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COMPREHENSIVE RADIOLOGICAL SURVEY OF OFF-SITE PROPERTY O NIAGARA FALLS STORAGE SITE LEWISTON, NEW YORK

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DEPARTMENT OF ENERGY

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COMPREHENSIVE RADIOLOGICAL SURVEY OF OFF-SITE PROPERTY 0 NIAGARA FALLS STORAGE SITE LEWISTON, NEW YORK

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Work performed as part of the
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COMPREHENSIVE RADIOLOGICAL SURVEY OF OFF-SITE PROPERTY O NIAGARA FALLS STORAGE SITE LEWISTON, NEW YORK*

INTRODUCTION

Beginning in 1944, the Manhattan Engineer District (MED) 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) located 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 Company, 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 government agencies.[1]

The United States Government is the current owner of a tract identified as off-site Property O (Fig. 1). A radiological survey of that tract, conducted in June 1985, is the subject of this report.

SITE DESCRIPTION

A plot plan of off-site Property O is shown in Fig. 2. The property is relatively square in shape and measures approximately 590 m long by 610 m wide. It occupies a total area of 40 hectares. Fence lines delineate the four boundaries. The northern border parallels

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* The survey was performed by members of the Radiological Survey Activities Group of the Health and Safety Research Division at Oak Ridge National Laboratory under DOE contract DE-AC05-84OR21400.

Balmer Road. The western border adjoins property owned by the SCA Chemical Services, Inc. (SCA). The eastern property line parallels Porter Center Road. And the southern section borders an area that has been designated a "wetlands area" by the state of New York. At the present time, the land is used by SCA only as a source of construction fill dirt.[5]

Abandoned gravel and asphalt roadways traverse the most northern section of the property with an asphalt roadway paralleling the eastern border. A drainage ditch traverses the northern border parallel to Balmer Road. The southwest and southeast portions are heavily wooded. The northeast and southeast are largely occupied by swamps.

Located in the north central section of Property O is an active microwave relay station (enclosed by a thirty-foot fence) using twenty-eight feet dish antennas. This station is set up at a former Nike missile base (the base operated from 1958 until 1965, and at that time the missiles and support equipment were removed). Three buildings exist on the site. Building 116 houses the Operations for the active microwave relay station. Building 108 and 109 are used for materials storage. Six abandoned Nike missile encasements exist on the site. One encasement is accessible and the remaining five encasements are flooded from rain and groundwater and are "permanently closed." Remnants of a formerly occupied Nike missile site remain (i.e. concrete slabs, asphalt, and disposal areas containing discarded materials). The land is relatively level, but the inactive areas are heavily overgrown with weeds, brush, and trees (Fig. 2).

RADIOLOGICAL HISTORY

There is no documented evidence of burial or storage of contaminated material on this property. The 1971 and 1972 AEC surveys found no gamma radiation levels in excess of 20 μR/h; however, slightly elevated uranium and radium concentrations were noted in surface soil from the site. The 1980 mobile scan by the Oak Ridge National Laboratory (ORNL) did not identify any significant radiation levels above background.[3] The background and resurvey recommendations for the AEC portion of the Lake Ontario Ordnance Works (November 1982) indicated

only a small area in the north-central section of Property O as having gamma exposure rates in the range of 20-30 μR/h.[1] The property is part of the decommissioned Nike missile base and is owned by the Federal Government.[1]

SURVEY PROCEDURES

The comprehensive survey of the NFSS, off-site Property O, was performed by the Radiological Survey Activities (RASA) group of the Health and Safety Research Division (HASRD) of ORNL during June 1985. The survey was in accordance with a plan approved by the Department of Energy (DOE) for use in surveying NFSS off-site properties. The objective and procedures from that plan are presented in this section.

OBJECTIVE

The objective of the survey is to provide a comprehensive assessment of the radiological condition on Property O. The radiological survey included the following:

1. Gamma radiation exposure rates at the surface and at 1 m from the surface at grid locations on the site.
2. Concentrations of radionuclides in 0-15 cm surface soil onsite.
3. Concentrations of radionuclides in surface water.
4. Gamma radiation exposure rates in structures.
5. Direct and transferable alpha and beta contamination in structures.

SURVEY METHODS

The following activities were performed to prepare the site and conduct the radiological survey:

1. Weeds, brush, and trees were cleared to provide access for gridding and surveying.
2. A 40 m grid system was established on the site as shown in Fig. 2.
3. Walkover surface scans were conducted over all areas of the property

to identify locations of elevated surface gamma radiation levels, if any. Traverses were made at 1-2 m intervals on all areas.

4. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at grid points. Measurements were performed using portable gamma NaI(Tl) scintillation survey meters. Conversion of these measurements to exposure rates in units of microroentgens per hour (μR/h) was in accordance with cross calibration measurements made with a pressurized ionization chamber (PIC).[4]
5. Systematic surface (0-15 cm) soil samples were collected to provide representative sampling of the area (Fig. 3).
6. Biased samples were collected from areas shown to have elevated gamma exposure rates (Fig. 3).
7. Water samples of approximately 2 liters each were collected from two locations on the site (Fig. 3).
8. Soil 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.
9. The survey also included measurements from accessible structures onsite (Figs. 5,6,7,and 8); the measurements included the following: (1) gamma radiation exposure rates; and (2) direct and transferable alpha and beta contamination.

SAMPLE ANALYSES

Soil samples were analyzed for gamma emitting radionuclides by gamma spectrometry.[4] Concentrations of ^{238}U were determined by neutron activation methods. Water samples were analyzed for gross alpha and gross beta concentrations.[4]

SURVEY RESULTS

Background exposure rates and baseline radionuclide concentrations in soil determined from four locations (Fig. 4) in the vicinity of the NFSS are presented in Table 1. With the exception of measurements of

transferable activity (which are reported as net count rates), all direct measurements presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations measured in environmental samples.

OUTDOOR SURVEY RESULTS

Gamma Radiation Levels

Gamma radiation levels measured at grid points are presented in Table 2. Gamma exposure rates measured at the surface and 1 m from the surface both averaged 9.0 μR/h. This rate compares favorably with an average of 8.8 μR/h (Table 1) measured at four locations in the Lewiston, New York area outside the influence of the NFSS. Gamma exposure rates measured during the gamma scan of the property, with a few exceptions, were not significantly different from those measured at grid points. At locations where gamma radiation anomalies were detected, the elevated gamma levels were associated with slag or rock common to the Niagara Falls area and are not characteristic of radioactive materials associated with the NFSS.

Radionuclide Concentrations in Surface Soil

Radionuclide concentrations in surface soil are given in Tables 3 and 4. Concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in all systematic soil samples were in the range of background for the Niagara Falls/Lewiston, New York area (Table 1). Rock and slag samples collected from areas showing elevated gamma radiation levels had maximum concentrations of ^{226}Ra, ^{232}Th, and ^{238}U of 500 pCi/g, 550 pCi/g, and 470 pCi/g, respectively. In all cases, these radionuclides were found in either naturally-occurring rocks or in a slag-like material previously identified as having originated from an industrial process in Niagara Falls. This slag is found throughout the Niagara Falls/Lewiston area.

Radionuclide Concentrations in Water

Water samples were collected from two locations onsite (one from a ditch near the southern boundary and one from a well located in the north central section of the property. Results of analyses of these samples are given in Table 5.

INDOOR SURVEY RESULTS

Alpha, Beta-gamma, and Gamma Measurements

Diagrams of the interior of buildings surveyed are provided in Figs. 5 through 8. The locations of the buildings onsite are shown in Fig. 2. The results of indoor measurements are presented in Table 7. No transferable activity was detected in the buildings.

Direct alpha activity on surfaces inside buildings ranged from 0 dpm/100 cm^2 to 36 dpm/100 cm^2 and averaged 17 dpm/100 cm^2. This activity is within acceptable guidelines. Beta-gamma dose rates in all buildings were within the background range of 0.01 mrad/h to 0.03 mrad/h.

Gamma exposure rates at the surface and at 1 m above the surface ranged from 6 μR/h to 9 μR/h with a mean of 7.5 μR/h. These values are within normal background levels. The results of the indoor survey indicate that no areas of elevated contamination are present in the buildings.

SIGNIFICANCE OF FINDINGS

A radiological survey was conducted at a NFSS vicinity property near Lewiston, New York known as Property O. The results of this survey indicate that no radioactive materials that were associated with the operation of the NFSS are present on or near the surface of this site.

Soil sample results indicate only naturally-occurring radionuclides to be present at background concentrations in the surface soil onsite. Analyses of water samples collected from the site indicate no significant concentrations of radionuclides above background levels. Gamma anomalies detected on the property were due to the presence of rock and

slag containing naturally-occurring radionuclides. This slag-like material has been identified as originating from an industrial process in Niagara Falls and has been used extensively as a bedding material in the construction of roads, driveways, and parking lots in the Niagara Falls/Lewiston area.[6] Indoor measurement results indicate that there are no radioactive materials present in buildings on the site.

The topography and physical appearance of the site (i.e. shallow water table, swampy, wooded and lack of evidence of roadways leading to the site interior indicate that it is highly unlikely that the property was used as a waste disposal site.

Based on the results of this survey, Property O appears to contain no residual radioactive materials associated with MED/AEC operation of the NFSS and no further action is required on this property.

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).

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4. Oak Ridge National Laboratory, Procedures Manual for the ORNL Remedial Action Survey and Certification Activities (RASCA) Program, ORNL/TM-8600 (October 1982).

5. A. J. Boerner, Comprehensive Radiological Survey of Off-Site Property K, Niagara Falls Storage Site, Lewiston, New York (March 1984).

6. W. D. Cottrell, et. al., Radiological Survey at Selected Locations in Niagara Falls, New York, ORNL/CF-80/320.

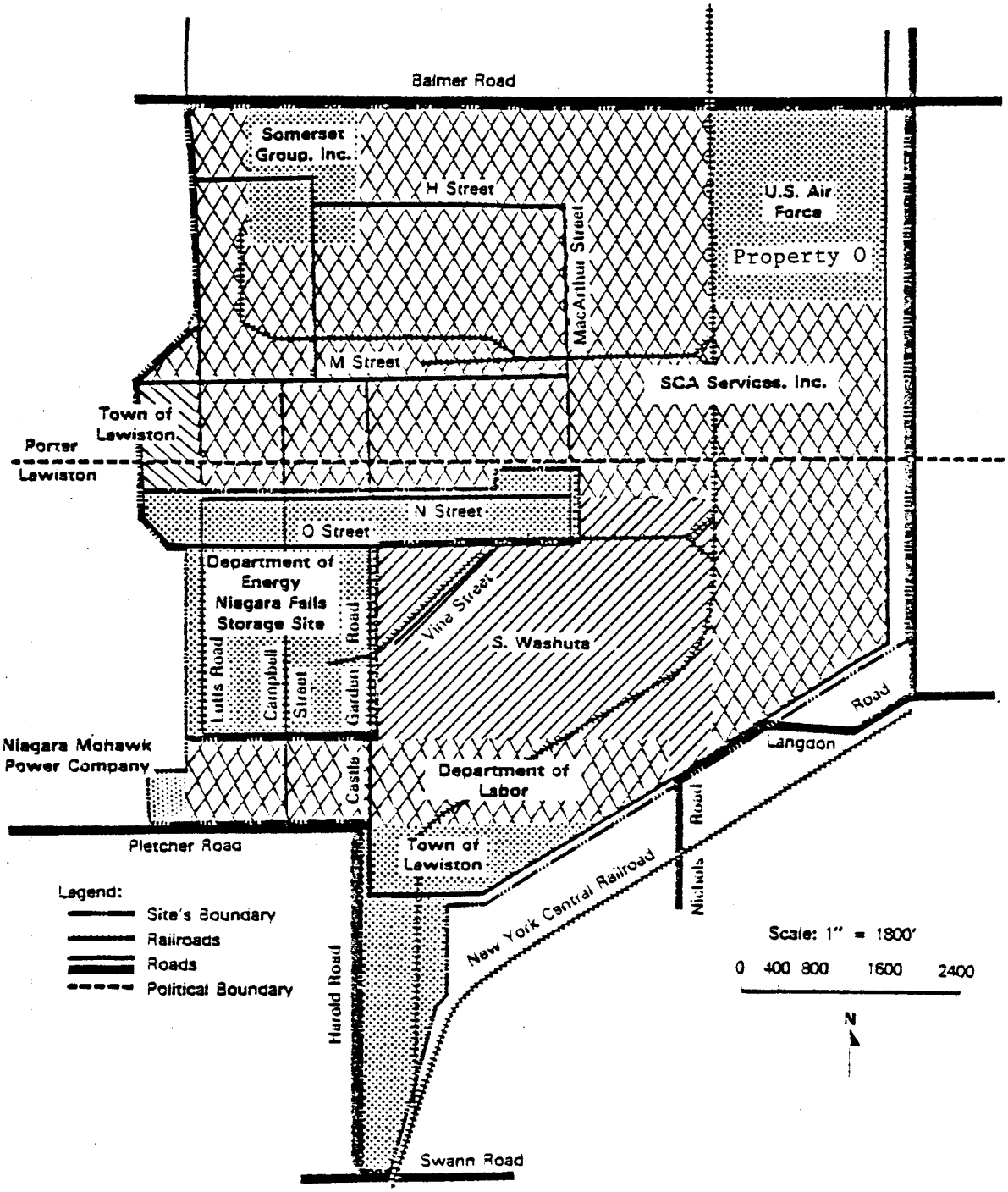

Fig. 1. Map of the Niagara Falls Storage Site and off-site properties, Lewiston, New York.

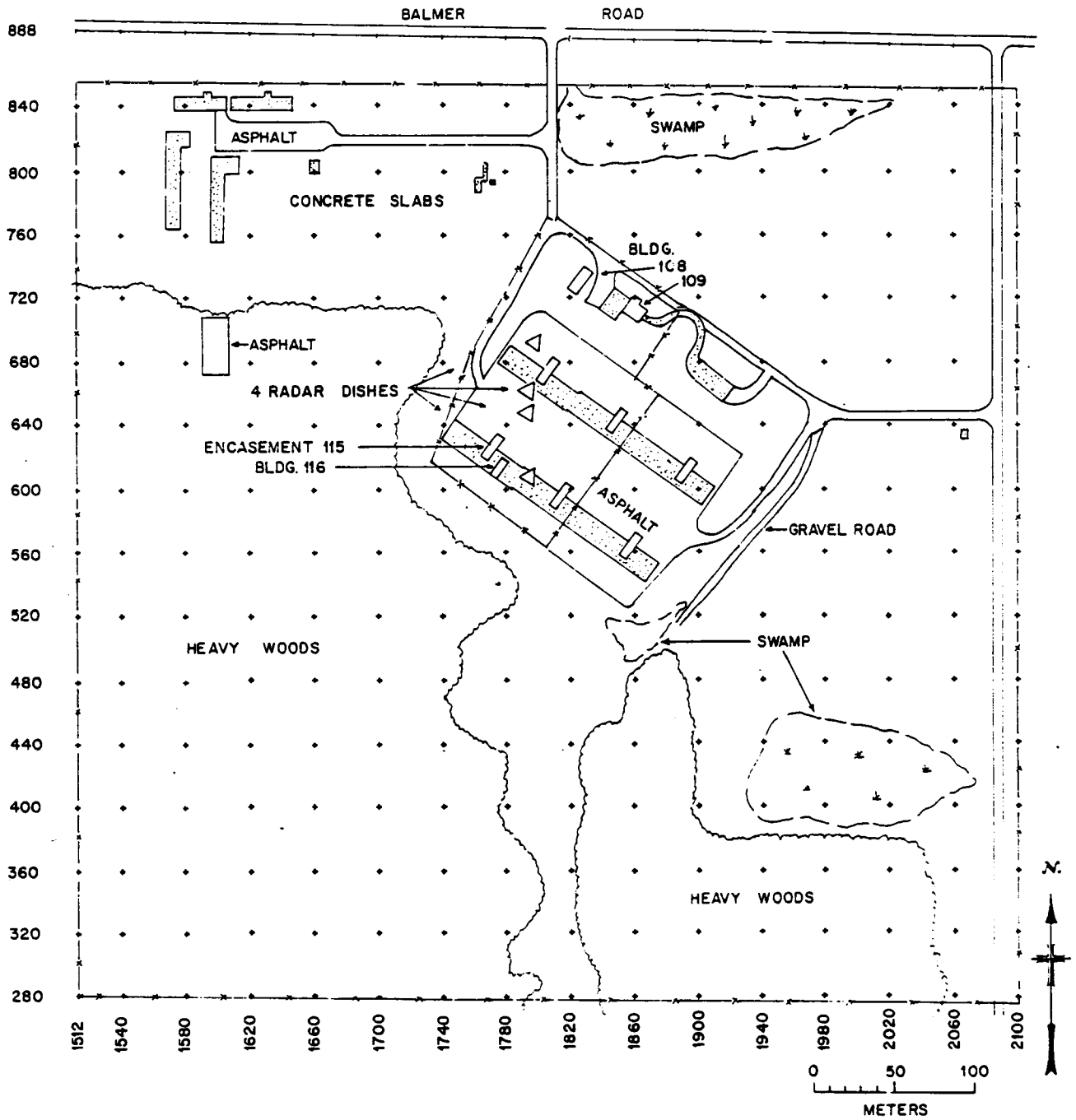

Fig. 2. Plan view of Property O showing the grid system established for survey reference.

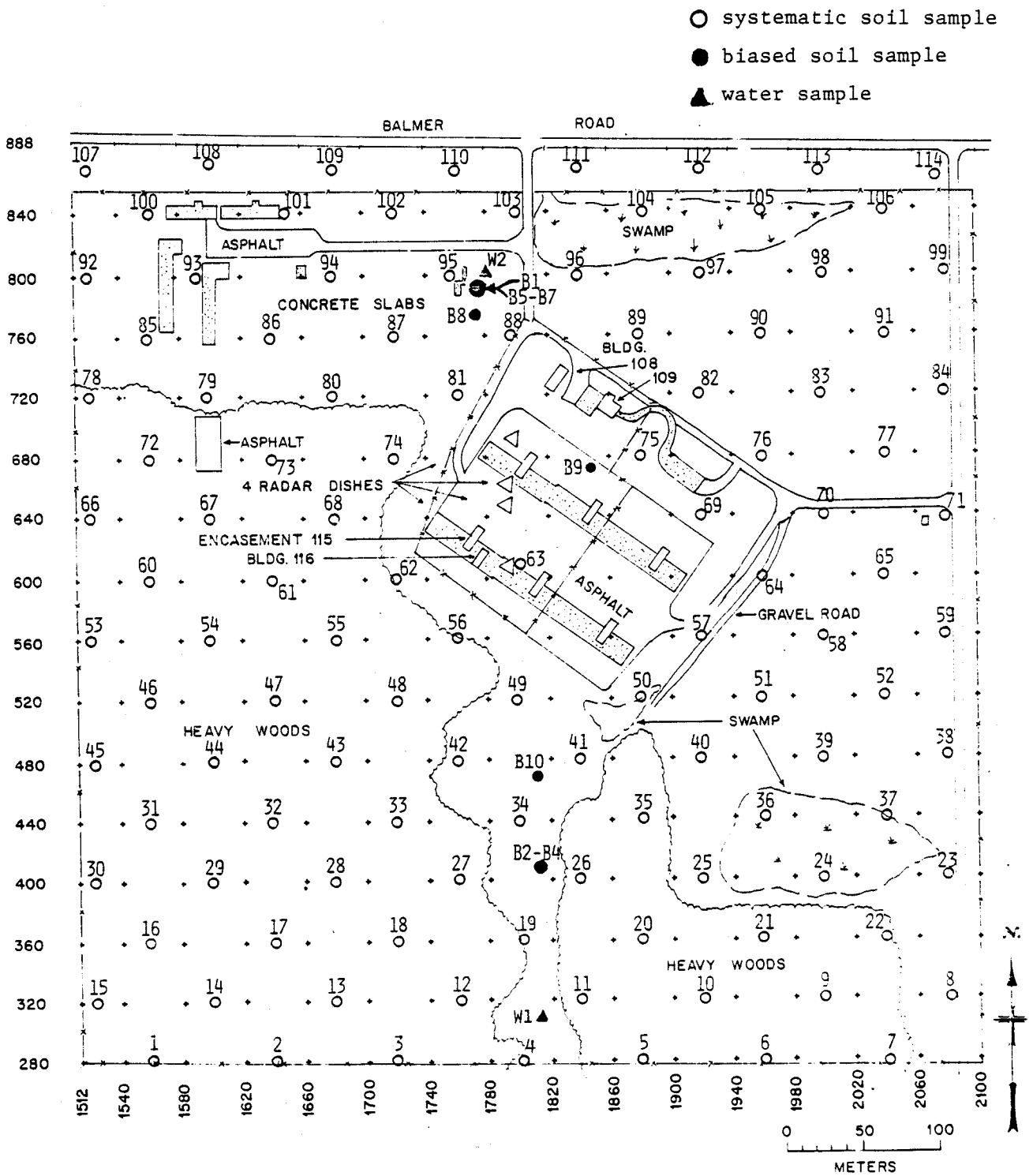

Fig. 3. Locations of soil and water samples on Property O.

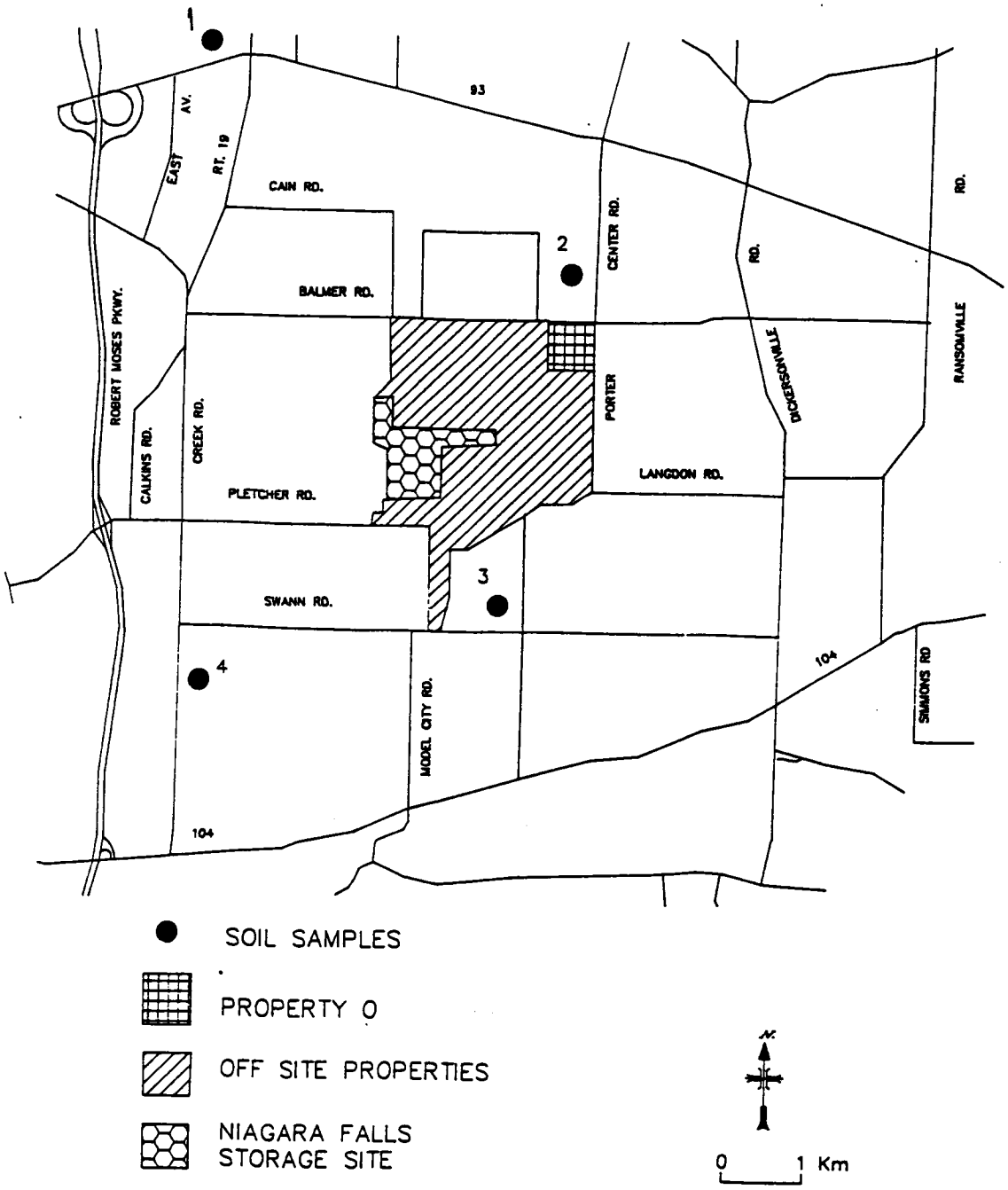

Fig. 4. Map of northern Niagara County, New York, showing relative locations of perty O and of background measurements and baseline samples (1-4: soil samples direct measurements).

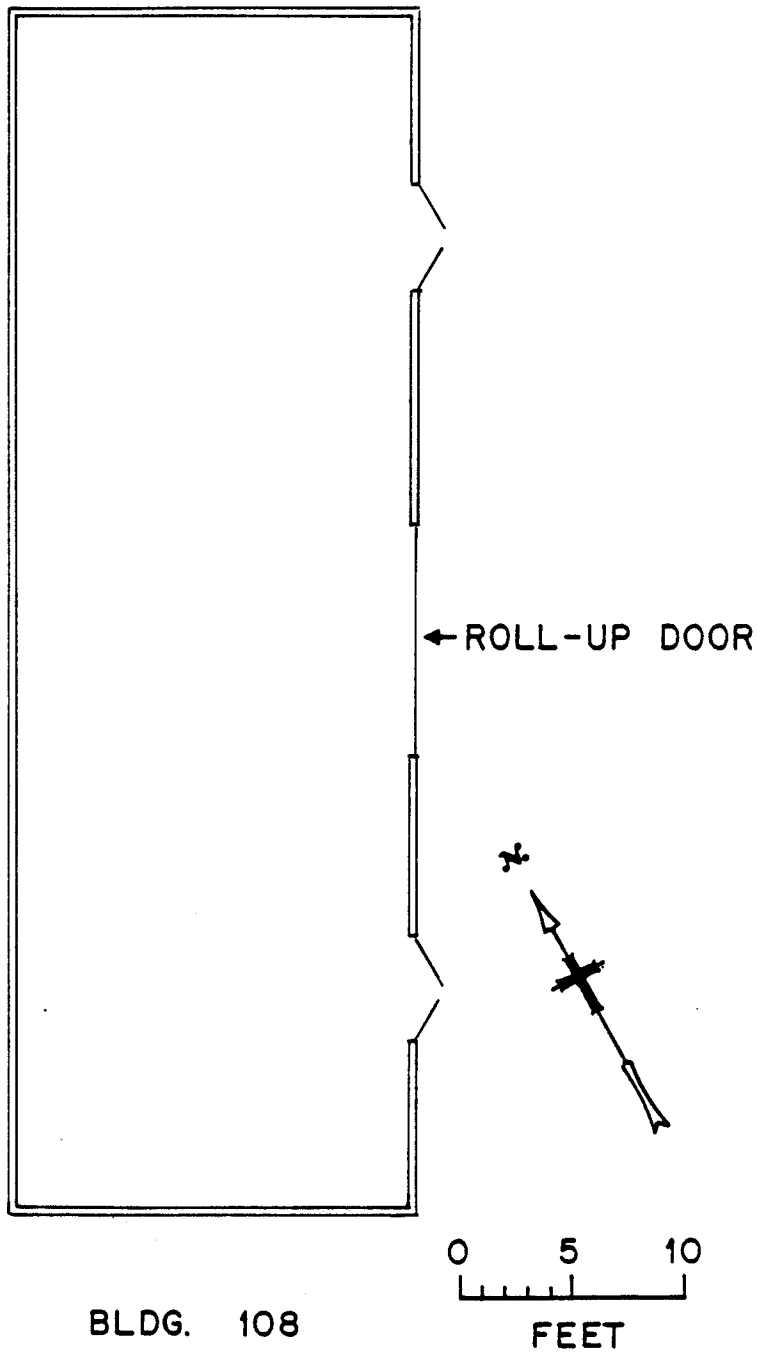

Fig. 5. Building 108, used for materials storage.

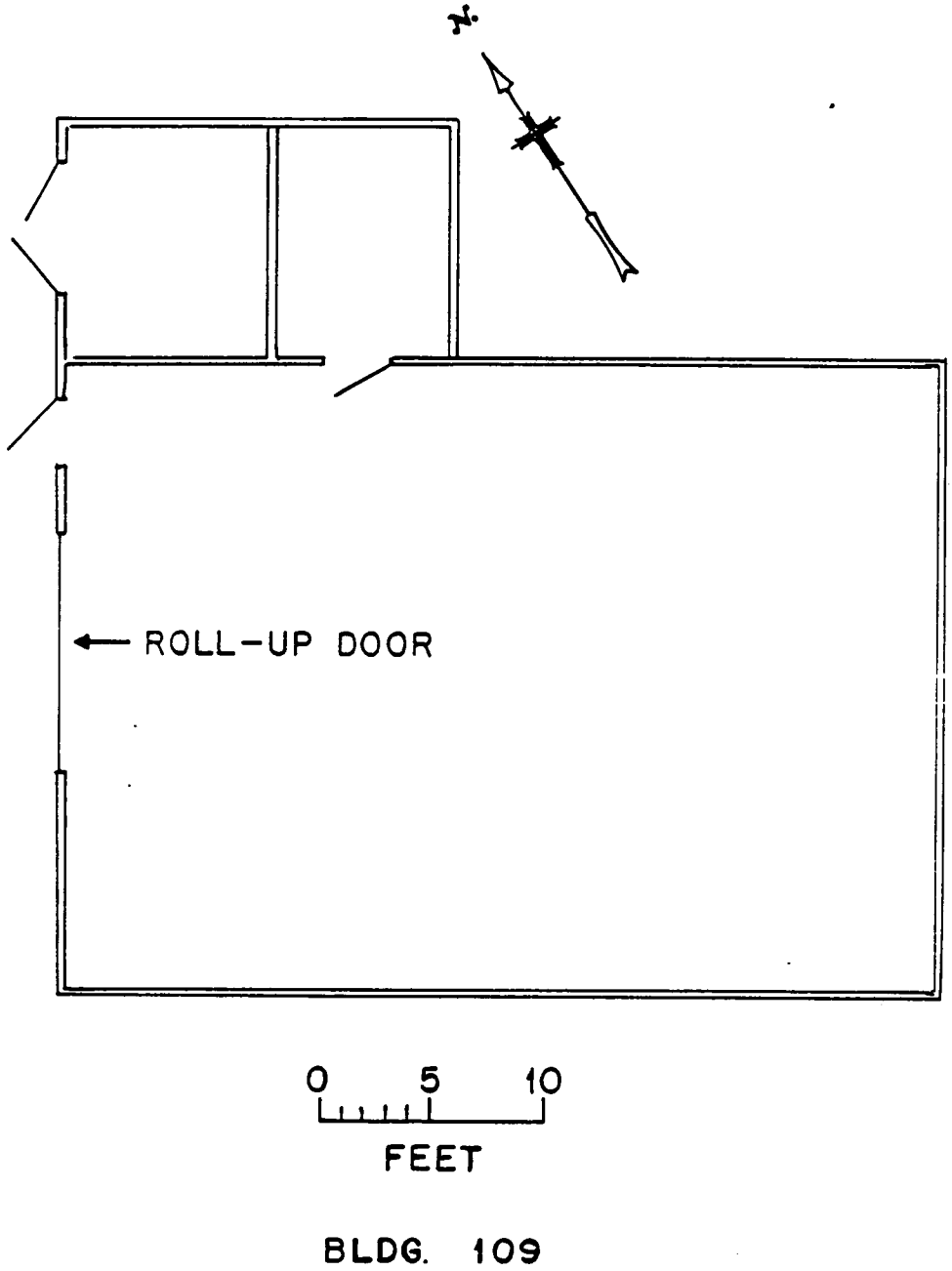

Fig. 6. Building 109, used for materials storage.

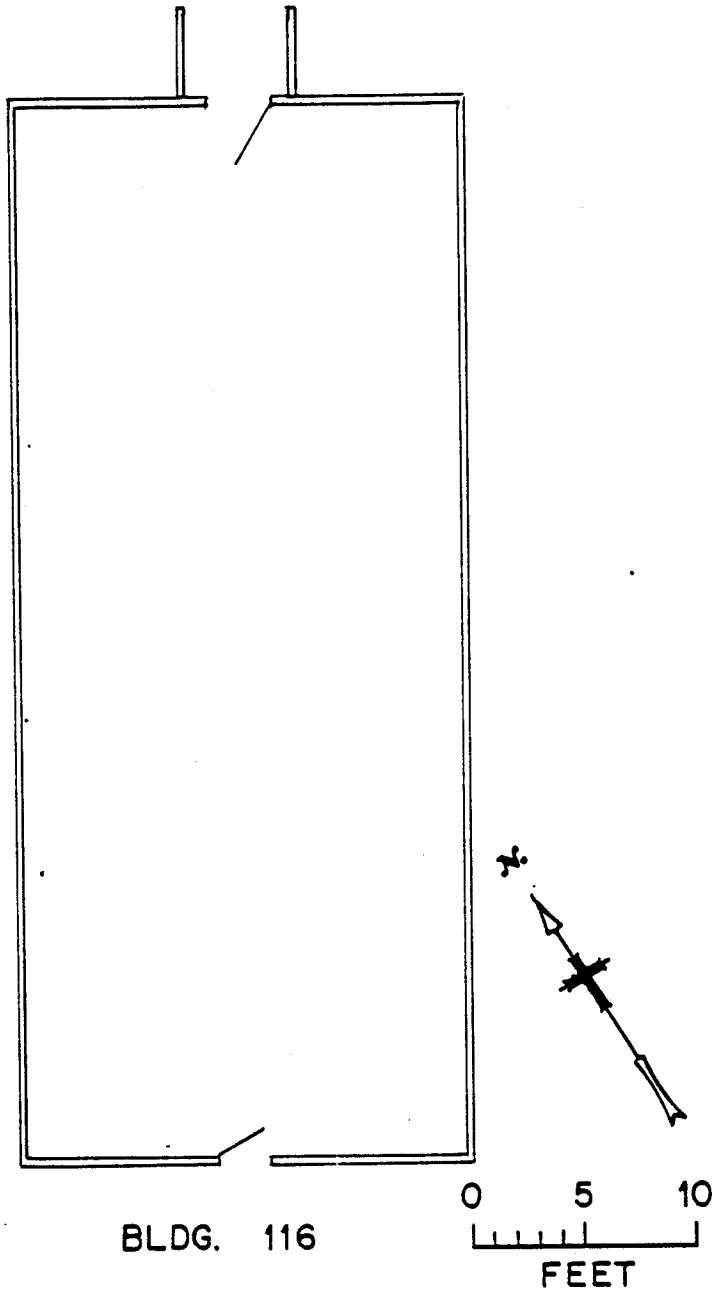

Fig. 7. Building 116, used for housing the operations for the active microwave relay station.

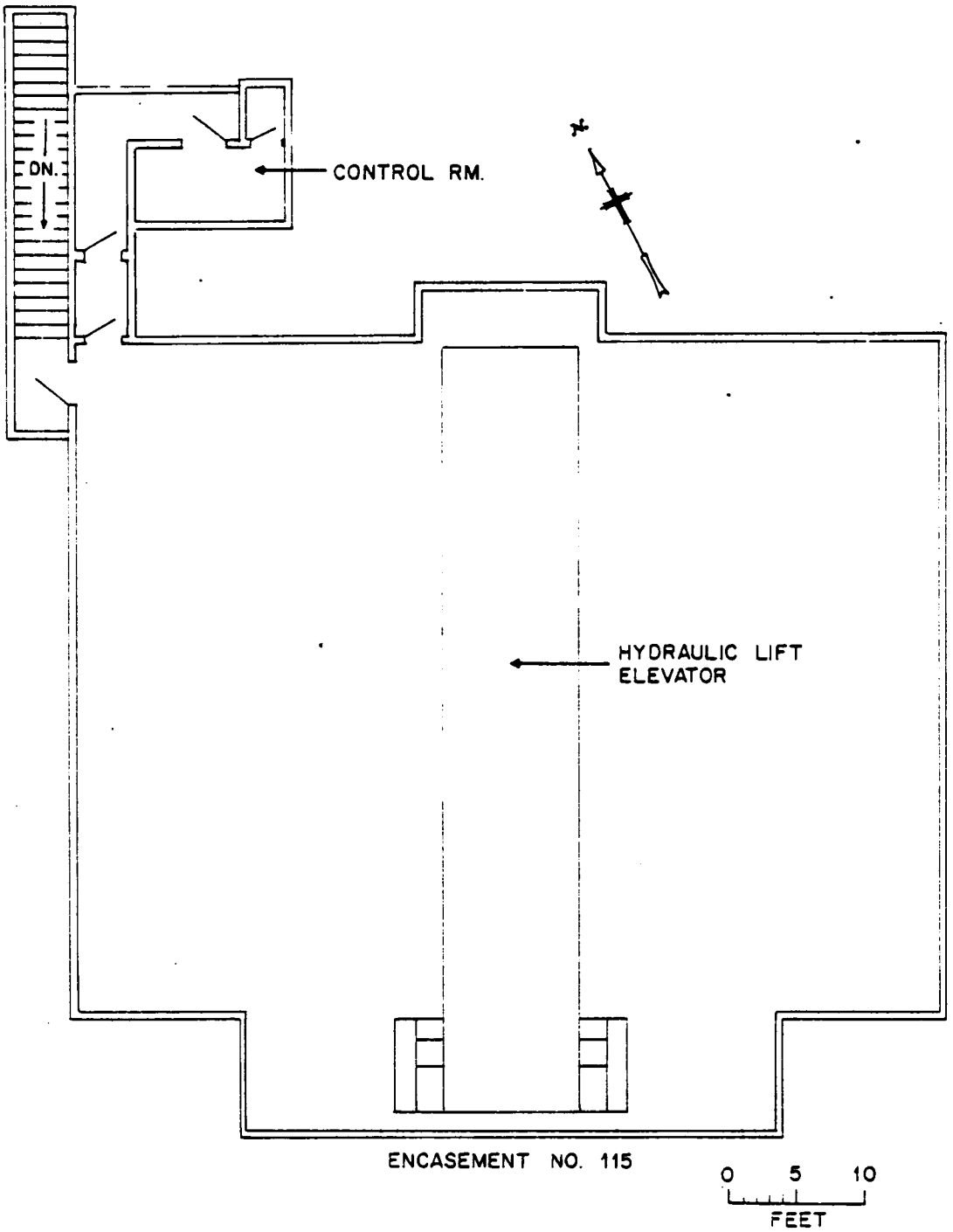

Fig. 8. Abandoned Nike Missile Encasement #115.

Table 1. Background radiation levels in the Niagara Falls area

Type of radiation measurement or sample	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at 1 m above floor or ground surface (μR/h)[a]	8-9	8.8
Concentration of radionuclides in soil (pCi/g)[b]		
^{238}U	0.93-1.3	1.10
^{226}Ra	0.86-1.0	0.93
^{232}Th	0.81-1.0	0.91

[a]Values obtained from four locations in the New York area.

[b]Soil samples obtained from four locations around the Niagara Falls area (Fig. 4).

Table 2. Direct radiation levels measured at 40 m grid intervals at Property O

Grid location[a] (East ∕ North)	Grid point measurements[b] (μR/h) Gamma exposure rate at 1 m	Gamma exposure rate at the surface	Range of gamma exposure rate during scan of grid block (μR/h)[c]
1513, 282	9	9	7-11
1513, 320	10	11	8-11
1513, 360	11	11	7-12
1513, 400	11	11	8-12
1513, 440	9	9	7-12
1513, 480	10	10	7-12
1513, 520	10	10	7-11
1513, 560	10	11	8-12
1513, 600	10	9	8-12
1513, 640	9	10	8-12
1513, 680	10	11	8-11
1513, 720	11	10	8-12
1513, 760	10	11	8-12
1513, 800	9	10	8-12
1513, 832	10	9	9-12
1515, 840	9	10	-
1515, 888	9	10	-
1540, 280	9	8	7-11
1540, 320	9	9	8-13
1540, 360	10	9	7-12
1540, 400	9	10	8-12
1540, 440	9	10	7-12
1540, 480	9	9	7-12
1540, 520	10	11	7-11
1540, 560	9	9	8-12
1540, 600	9	10	8-12
1540, 640	10	9	8-12
1540, 680	11	9	8-12
1540, 720	10	10	8-12
1540, 760	11	11	8-12
1540, 800	10	10	10-12
1540, 832	9	10	8-12
1540, 840	9	9	-
1540, 888	8	8	-
1580, 281	8	9	7-11
1580, 320	8	8	8-42
1580, 360	8	8	7-12
1580, 400	9	8	8-12
1580, 440	9	9	7-12
1580, 480	8	9	7-12

Table 2. (continued)

Grid location[a] (East & North)	Grid point measurements[b] (μR/h) Gamma exposure rate at 1 m	Gamma exposure rate at the surface	Range of gamma exposure rate during scan of grid block (μR/h)[c]
1580, 520	9	9	7-11
1580, 560	9	9	8-12
1580, 600	9	9	8-11
1580, 640	8	9	8-11
1580, 680	8	9	9-11
1580, 720	8	9	8-12
1580, 760	8	7	7-12
1580, 800	9	9	9-11
1580, 832	9	9	8-12
1580, 840	10	8	8-12
1580, 887	9	10	-
1620, 279	8	8	7-11
1620, 280	8	7	7-11
1620, 320	8	8	7-11
1620, 360	9	10	7-11
1620, 400	9	8	7-11
1620, 440	9	10	7-11
1620, 480	8	8	7-12
1620, 520	8	8	7-11
1620, 560	8	8	8-12
1620, 600	8	8	8-11
1620, 640	9	9	9-12
1620, 680	10	11	8-37
1620, 720	10	12	8-12
1620, 760	9	10	8-12
1620, 800	9	10	8-12
1620, 832	9	8	8-12
1620, 840	7	8	8-12
1620, 887	8	10	-
1660, 280	9	11	8-12
1660, 320	9	9	8-12
1660, 360	8	9	8-19
1660, 400	8	8	8-12
1660, 440	8	9	8-12
1660, 480	8	9	7-12
1660, 520	8	8	7-11
1660, 560	8	9	8-12
1660, 600	8	8	8-11
1660, 640	11	10	8-12

Table 2. (continued)

Grid location[a] (East ¢ North)	Grid point measurements[b] (μR/h) Gamma exposure rate at 1 m	Gamma exposure rate at the surface	Range of gamma exposure rate during scan of grid block (μR/h)[c]
1660, 680	10	9	8-230
1660, 720	9	10	8-12
1660, 760	8	9	8-12
1660, 800	7	10	8-12
1660, 832	9	10	7-12
1660, 840	9	10	8-12
1660, 886	10	10	-
1700, 279	8	9	8-10
1700, 280	8	9	8-11
1700, 320	9	9	8-11
1700, 360	11	8	8-11
1700, 400	8	9	8-11
1700, 440	9	9	8-11
1700, 480	9	10	8-11
1700, 520	7	8	8-16
1700, 560	9	8	8-11
1700, 600	9	8	8-11
1700, 640	8	8	8-12
1700, 680	10	9	8-12
1700, 720	9	10	9-12
1700, 760	9	9	8-12
1700, 800	9	9	9-10
1700, 832	8	9	7-12
1700, 840	8	9	8-12
1700, 886	9	10	-
1740, 278	8	9	9-11
1740, 280	8	10	8-11
1740, 320	8	9	8-17
1740, 360	9	8	8-11
1740, 400	8	8	8-11
1740, 440	9	11	8-11
1740, 480	9	9	8-11
1740, 520	8	9	8-47
1740, 560	9	9	9-12
1740, 600	9	9	9-12
1740, 640	9	8	8-12
1740, 680	9	8	8-12
1740, 720	9	10	8-10
1740, 760	10	9	9-47
1740, 800	9	10	9-23

Table 2 (continued)

Grid location[a] (East & North)	Grid point measurements[b] (μR/h)		Range of gamma exposure rate during scan of grid block (μR/h)[c]
	Gamma exposure rate at 1 m	Gamma exposure rate at the surface	
1740, 832	9	9	7-12
1740, 840	8	8	8-12
1740, 886	9	9	-
1780, 278	9	9	8-11
1780, 280	8	9	8-16
1780, 320	9	9	8-14
1780, 360	8	8	8-12
1780, 400	11	10	8-12
1780, 440	10	9	8-12
1780, 480	9	10	8-12
1780, 520	9	9	9-11
1780, 560	8	9	7-12
1780, 600	7	7	7-12
1780, 640	6	7	7-12
1780, 680	7	7	7-12
1780, 720	8	9	9-12
1780, 760	9	11	9-47
1780, 800	12	12	7-47
1780, 832	9	10	7-12
1780, 840	10	9	8-12
1780, 885	10	7	-
1820, 278	8	8	8-12
1820, 280	10	10	8-12
1820, 320	9	9	9-11
1820, 360	9	9	9-11
1820, 400	9	9	9-11
1820, 440	9	9	9-11
1820, 480	9	9	8-11
1820, 520	9	10	7-12
1820, 560	9	7	7-12
1820, 600	6	7	7-12
1820, 640	7	8	8-12
1820, 680	7	9	9-12
1820, 720	8	9	9-12
1820, 760	8	8	8-12
1820, 800	9	10	8-11
1820, 832	8	9	-
1820, 840	8	8	7-11
1820, 885	9	9	-

Table 2 (continued)

Grid location[a] (East ∕ North)	Grid point measurements[b] (μR/h) Gamma exposure rate at 1 m	Gamma exposure rate at the surface	Range of gamma exposure rate during scan of grid block (μR/h)[c]
1860, 277	10	8	8-11
1860, 280	9	9	8-11
1860, 320	9	9	7-28
1860, 360	9	10	8-11
1860, 400	8	9	8-28
1860, 440	8	8	8-12
1860, 480	9	8	8-11
1860, 520	8	9	8-12
1860, 560	9	7	7-12
1860, 600	8	8	7-12
1860, 640	8	8	8-12
1860, 680	7	8	8-12
1860, 720	9	10	9-12
1860, 760	11	11	8-23
1860, 800	9	9	8-11
1860, 832	9	9	-
1860, 840	9	9	7-10
1860, 884	7	9	-
1900, 277	8	8	8-12
1900, 280	9	9	8-12
1900, 320	9	9	8-11
1900, 360	8	9	8-12
1900, 400	9	10	8-12
1900, 440	8	9	8-11
1900, 480	9	11	8-11
1900, 520	11	11	8-12
1900, 560	9	9	7-12
1900, 600	9	8	8-11
1900, 640	9	9	8-11
1900, 680	9	9	9-12
1900, 720	9	9	9-12
1900, 760	9	10	8-11
1900, 800	9	10	8-10
1900, 832	9	10	-
1900, 840	8	7	7-12
1900, 884	7	9	-
1940, 275	8	9	8-11
1940, 280	9	9	8-11
1940, 320	9	9	8-12
1940, 360	9	9	8-11

Table 2 (continued)

Grid location[a] (East & North)	Grid point measurements[b] (μR/h) Gamma exposure rate at 1 m	Gamma exposure rate at the surface	Range of gamma exposure rate during scan of grid block (μR/h)[c]
1940, 400	10	12	8-12
1940, 440	9	9	8-11
1940, 480	9	9	8-11
1940, 520	9	9	8-11
1940, 560	10	9	7-12
1940, 600	9	11	8-12
1940, 640	10	8	8-12
1940, 680	7	7	7-12
1940, 720	9	10	8-12
1940, 760	10	11	8-12
1940, 800	9	10	8-12
1940, 832	9	10	-
1940, 840	9	7	7-11
1940, 883	8	9	-
1980, 275	8	8	8-12
1980, 280	8	8	8-12
1980, 320	8	11	8-11
1980, 360	9	8	8-12
1980, 400	10	9	8-11
1980, 440	8	9	8-11
1980, 480	9	9	8-12
1980, 520	9	11	9-12
1980, 560	10	11	9-12
1980, 600	9	9	8-12
1980, 640	8	7	7-12
1980, 680	10	9	8-12
1980, 720	9	10	8-12
1980, 760	10	11	8-12
1980, 800	9	10	9-12
1980, 832	10	11	-
1980, 840	10	9	10-12
1980, 882	7	9	-
2020, 275	8	9	8-12
2020, 280	9	10	8-12
2020, 320	8	8	8-12
2020, 360	9	9	8-12
2020, 400	8	9	8-12
2020, 440	9	9	8-11

Table 2 (continued)

Grid location[a] (East & North)	Grid point measurements[b] (μR/h)		Range of gamma exposure rate during scan of grid block (μR/h)[c]
	Gamma exposure rate at 1 m	Gamma exposure rate at the surface	
2020, 480	9	10	8-11
2020, 520	10	11	8-12
2020, 560	11	10	8-12
2020, 600	9	11	8-12
2020, 640	11	10	7-11
2020, 680	8	9	8-12
2020, 720	8	9	7-12
2020, 760	9	11	9-12
2020, 800	10	9	8-12
2020, 832	9	9	-
2020, 840	10	9	8-11
2020, 882	8	8	-
2060, 274.8	8	9	7-12
2060, 280	9	11	8-12
2060, 320	8	9	7-12
2060, 360	9	9	7-12
2060, 400	9	10	7-12
2060, 440	9	8	8-12
2060, 480	11	8	7-12
2060, 520	9	11	7-11
2060, 560	12	11	7-12
2060, 600	9	10	9-12
2060, 640	9	10	9-12
2060, 680	10	9	8-12
2060, 720	10	11	8-12
2060, 760	9	9	9-12
2060, 800	9	10	8-12
2060, 832	10	9	-
2060, 840	8	10	8-11
2060, 882	8	9	-
2099.8, 274.8	8	9	-
2099.8, 280	8	10	-
2099.4, 320	9	10	-
2099.5, 360	9	9	-
2099.5, 400	8	9	-
2099.5, 440	9	9	-
2099.5, 480	8	9	-
2099.5, 520	8	8	-
2099.5, 560	9	9	-
2099.5, 600	8	8	-

Table 2. (continued)

Grid location[a] (East & North)	Grid point measurements[b] (μR/h)		Range of gamma exposure rate during scan of grid block (μR/h)[c]
	Gamma exposure rate at 1 m	Gamma exposure rate at the surface	
2099.5, 640	8	7	-
2099.5, 680	8	10	-
2099.5, 720	9	10	-
2099.5, 760	8	9	-
2099.5, 800	9	9	-
2099.5, 832	8	8	-
2099.5, 840	10	11	-
2099.5, 882	10	10	-

[a]Grid location shown on Fig. 2

[b]Grid point measurements are discrete measurements at each grid point.

[c]Grid block measurements are obtained by a gamma scan of the entire block.

Table 3. Radionuclide concentrations in surface soil samples on Property O

Sample	Location[a] (East & North)	Depth (cm)	Radionuclide concentration (pCi/g)		
			$^{226}Ra^{b}$	$^{232}Th^{c}$	$^{238}U^{c}$
S001	1560, 280	0-15	0.90 ± 0.09	0.78 ± 0.2	0.90
S002	1640, 280	0-15	0.79 ± 0.1	0.79 ± 0.4	0.90
S003	1720, 280	0-15	0.81 ± 0.06	0.65 ± 0.2	0.73
S004	1800, 280	0-15	0.84 ± 0.1	0.77 ± 0.1	0.87
S005	1880, 280	0-15	0.74 ± 0.05	0.61 ± 0.2	0.77
S006	1960, 280	0-15	0.70 ± 0.08	0.56 ± 0.2	0.67
S007	2040, 280	0-15	0.64 ± 1	0.73 ± 0.3	0.70
S008	2080, 320	0-15	0.79 ± 0.1	0.76 ± 0.2	0.70
S009	2000, 320	0-15	0.58 ± 0.2	0.53 ± 0.1	0.67
S010	1920, 320	0-15	0.68 ± 0.05	0.62 ± 0.2	0.73
S011	1840, 320	0-15	0.91 ± 0.09	0.87 ± 0.3	1.3
S012	1760, 320	0-15	0.76 ± 0.1	0.71 ± 0.2	0.87
S013	1680, 320	0-15	0.76 ± 0.09	0.66 ± 0.3	0.83
S014	1600, 320	0-15	0.64 ± 0.06	0.57 ± 0.1	0.80
S015	1520, 320	0-15	0.95 ± 0.2	0.90 ± 0.4	0.80
S016	1560, 360	0-15	0.88 ± 0.09	0.91 ± 0.4	0.87
S017	1640, 360	0-15	0.98 ± 0.07	0.95 ± 0.2	1.1
S018	1720, 360	0-15	0.69 ± 0.2	0.72 ± 0.2	0.83
S019	1800, 360	0-15	0.82 ± 0.1	0.74 ± 0.3	0.93
S020	1880, 360	0-15	0.64 ± 0.1	0.56 ± 0.1	0.57
S021	1960, 360	0-15	0.80 ± 0.06	0.77 ± 0.2	0.77
S022	2040, 360	0-15	0.66 ± 0.09	0.59 ± 0.2	0.70
S023	2080, 400	0-15	0.93 ± 0.09	0.90 ± 0.2	0.93
S024	2000, 400	0-15	0.86 ± 0.06	0.94 ± 0.3	0.77
S025	1920, 400	0-15	0.77 ± 0.06	0.76 ± 0.2	0.77
S026	1840, 400	0-15	0.81 ± 0.07	0.74 ± 0.3	0.77
S027	1760, 400	0-15	0.77 ± 0.1	0.82 ± 0.3	0.77
S028	1680, 400	0-15	0.72 ± 0.1	0.76 ± 0.3	0.73
S029	1600, 400	0-15	0.96 ± 0.1	0.73 ± 0.4	1.5
S030	1520, 400	0-15	0.97 ± 0.1	0.90 ± 0.2	0.90
S031	1560, 440	0-15	0.80 ± 0.07	0.63 ± 0.2	0.83
S032	1640, 440	0-15	0.87 ± 0.08	0.74 ± 0.3	0.90
S033	1720, 440	0-15	0.85 ± 0.07	0.91 ± 0.3	1.0
S034	1800, 440	0-15	0.75 ± 0.09	0.71 ± 0.2	0.63
S035	1880, 440	0-15	0.79 ± 0.11	0.79 ± 0.3	0.70
S036	1960, 440	0-15	0.84 ± 0.04	0.82 ± 0.3	0.93
S037	2040, 440	0-15	0.73 ± 0.1	0.91 ± 0.3	0.80
S038	2080, 440	0-15	0.93 ± 0.09	0.86 ± 0.4	0.83
S039	2000, 440	0-15	0.75 ± 0.07	0.71 ± 0.2	0.80
S040	1920, 440	0-15	0.81 ± 0.1	0.88 ± 0.3	0.77
S041	1840, 480	0-15	0.87 ± 0.1	0.55 ± 0.1	0.80
S042	1760, 480	0-15	0.80 ± 0.05	0.75 ± 0.2	0.67

Table 3 (continued)

Sample	Location[a] (East & North)	Depth (cm)	Radionuclide concentration (pCi/g)		
			$^{226}Ra^{b}$	$^{232}Th^{c}$	$^{238}U^{c}$
S043	1680, 480	0-15	0.80 ± 0.06	0.73 ± 0.2	0.80
S044	1600, 480	0-15	0.82 ± 0.1	0.78 ± 0.3	0.77
S045	1520, 480	0-15	0.86 ± 0.1	0.74 ± 0.2	0.77
S046	1560, 520	0-15	0.72 ± 0.1	0.57 ± 0.2	0.63
S047	1640, 520	0-15	0.46 ± 0.06	0.35 ± 0.1	0.50
S048	1760, 520	0-15	0.84 ± 0.1	0.68 ± 0.2	0.83
S049	1800, 520	0-15	0.80 ± 0.1	0.76 ± 0.3	0.77
S050	1880, 520	0-15	0.87 ± 0.2	0.73 ± 0.1	0.80
S051	1960, 520	0-15	0.77 ± 0.06	0.64 ± 0.1	0.73
S052	2040, 520	0-15	0.64 ± 0.07	0.61 ± 0.09	0.63
S053	1520, 560	0-15	0.80 ± 0.1	0.74 ± 0.2	0.73
S054	1600, 280	0-15	0.80 ± 0.08	0.71 ± 0.1	0.63
S055	1688, 560	0-15	0.63 ± 0.08	0.47 ± 0.1	0.83
S056	1760, 560	0-15	0.81 ± 0.2	0.83 ± 0.3	0.80
S057	1920, 560	0-15	0.70 ± 0.04	0.81 ± 0.2	0.60
S058	2000, 560	0-15	0.82 ± 0.06	0.84 ± 0.3	0.87
S059	2080, 560	0-15	1.3 ± 0.2	1.1 ± 0.3	1.3
S060	1560, 600	0-15	0.87 ± 0.1	0.79 ± 0.1	0.83
S061	1640, 600	0-15	0.55 ± 0.1	0.46 ± 0.1	0.70
S062	1720, 600	0-15	0.75 ± 0.09	0.75 ± 0.2	0.77
S063	1800, 600	0-15	0.79 ± 0.1	0.69 ± 0.2	0.73
S064	1960, 600	0-15	0.91 ± 0.1	1.1 ± 0.3	0.73
S065	2040, 600	0-15	0.71 ± 0.1	0.71 ± 0.2	0.73
S066	1520, 640	0-15	0.91 ± 0.06	0.83 ± 0.1	0.80
S067	1600, 640	0-15	0.84 ± 0.04	0.89 ± 0.3	0.80
S068	1680, 640	0-15	0.87 ± 0.10	0.75 ± 0.05	0.80
S069	1920, 640	0-15	0.79 ± 0.1	0.77 ± 0.08	0.83
S070	2000, 640	0-15	0.83 ± 0.03	0.85 ± 0.1	0.70
S071	2080, 640	0-15	0.76 ± 0.1	0.93 ± 0.3	0.70
S072	1560, 680	0-15	0.89 ± 0.06	0.90 ± 0.3	1.0
S073	1640, 680	0-15	0.88 ± 0.1	0.73 ± 0.2	0.73
S074	1720, 680	0-15	0.76 ± 0.09	0.77 ± 0.2	0.70
S075	1880, 680	0-15	0.84 ± 0.07	0.93 ± 0.2	0.83
S076	1960, 680	0-15	0.89 ± 0.06	0.98 ± 0.3	0.83
S077	2040, 680	0-15	0.76 ± 0.08	0.72 ± 0.2	0.70
S078	1520, 720	0-15	0.86 ± 0.07	0.87 ± 0.3	0.77
S079	1600, 720	0-15	0.85 ± 0.1	0.85 ± 0.1	0.97
S080	1680, 720	0-15	0.82 ± 0.09	0.79 ± 0.2	0.83
S081	1760, 720	0-15	0.81 ± 0.04	0.82 ± 0.08	0.77
S082	1920, 720	0-15	0.77 ± 0.2	0.83 ± 0.1	0.73
S083	2000, 720	0-15	0.74 ± 0.09	0.85 ± 0.3	0.73
S084	2080, 720	0-15	0.86 ± 0.05	0.86 ± 0.1	0.73
S085	1560, 760	0-15	0.76 ± 0.1	0.76 ± 0.1	0.80

Table 3 (continued)

Sample	Location[a] (East & North)	Depth (cm)	Radionuclide concentration (pCi/g)		
			^{226}Ra[b]	^{232}Th[c]	^{238}U[c]
S086	1640, 760	0-15	0.84 ± 0.1	0.82 ± 0.2	0.77
S087	1720, 760	0-15	0.85 ± 0.2	0.76 ± 0.1	1.1
S088	1800, 760	0-15	0.83 ± 0.05	0.81 ± 0.1	0.87
S089	1880, 760	0-15	0.79 ± 0.1	0.73 ± 0.2	0.87
S090	1960, 760	0-15	0.87 ± 0.1	0.78 ± 0.3	0.87
S091	2040, 760	0-15	0.78 ± 0.1	0.77 ± 0.2	0.83
S092	1520, 800	0-15	0.88 ± 0.1	0.72 ± 0.1	0.87
S093	1591, 800	0-15	0.86 ± 0.1	0.90 ± 0.3	0.87
S094	1680, 800	0-15	0.68 ± 0.1	0.72 ± 0.3	0.73
S095	1760, 800	0-15	1.1 ± 0.09	0.69 ± 0.2	1.2
S096	1840, 800	0-15	0.79 ± 0.2	0.76 ± 0.2	0.77
S097	1920, 800	0-15	0.87 ± 0.05	0.74 ± 0.2	0.93
S098	2000, 800	0-15	0.74 ± 0.2	0.82 ± 0.3	0.87
S099	2080, 800	0-15	0.86 ± 0.02	0.79 ± 0.3	0.73
S100	1560, 840	0-15	1.0 ± 0.1	0.63 ± 0.2	0.87
S101	1650, 840	0-15	0.75 ± 0.08	0.71 ± 0.3	0.70
S102	1720, 840	0-15	0.87 ± 0.09	0.83 ± 0.3	0.80
S103	1800, 840	0-15	0.80 ± 0.03	0.72 ± 0.2	0.87
S104	1880, 840	0-15	0.85 ± 0.09	0.75 ± 0.3	0.80
S105	1960, 840	0-15	0.80 ± 0.1	0.76 ± 0.3	1.1
S106	2040, 840	0-15	0.82 ± 0.1	0.81 ± 0.2	0.90
S107	1520, 880	0-15	0.72 ± 0.2	0.78 ± 0.4	0.70
S108	1600, 882	0-15	0.61 ± 0.07	0.61 ± 0.2	0.73
S109	1680, 879	0-15	0.94 ± 0.08	1.0 ± 0.4	0.90
S110	1760, 879	0-15	0.94 ± 0.06	0.87 ± 0.2	1.0
S111	1840, 880	0-15	0.84 ± 0.1	0.73 ± 0.2	0.87
S112	1920, 879	0-15	1.0 ± 0.05	0.95 ± 0.3	0.90
S113	2000, 879	0-15	0.80 ± 0.07	0.77 ± 0.3	0.80
S114	2074, 877	0-15	1.0 ± 0.05	0.88 ± 0.2	1.1

[a]Locations of soil samples are shown on Fig. 3.

[b]Indicated counting error is at the 95% confidence level (± 2σ).

[c]Analytical error of measurement results is < ± 5% (95% confidence level).

[d]Systematic samples are taken at grid locations irrespective of gamma exposure.

Table 4. Radionuclide concentrations in biased soil samples.

Sample	Location[a] (East ¢ North)	Depth (cm)	Radionuclide concentration (pCi/g)		
			^{226}Ra[b]	^{232}Th[b]	^{238}U[c]
B001A	1774, 791	0-15	11 ± 0.2	0.61 ± 0.2	9.7
B001B	1774, 791	0-15	46 ± 0.5	0.67 ± 0.5	45
B002	1814, 405	0-15	5.4 ± 0.2	0.80 ± 0.5	5.3
B003	1814, 405	0-15	3.7 ± 0.3	0.98 ± 0.3	3.7
B004	1812, 407	0-15	1.0 ± 0.1	0.94 ± 0.3	0.83
B005	1773, 791	0-15	50 ± 1	0.51 ± 0.3	19
B006	1781, 796	0-15	4.1 ± 0.1	0.74 ± 0.4	4.3
B007	1783, 786	0-15	1.7 ± 0.2	0.72 ± 0.2	1.6
B008	1777, 778	0-15	1.3 ± 0.03	0.74 ± 0.2	1.4
B009	1850, 672	0-15	460 ± 8.4	500 ± 120	470
B010	1826, 472	0-15	500 ± 13	550 ± 120	430

[a]Locations of soil samples are shown on Fig. 3.
[b]Indicated counting error is at the 95% confidence level (± 2σ).
[c]Analytical error of measurement results is < ± 5% (95% confidence level).

Table 5. Radionuclide concentrations in water samples

Sample no.	Location[a]	Sample type	Concentration of radionuclide (pCi/L)[b,c]			
			^{226}Ra	^{238}U	^{210}Pb	^{230}Th
W001	1815E 312N	Liquid	0.81 ± 3.8	9.2	1.9 ± 2.4	<0.27
W002	1786E 805N	Liquid	<0.27	1.9	<2.4	<2.7
		Solids	<0.54	0.02	1.4 ± 3.2	<2.2

[a]For location see Fig. 3.

[b]Indicated errors associated with ^{226}Ra, ^{210}Pb, and ^{230}Th are at 2σ (95% confidence level).

[c]The error of the ^{238}U concentration is < ± 3% (95% confidence level).

Table 6. Summary of outdoor measurements and sample results at Property O

Measurement or sample type	Number of measurements/ samples	Range	Mean
Gamma exposure rate at 1 m (μR/h)[a]	284	7-12	9
Gamma exposure rate at surface (μR/h)[a]	284	7-12	9
Scan, gamma exposure rate near surface (μR/h)[b]	-	7-230	-
Concentration of radionuclides in surface soil (pCi/g), systematic locations[c]	-	-	-
^{226}Ra	114	0.46-1.3	0.81
^{232}Th	114	0.46-1.1	0.77
^{238}U	114	0.50-1.5	0.82

[a]At grid points.
[b]Scan of entire property.
[c]Systematic samples, Table 4.

Table 7. Indoor measurements at Property O

Location[a]	Gamma exposure rate at 1 m μR/h)	Gamma exposure rate at the surface μR/h)	Range of gamma exposure rate during scan of building μR/h)	Beta-gamma dose rate at 1 cm (mrad/h)	Direct alpha activity on surfaces (dpm/100 cm^2)
Bldg. 115	9	9	6-9	0.02-0.02	0.0-36
Bldg. 107	8	8	6-8	0.02-0.03	0.0-21
Bldg. 109	8	8	6-8	0.02-0.03	7-14
Bldg. 116	8	8	6-8	0.01-0.02	7-14

[a]Diagrams of the interior of buildings surveyed are provided in Figs. 5-8. The locations of the buildings onsite are shown in Fig. 2.

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