

COMPREHENSIVE RADIOLOGICAL SURVEY

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

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## COMPREHENSIVE RADIOLOGICAL SURVEY

### OFF-SITE PROPERTY A NIAGARA FALLS STORAGE SITE LEWISTON, NEW YORK

#### INTRODUCTION

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

SCA Chemical Services, Inc., is the current owner of a tract from the NFSS, identified as off-site property A (see Figure 1). A radiological survey of that tract, conducted July and August, 1983, is the subject of this report.

#### SITE DESCRIPTION

Figure 2 is a plot plan of off-site property A. This tract actually includes the extreme eastern section of the adjacent original off-site property V. This section has been included with property A for the purposes of this survey, because of the current ownership status and the similarity in surface conditions and use history of these tracts. Property A is approximately 1285 m long and varies from about 345 m to 365 m wide; the total area is 45.6 hectares. The site is bounded on the north by Balmer Road and on the south by "H" Street. Security fences form

the east and west property boundaries and also parallel Balmer Road the length of the property. An unused railroad track crosses the property near the eastern perimeter. Marshall Street, near the eastern edge of the property, is the main entrance to the SCA treatment facilities. The area along this street is cleared and maintained and includes a small guard house. A narrow strip has also been cleared along the western boundary to provide access to a drainage ditch. Castle Garden Road - the boundary line between original properties A and V - passes through the property. With the exception of the areas mentioned above, the property is unused and is heavily overgrown with brush and trees.

#### Radiological History

There is no history of contaminated material burial on property A; however, "H" Street is believed to have been used for temporary storage of K-65 residues.<sup>1</sup> The 1971 AEC survey showed one area with elevated gamma exposure rates.<sup>2</sup> This area was just east of the intersection of "5" Street with an unnamed east-west road. Slightly elevated radiation levels were identified along the western half of "H" Street and the southern half of Marshall Street by the ORNL mobile scan.<sup>3</sup>

#### SURVEY PROCEDURES

The comprehensive survey of off-site property A was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during July and August, 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 objectives 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 A. Radiological information collected included:

1. direct gamma 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 subsurface water, and
5. concentrations of radionuclides in sediment from major drainage ditches on the property.

#### Procedures

1. Brush and weeds were cleared as needed to provide access for gridding and surveying. This operation was performed by Modern Landfill, Inc., of Model City, NY, under subcontract.
2. Under subcontract, McIntosh and McIntosh of Lockport, NY, established a 80 m grid system. This grid is shown on Figure 3.
3. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at 80 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 ( $\mu R/h$ ) was in accordance with cross calibration with a pressurized ionization chamber.
4. Beta-gamma dose rate measurements were performed 1 cm above the surface at 80 m grid intervals. These measurements were conducted using thin-window ( $<7 \text{ mg/cm}^2$ ) G-M detectors and portable scaler/ratemeters. Measurements were also obtained with the detector shielded to evaluate contributions of non-penetrating beta and low-energy gamma radiations. Meter readings were converted to dose rates in microrads per hour ( $\mu rad/h$ ) 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 80 m grid intervals.

6. Walkover surface scans were conducted over accessible areas of the property. Scanning intervals were 1-2 m along roads and in areas where elevated surface radiation levels were measured; other areas were scanned at 5-10 m intervals. Locations of elevated contact radiation levels were noted.
7. At selected locations of elevated surface radiation levels, beta-gamma dose rates and exposure rates at 1 m above the surface were also measured. Surface soil samples were obtained from these locations and, following sampling, the surface exposure levels were remeasured to evaluate the effectiveness of shallow sampling on removal of the radiation source.
8. 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.
9. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Boreholes were drilled by Site Engineers, Inc., of Cherry Hill, NJ, and Earth Dimensions, of Aurora, NY, using truck mounted 20 cm diameter hollow-stem augers. Eleven holes were drilled at locations selected to be representative of the average property conditions; two holes were drilled in a general area identified as having elevated direct radiation levels. The locations of these boreholes are shown on Figure 4.

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 nine 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 an ORAU designed sampling tool.

10. Samples of sediment were collected from two locations in a major ditch, crossing the northwest corner of the property (see Figure 5).
11. 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 6.

#### 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 U-235, U-238, Cs-137, Th-232, and other gamma emitters. Water was analyzed for gross alpha and beta concentrations. One water sample was also analyzed for Ra-226.

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 6) in the vicinity of the NFSS, are presented in Table 1-A. Exposure rates ranged from 6.8 to 8.8  $\mu\text{R/h}$  (typical levels for this area of New York). Concentrations of radionuclides in soil were: Ra-226, <0.09 to 1.22 pCi/g (picocuries per gram); U-235, <0.14 to 0.46 pCi/g; U-238, <2.20 to 6.26 pCi/g; Th-232, 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, systematically measured at 80 m grid intervals, are presented in Table 2. The gamma exposure rates at 1 m above the surface ranged from 5 to 12  $\mu\text{R/h}$  (average 7  $\mu\text{R/h}$ ). At surface contact, the rates ranged from 5 to 14  $\mu\text{R/h}$  (average 8  $\mu\text{R/h}$ ). Beta-gamma dose rates ranged from 5 to 50  $\mu\text{rad/h}$  (average 18  $\mu\text{rad/h}$ ). 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. Direct radiation levels were generally slightly higher along the railroad tracks on the eastern boundary of the property.

The walkover survey identified one general area and additional small isolated locations having elevated surface radiation levels. These locations are indicated on Figure 6 and associated direct radiation levels are presented in Table 3. The general area is bounded by grid line 588N, 598N, 230E, and 250E. Contact radiation levels over this area are

relatively consistent, ranging from 38 to 42  $\mu\text{R/h}$ . The isolated "hot spots" are located primarily along a reconstructed off-set section of "H" Street, near the south central portion of the property. Several additional spots were identified near the extreme southwest corner, in an area of recent earthmoving activity, and along the shoulder of Marshall Street. Contact exposure rates at these spots ranged up to 580  $\mu\text{R/h}$  (this location and all of the others exceeding 100  $\mu\text{R/h}$  on contact were along "H" Street). The maximum beta-gamma dose rate was 79,300  $\mu\text{rad/h}$  at grid location 563N, 320E - the same location as the highest contact exposure level. At most of the isolated spots, sampling was effective in significantly reducing the radiation levels. The exceptions to this were in the southwest corner of the property, where the source of the radiation appeared to be more widely distributed rather than in individual discrete sources.

#### Radionuclide Concentrations in Surface Soil

Table 4 lists the concentrations of radionuclides measured in surface soil from 80 m grid intervals. These samples contained Ra-226 concentrations ranging from <0.18 to 1.74 pCi/g. Only about 11% of these systematic samples exceeded the range of Ra-226 in baseline soil. Concentrations of other radionuclides also exceeded the range of baseline levels in a small fraction of the samples; the maximum concentrations were less than twice the baseline levels, however.

Samples from locations of elevated contact radiation levels contained Ra-226 concentrations ranging from 4.19 to 6690 pCi/g (see Table 5). The maximum level of Ra-226 was in sample B5 from grid location 562N, 802E. Two of the samples, B8 and B9, contained small white chips which had Ra-226 activities of 1.68  $\mu\text{Ci}$  and 0.82  $\mu\text{Ci}$ , respectively. Most of the samples collected at these locations were individual rock-type material, with high concentrations of Ra-226 and little evidence of other significant radionuclide content. Samples B14 and B15, from the vicinity of the generally elevated area, were a smaller crushed rock material. These samples contained comparable concentrations of Ra-226 and U-238, suggesting

that the material is similar to that identified on other off-site properties, and commonly used as paving base or fill throughout the Niagara Falls area.

#### Borehole Gamma Logging Measurements

Gamma scintillation measurements performed in boreholes indicated that contamination was limited to the upper 15-30 cm of soil. Gamma logging data was not used to quantify radionuclide concentrations in the subsurface soil because of the varying ratios of Ra-226, U-235, U-238, Cs-137, and Th-232 occurring in soils from this site.

#### Radionuclide Concentrations in Subsurface Soil

Table 6 presents the radionuclide concentrations measured in soil samples from boreholes. Boreholes H1 to H11, located to provide representative coverage of the property, did not contain radionuclide concentrations significantly different from baseline soil concentrations. Boreholes H12 and H13 were in the vicinity of the general area of elevated direct radiation levels. Surface and 15 cm samples from both of these boreholes were elevated in Ra-226 and U-238 concentrations. The highest subsurface Ra-226 and U-238 levels were 16.4 pCi/g and 15.1 pCi/g, respectively at 15 cm deep. The comparable levels of Ra-226 and U-238 suggest that the source is naturally occurring (likely pseudowallastonite), and not attributable to previous MED/AEC activities.

#### Radionuclide Concentrations in Ditch Sediment Samples

Two sediment samples, collected from a major drainage ditch near the northwest corner of the site, did not contain radionuclide concentrations differing from those in baseline soil samples (see Table 7).

#### Radionuclide Concentrations in Water

Water obtained from nine of the boreholes contained gross alpha and gross beta concentrations ranging from 3.47 to 15.6 pCi/l and 2.42 to

11.5 pCi/l, respectively (see Table 8). These levels are above the range noted in baseline water samples. Sample W5, containing the highest gross alpha level, was also analyzed for Ra-226; the concentration of that radionuclide was 0.18 pCi/l.

#### COMPARISON OF RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of the off-site properties at NFSS are presented in Appendix B. The maximum exposure rate at 1 m above the ground surface on property A is 28  $\mu$ R/h and the average is 7  $\mu$ R/h. These levels are well below 60  $\mu$ R/h, which is the continuous exposure rate equivalent to the recommended annual limit of 500 mrem for the general public.

Areas of surface contamination, identified by the walkover scan, contain Ra-226 concentrations in excess of the 5 pCi/g guideline. Many of these areas of contamination are small and isolated; averaged over an area of 100 m<sup>2</sup> the resulting concentrations of Ra-226 would satisfy the criteria of 5 pCi/g above background. The source of contamination at most of these locations was found to be individual pieces of rock-like material. These could be eliminated by removal of less than 1 m<sup>3</sup> of material. One general area of elevated radiation levels and radionuclide concentrations is due to the naturally occurring uranium decay series in crushed rock and is not attributable to previous government operations on this property. The areas exceeding the Ra-226 criteria are summarized in Table 9 and their locations shown on Figure 8.

Subsurface measurements and sampling indicate that the Ra-226 contamination below 15 cm is within the 15 pCi/g guideline or is due to naturally occurring materials.

The gross alpha concentration in one subsurface water sample slightly exceeds the EPA Interim Drinking Water Standard of 15 pCi/l; this sample contains well below the 3 pCi/l guideline level of Ra-226. Other water samples contain less than the 15 pCi/l gross alpha and 50 pCi/l gross beta criteria.

Samples of ditch sediment do not contain any elevated radionuclide levels.

#### SUMMARY

A comprehensive survey of off-site property A at the Niagara Falls Storage Site was conducted during July and August, 1983. The survey included surface radiation scans, measurements of direct radiation levels, and analyses of radionuclide concentrations in surface and subsurface soil, subsurface water, and ditch sediments.

The survey identified areas of surface Ra-226 contamination (see Figure 8 and Table 9). The contamination is contained in individual isolated pieces of rock-type material and in a general area of crushed-rock fill. The individual pieces of rock are probably attributable to the previous MED/AEC activities, the crushed rock is not. Elimination of the remaining pieces of contaminated rock would require removal of less than 1 m<sup>3</sup> of material.

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

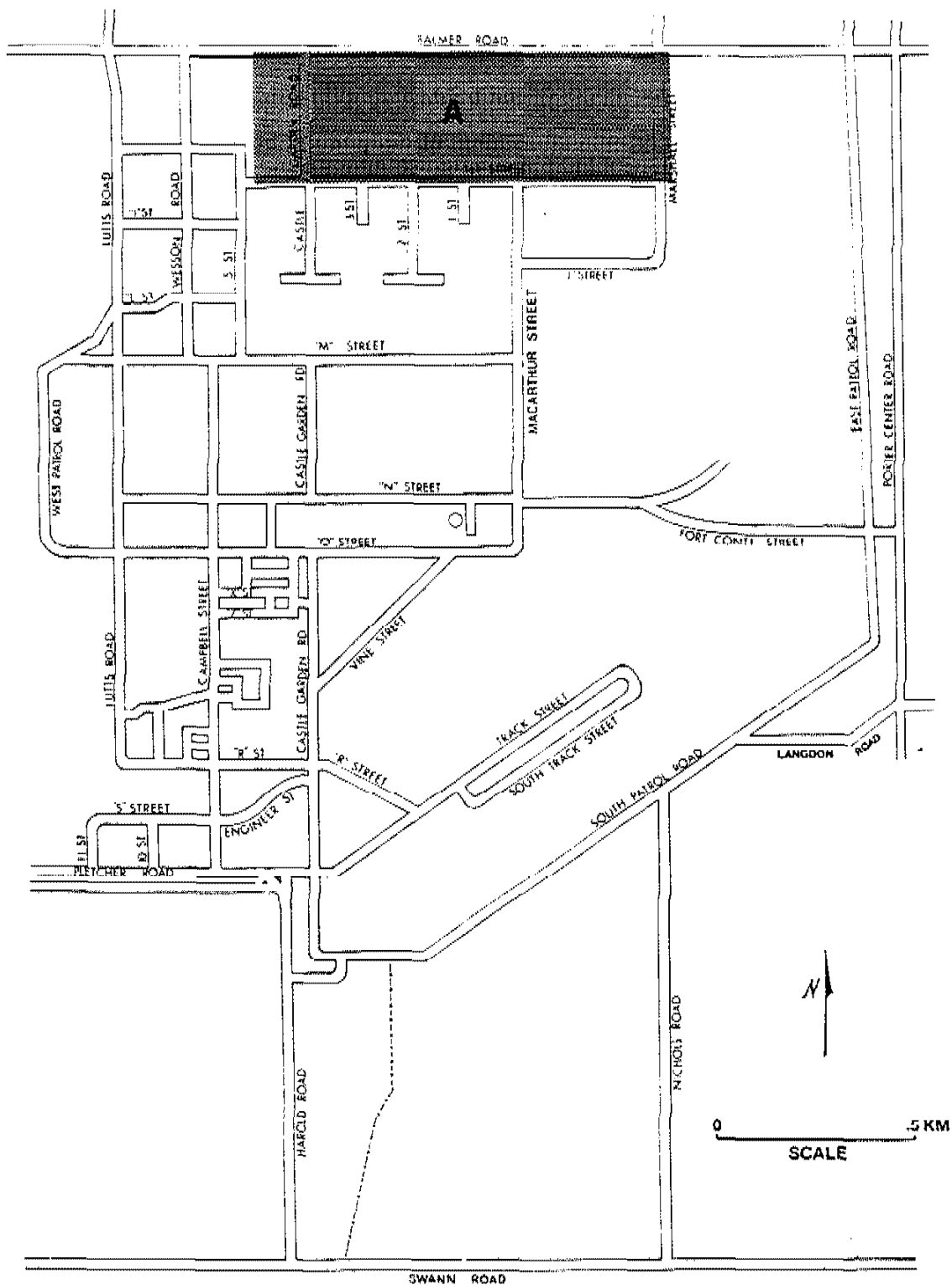


FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property A. (Boundaries of original property V are also indicated.)

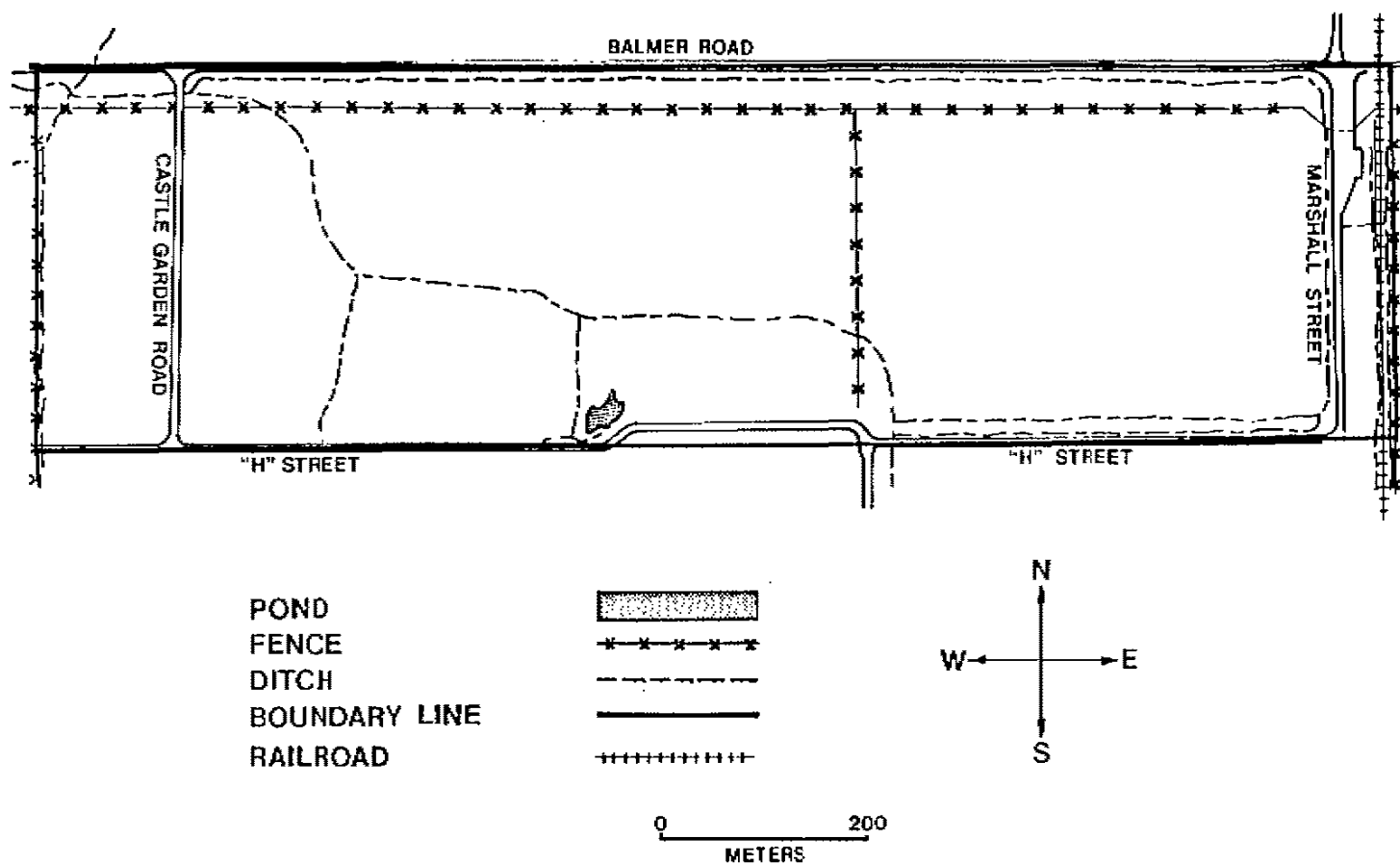


FIGURE 2. Plan View of NFSS Off-Site Property A Indicating Prominent Surface Features.  
(The portion of this property west of Castle Garden Road was originally part of off-site property V.)



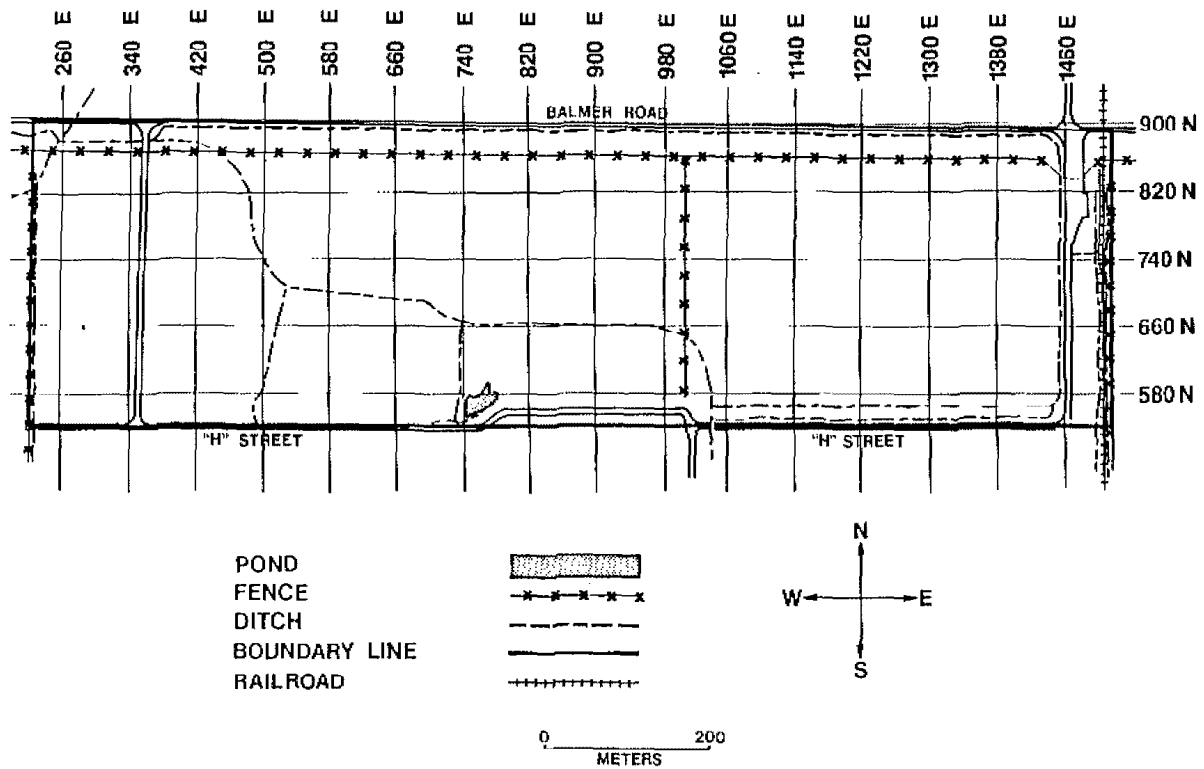


FIGURE 3. Plan View of NFSS Off-Site Property A Indicating the Grid System Established for Survey Reference.

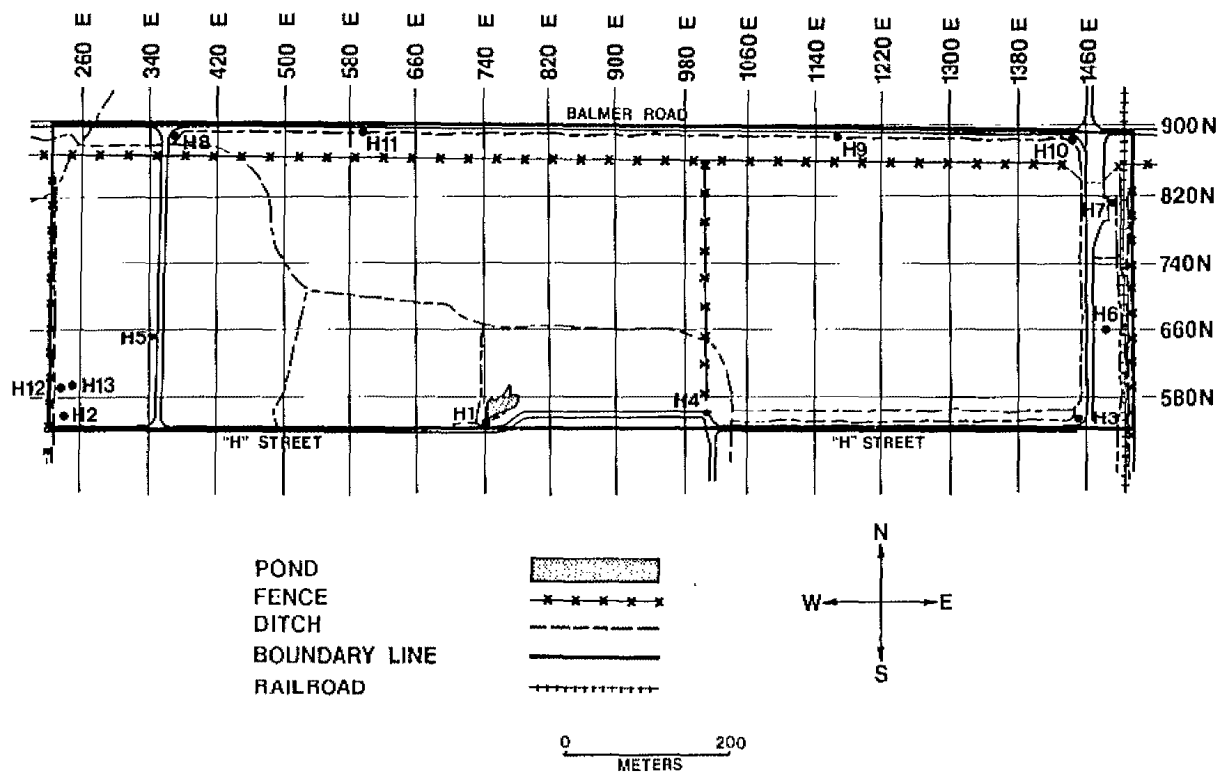


FIGURE 4. Locations of Boreholes for Subsurface Investigations.

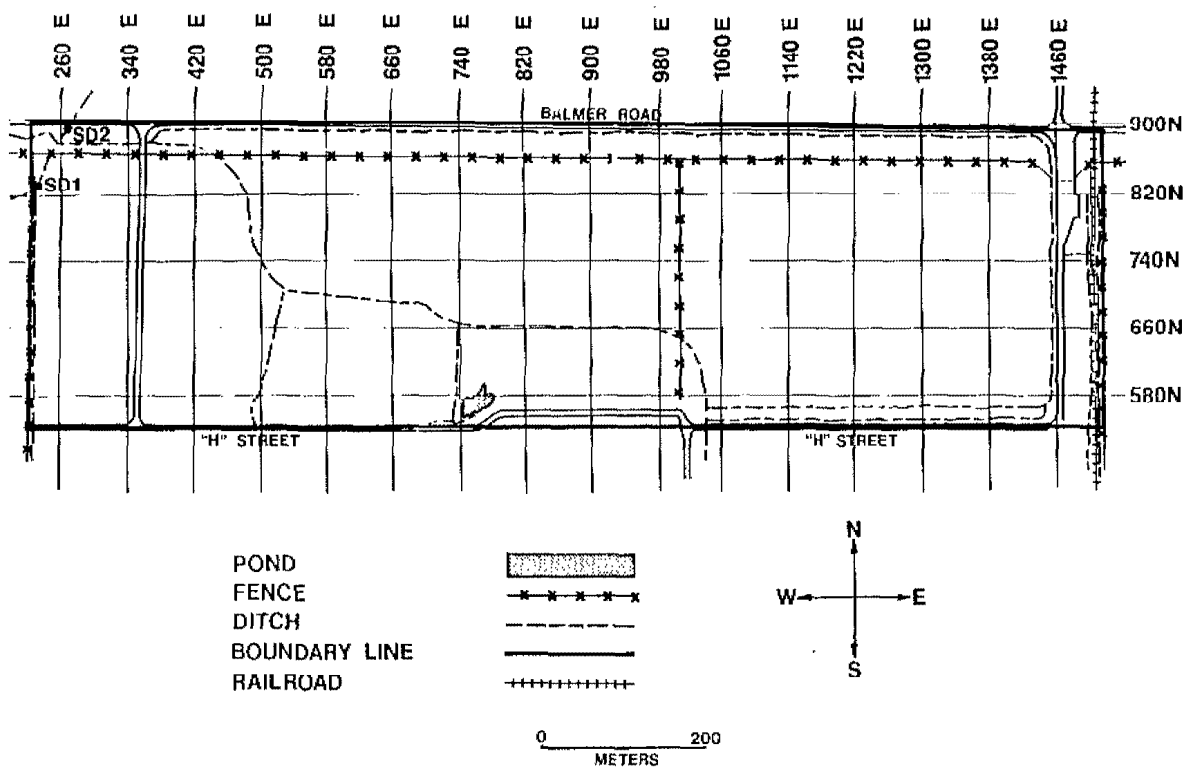


FIGURE 5. Locations of Sediment Samples from Ditches.

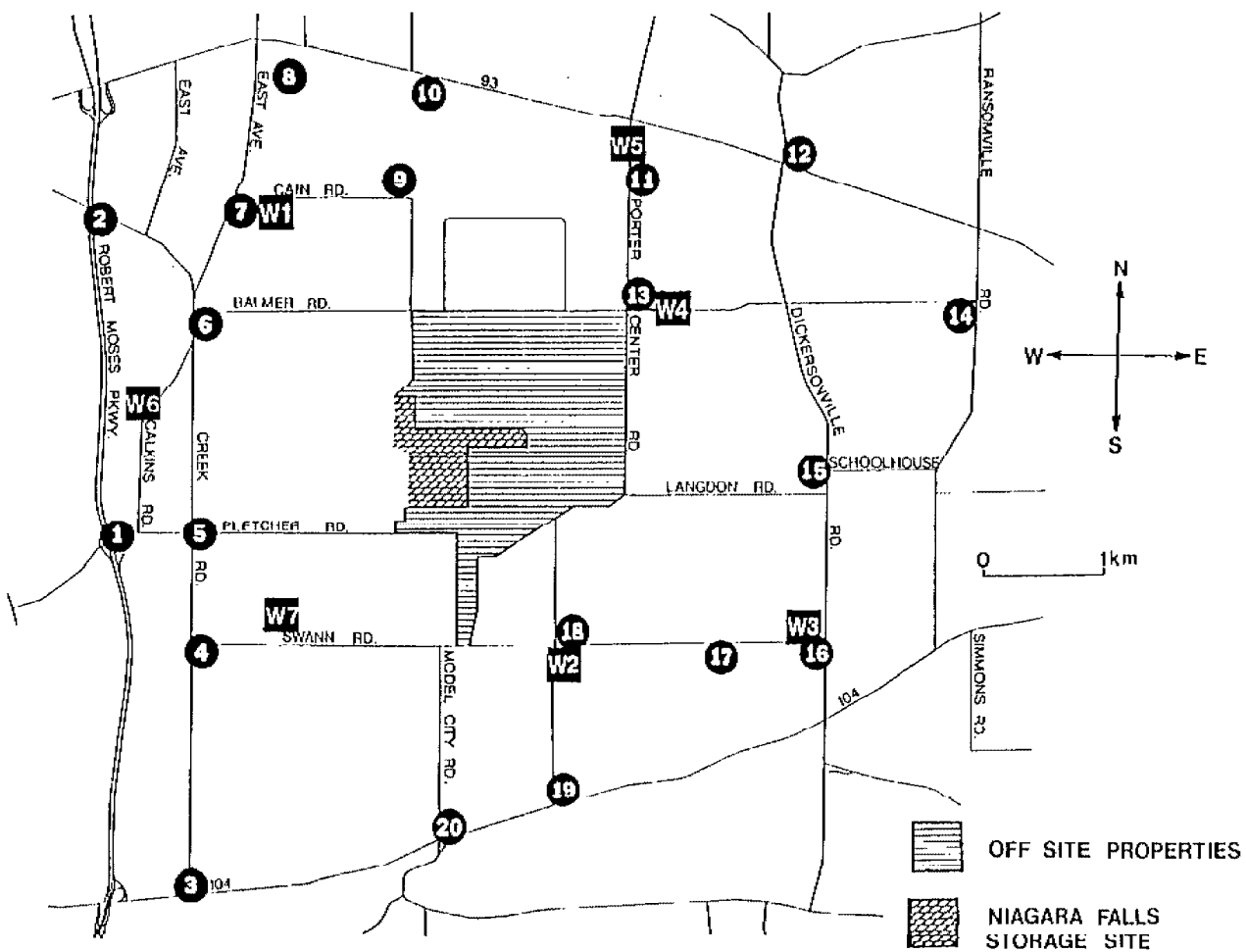


FIGURE 6. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples.)

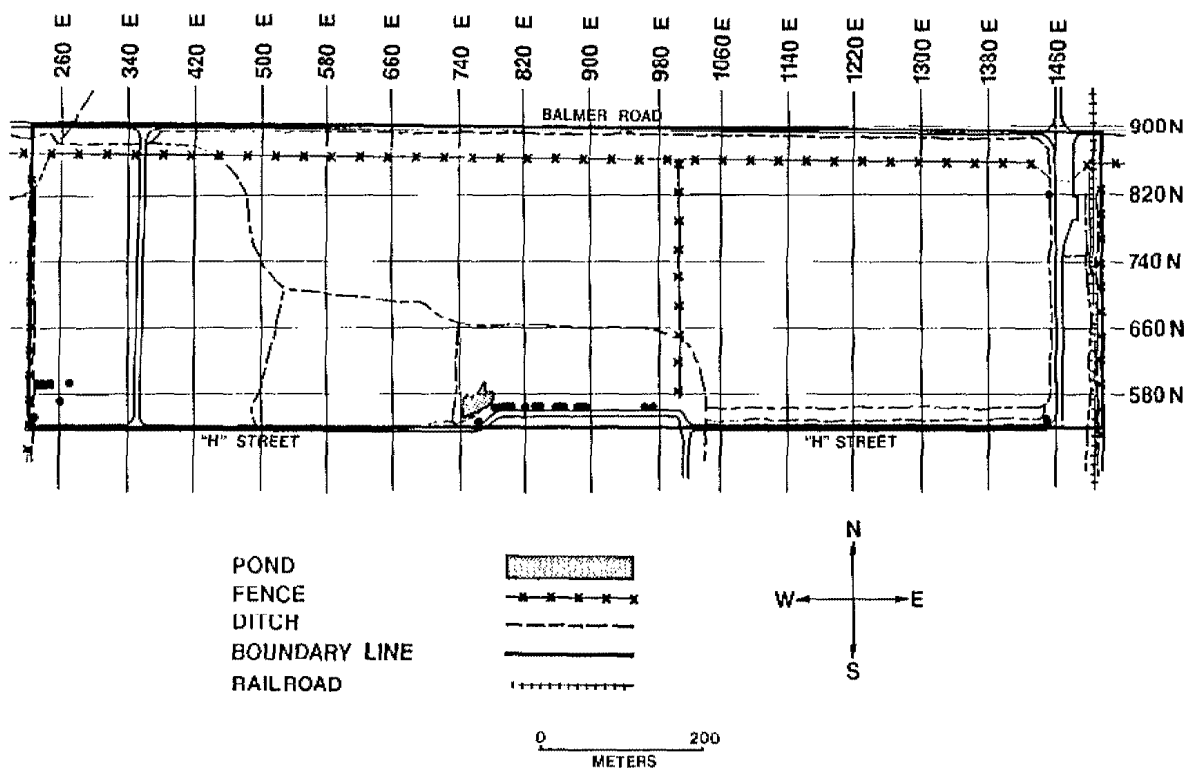


FIGURE 7. Locations (darkly shaded) of Areas of Elevated Direct Radiation.

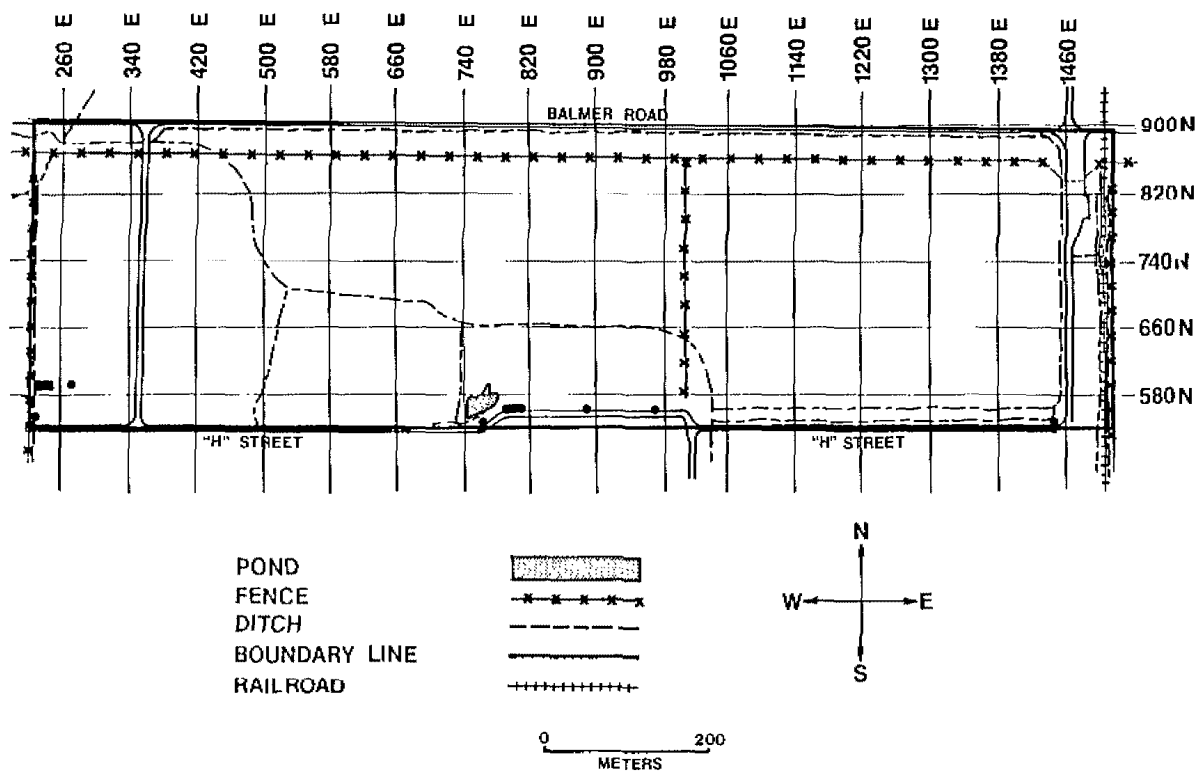


FIGURE 8. Map of NFSS Off-Site Property A Indicating Areas (darkly shaded) Where Radionuclide Concentrations in Soil Exceed Criteria.

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

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

<sup>a</sup> Refer to Figure 6.

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

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

TABLE 1-B  
RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

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

<sup>a</sup> Refer to Figure 6.

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



TABLE 2  
DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT 80 M GRID INTERVALS

Grid Location N      E		Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at 1 cm Above the Surface ( $\mu\text{rad/h}$ )
540	220	10	12	12
540	260	12	12	12
540	340	8	9	29
540	420	9	12	25
540	500	10	12	31
540	580	10	10	29
540	660	11	11	15
540	740	6	7	14
540	820	9	8	11
540	900	9	9	14
540	980	9	9	25
540	1060	7	8	15
540	1140	8	8	22
540	1220	7	6	16
540	1300	7	6	14
540	1380	7	7	9
540	1460	8	8	8
540	1505	12	13	50
580	220	8	9	22
580	260	8	8	22
580	340	7	7	17
580	420	7	8	8
580	500	7	7	13
580	580	6	7	10
580	660	7	8	9
580	740	7	8	35
580	820	8	9	26
580	900	7	7	26
580	980	8	8	18
580	1060	7	7	7
580	1140	7	8	17
580	1220	7	8	8
580	1300	7	7	9
580	1380	7	7	7
580	1460	7	8	16
580	1505	12	14	50
660	220	7	7	12
660	260	7	7	17
660	340	7	7	7
660	420	7	8	8
660	500	7	7	11

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT 80 M GRID INTERVALS

Grid Location		Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at 1 cm Above the Surface ( $\mu\text{rad/h}$ )
N	E			
660	580	7	7	17
660	660	6	6	12
660	740	7	7	7
660	820	7	8	16
660	900	8	8	11
660	980	8	8	15
660	1060	7	7	7
660	1140	7	7	27
660	1120	7	8	8
660	1300	7	7	12
660	1380	7	7	7
660	1460	6	7	7
660	1505	10	12	43
740	220	8	8	19
740	260	7	8	18
740	340	8	8	11
740	420	7	7	9
740	500	8	8	10
740	580	7	7	7
740	660	6	8	24
740	740	7	8	9
740	820	7	8	19
740	900	7	8	12
740	980	8	8	24
740	1060	8	8	8
740	1140	7	8	11
740	1220	8	8	34
740	1300	7	7	25
740	1380	8	8	21
740	1460	8	8	9
740	1505	10	12	45
820	220	7	8	24
820	260	7	8	24
820	340	7	7	13
820	420	7	7	24
820	500	7	7	7
820	580	7	7	7
820	660	7	7	7
820	740	6	7	7
820	820	7	7	18
820	900	7	7	14

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY  
MEASURED AT 80 M GRID INTERVALS

Grid Location		Gamma Exposure Rates at 1 m Above the Surface ( $\mu\text{R/h}$ )	Gamma Exposure Rates at the Surface ( $\mu\text{R/h}$ )	Beta-Gamma Dose Rates at 1 cm Above the Surface ( $\mu\text{rad/h}$ )
N	E			
820	980	7	7	20
820	1060	7	7	18
820	1140	7	7	7
820	1220	7	8	14
820	1300	7	7	9
820	1380	7	7	12
820	1460	8	8	8
820	1505	9	12	29
900	220	7	8	19
900	260	7	7	16
900	340	8	8	21
900	420	6	7	11
900	500	6	6	15
900	580	5	5	5
900	660	5	5	5
899	740	6	6	25
899	820	5	5	5
898	900	6	6	15
897	980	6	6	12
896	1060	6	6	22
895	1140	6	6	6
894	1220	6	6	6
893	1300	6	7	10
892	1380	7	7	17
891	1460	6	6	7
890	1505	8	7	7

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

Grid Location <sup>a</sup>		Exposure Rate( $\mu$ R/h)		Surface Dose Rate ( $\mu$ rad/h)	Sample Identification <sup>b</sup>	Contact Exposure Rate After Sample Removal ( $\mu$ R/h)
N	E	Contact	1 m Above Surface			
541	222	60	20	110	B1	470
542	760	17	----- <sup>c</sup>	---	---	---
548	1440	16	12	35	B2	20
561	807	93	---	---	---	---
561	838	150	12	---	B3	8
561	860	54	12	---	B4	17
562	802	50	14	1030	B5	12
562	803	31	---	---	---	---
562	869	200	12	---	B6	14
562	896	38	14	---	---	---
563	780	310	17	1640	B7	13
563	807	470	17	---	---	---
563	820	580	12	79,300	B8	8
563	960	230	16	---	---	---
564	805	240	14	17,900	B9	8
565	890	100	12	---	B10	9
565	977	190	12	---	B11	12
566	826	60	8	---	B12	10
570	260	42	14	450	B13	8
588-589	230-250	38-42	---	---	---	---
590	230	39	16	95	B14	46
595	270	50	28	110	B15	67
820	1457	50	17	1210	B16	12

<sup>a</sup> Refer to Figure 7.

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

<sup>c</sup> Dash indicates measurement or sampling not performed.

TABLE 4  
RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM 80 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
542	220	$1.09 \pm 0.23^a$	<0.16	$0.76 \pm 0.80$	$0.09 \pm 0.06$	$0.81 \pm 0.34$
542	260	$1.34 \pm 0.29$	<0.33	$6.40 \pm 1.91$	$1.03 \pm 0.15$	$1.02 \pm 0.41$
542	340	$1.74 \pm 0.30$	<0.34	<1.02	$1.42 \pm 0.18$	$1.33 \pm 0.43$
542	420	$0.94 \pm 0.25$	<0.27	<0.82	$0.27 \pm 0.15$	$0.66 \pm 0.31$
542	500	$0.74 \pm 0.28$	<0.14	$2.16 \pm 0.96$	$0.29 \pm 0.09$	$0.64 \pm 0.25$
542	580	$0.84 \pm 0.28$	<0.15	<0.43	$0.16 \pm 0.10$	$0.66 \pm 0.34$
542	610	$0.79 \pm 0.23$	<0.15	$0.24 \pm 0.72$	$0.06 \pm 0.07$	$0.89 \pm 0.37$
542	740	$0.91 \pm 0.25$	<0.28	$1.54 \pm 0.98$	$0.45 \pm 0.12$	$0.73 \pm 0.41$
555	820	$1.29 \pm 0.35$	<0.29	$6.96 \pm 1.90$	<0.04	$0.80 \pm 0.34$
555	900	$1.13 \pm 0.38$	<0.28	<0.88	$0.19 \pm 0.10$	$1.15 \pm 0.45$
555	980	$1.33 \pm 0.24$	<0.13	$1.38 \pm 0.69$	$0.09 \pm 0.04$	$0.66 \pm 0.29$
542	1060	$0.88 \pm 0.22$	<0.25	<0.71	$0.90 \pm 0.12$	$0.61 \pm 0.31$
542	1140	$1.31 \pm 0.33$	<0.16	$0.89 \pm 0.77$	$0.88 \pm 0.12$	$0.45 \pm 0.28$
542	1220	$1.30 \pm 0.29$	<0.30	<0.89	$0.84 \pm 0.13$	$1.37 \pm 0.56$
542	1300	$1.04 \pm 0.19$	<0.16	$1.62 \pm 0.72$	$1.11 \pm 0.16$	$0.43 \pm 0.27$
542	1380	$0.88 \pm 0.25$	<0.16	$0.74 \pm 1.04$	$1.47 \pm 0.17$	$0.46 \pm 0.46$
542	1458	$0.56 \pm 0.20$	<0.13	$1.12 \pm 0.55$	<0.03	$0.38 \pm 0.26$
542	1503	$1.44 \pm 0.33$	<0.19	$0.99 \pm 1.06$	$0.97 \pm 0.15$	$1.08 \pm 0.33$
580	220	$1.23 \pm 0.29$	<0.35	$3.75 \pm 1.36$	$0.22 \pm 0.10$	$0.68 \pm 0.27$
580	260	$0.73 \pm 0.23$	<0.19	$1.43 \pm 1.03$	$0.66 \pm 0.15$	$0.80 \pm 0.43$
580	340	$0.74 \pm 0.22$	<0.37	$1.60 \pm 1.54$	$0.96 \pm 0.16$	<0.25
580	420	$0.99 \pm 0.29$	<0.35	$3.24 \pm 1.80$	$0.51 \pm 0.15$	$1.04 \pm 0.38$
580	500	$0.94 \pm 0.25$	<0.30	<1.02	$0.69 \pm 0.15$	$1.09 \pm 0.50$
580	580	$1.01 \pm 0.23$	<0.28	$2.09 \pm 1.02$	$0.64 \pm 0.14$	$0.63 \pm 0.24$
580	660	$0.76 \pm 0.24$	<0.30	$0.79 \pm 1.76$	$0.74 \pm 0.14$	<0.27
580	740	$1.24 \pm 0.30$	<0.29	<0.96	$0.26 \pm 0.11$	$0.97 \pm 0.42$
580	820	$1.15 \pm 0.24$	<0.31	$1.75 \pm 1.53$	$0.35 \pm 0.10$	$0.81 \pm 0.35$

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM 80 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
580	900	0.93 ± 0.35	<0.22	<0.69	0.19 ± 0.10	0.94 ± 0.34
580	980	0.93 ± 0.22	<0.33	2.36 ± 1.68	0.21 ± 0.18	1.16 ± 0.34
580	1067	0.96 ± 0.28	<0.17	0.81 ± 0.56	0.73 ± 0.13	0.97 ± 0.50
580	1140	1.18 ± 0.30	<0.17	0.66 ± 0.53	0.81 ± 0.14	0.87 ± 0.45
580	1220	0.90 ± 0.25	<0.19	1.12 ± 1.18	0.22 ± 0.11	0.93 ± 0.41
580	1300	1.01 ± 0.24	<0.22	<0.71	0.63 ± 0.13	0.83 ± 0.29
580	1380	0.84 ± 0.23	<0.34	1.10 ± 2.40	0.72 ± 0.19	1.08 ± 0.49
580	1458	0.90 ± 0.34	<0.20	0.86 ± 1.33	0.77 ± 0.13	1.03 ± 0.31
580	1503	1.00 ± 0.24	<0.15	0.74 ± 0.77	0.42 ± 0.10	0.73 ± 0.34
660	220	0.85 ± 0.19	<0.15	0.67 ± 0.85	0.58 ± 0.11	0.53 ± 0.37
660	260	0.51 ± 0.22	<0.15	0.84 ± 1.46	0.46 ± 0.11	0.44 ± 0.20
660	340	1.11 ± 0.31	0.57 ± 0.67	<1.00	0.72 ± 0.13	1.35 ± 0.56
660	420	0.54 ± 0.28	0.15 ± 0.32	0.27 ± 0.41	0.59 ± 0.18	0.57 ± 0.38
660	500	1.06 ± 0.25	<0.30	0.99 ± 0.96	0.68 ± 0.14	1.04 ± 0.74
660	580	0.95 ± 0.29	<0.34	<1.01	0.78 ± 0.17	<0.27
660	660	0.98 ± 0.26	<0.15	1.48 ± 0.80	<0.30	0.86 ± 0.48
660	740	<0.23	<0.36	<1.07	0.49 ± 0.13	0.94 ± 0.34
660	820	0.94 ± 0.29	<0.16	<0.41	0.42 ± 0.16	0.56 ± 0.31
660	900	1.00 ± 0.24	<0.15	1.14 ± 0.53	0.37 ± 0.10	0.61 ± 0.39
660	980	1.23 ± 0.43	<0.32	4.21 ± 1.59	0.53 ± 0.11	0.66 ± 0.56
660	1060	0.75 ± 0.23	<0.16	1.68 ± 0.57	0.67 ± 0.13	0.65 ± 0.37
660	1140	0.99 ± 0.25	<0.21	1.20 ± 1.68	0.41 ± 0.13	0.54 ± 0.30
660	1220	0.86 ± 0.20	<0.18	1.87 ± 0.85	0.54 ± 0.15	1.00 ± 0.32
660	1300	0.79 ± 0.28	<0.28	<0.88	0.47 ± 0.11	0.22 ± 0.25
660	1380	1.48 ± 0.30	<0.32	<0.95	0.90 ± 0.14	0.95 ± 0.30
660	1458	0.71 ± 0.25	0.19 ± 0.29	0.49 ± 0.98	0.44 ± 0.11	0.59 ± 0.44
660	1503	0.94 ± 0.26	0.36 ± 0.45	1.89 ± 1.61	0.40 ± 0.13	1.34 ± 0.45

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
FROM 80 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
740	220	0.74 ± 0.20	<0.13	<0.45	0.08 ± 0.06	0.82 ± 0.32
740	260	0.78 ± 0.31	<0.28	<0.89	0.65 ± 0.12	0.61 ± 0.30
740	340	0.79 ± 0.26	<0.17	0.84 ± 0.54	0.40 ± 0.12	0.55 ± 0.33
740	420	1.05 ± 0.30	<0.35	1.87 ± 1.67	0.90 ± 0.16	0.72 ± 0.47
740	500	0.95 ± 0.22	<0.16	1.34 ± 0.81	0.58 ± 0.15	0.83 ± 0.38
740	580	1.11 ± 0.34	<0.32	1.06 ± 1.68	0.50 ± 0.19	1.04 ± 0.54
740	660	0.76 ± 0.39	<0.35	<1.11	0.91 ± 0.14	1.12 ± 0.51
740	740	0.69 ± 0.34	<0.38	4.51 ± 1.60	0.82 ± 0.16	1.16 ± 0.44
740	820	1.40 ± 0.33	<0.39	1.50 ± 2.39	1.07 ± 0.19	1.86 ± 0.58
740	900	0.88 ± 0.30	<0.33	2.20 ± 1.75	0.65 ± 0.14	1.49 ± 0.41
740	980	0.61 ± 0.28	<0.19	0.72 ± 0.86	0.91 ± 0.17	0.65 ± 0.27
740	1060	0.81 ± 0.25	<0.17	1.04 ± 0.63	0.69 ± 0.13	0.53 ± 0.49
740	1140	0.75 ± 0.36	<0.25	0.79 ± 2.16	0.77 ± 0.18	0.88 ± 0.43
740	1220	1.09 ± 0.28	<0.30	<0.98	0.40 ± 0.13	1.46 ± 0.42
740	1300	1.06 ± 0.24	<0.29	2.31 ± 1.80	<0.09	1.20 ± 0.42
740	1380	1.03 ± 0.30	<0.31	1.86 ± 1.54	0.68 ± 0.17	1.11 ± 0.41
740	1458	1.11 ± 0.39	<0.29	<0.99	0.42 ± 0.13	1.11 ± 0.40
740	1503	1.40 ± 0.35	<0.24	1.82 ± 2.01	0.45 ± 0.14	0.94 ± 0.38
820	220	0.54 ± 0.24	<0.15	0.78 ± 0.83	<0.04	0.71 ± 0.25
820	260	0.90 ± 0.28	<0.19	2.24 ± 0.75	0.66 ± 0.13	1.08 ± 0.43
820	340	0.65 ± 0.18	<0.25	<0.83	0.52 ± 0.13	1.36 ± 0.45
820	420	1.10 ± 0.33	<0.34	3.90 ± 1.34	0.69 ± 0.15	1.08 ± 0.39
820	500	1.15 ± 0.36	<0.34	6.57 ± 1.76	0.63 ± 0.12	1.80 ± 0.49
820	580	0.98 ± 0.29	<0.37	2.75 ± 1.82	0.88 ± 0.15	0.75 ± 0.28
820	660	0.76 ± 0.26	<0.30	0.42 ± 1.83	0.65 ± 0.13	1.20 ± 0.38
820	740	0.78 ± 0.25	<0.26	<0.81	0.67 ± 0.11	0.76 ± 0.35
820	820	0.89 ± 0.25	<0.32	<0.93	0.66 ± 0.15	<0.27

TABLE 4, cont.  
 RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES  
 FROM 80 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
820	900	0.91 ± 0.28	<0.28	0.87 ± 1.95	0.86 ± 0.15	1.25 ± 0.38
820	980	1.03 ± 0.38	<0.31	1.47 ± 2.06	0.93 ± 0.17	1.31 ± 0.39
820	1060	0.88 ± 0.31	0.25 ± 0.37	0.94 ± 1.32	0.47 ± 0.14	0.47 ± 0.51
820	1140	1.15 ± 0.28	<0.34	<1.12	0.61 ± 0.11	1.20 ± 0.49
820	1220	0.79 ± 0.25	<0.16	0.90 ± 0.82	0.56 ± 0.82	0.56 ± 0.13
820	1300	1.09 ± 0.24	<0.14	0.79 ± 1.41	0.60 ± 0.12	0.79 ± 0.38
820	1380	1.00 ± 0.31	<0.30	<0.96	0.66 ± 0.16	1.06 ± 0.32
820	1458	0.84 ± 0.26	<0.20	1.44 ± 1.76	0.09 ± 0.10	0.45 ± 0.37
820	1503	1.36 ± 0.29	<0.36	1.76 ± 1.70	0.82 ± 0.14	1.25 ± 0.46
900	220	0.93 ± 0.29	<0.21	1.24 ± 1.16	0.34 ± 0.15	0.67 ± 0.53
900	260	0.86 ± 0.30	<0.23	0.82 ± 1.17	0.58 ± 0.13	0.61 ± 0.29
900	340	0.66 ± 0.18	<0.30	<0.98	0.76 ± 0.15	0.95 ± 0.30
900	420	0.89 ± 0.20	<0.13	<0.38	0.49 ± 0.11	0.52 ± 0.21
900	500	0.83 ± 0.20	<0.14	<0.35	0.50 ± 0.12	0.41 ± 0.22
900	580	0.79 ± 0.23	<0.13	0.91 ± 0.73	0.61 ± 0.17	0.68 ± 0.25
900	660	0.63 ± 0.28	<0.19	0.46 ± 2.53	0.34 ± 0.09	0.63 ± 0.30
899	740	0.98 ± 0.30	<0.27	3.91 ± 1.91	0.27 ± 0.13	0.95 ± 0.43
899	820	0.57 ± 0.33	<0.18	<0.60	1.01 ± 0.15	0.57 ± 0.35
898	900	0.58 ± 0.34	<0.18	<0.61	1.02 ± 0.15	0.58 ± 0.36
897	980	0.73 ± 0.22	<0.14	0.62 ± 0.43	<0.04	<0.12
896	1060	0.56 ± 0.23	<0.14	0.51 ± 0.69	0.37 ± 0.08	0.64 ± 0.32
895	1140	0.91 ± 0.25	<0.32	<0.92	0.64 ± 0.14	0.64 ± 0.36
894	1220	1.23 ± 0.31	<0.28	<0.94	0.61 ± 0.10	0.73 ± 0.35
893	1300	0.79 ± 0.18	<0.13	1.41 ± 0.49	0.50 ± 0.10	0.47 ± 0.30
892	1380	0.89 ± 0.31	<0.20	<0.63	0.65 ± 0.15	0.79 ± 0.25
891	1460	0.71 ± 0.18	<0.27	<0.76	2.09 ± 0.17	0.44 ± 0.28
890	1503	0.79 ± 0.23	<0.12	0.80 ± 0.53	1.24 ± 0.15	0.48 ± 0.28

a Errors are 2σ based on counting statistics.



TABLE 5  
RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES  
FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN

Sample ID	Sample Description	Grid Location		Radionuclide Concentrations (pCi/g) <sup>a</sup>					
		N	E	Ra-226	U-235	U-238	Cs-137	Th-232	
B1	Rock	541	222	14.8 ± 0.9 <sup>b</sup>	<0.59	<1.71	<0.10	2.80 ± 0.75	
B2	Rock	548	1440	4.19 ± 0.66	<0.55	5.78 ± 1.54	0.11 ± 0.21	1.20 ± 0.70	
B3	Rock	561	838	1770 ± 53	<19.5	<36.8	<3.80	<18.1	
B4	Rock	561	870	4530 ± 68	<23.7	<43.3	<4.82	<21.8	
B5	Rock	562	802	6690 ± 36	177 ± 59	<35.7	<2.98	<12.0	
B6	Rock	562	869	3200 ± 32	<18.1	<28.8	<2.46	<10.4	
B7	Rock	563	780	2090 ± 56	<20.3	<34.2	<4.13	<17.2	
B8	Chip	563	820	c	c	c	c	c	
B9	Chip	564	805	d	d	d	d	d	
B10	Rock	565	890	1810 ± 13	<9.28	<14.8	<1.3	40.3 ± 8.5	
B11	Rock	565	977	3830 ± 21	<15.0	<23.6	<1.89	<7.67	
B12	Rock	566	826	1430 ± 14	<8.75	<13.4	<1.05	<4.48	
B13	Rock	570	260	1650 ± 22	<1.41	<23.9	<1.82	72.6 ± 15.5	
B14	Soil & Rock	590	230	26.6 ± 1.0	1.78 ± 1.46	42.3 ± 3.8	<0.12	<0.36	
B15	Gravel	595	270	37.5 ± 2.7	<1.25	31.4 ± 5.1	0.46 ± 0.20	<0.61	
B16	Rock	820	1457	906 ± 14	<11.0	122 ± 46	<1.49	90.7 ± 12.5	

<sup>a</sup> Refer to Table 3 for direct radiation levels.

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

<sup>c</sup> Activity too high for gamma spectrometry; contains 1.68 μCi of Ra-226.

<sup>d</sup> Activity too high for gamma spectrometry; contains 0.82 μCi of Ra-226.

TABLE 6

## RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.	Grid Location <sup>a</sup>		Depth (m)	Radionuclide Concentrations (pCi/g)				
				Ra-226	U-235	U-238	Cs-137	Th-232
	N	E						
H1	545	740	Surface	$1.84 \pm 0.15^b$	<0.12	$0.82 \pm 0.43$	<0.04	$0.42 \pm 0.24$
			0.5	$0.74 \pm 0.24$	<0.18	$0.82 \pm 1.10$	<0.04	$0.66 \pm 0.37$
			1.0	$0.89 \pm 0.23$	<0.18	$0.92 \pm 1.51$	<0.03	$0.77 \pm 0.24$
H2	549	235	Surface	$1.08 \pm 0.24$	<0.13	$0.69 \pm 0.76$	$0.39 \pm 0.10$	$0.47 \pm 0.27$
			0.5	$1.14 \pm 0.28$	<0.27	$1.38 \pm 1.28$	<0.04	$0.76 \pm 0.40$
			1.0	$0.71 \pm 0.20$	<0.12	$0.62 \pm 0.61$	<0.02	$0.56 \pm 0.19$
H3	550	1449	Surface	$0.75 \pm 0.18$	<0.29	$1.61 \pm 1.58$	$0.52 \pm 0.10$	$0.79 \pm 0.49$
			0.5	$1.41 \pm 0.25$	<0.29	$1.46 \pm 0.91$	<0.04	$0.89 \pm 0.40$
H4	558	1007	Surface	$1.16 \pm 0.20$	<0.13	$0.68 \pm 1.12$	$0.22 \pm 0.07$	$0.72 \pm 0.28$
			0.5	$0.78 \pm 0.34$	<0.23	<0.74	<0.04	$1.13 \pm 0.44$
			1.0	$1.53 \pm 0.25$	<0.32	<0.96	<0.04	$1.20 \pm 0.36$
H5	657	346	Surface	$1.00 \pm 0.26$	<0.21	$0.51 \pm 2.12$	$0.49 \pm 0.10$	$0.65 \pm 0.31$
			0.5	$0.86 \pm 0.26$	$0.47 \pm 0.49$	<0.94	$0.51 \pm 0.14$	$0.89 \pm 0.32$
			2.0	$0.83 \pm 0.16$	<0.13	$0.82 \pm 0.67$	<0.02	$0.87 \pm 0.25$
H6	660	1487	Surface	$0.93 \pm 0.31$	<0.29	<0.91	$0.52 \pm 0.17$	$1.05 \pm 0.32$
			0.5	$0.78 \pm 0.23$	<0.15	$0.50 \pm 1.39$	<0.03	$0.97 \pm 0.32$
			1.0	$0.80 \pm 0.28$	<0.20	$1.18 \pm 1.59$	<0.04	$0.75 \pm 0.49$
H7	816	1495	Surface	$0.71 \pm 0.20$	<0.14	$1.11 \pm 0.44$	$0.07 \pm 0.018$	$0.83 \pm 0.26$
			0.5	$0.83 \pm 0.24$	<0.18	<0.66	<0.04	$1.07 \pm 0.34$
			1.0	$0.96 \pm 0.25$	<0.19	<0.63	<0.03	$1.01 \pm 0.34$

TABLE 6, cont.

## RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.	Grid Location		Depth (m)	Radionuclide Concentrations (pCi/g)				
	N	E		Ra-226	U-235	U-238	Cs-137	Th-232
H8	885	359	Surface	$1.14 \pm 0.26$	$<0.20$	$1.37 \pm 1.49$	$0.40 \pm 0.10$	$0.62 \pm 0.36$
			0.5	$1.08 \pm 0.23$	$<0.28$	$2.04 \pm 1.81$	$<0.04$	$0.93 \pm 0.29$
			1.0	$0.73 \pm 0.26$	$<0.16$	$1.50 \pm 0.56$	$<0.04$	$0.85 \pm 0.60$
H9	890	1073	Surface	$0.74 \pm 0.24$	$<0.15$	$1.39 \pm 1.28$	$0.27 \pm 0.10$	$0.84 \pm 0.35$
			0.5	$1.03 \pm 0.36$	$<0.29$	$<0.92$	$<0.03$	$1.21 \pm 0.41$
			1.0	$0.84 \pm 0.39$	$<0.22$	$1.42 \pm 1.24$	$<0.04$	$0.85 \pm 0.32$
H10	892	1435	Surface	$1.54 \pm 0.29$	$<0.32$	$0.91 \pm 0.97$	$0.44 \pm 0.10$	$1.24 \pm 0.34$
			0.5	$0.57 \pm 0.23$	$<0.13$	$0.96 \pm 0.40$	$<0.02$	$0.61 \pm 0.34$
			2.0	$0.60 \pm 0.18$	$<0.14$	$1.03 \pm 0.95$	$<0.03$	$0.52 \pm 0.32$
H11	895	591	Surface	$0.51 \pm 0.23$	$<0.19$	$1.18 \pm 1.56$	$0.90 \pm 0.15$	$0.32 \pm 0.43$
			0.5	$0.84 \pm 0.19$	$<0.26$	$0.77 \pm 1.32$	$0.06 \pm 0.10$	$1.22 \pm 0.38$
			2.0	$1.03 \pm 0.26$	$<0.17$	$<0.43$	$<0.03$	$1.07 \pm 0.32$
H12	590	235	Surface	$3.60 \pm 0.36$	$<0.21$	$1.60 \pm 0.71$	$0.17 \pm 0.09$	$0.78 \pm 0.26$
			0.15	$2.31 \pm 0.34$	$<0.22$	$5.36 \pm 1.50$	$<0.04$	$1.07 \pm 0.37$
			0.30	$0.69 \pm 0.18$	$<0.18$	$0.96 \pm 1.18$	$<0.03$	$0.90 \pm 0.29$
			1.0	$0.88 \pm 0.24$	$<0.24$	$1.44 \pm 1.12$	$<0.03$	$1.11 \pm 0.44$
H13	592	243	Surface	$20.7 \pm 0.8$	$2.31 \pm 1.09$	$22.1 \pm 2.4$	$0.53 \pm 0.11$	$0.51 \pm 0.62$
			0.15	$16.4 \pm 0.8$	$1.07 \pm 1.10$	$15.1 \pm 6.9$	$<0.07$	$<0.35$
			1.0	$0.95 \pm 0.25$	$<0.20$	$1.03 \pm 1.91$	$<0.04$	$0.67 \pm 0.40$

a Refer to Figure 4.

b Errors are  $2\sigma$  based on counting statistics.

TABLE 7  
RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES  
FROM DRAINAGE DITCHES

Sample <sup>a</sup> Identification	Grid Location		Radionuclide Concentrations (pCi/g)				
	N	E	Ra-226	U-235	U-238	Cs-137	Th-232
SD1	824	226	$0.81 \pm 0.23^b$	<0.15	$0.89 \pm 0.45$	<0.04	$0.61 \pm 0.24$
SD2	900	270	$0.96 \pm 0.23$	<0.30	$2.77 \pm 1.80$	<0.05	$1.43 \pm 0.44$

<sup>a</sup> Refer to Figure 5.

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

TABLE 8

## RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

Sample Identification	Sample Type	Grid Location		Radionuclide Concentrations (pCi/l)		
		N	E	Gross Alpha	Gross Beta	Ra-226
W1	Subsurface, Borehole H1	545	740	$3.47 \pm 1.74^a$	$2.42 \pm 1.73$	---- <sup>b</sup>
W2	Subsurface, Borehole H2	549N	235	$6.04 \pm 1.34$	$8.93 \pm 1.19$	----
W3	Subsurface, Borehole H3	550	1449	<1.44	$11.5 \pm 2.7$	----
W4	Subsurface, Borehole H4	558	1007	$9.72 \pm 1.98$	$9.16 \pm 1.45$	----
W5	Subsurface, Borehole H6	660	1487	$5.6 \pm 2.15$	$10.9 \pm 1.4$	$0.18 \pm 0.18$
W6	Subsurface, Borehole H7	816	1495	$6.51 \pm 1.69$	$6.43 \pm 1.30$	----
W7	Subsurface, Borehole H9	890	1073	$5.16 \pm 2.37$	$7.16 \pm 2.48$	----
W8	Subsurface, Borehole H10	892	1435	$5.06 \pm 1.42$	$7.46 \pm 1.22$	----
W9	Subsurface, Borehole H11	895	591	$6.95 \pm 2.72$	$10.9 \pm 2.5$	----

<sup>a</sup> Errors are 2σ based on counting statistics.<sup>b</sup> Dash indicates analysis not performed.

TABLE 9

LISTING OF AREAS ON PROPERTY A WHICH  
EXCEED RESIDUAL CONTAMINATION CRITERIA

Grid Location <sup>a</sup>		Radionuclides	Estimated Quantities of Material Exceeding Guidelines			Remarks
N	E		Area (m <sup>2</sup> )	Depth (m)	Volume (m <sup>3</sup> )	
588-589	230-250	Ra-226, U-238 <sup>b</sup>	200	0.15	30	General area of crushed rock fill.
541	222	Ra-226	----	----	----	Isolated pieces of rock like material. Total volume is estimated as less than 1 m <sup>3</sup> .
542	760	Ra-226	----	----	----	
548	1440	Ra-226	----	----	----	
561	807	Ra-226	----	----	----	
562	803	Ra-226	----	----	----	
562	896	Ra-226	----	----	----	
563	807	Ra-226	----	----	----	
563	960	Ra-226	----	----	----	
595	270	Ra-226, U-238 <sup>b</sup>	----	----	----	

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

<sup>b</sup> Naturally occurring material in rock fill.

<sup>c</sup> Dash indicates determination was not made.

## 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 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 ( $\mu\text{R/h}$ ) 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 NFSS 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 ( $\mu\text{rad/h}$ ) 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 and Sediment Sample Analysis

### Gamma Spectrometry

Soil and sediment samples were dried, mixed, and a portion placed in a 0.5 l 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)  
Th-232 - 0.911 MeV from Ac-228 (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  $\mu$ m membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. Fifty milliliters of each 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 600/4-80-032 (August 1980).

### 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<sup>1/</sup>. 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<sup>2/</sup> or termination of licenses for byproduct, source, or special nuclear material<sup>2/</sup>. The waste control guidelines are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR Part 192.

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<sup>1/</sup> 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<sup>1/</sup> as was used for those represented here.

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

<u>Radionuclide</u>	<u>Soil Criteria<sup>2/.3/.4/</sup> (pCi/g above background)</u>
U-Natural <sup>5/</sup>	75
U-238 <sup>6/</sup>	150
U-234 <sup>6/</sup>	150
Th-230 <sup>7/</sup>	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 <sup>6/</sup>	140
Pa-231	40
Ac-227	190
Th-232	15
Am-241	60
Pu-241 <sup>8/</sup>	2400
Pu-238, 239, 240	300
Cs-137	80

Sr-90  
H-3 (pCi/ml soil moisture)

300  
5,200

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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<sup>2</sup> 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<sup>2</sup> 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  $3.7 \times 10^{10}$  disintegrations per second (dis/s) over any 15cm thick layers from U-238 plus  $3.7 \times 10^{10}$  dis/s from U-234 plus  $1.7 \times 10^9$  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 microrentgen per hour (20 R/h) above background in any occupied or habitable building.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides <sup>2/</sup>	Allowable Surface Residual Contamination <sup>+1</sup> (dpm/100 cm <sup>2</sup> )		
	Average <sup>3/,4/</sup>	Maximum <sup>4/,5/</sup>	Removable <sup>4/,6/</sup>
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

<sup>1/</sup> 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.

<sup>2/</sup> 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.

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

<sup>4/</sup> 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<sub>2</sub> respectively, measured through not more than 7 mg/cm<sup>2</sup> of total absorber.

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

6/ The amount of removable radioactive material per 100 cm<sup>2</sup> 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).

1. 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<sup>2</sup>/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

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

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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.