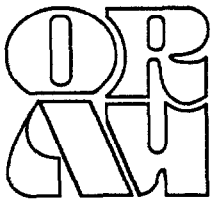
ORAU 89/E-93



Prepared by
Oak Ridge Associated Universities

Prepared for
U.S. Nuclear Regulatory Commission's
Region I Office

Supported by
Division of Industrial and Medical Nuclear Safety

FOLLOW-UP CONFIRMATORY RADIOLOGICAL SURVEY OF THE DRUM STORAGE AREA COMBUSTION ENGINEERING PROPERTY WINDSOR, CONNECTICUT

M. R. LANDIS

Radiological Site Assessment Program
Energy/Environment Systems Division

FINAL REPORT
MAY 1989

NOTICES

The opinions expressed herein do not necessarily reflect the opinions of the sponsoring institutions of Oak Ridge Associated Universities.

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Final Report

May 1989

This report is based on work performed under Interagency Agreement (NRC Fin. No. A-9076) between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy. Oak Ridge Associated Universities performs complementary work under contract number DE-AC05-760R00033 with the U.S. Department of Energy.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FOLLOW-UP
CONFIRMATORY RADIOLOGICAL SURVEY
OF THE
DRUM STORAGE AREA
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

INTRODUCTION

Combustion Engineering decontaminated and decommissioned a former high-enrichment uranium facility at their Windsor, Connecticut, site approximately 25 years ago. Some of the waste from decontamination operations was burned and the ash placed in drums for disposal; however, subsequent surveys identified some areas of residual soil contamination. Combustion Engineering performed cleanup of this area and packed and shipped residual ash to the Barnwell Radioactive Waste Disposal site. Soil samples collected after cleanup identified surface uranium contamination at some locations of the drum storage area still exceeding Nuclear Regulatory Commission (NRC) guidelines. An additional 5 to 7 cm of soil was removed from these areas. At the request of the NRC the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU) conducted a confirmatory survey of the site in October of 1984.[1] The results of that survey indicated that several areas had residual enriched uranium and thorium surface soil contamination in excess of the guidelines established for unrestricted use.

In June of 1986 an additional 15 to 30 cm of soil was removed from the surface of this area by the licensee. ORAU at the request of NRC Region I conducted a follow-up confirmatory survey to evaluate radiological conditions relative to the guidelines established for unrestricted release.

SITE DESCRIPTION

The site encompasses an area of approximately 0.5 ha (75 ft X 75 ft) and is located at 1000 Prospect Hill Road, Windsor, Connecticut which is 13 kilometers north of Hartford and within 5 kilometers of Bradley International Airport (Figure 1). The site is adjacent to an active low-enriched uranium fuel fabrication plant and a naval reactor training center. A plot plan of the

Combustion Engineering Property, showing the location of the drum storage area is shown in Figure 2.

SURVEY PROCEDURES

At the request of the Nuclear Regulatory Commission, a confirmatory survey of the burn and drum storage area of the Combustion Engineering site was performed by the Radiological Site Assessment Program on March 28, 1989. This section describes the survey objectives and the procedures followed.

Objectives

The objectives of the ORAU survey were to confirm the radiological data developed by Combustion Engineering and to determine the nature and extent of residual radioactive material present in this area. Radiological information collected included:

1. direct radiation levels,
2. locations of elevated surface radiation,
3. concentrations of radionuclides in surface soil, and
4. baseline radionuclide concentrations in the surrounding area.

Background and Baseline Samples

Radiation measurements and soil samples were obtained at five locations off of the Combustion Engineering property, to establish background radiation levels and baseline radionuclide concentrations. The locations of the baseline samples and background radiation levels are shown on Figure 3.

Gridding

A 30 foot grid pattern, established as part of the licensee's cleanup and survey activities, was used for ORAU survey reference. This grid system is shown on Figure 4.

Surface Measurements and Sampling

1. Portable ratemeters (audible) attached to NaI(Tl) gamma scintillation detectors were used for the walkover surface scan. The walkover surface scan was conducted at 1-2 m intervals over all areas of the site. Locations of elevated contact radiation were noted.

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

3. Surface (0-15 cm) composites of soil, taken from the center and four points equidistant between the center and the grid block corners, were collected from each grid block. Samples were also taken from areas of elevated contact radiation, identified by the walkover scan.

Sample Analysis and Interpretation of Results

Soil samples were analyzed by gamma spectrometry. Radionuclides of primary interest were U-235, U-238, Th-232, and Th-228; however, spectra were reviewed for other gamma emitters. Selected samples were analyzed for isotopic uranium and thorium. Additional information concerning measurement and analytical equipment and procedures are described in Appendices A and B.

Survey findings were compared with NRC guidelines for residual thorium and uranium contamination in soil.

RESULTS

Background Levels and Baseline Concentrations

Background radiation levels and baseline radionuclide concentrations in soil, determined for five locations in the vicinity of the Combustion

Engineering site are presented in Tables 1 and 2. Exposure rates at the surface and 1 m above the surface ranged from 9 to 10 uR/h. Concentrations of radionuclides in soil were: U-235, <0.2 pCi/g; U-238, <0.7 to 1.8 pCi/g; Th-232, 0.5 to 0.8 pCi/g and Th-228, 0.7 to 0.9 pCi/g. These values are within the ranges that typically occur in the environment.

Direct Radiation Levels

Gross gamma scanning identified four locations of elevated contact radiation levels in small isolated areas on the site (Figure 5). There was no evidence of significant or widespread contamination. Gamma exposure rates measured at grid line intersections ranged from 8 - 11 μR/h and 8 - 15 μR/h at 1 m and contact respectively (Table 3). Exposure rates measured at locations identified by the surface scan initially ranged from 13 - 15 μR/h at 1 m and 23 - 26 μR/h at contact (Table 4). Additional remediation reduced exposure rates to 9 - 11 μR/h and 11 - 15 μR/h at 1 m and contact, respectively.

Radionuclide Concentrations in Soil

Radionuclide concentrations in composite surface soil samples from grid blocks are presented in Table 5. Concentration ranges were: U-235, <0.2 to 0.8 pCi/g; U-238, <0.4 to 2.9 pCi/g; Th-232, <0.3 to 3.7 pCi/g; and Th-228, 0.6 to 4.2 pCi/g.

Table 6 lists the pre- and post-remediation concentrations of radionuclides measured in soil samples from locations of elevated direct radiation. Concentrations prior to remediation ranged to 12.8 pCi/g for U-238, 27.9 pCi/g for Th-232, and 28.2 pCi/g for Th-228. Following remediations, the radionuclide levels were significantly reduced. Concentrations of U-235 were below detection limits (<0.3 pCi/g); the highest U-238 concentration was 4.6 pCi/g, and the highest total thorium concentration was 14.6 pCi/g.

Alpha spectrometry for uranium and thorium was performed on three samples; results are presented in Table 7. Based on the relative levels of the uranium isotopes the contaminants at locations 45N, 45E and 165N, 57E appear to be slightly enriched in U-235 with correspondingly higher levels of U-234 than

U-238. The uranium in the composite sample from grid block 120-150N, 30-60E is natural uranium at essentially baseline levels. The U-238 concentrations from these analyses are the same as or slightly lower than those determined by gamma spectrometry, suggesting that the contamination was unevenly distributed and may have been due to small pieces of material, not readily homogenized by conventional physical grinding methods. Concentrations of Th-228 and Th-232 were in good agreement with those determined from the gamma spectrometry analyses. Samples from grid block 120-150N, 30-60E and 165N, 57E contained elevated levels of Th-230. The highest level was 13.5 pCi/g in the sample from 165N, 57E, after further cleanup was performed. The source of the Th-230 is unknown, review of gamma spectra did not indicate significant concentrations of this radionuclide in any of the samples. No Ra-226 levels exceeding typical baseline concentrations were noted.

DISCUSSION OF RESULTS

The soil guidelines applicable to the drum storage area are presented in Appendix C. Under Option 1, for unrestricted release, the guideline concentrations are 30 pCi/g for enriched uranium and 10 pCi/g for natural thorium (Th-232 + Th-228). The exposure rate guideline at 1 m above the surface is 10 μR/h above background or 20 μR/h total.

Following remediation, radionuclide concentrations were within guideline levels, with one exception. The post-remediation sample from 45N, 45E had a Th-232 + Th-228 concentration of 14.6 pCi/g (17.4 pCi/g based on alpha spectrometry) which exceeds the 10 pCi/g guideline. The area of contamination is small (less than 10 ft^2) and isolated. The average Th-232 + Th-228 concentration throughout the grid block, based on the concentration in the composite sample, is less than 2 pCi/g; therefore, averaging with the remainder of the grid block results in a concentration which satisfies guidelines.

The highest exposure rate measured at the site, after completion of remedial activities, was 15 μR/h; this is within the guideline level of 20 μR/h, total.

SUMMARY

On March 28, 1989, the Radiological Site Assessment Program of Oak Ridge Associated Universities conducted a follow-up confirmatory radiological survey of the drum storage area on the Combustion Engineering Property in Windsor, Connecticut. The purpose of this survey was to evaluate the radiological status relative to the NRC guidelines established for release for unrestricted use. Initial measurements identified four isolated areas with elevated direct radiation levels. Additional remediation was performed by the licensee and follow-up evaluations indicated that the applicable guidelines had been satisfied. Based on the final survey results, it is ORAU's opinion that the drum storage area satisfies the criteria for release for unrestricted use.

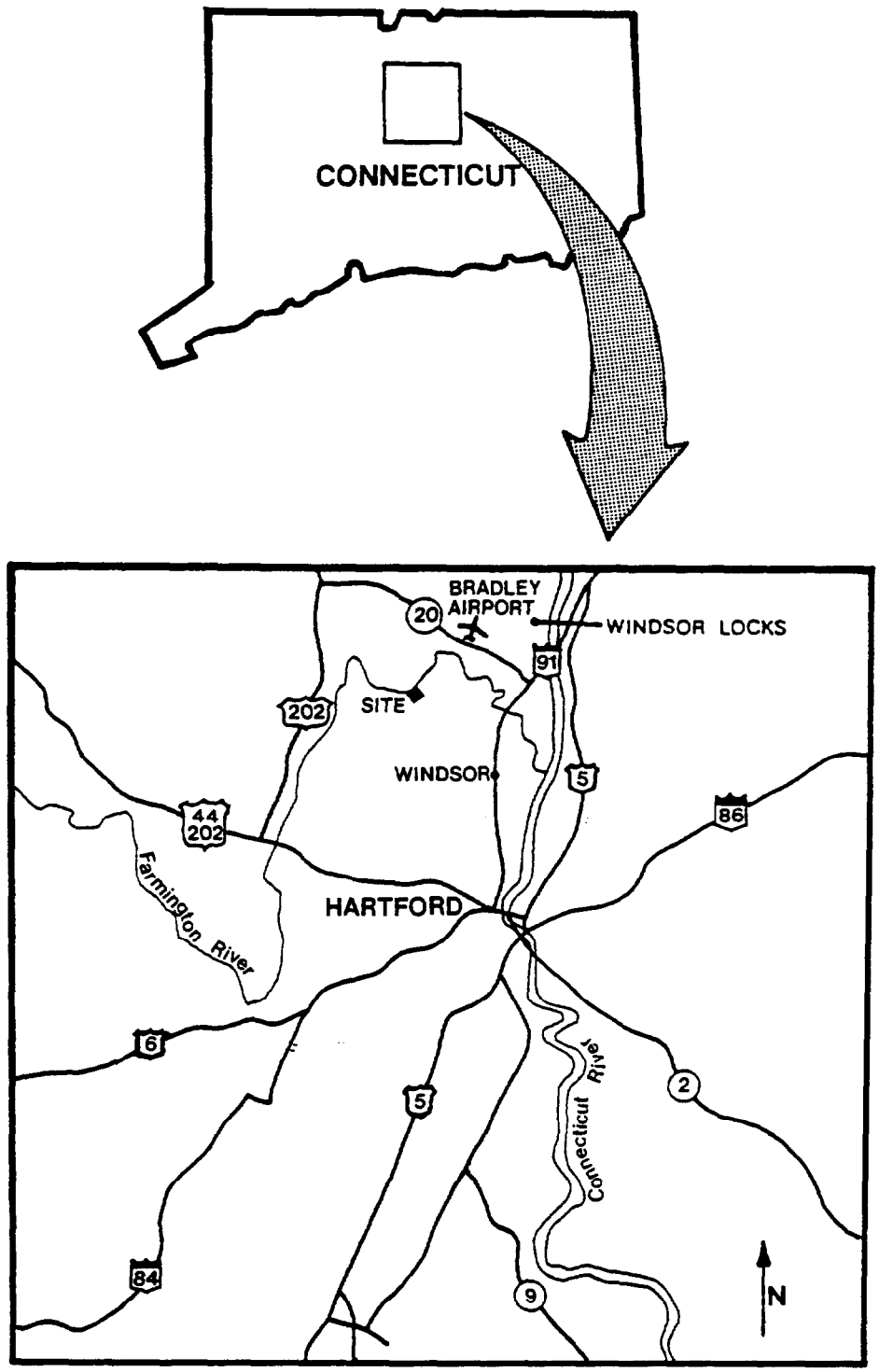

FIGURE 1: Map of Hartford Area Showing the Location of the Combustion Engineering Property

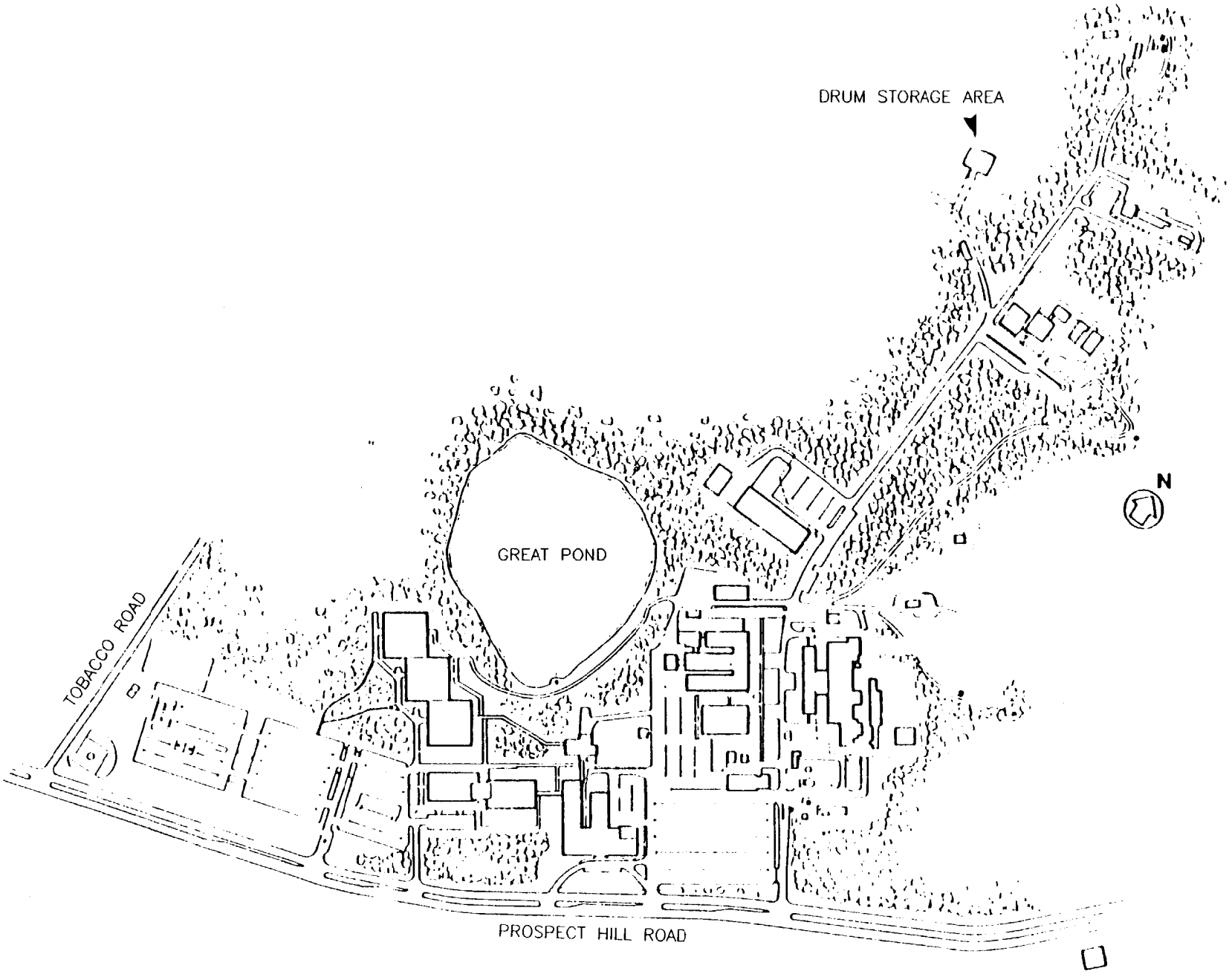

FIGURE 2: Plot Plan of the Combustion Engineering Property Showing the Location of the Drum Storage Area

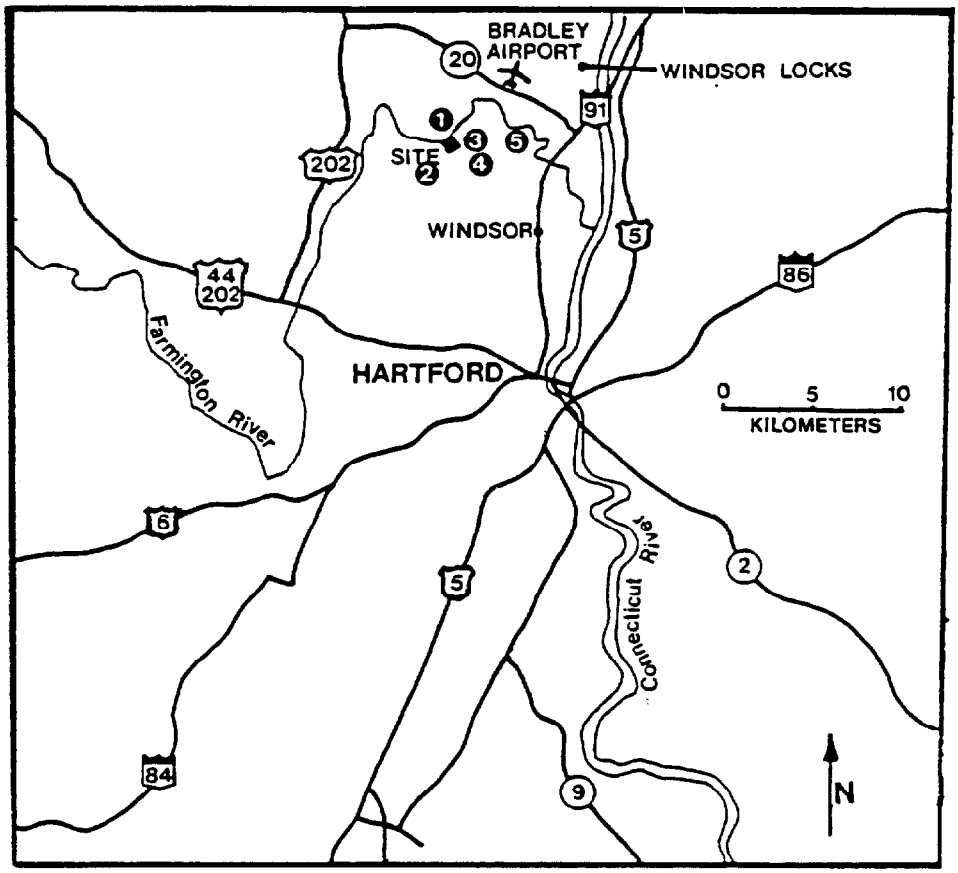

FIGURE 3: Map of Hartford Area Showing the Locations (●) of Background Measurements and Baseline Samples

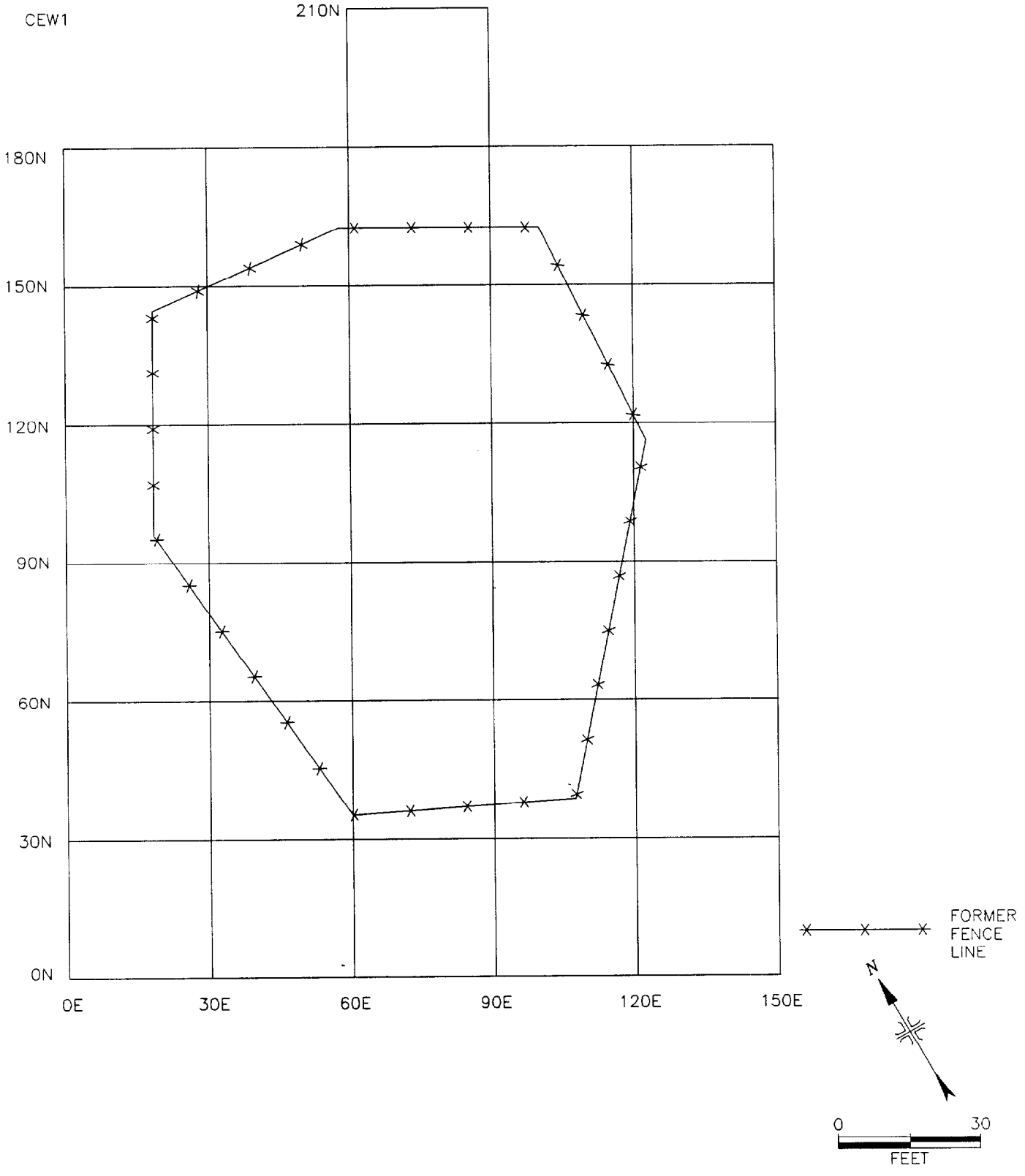

FIGURE 4: Grid System Established on the Drum Storage Area

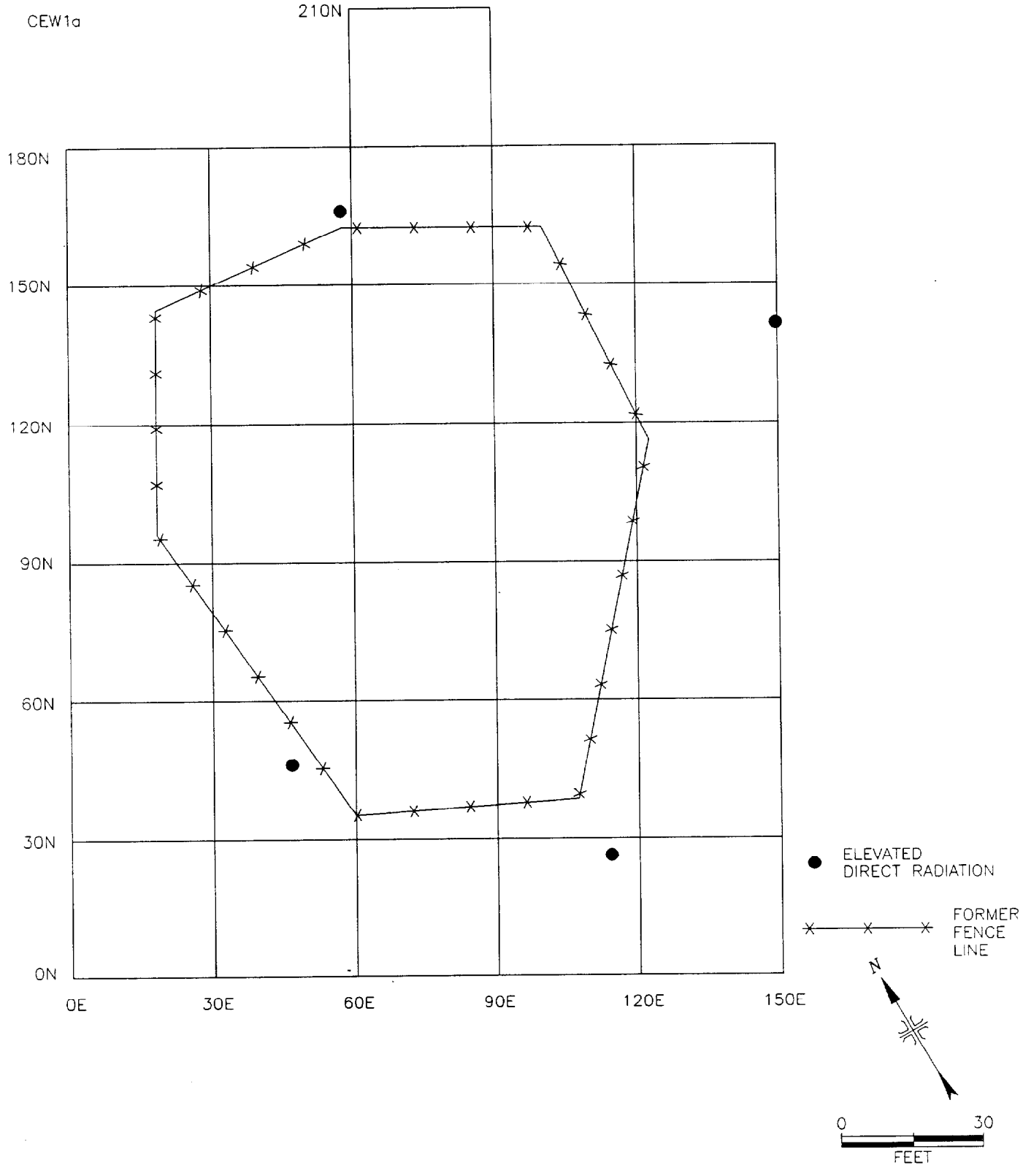

FIGURE 5: Locations of Elevated Direct Radiation Levels Identified by the Surface Scan

TABLE 1

BACKGROUND DIRECT RADIATION LEVELS
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Location[a]	Gamma Exposure Rates at 1 m above the Surface (μR/h)	Gamma Exposures Rates at the Surface (μR/h)
1	10	10
2	10	10
3	9	10
4	9	9
5	9	9

[a]Refer to Figure 3.

TABLE 2

RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Location[a]	Radionuclide Concentrations (pCi/g)			
	U-235	U-238	Th-232	Th-228
1	<0.2	<0.8	0.6 ± 0.2[b]	0.9 ± 0.1
2	<0.2	<0.7	0.5 ± 0.1	0.7 ± 0.1
3	<0.2	0.9 ± 0.2	0.6 ± 0.2	0.7 ± 0.1
4	<0.2	<0.7	0.8 ± 0.1	0.8 ± 0.1
5	<0.2	1.8 ± 0.5	0.5 ± 0.1	0.9 ± 0.1

[a]Refer to Figure 3.
[b]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

TABLE 3

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Grid Location[a] N	Grid Location[a] E	Gamma Exposure Rates at 1 m above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0	0	10	10
0	30	8	8
0	60	8	9
0	90	9	9
0	120	10	11
0	150	10	10
30	0	9	9
30	30	9	9
30	60	9	9
30	90	9	11
30	120	10	12
30	150	9	9
60	0	8	9
60	30	8	9
60	60	10	10
60	90	10	15
60	120	9	9
60	150	9	10
90	0	9	10
90	30	9	15
90	60	9	9
90	90	10	11
90	120	10	12
90	150	9	10
120	0	10	9
120	30	11	11
120	60	9	10
120	90	9	9
120	120	10	10
120	150	10	10
150	0	9	10
150	30	11	11
150	60	10	11
150	90	10	11
150	120	9	9
150	150	10	12

TABLE 3 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Grid Location[a] N	Grid Location[a] E	Gamma Exposure Rates at 1 m above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
180	0	10	10
180	30	10	10
180	60	9	11
180	90	9	10
180	120	9	9
180	150	10	11
210	60	9	9
210	90	9	11

[a]Refer to Figure 4

TABLE 4

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY SURFACE SCANS
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Grid Location[a]	Gamma Exposure Rates at 1 m above the Surface (μR/h)		Gamma Exposures Rates at the Surface (μR/h)	
	Prior to Remediation	Post-Remediation	Prior to Remediation	Post-Remediation
25N 115E	15	11	26	11
45N 45E	13	9	23	15
140N 150E	13	11	26	11
165N 57E	15	11	23	15

[a]Refer to Figure 5.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN COMPOSITE SURFACE SOIL SAMPLES
FROM GRID BLOCKS
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Grid Block Location[a]		Radionuclide Concentrations (pCi/g)			
		U-235	U-238	Th-232	Th-228
0N- 30N	-30E- 0E	0.2	0.8 ± 0.2[b]	0.5 ± 0.1	0.6 ± 0.3
	0E- 30E	<0.2	1.3 ± 0.2	0.6 ± 0.2	0.6 ± 0.3
	30E- 60E	<0.2	0.7 ± 0.3	0.6 ± 0.1	0.6 ± 0.3
	60E- 90E	<0.2	<0.4	0.8 ± 0.1	0.9 ± 0.3
	90E-120E	<0.2	1.6 ± 0.5	0.9 ± 0.2	0.9 ± 0.3
	120E-150E	0.7 ± 0.1	1.7 ± 0.3	1.1 ± 0.2	1.2 ± 0.3
30N- 60N	0E- 30E	<0.2	0.7 ± 0.6	<0.3	0.6 ± 0.3
	30E- 60E	<0.2	0.7 ± 0.2	0.9 ± 0.1	0.9 ± 0.3
	60E- 90E	<0.2	0.7 ± 0.3	0.9 ± 0.2	0.9 ± 0.3
	90E-120E	0.8 ± 0.2	0.7 ± 0.4	1.8 ± 0.3	1.5 ± 0.3
	120E-150E	<0.2	1.2 ± 0.3	0.9 ± 0.2	1.2 ± 0.3
60N- 90N	0E- 30E	<0.2	<0.4	1.0 ± 0.2	0.9 ± 0.3
	30E- 60E	<0.2	0.3 ± 0.4	0.9 ± 0.1	0.9 ± 0.3
	60E- 90E	0.2 ± 0.2	0.6 ± 0.2	1.5 ± 0.3	1.8 ± 0.3
	90E-120E	<0.2	0.3 ± 0.2	1.1 ± 0.1	0.9 ± 0.3
	120E-150E	<0.2	1.5 ± 0.3	0.8 ± 0.1	0.6 ± 0.3
90N-120N	0E- 30E	<0.2	0.7 ± 0.4	1.4 ± 0.2	1.8 ± 0.3
	30E- 60E	<0.2	0.4 ± 0.2	0.8 ± 0.2	0.9 ± 0.3
	60E- 90E	<0.2	0.5 ± 0.2	0.7 ± 0.2	0.6 ± 0.3
	90E-120E	<0.2	0.7 ± 0.4	0.8 ± 0.1	0.9 ± 0.3
	120E-150E	<0.2	1.5 ± 0.2	0.9 ± 0.2	0.9 ± 0.3
120N-150N	0E- 30E	0.5 ± 0.3	1.7 ± 0.6	3.7 ± 0.3	4.2 ± 0.3
	30E- 60E	<0.2	2.9 ± 0.3	2.6 ± 0.3	2.7 ± 0.3
	60E- 90E	<0.2	1.0 ± 0.2	1.1 ± 0.3	1.2 ± 0.3
	90E-120E	<0.2	1.3 ± 0.2	0.7 ± 0.2	0.6 ± 0.3
	120E-150E	<0.2	1.0 ± 0.3	<0.3	0.9 ± 0.3

TABLE 5 (Continued)

RADIONUCLIDE CONCENTRATIONS IN COMPOSITE SURFACE SOIL SAMPLES
FROM GRID BLOCKS
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Grid Block Location[a]		Radionuclide Concentrations (pCi/g)			
		U-235	U-238	Th-232	Th-228
150N-180N	0E- 30E	<0.2	<0.5	1.3 ± 0.2	1.5 ± 0.3
	30E- 60E	<0.2	0.9 ± 0.4	2.6 ± 0.2	2.1 ± 0.3
	60E- 90E	<0.3	2.2 ± 0.3	2.6 ± 0.2	2.7 ± 0.3
	90E-120E	<0.2	0.9 ± 0.4	1.7 ± 0.3	1.8 ± 0.3
	120E-150E	<0.3	1.9 ± 0.3	2.5 ± 0.2	2.4 ± 0.3
180N-210N	60E- 90E	<0.3	0.1 ± 0.3	1.5 ± 0.2	1.5 ± 0.3

[a]Refer to Figure 4.
[b]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM LOCATIONS OF ELEVATED DIRECT RADIATION
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Location[a]			Radionuclide Concentrations (pCi/g)			
			U-235	U-238	Th-232	Th-228
25N	115E	Prior to Remediation	<0.7	11.7 ± 1.4[b]	27.7 ± 0.6	28.2 ± 0.6
		Post-Remediation	<0.2	1.2 ± 0.4	2.5 ± 0.2	2.1 ± 0.3
45N	45E	Prior to Remediation	0.7 ± 0.6	12.8 ± 0.8	18.4 ± 0.6	19.5 ± 0.6
		Post-Remediation	<0.3	<1.0	7.7 ± 0.4	6.9 ± 0.3
140N	150E	Prior to Remediation	<0.8	12.3 ± 1.3	27.9 ± 0.8	26.7 ± 0.6
		Post-Remediation	<0.2	1.3 ± 0.4	1.9 ± 0.2	2.4 ± 0.3
165N	57E	Prior to Remediation	<0.5	5.9 ± 1.0	14.1 ± 0.5	14.7 ± 0.3
		Post-Remediation	<0.3	4.6 ± 0.4	5.7 ± 0.3	4.8 ± 0.3

[a]Refer to Figure 5.
[b]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

TABLE 7

RESULTS OF ISOTOPIC URANIUM AND THORIUM ANALYSES
OF SELECTED SAMPLES
COMBUSTION ENGINEERING PROPERTY
WINDSOR, CONNECTICUT

Sample Location[a]	Radionuclide Concentrations (pCi/g)					
	U-234	U-235	U-238	Th-228	Th-230	Th-232
120-150N, 30-60E	1.2 ± 0.2[b]	0.1 ± 0.1	1.1 ± 0.2	1.9 ± 0.2	10.0 ± 0.5	2.0 ± 0.2
45N, 45E (Post-Remediation)	15.5 ± 0.7	0.4 ± 0.2	0.7 ± 0.2	8.4 ± 0.4	1.7 ± 0.2	9.0 ± 0.4
165N, 57E (Post-Remediation)	4.0 ± 0.4	0.1 ± 0.1	0.8 ± 0.2	4.6 ± 0.3	13.5 ± 0.6	5.0 ± 0.3

[a]Refer to Figure 4.
[b]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainties of up to ± 30% have not been propagated into these data.

REFERENCES

1. Confirmatory Radiological Survey of the Combustion Engineering Property, Windsor, Connecticut, A. D. Luck, March 1985.

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

The display or description of a specific product is not to be construed as an endorsement of that product or its manufacturer by the authors or their employer.

A. Direct Radiation Measurements

Eberline PRM-6
Portable Ratemeter
(Eberline, Santa Fe, NM)

Reuter-Stokes Pressurized Ionization Chamber
Model RSS-111
(Reuter-Stokes, Cleveland, OH)

Victoreen Gamma Scintillation (NaI) Detector
Model 489-55
(Victoreen, Inc., Cleveland, OH)

B. Laboratory Analyses

High-Purity Germanium Detector
Model GMX-23195-S, 23% efficiency
(EG&G ORTEC, Oak Ridge, TN)

Used in conjunction with:
Lead Shield, G-16
(Gamma Products, Inc., Palos Hills, IL)

Multichannel Analyzer
ND-66/ND-680 System
(Nuclear Data Inc., Schaumburg, IL)

Alpha Spectrometer
Tennelec TC-256
(Tennelec Inc., Oak Ridge, TN)

Surface Barrier Detector
Model CR-25-450-100
(EG&G ORTEC, Oak Right, TN)

Multichannel Analyzer
Model ND-66
(Nuclear Data, Schaumburg, IL)

APPENDIX B

MEASUREMENT AND ANALYTICAL PROCEDURES

APPENDIX B

MEASUREMENT AND ANALYTICAL PROCEDURES

Surface Scans

Walkover surface scans of open land areas were performed at approximately 1-2 m intervals using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation detectors containing 3.2 cm x 3.8 cm NaI(Tl) crystals. Relative count rates were monitored using earphones and rates above the ambient background levels were noted.

Exposure Rate Measurements

Measurements of gamma exposure rates were performed using Eberline PRM-6 portable ratemeters with a Victoreen Model 489-55 gamma scintillation probe containing 3.2 cm x 3.8 cm NaI(Tl) scintillation crystals. Count rates were converted to exposure rates (μR/h) by cross-calibrating with a Reuter-Stokes Model RSS-111 pressurized ionization chamber.

Soil Sample Analysis

Gamma Spectrometry

Soil and sediment samples were dried, mixed, and a portion placed in a 0.5 liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 600 to 1000 g of sample. Net weights were determined and the samples counted using solid state germanium 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:

U-235	0.143 MeV
U-238	0.094 MeV from Th-234 or 1.001 MeV from Pa-234m*

Th-232	0.911 MeV from Ac-228*
Th-228	0.583 MeV from Tl-208*

*Secular equilibrium was assumed.

Spectra were also reviewed for the presence of other radionuclides.

Alpha Spectroscopy

Aliquots of soil were acidified and evaporated to dryness. The residues were then dissolved by pyrosulfate fusion and precipitated with barium sulfate. The barium sulfate precipitates were redissolved and uranium and thorium were separated by liquid - liquid extraction, precipitated with a cerium fluoride carrier, and counted using surface barrier detectors (ORTEC), alpha spectrometers (Tennelec), and an ND-66 Multichannel Analyzer (Nuclear Data).

Uncertainties and Detection Limits

The uncertainties associated with the analytical data presented in the tables of this report, represent the 95% confidence levels for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels. When the net sample count was less than the 95% statistical deviation of the background count, the sample concentration was reported as less than the detection limits of the procedures. Because of variations in background levels and Compton contributions from other radionuclides in samples, the detection limits differ from sample to sample. Additional uncertainties of $\pm$ 6 to 10%, associated with sampling and laboratory procedures, have not been propagated into the data presented in this report.

Calibration and Quality Assurance

Laboratory and field survey procedures are documented in manuals developed specifically for the Oak Ridge Associated Universities' Radiological Site Assessment Program.

With the exception of the measurements conducted with portable gamma scintillation survey meters, instruments were calibrated with NBS-traceable standards. The calibration procedures for the portable gamma instruments are performed by comparison with an NBS calibrated pressurized ionization chamber.

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 and DOE/EML Quality Assurance Programs.

APPENDIX C

NUCLEAR REGULATORY COMMISSION GUIDELINES FOR RESIDUAL CONCENTRATIONS OF THORIUM AND URANIUM WASTES IN SOIL

Guidelines For Residual Concentrations Of Thorium And Uranium Wastes In Soil

On October 23, 1981, the Nuclear Regulatory Commission published in the Federal Register a notice of Branch Technical Position on "Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations." This document establishes guidelines for concentrations of uranium and thorium in soil, that will limit maximum radiation received by the public under various conditions of future land usage. These concentrations are as follows:

Material	Maximum Concentrations (pCi/g) for various options			
	1[a]	2[b]	3[c]	4[d]
Natural Thorium (Th-232 + Th-228) with daughters present and in equilibrium	10	50	--	500
Natural Uranium (U-238 + U-234) with daughters present and in equilibrium	10	--	40	200
Depleted Uranium:				
Soluble	35	100	--	1,000
Insoluble	35	300	--	3,000
Enriched Uranium:				
Soluble	30	100	--	1,000
Insoluble	30	250	--	2,500

[a]Based on EPA cleanup standards which limit radiation to 1 mrad/yr to lung and 3 mrad/yr to bone from ingestion and inhalation and 10 μR/h above background from direct external exposure.
[b]Based on limiting individual doses to 170 mrem/yr.
[c]Based on limiting equivalent exposure to 0.02 working level or less.
[d]Based on limiting individual doses to 500 mrem/yr and in case of natural uranium, limiting exposure to 0.02 working level or less.

Option 1 concentrations permit unrestricted use of the property and is the guideline applicable to surface soils. Options 2, 3, and 4 apply to buried wastes and assume that intrusions into the burial sites may occur. Regardless of the concentrations in the buried materials, surface soil must meet the Option 1 concentrations guidelines.