ± 0.76
440N	200E	0.89 ± 0.23	<0.35	<1.15	0.73 ± 0.16	1.39 ± 0.42
440N	220E	1.05 ± 0.29	<0.22	1.83 ± 1.56	0.85 ± 0.16	1.07 ± 0.45
428N	80W	2.48 ± 0.38	<0.29	1.59 ± 2.21	0.63 ± 0.11	0.61 ± 0.27
428N	60W	1.85 ± 0.44	<0.27	2.92 ± 2.31	0.07 ± 0.07	0.67 ± 0.32
428N	40W	1.63 ± 0.34	<0.23	2.65 ± 1.79	0.49 ± 0.15	0.71 ± 0.44
428N	20W	6.69 ± 0.56	<0.35	4.86 ± 1.89	0.62 ± 0.11	0.68 ± 0.42
428N	3W	0.78 ± 0.31	<0.23	<0.89	0.59 ± 0.14	1.78 ± 0.45
428N	20E	1.78 ± 0.40	<0.27	<1.10	0.97 ± 0.20	0.40 ± 0.35

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Cs-137	Th-232
428N	40E	3.73 ± 0.45	<0.33	1.69 ± 2.32	0.51 ± 0.13	0.77 ± 0.52
428N	60E	1.56 ± 0.35	<0.36	2.12 ± 1.78	0.78 ± 0.14	0.65 ± 0.32
428N	80E	1.56 ± 0.36	<0.27	<0.86	0.62 ± 0.12	0.64 ± 0.42
428N	100E	9.14 ± 0.81	1.54 ± 1.02	5.09 ± 3.77	0.68 ± 0.15	1.01 ± 0.57
428N	120E	1.80 ± 0.49	<0.33	2.42 ± 2.27	0.93 ± 0.26	1.28 ± 0.50
428N	140E	1.00 ± 0.28	<0.33	1.30 ± 2.37	0.44 ± 0.12	0.99 ± 0.62
428N	160E	1.43 ± 0.38	<0.33	<1.10	0.78 ± 0.15	1.18 ± 0.35
428N	183E	0.95 ± 0.30	0.59 ± 0.41	2.03 ± 1.62	0.96 ± 0.15	0.55 ± 0.23
428N	200E	0.65 ± 0.25	<0.21	<0.78	0.28 ± 0.11	0.72 ± 0.27

[a] Errors are 2σ based on counting statistics.
[b] No sample taken; grid point inaccessible due to presence of building.

TABLE 5

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

Sample ID	Sample Description	Grid[a] Location	Radionuclide Concentrations (pCi/g)				
			Ra-226	U-235[c]	U-238[c]	Cs-137[c]	Th-232
B1	Rock	540N 8E	18.7 ± 0.8[b]	1.37 ± 1.14	17.8 ± 2.8	<0.07	<0.31
B2	Rock	540N 70E	6.20 ± 0.46	<0.34	4.65 ± 2.38	0.15 ± 0.10	0.38 ± 0.49
B3	Rock	540N 126E	160 ± 2	3.86 ± 3.36	20.3 ± 9.2	<0.25	16.4 ± 2.1
B4A	Soil	539N 177E	12.5 ± 0.9	<0.51	<1.75	1.04 ± 0.16	1.00 ± 0.74
B4B	Rock	539N 177E	638 ± 20	<1.21	28.7 ± 21.6	2.36 ± 2.5	49.8 ± 22.1
B5A	Soil	538N 176E	29.5 ± 1.1	2.40 ± 1.46	<2.70	0.60 ± 0.15	3.76 ± 0.98
B5B	Rock	538N 176E	31.2 ± 1.2	<0.90	6.01 ± 4.93	<0.12	4.03 ± 1.08
B6	Rock	535N 120E	7.43 ± 0.53	0.60 ± 0.93	1.99 ± 2.51	<0.07	1.37 ± 1.18
B7	Soil	529N 10E	32.9 ± 1.1	2.98 ± 1.53	38.0 ± 3.5	<0.11	<0.41
B8	Soil	523N 54E	25.1 ± 1.2	1.15 ± 1.43	15.7 ± 2.5	<0.05	0.71 ± 0.38
B9	Rock	520N 80E	894 ± 28	17.1 ± 24.4	85.6 ± 44.4	<2.26	70.2 ± 25.5
B10	Soil	519N 80E	0.26 ± 0.16	0.17 ± 0.22	0.50 ± 0.70	0.71 ± 0.10	<0.22
B11	Rock	505N 48W	281 ± 29	12.8 ± 4.2	254 ± 13	<5.10	933 ± 48
B12	Rock	491N 24E	11.1 ± 0.6	<0.32	<0.68	0.27 ± 0.19	0.61 ± 0.42
B13	Rock	489N 23E	512 ± 4	<3.03	60.4 ± 10.3	<0.42	59.6 ± 3.8
B14	Rock	485N 174E	41.9 ± 1.8	4.09 ± 1.37	37.3 ± 2.2	0.21 ± 0.10	<0.33
B15	Rock	481N 100E	0.76 ± 0.21	<0.19	1.30 ± 1.50	0.36 ± 0.09	2.14 ± 0.38
B16	Rock	480N 112E	15.0 ± 0.9	2.18 ± 1.19	14.6 ± 2.5	0.45 ± 0.12	<0.36
B17	Rock	480N 175E	20.6 ± 0.5	1.48 ± 0.81	17.52 ± 1.3	0.12 ± 0.06	<0.29
B18	Rock	482N 54W	12.4 ± 0.7	1.88 ± 1.27	27.4 ± 3.5	0.81 ± 0.20	0.59 ± 0.45
B19	Rock	479N 20E	470 ± 7	<4.39	<6.68	<0.53	<2.29
B20	Rock	442N 90W	36.6 ± 0.8	1.78 ± 1.14	33.2 ± 19.4	0.10 ± 0.08	0.47 ± 0.53
B21	Rock	460N 94E	24.9 ± 0.6	1.52 ± 0.9	20.3 ± 1.5	<0.05	0.40 ± 0.38

TABLE 5, cont.

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

Sample ID	Sample Description	Grid Location	Radionuclide Concentrations (pCi/g)				
			Ra-226	U-235	U-238	Cs-137	Th-232
B22	Rock	455N 48W	276 ± 25	129 ± 43	267 ± 11	<4.09	934 ± 39
B23	Rock	441N 78W	273 ± 28	106 ± 37	257 ± 11	<4.12	942 ± 41
B24	Soil	430N 75W	17.8 ± 1.0	1.58 ± 1.21	15.4 ± 5.3	<0.08	<0.34
B25	Rock	430N 55W	28.6 ± 0.6	2.48 ± 0.99	37.3 ± 13.2	<0.05	<0.24

[a] Refer to Table 3 for direct radiation levels.
[b] Errors are 2σ based on counting statistics.
[c] Large errors and poor detection sensitivities result from high activity of Ra-226 or Th-232.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.[a]	Grid Location	Depth (m)	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137	Th-232
H1	507N 188E	Surface	1.16 ± 0.26[b]	<0.25	2.75 ± 1.58	<0.04	1.07 ± 0.41
		1.0	0.81 ± 0.25	<0.16	0.61 ± 0.82	<0.03	0.86 ± 0.39
H2	480N 200E	Surface[c]	0.96 ± 0.30	<0.20	1.17 ± 0.57	0.45 + 0.12	0.91 ± 0.32
H3	470N 9E	Surface[c]	0.94 ± 0.24	<0.28	<0.82	<0.04	0.89 ± 0.40
H4	436N 64W	Surface	0.79 ± 0.23	<0.24	2.37 ± 0.82	<0.03	0.81 ± 0.34
		1.0	0.96 ± 0.26	<0.23	<0.63	<0.03	0.99 ± 0.35
		2.0	0.96 ± 0.20	<0.26	2.41 ± 1.02	<0.03	1.18 ± 0.39
H5	538N 176E	Surface	29.5 ± 1.1	2.40 ± 1.46	<2.70	0.60 ± 0.15	3.76 ± 0.98
		0.15	21.9 ± 1.0	<0.44	2.08 ± 3.53	<0.07	2.57 ± 0.70
H6	535N 120E	Surface	7.43 ± 0.43	0.60 ± 0.93	1.99 ± 2.51	<0.07	1.37 ± 1.18
		0.15	0.91 ± 0.24	<0.28	<0.91	<0.04	1.12 ± 0.34
H7	520N 80E	Surface	894 ± 28	17.1 ± 24.4	85.6 ± 44.4	<2.26	70.2 ± 25.5
		0.15	4.48 ± 0.49	<0.38	4.12 ± 1.30	0.37 ± 0.10	1.09 ± 0.31
		0.60	0.90 ± 0.16	<0.13	0.97 ± 0.45	<0.03	0.79 ± 0.27
H8	492N 25E	Surface[c]	1.59 ± 0.26	0.57 ± 0.55	1.46 ± 1.63	<0.04	1.14 ± 0.36
H9	479N 20E	Surface[c]	470 ± 5	14.5 ± 10.3		<0.97	608 ± 12
H10	455N 60W	Surface	1.01 ± 0.24	<0.27	<0.87	<0.04	1.70 ± 0.46
		0.50	0.73 ± 0.21	<0.19	1.32 ± 1.11	<0.02	0.73 ± 0.24

TABLE 6, cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.	Grid Location	Depth (m)	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137	Th-232
H11	441N 78W	Surface	273 ± 28	106 ± 37	257 ± 11	<4.12	942 ± 41
		0.15	0.86 ± 0.23	<0.26	<0.78	<0.03	1.15 ± 0.32
		0.50	0.45 ± 0.19	<0.17	<0.55	<0.02	0.54 ± 0.27

[a] Refer to Figure 4.
[b] Errors are 2σ based on counting statistics.
[c] Subsurface samples not collected due to negative findings of borehole gamma profile.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLE

Sample No.[a]	Sample Type	Grid Location	Radionuclide Concentrations (pCi/l) Gross Alpha	Gross Beta
W1	Storm Drain	503N 26E	<0.56	33.9 ± 2.2[b]

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

TABLE 8

SUMMARY OF AREAS ON PROPERTY U WHICH
EXCEED RESIDUAL CONTAMINATION CRITERIA

Grid Location[a]		Radionuclides	Estimated Quantities of Material Exceeding Guidelines			Remarks
			Area (m^2)	Depth (m)	Volume (m^3)	
536-539N	176-177E	Ra-226	6	0.15-0.30	0.9-1.8	General Area
515-520N	80-83E	Ra-226	15	<0.15	2.3	" "
502-506N	46-48W	Ra-226, U-238, Th-232[b]	8	<0.15	1.2	" "
480-488N	52-56W	Ra-226, U-238[b]	32	<0.15	4.8	" "
440-460N	90-92W	Ra-226, U-238, Th-232[b]	40	<0.15	6.0	" "
440-460N	51-60W	Ra-226, U-238, Th-232[b]	180	<0.15	27.0	" "
440-433N	72-79W	Ra-226, U-238[b]	21	<0.15	3.2	" "
430-433N	48-60W	Ra-226, U-238[b]	36	<0.15	5.4	" "
427-431N	83-88W	----	20	<0.15	3.0	" "
540N	8E	Ra-226, U-238[b]	----	----	----	
540N	70E	Ra-226, U-238[b]	----	----	----	
540N	126E	Ra-226	----	----	----	
537N	123E	----	----	----	----	
536N	172E	----	----	----	----	
535N	120E	Ra-226	----	----	----	
529N	10E	Ra-226, U-238[b]	----	----	----	
523N	54E	Ra-226, U-238[b]	----	----	----	Isolated "hot spots" each having a volume estimated as less than 1 m^3.
492N	20E	----	----	----	----	
491N	24E	Ra-226	----	----	----	
491N	25E	----	----	----	----	
490N	90E	----	----	----	----	
485N	174E	Ra-226, U-238[b]	----	----	----	
484N	166E	----	----	----	----	
480N	112E	Ra-226, U-238[b]	----	----	----	
480N	167E	----	----	----	----	
480N	175E	Ra-226, U-238[b]	----	----	----	

TABLE 8, cont.

SUMMARY OF AREAS ON PROPERTY U WHICH
EXCEED RESIDUAL CONTAMINATION CRITERIA

Grid Location[a]		Radionuclides	Estimated Quantities of Material Exceeding Guidelines			Remarks
			Area (m^2)	Depth (m)	Volume (m^3)	
460N	94E	Ra-226, U-238[b]	----	----	----	Isolated "hot spots" each having a volume estimated as less than 1 m^3.
458N	48W	----	----	----	----	
444N	80W	----	----	----	----	
430N	75W	Ra-226, U-238[b]	----	----	----	
429N	74W	----	----	----	----	

[a] Refer to Figure 8.
[b] Radionuclide content is believed to be of natural origin.

REFERENCES

1. E.A. Vierzba and A. Wallo, Background 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 the 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 rates (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 several 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 of the response of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes.

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 was used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-235, U-238, Th-232, and Cs-137 there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

Soil Sample Analysis

Gamma Spectrometry

Soil 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 solid state 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 - 0.093 MeV from Th-234 (secular equilibrium assumed)
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)
Cs-137 - 0.662 MeV

Water Sample Analysis

The water sample was 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. Fifty ml of sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter.

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 equipment operation within acceptable statistical fluctuations. 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

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

(Review Within DOE Continuing)

Presented here are the residual contamination cleanup and waste control guidelines of general applicability to the FUSRAP project and remote SFMP sites[1/]. A site-specific analysis will be prepared for each FUSRAP and remote SFMP site prior to determining residual contamination guidelines for a specific site. In addition, it is the policy of the DOE to decontaminate sites in a manner consistent with DOE's as-low-as-reasonably-achievable (ALARA) policy. ALARA will be considered in reducing levels of residual contamination below applicable dose limits. ALARA will be implemented using cost/benefit considerations, and applied on a site-specific basis.

The soil residual contamination guidelines 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 radium-226 and thorium-230 guidelines include an additional limitation for buildup of radon-222 decay products in buildings. The aggregate of the contribution from all major pathways, based on scenarios for permanent intrusion, e.g., establishing residences on the site, was assumed. In most circumstances, the probability is low that such an intrusion will occur. Also, conservative assumptions were used in deriving these guidelines to ensure that a particular dose limit would not be exceeded. Use of these guidelines is additionally conservative because the pathways considered in the derivation of the guidelines assume all water intake and most food intake is from the site. Also, the FUSRAP and remote SFMP 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 or remote SFMP sites decontaminated to these guidelines will not be appreciably different from that normally received from natural background radiation.

The residual contamination guidelines for surface contamination of structures were adapted from guidelines developed by the U. S. Nuclear Regulatory Commission (NRC) for decontamination of facilities and equipment prior to release for unrestricted use or termination of licenses for byproduct, source, or special nuclear material [2/]. The waste control guidelines are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR Part 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/ U. S. Nuclear Regulatory Commission 1982 Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, DC.

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

The following guidelines 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. A site-specific analysis will be prepared for each site prior to determining residual contamination guidelines for a specific site. 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 on a site-specific basis. Site-specific guidelines and ALARA policy will be determined by DOE on a site-specific basis and an ALARA report filed on completion of remedial action at a site. Existing state and federal standards will be applied for water protection. 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) Guidelines (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	60
Pu-241[8/]	2400
Pu-238, 239, 240	300
Cs-137	80

Sr-90	300
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 guideline 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 guidelines 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 guidelines are allowable provided that the average over 100 m^2 is not exceeded. However, DOE ALARA policy will be considered on a site-specific basis when dealing with elevated localized concentrations.

5/ A curie of natural uranium means the sum of 3.7×10^{10} disintegrations per second (dis/s) over any 15cm thick layers from U-238 plus 3.7×10^{10} dis/s from U-234 plus 1.7×10^{9} 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 guideline was derived from the Am-241 concentration.

2. Structure Guidelines (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 R/h) above background in any occupied or habitable building.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides[2]	Allowable Surface Residual Contamination[+1] (dpm/100 cm^2) Average[3,4]	Maximum[4,5]	Removable[4,6]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
U-Natural, Th-232, Sr-90, Fr-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000	15,000	1,000

1/ As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

2/ Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides shall apply independently.

3/ Measurements of average contaminant should not be averaged over more than 1 m^2. For objects of less surface area, the average shall be derived for each such object.

4/ The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should

not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber.

5/ The maximum contamination level applies to an area of not more than 100 cm^2.

6/ The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels shall be reduced proportionately and the entire surface shall be wiped.

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

Specified here are the control requirements for radioactive wastes and residues related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. It is the policy of DOE to store radioactive wastes in a manner representing sound engineering practices consistent with DOE's ALARA policy.

1. Interim Storage

All operational and control requirements specified in the following DOE Orders and other items 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. 5820, Radioactive Waste Management.

g. 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.

h. 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).

i. 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 requirement 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 requirements 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

Exceptions may be made to the guidelines presented herein following analysis of the site-specific aspects of a candidate site. Specific situations that warrant consideration for modifying these guidelines are:

1. Where remedial actions would pose a clear and present risk of injury to workers or members of the public, notwithstanding reasonable measures to avoid or reduce risk.

2. Where remedial actions would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future, notwithstanding reasonable measures to limit damage to the environment. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

3. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and the residual radioactive materials do not pose a clear present or future hazard. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this hazard. Remedial actions will generally not be necessary where residual radioactive materials have been placed semipermanently in a location where site-specific factors limit their hazard and from which they are costly or difficult to remove, or where only minor quantities of residual radioactive materials are involved. Examples are residual radioactive materials under hard surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. Supplemental standards shall not be applied at such sites, however, if individuals are likely to be exposed for long periods of time to radiation from such materials at levels above those that would prevail in Subpart A.

4. Where the cost of cleanup of a contaminated building is clearly unreasonably high relative to the benefits. Factors that shall be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be affected by remedial actions, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of less costly remedial methods than removal of residual radioactive materials.

5. Where there is no known remedial action.

D. GUIDELINE SOURCE

Guideline	Source
Residual Contamination Criteria[1/]	
Soil Guideline	DOE Order 5480.1A, 40 CFR Part 192[2/]
Structure Guideline	40 CFR Part 192, NRC Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material (July 1982).
Control of Radioactive Wastes and Residues	
Interim Storage Long-Term Management	DOE Order 5480.1A 40 CFR Part 192

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

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