CONFIRMATORY RADIOLOGICAL SURVEY FOR PORTIONS OF THE CABOT CORPORATION REVERE PLANT REVERE, PENNSYLVANIA

J. D. BERGER AND B. M. SMITH

Prepared for
U. S. Nuclear Regulatory Commission
Division of Industrial and
Nuclear Medical Safety

ORISE

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

Environmental Survey and Site Assessment Program
Energy/Environment Systems Division

The **Oak Ridge Institute for Science and Education** (ORISE) was established by the U.S. Department of Energy to undertake national and international programs in science and engineering education, training and management systems, energy and environment systems, and medical sciences. ORISE and its programs are operated by Oak Ridge Associated Universities (ORAU) through a management and operating contract with the U.S. Department of Energy. Established in 1946, ORAU is a consortium of 65 colleges and universities.

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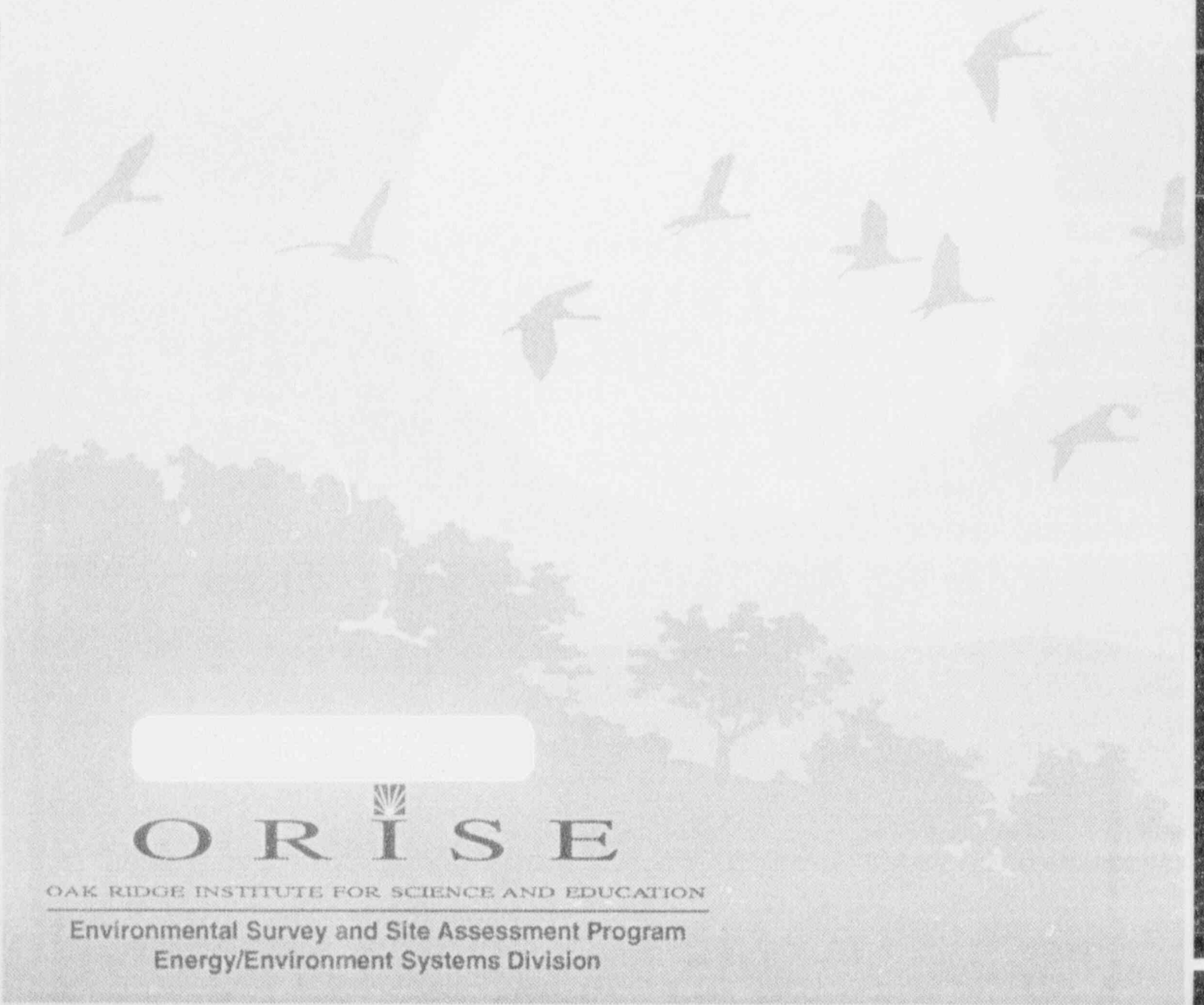

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Division of Industrial and Nuclear Medical Safety

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FINAL REPORT

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CONFIRMATORY RADIOLOGICAL SURVEY
FOR PORTIONS OF THE
CABOT CORPORATION REVERE PLANT
REVERE, PENNSYLVANIA

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ABBREVIATIONS

cm	centimeter
cm^2	square centimeter
cpm	counts per minute
dpm/100 cm^2	disintegrations per minute/100 square centimeters
ft	foot
ft^2	square foot
GM	Geiger-Mueller
h	hour
km	kilometer
m	meter
m^2	square meter
NaI	Sodium Iodide
pCi/l	picocuries per liter
pCi/g	picocuries per gram
μR/h	microroentgen per hour

ACRONYMS

AEC	Atomic Energy Commission
ESSAP	Environmental Survey and Site Assessment Program
KBI	Kawecki Berylco Industries
NRC	Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
PIC	Pressurized Ionization Chamber

CONFIRMATORY RADIOLOGICAL SURVEY FOR PORTIONS OF THE CABOT CORPORATION REVERE PLANT REVERE, PENNSYLVANIA

INTRODUCTION AND SITE HISTORY

Beginning in July 1970, Kawecki Berylco Industries (KBI), currently Cabot Corporation, conducted processing of columbium-tantalum ores which contained traces of natural uranium (0.04%) and thorium (0.12%). This activity was conducted under Source Material License #SMB-920, Docket 40-6940, with the Atomic Energy Commission (AEC), predecessor to the Nuclear Regulatory Commission (NRC). The process used was a thermite reduction with powdered aluminum; the process produced a final product of columbium-tantalum alloy, which contained less than 0.01% of uranium and thorium, and a waste slag, which contained 0.14% of the source materials. The slag was stored on-site in the Old Pit and Drum Storage Areas and later transferred to the company's site in Boyertown, Pennsylvania, for longer-term storage. Information provided by Cabot Corporation indicates that approximately 4500 kilograms of columbium-tantalum ore were processed in two initial experimental test runs; no subsequent processing of radioactive ores occurred.

In late 1988 Cabot Corporation initiated actions to decontaminate the Revere Plant site and terminate the NRC license. Bullinger's Mills, Inc., of Fleetwood, Pennsylvania, was contracted by the licensee to assist with the cleanup and radiological survey of the site. An initial survey identified elevated direct radiation levels at the Old Pit, the Drum Storage Area, the Buildings 4 and 5 Storage Area, and the area north of the Warehouse. In August 1990, Bullinger's Mills, Inc. began decontamination operations in these areas. Decontamination involved the excavation and removal of slag at the Old Pit, the Drum Storage Area, and the Buildings 4 and 5 Storage Area. The remediation and final survey were completed in October 1990. The final survey report indicates that direct radiation levels are below the NRC guideline values, and an addendum to the final report indicates that soil concentrations are also below the guideline values.[1,2]

At the request of the NRC's Headquarters Office of the Division of Industrial and Medical Nuclear Safety, the Environmental Survey and Site Assessment Program (ESSAP) of Oak Ridge Associated Universities (ORAU), now Oak Ridge Institute for Science and Education (ORISE), conducted a confirmatory radiological survey of portions of the Cabot Corporation Revere Plant, during the period of July 22 through 26, 1991. The purpose of the survey was to independently assess the adequacy of the decontamination and the accuracy of the licensee's final-status radiological data, to support the NRC's decision regarding decommissioning. This report presents the procedures and findings of the ESSAP survey.

SITE DESCRIPTION

The Revere Plant Site occupies approximately 41 hectares (102 acres) and is located on Beaver Run Road in Revere, Pennsylvania (Figure 1). The portion of the site involved in the decontamination and survey operations includes the Old Pit, the Drum Storage Area, the Buildings 4 and 5 Storage Area, and the grounds within 10 m of the Warehouse (Figure 2). The Old Pit, an area of approximately 3200 m^2, contains three standing walls of the former Blending Building and rubble from the demolition of the former Reaction Building (Figure 3). The Drum Storage Area, which contains approximately 4000 m^2, is a flat, gravel filled area surrounded by shrubbery. It is bordered by a field to the south and east, and a swampy area to the west (Figure 4). The Buildings 4 and 5 Storage Area is approximately 400 m^2 and contains piping, equipment, and other debris (Figure 5). Excavated areas in the Drum Storage and Buildings 4 and 5 Storage Areas were backfilled by Bullinger's Mills, Inc. after remediation of the area. The floor space of the Warehouse is approximately 290 m^2 and the surrounding grassy area is approximately 400 m^2 (Figure 6).

OBJECTIVE

The objective of the ESSAP confirmatory activities was to develop independent information and data, relative to the radiological conditions of the Cabot Corporation's Revere site, to support the NRC's review of the licensee's final status survey report and the decision, regarding termination of the site license.

DOCUMENT REVIEWS

As part of the confirmatory activities, ESSAP reviewed the final survey report and other supporting documentation prepared by Cabot Corporation for the Revere Plant.[1,2] Data and survey results presented in the final report were reviewed to assess the adequacy of the decontamination activities and to compare the licensee's survey results to the established release guidelines.

SURVEY PROCEDURES

During the period of July 22 through 26, 1991, ESSAP performed a confirmatory radiological survey at the Cabot Corporation Revere Plant Site. Survey activities were performed in accordance with a plan developed by ESSAP and approved by the NRC. On the basis of the relatively small quantities of material processed and the limited time frame during which processing occurred, ORAU and NRC agreed to include in the survey only those portions of the site, considered to have the greatest potential for residual contamination. Therefore, the survey included only the Old Pit, the Drum Storage Area, the Buildings 4 and 5 Storage Area, and the grounds within 10 m of the Warehouse.

REFERENCE GRID

The 20 m grid system, utilized by the contractor, was re-established by ESSAP for referencing measurements and sampling at the Old Pit and the Drum Storage Area (Figures 3 and 4). A 10 m reference grid was established by ESSAP for the Buildings 4 and 5 Storage Area (Figure 5). No grid was established for the grounds adjacent to the Warehouse; measurement and sampling locations were referenced to pertinent building features (Figure 6).

SURFACE SCANS

Surface scans to identify the presence of elevated gamma radiation were performed over the four surveyed areas and in three trenches, excavated for subsurface investigations. Scans for alpha

and beta activity were performed on the standing walls of the former Blender Building at the Old Pit. NaI(Tl) gamma scintillation detectors were used for the gamma radiation scans; gas proportional detectors and thin-window GM detectors were used for scans for alpha and beta activity, respectively. All detectors were coupled to instruments with audible indicators. Locations of elevated direct radiation were noted for further investigation.

SURFACE SOIL SAMPLING

Background soil samples were collected from 8 off-site locations within 5 km of the Revere Plant (Figure 7). Surface soil samples (depth 0-15 cm) were collected from 45 grid line intersections and from 7 areas of elevated radiation, identified by surface scans. Sample locations are identified in Figures 3-6.

SUBSURFACE SOIL SAMPLING

With concurrence of the NRC project contact, two small trenches, 1 to 2 meters deep, were excavated at backfilled areas at the north end of the Drum Storage Area, and one small trench was excavated in a backfilled area at the Buildings 4 and 5 Storage Area. Locations of these excavations were selected, based on the identification of individual pieces of radioactive slag on the surface and generally higher gamma radiation levels in the vicinity.

ESSAP obtained two slag samples and two subsurface soil samples from the excavations for analyses (Figures 4 and 5). Licensee personnel identified and removed additional pieces of slag from the trenches in the Drum Storage and disposed of these as contaminated radioactive waste.

WATER AND SEDIMENT SAMPLING

One water sample was collected from the Fire Water Pond adjacent to the Drum Storage Areas and six sediment samples were collected from Rapp Creek and the Fire Water Pond (Figures 3 and 8).

EXPOSURE RATE MEASUREMENTS

Gamma radiation exposure rate measurements were performed at one meter above the surface at 8 off-site background locations within 5 km of the Revere Plant (Figure 7) and on-site at 45 grid line intersections. Measurements were performed using NaI(Tl) gamma scintillation detectors coupled to ratemeters and cross-calibrated with a PIC.

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and measurement data were returned to the ESSAP laboratory in Oak Ridge, TN for analyses and interpretation. Soil, slag, and sediment samples were analyzed by gamma spectrometry. Radioactive materials of primary interest were natural uranium and natural thorium; however, spectra were also reviewed for other identifiable photopeaks. The water sample was analyzed for gross alpha and gross beta activity. Additional information concerning major instrumentation, sampling equipment, and analytical procedures is provided in Appendices A and B. Results of the independent measurements were compared to the NRC guidelines (Appendix C).

FINDINGS AND RESULTS

DOCUMENT REVIEW

The documentation provided by Cabot Corporation included descriptions and results of the decontamination and decommissioning activities which were performed by Bullinger's Mills, Inc.[1,2] Survey activities performed by Bullinger's Mills, Inc. included exposure rate measurements and sampling of slag and soil. The radiological data, as presented in the reports, indicate that the direct radiation levels and soil concentrations satisfied the NRC guidelines. However, upon review of the report several deficiencies were noted:

- The report indicated elevated direct radiation levels were present beside the Warehouse. However, the final report does not indicate if these areas were remediated and does not provide final survey data for these areas.

- The final report does not discuss survey techniques and methodology.

- Appropriate surveys were not performed to identify areas of elevated direct radiation, and measurements for alpha and beta-gamma activities were not performed on the remains of the former Blender Building.

- Surface scans were not performed to identify areas of elevated direct radiation.

- The final report does not discuss the results of the gamma spectrometry analyses performed on soil and slag samples. Additionally, it does not indicate whether the data were reviewed to confirm that the radioactivity was natural uranium and natural thorium with the daughters present and in equilibrium.

Therefore, it is the opinion of ESSAP that the survey documentation is not adequate to demonstrate that the site meets all applicable NRC guidelines.

SURFACE SCANS

Gamma scans of outdoor surfaces identified areas of elevated direct radiation at the Old Pit, the Drum Storage Area, the Buildings 4 and 5 Storage Area, and the Warehouse. These locations were noted for further investigation.

The licensee removed individual pieces of slag that were identified by the scans; followup gamma monitoring indicated that removal had reduced the surface contact radiation level considerably, but that general area gamma radiation levels were often still elevated above background. This suggests the presence of additional residual contaminated slag at the site.

Surface scans of the walls and floor of the former Blender Building at the Old Pit did not identify any areas of elevated direct radiation.

RADIONUCLIDE CONCENTRATIONS IN SOIL AND SLAG SAMPLES

Uranium and thorium concentrations in background soil samples are presented in Table 1, and ranged from 1.7 to 5.0 pCi/g for total uranium (U-234 + U-235 + U-238) and from 1.2 to 2.3 pCi/g for total thorium (Th-228 + Th-232). The average concentrations of total uranium and total thorium were 3.2 and 1.7 pCi/g, respectively.

Gamma spectra for 6 samples (4 soil and 2 slag) were reviewed to determine the relative concentrations of gamma emitting radionuclides from the natural uranium and natural thorium decay series; results are presented in Table 2. Based on these results it was concluded that within associated analytical uncertainties the uranium and thorium decay series are essentially in secular equilibrium, i.e., daughter products are equivalent in activity level to the parent nuclides of U-238 and Th-232.

Total uranium and total thorium concentrations for samples were calculated, based on the secular equilibrium state of the two decay series. Total uranium was determined by multiplying the measured U-238 concentration, based on the Th-234 daughter, by 2 (to account for the U-234) and adding to that value, the measured U-235 concentration; total thorium was determined by multiplying the measured Th-232 concentration, based on the Ac-228 daughter, by 2. During review and evaluation of data, gamma spectra were reviewed for other significant radionuclides. In addition to the anticipated daughters in the uranium and thorium decay series, only naturally occurring amounts of Cs-137 (typically 0.2 to 1.0 pCi/g) and K-40 (typically 10 to 20 pCi/g) were present in the samples from this site.

Uranium and thorium concentrations determined for systematic surface soil samples are summarized in Table 3. Total uranium concentrations ranged from 0.3 to 13 pCi/g. Total thorium concentrations ranged from <0.6 to 15 pCi/g. The highest concentration was identified at location 0, 20E at the Buildings 4 and 5 Storage Area.

Uranium and thorium concentrations in soil samples, collected from areas of elevated radiation identified by the surface scans, are identified in Tables 4. Total uranium concentrations ranged from 2.9 to 21 pCi/g and total thorium concentrations ranged from 1.4 to 15 pCi/g. The highest concentration was identified at the SE corner of the Warehouse loading dock. One sample, obtained from an area of elevated direct radiation at the Warehouse, consisted of a small rock-like particle which contained about 10,000 pCi/g of total uranium and 2900 pCi/g of total thorium; this sample was not representative of the concentrations present in other soil or slag samples from this site.

Uranium and thorium concentrations in subsurface soil and slag samples are summarized in Table 5. Concentrations of total uranium in two soil samples were 4.5 and 4.7 pCi/g and for total thorium were 2.4 and 2.6 pCi/g at the Drum Storage Area and the Buildings 4 and 5 Storage Area, respectively. Two slag samples, obtained from one of the trenches at the Drum Storage Area, contained concentrations of 20 and 160 pCi/g of total uranium and 3.5 and 2200 pCi/g of total thorium.

RADIONUCLIDE CONCENTRATIONS IN WATER AND SEDIMENT SAMPLES

Gross alpha and gross beta concentrations in the water sample collected from the Fire Water Pond by the Drum Storage Area were <2.2 pCi/l and 2.9 pCi/l, respectively.

Uranium and thorium concentrations in sediment samples are presented in Table 6. Concentrations ranged from 0.3 to 3.0 pCi/g for total uranium and from 1.6 to 2.6 pCi/g for total thorium.

EXPOSURE RATE MEASUREMENTS

Background exposure rate measurements are presented in Table 1 and ranged from 5 to 11 μR/h (8 μR/h average). On-site exposure rate measurements are presented in Tables 3-5 and ranged from 6 to 19 μR/h at 1 m above the surface.

COMPARISON OF RESULTS WITH GUIDELINES

Surface activity guidelines, established for the release of formerly licensed facilities for unrestricted use, and the guidelines for residual concentrations of thorium and uranium wastes in soil are presented in Appendix C. The primary contaminants of concern identified for this site are natural uranium and natural thorium. The total surface activity guidelines for these contaminants are:

Natural Uranium

15,000 dpm α/100 cm^2 (maximum in a 100 cm^2 area)

5,000 dpm α/100 cm^2 (average over a 1 m^2 area)

Natural Thorium

3,000 dpm/100 cm^2 (maximum in a 100 cm^2 area)

1,000 dpm/100 cm^2 (average over a 1 m^2 area)

Natural uranium and thorium emit both alpha and beta radiations at comparable levels; either alpha or beta activity can therefore be measured and compared to the guideline values. Because rough or dirty surfaces, as were encountered on the walls of the former Blender Building, may selectively attenuate alpha radiation, both alpha and beta surface scans were performed on the surfaces. No locations of elevated direct alpha or beta radiation were detected on the wall surfaces.

Soil concentrations for residual uranium and thorium wastes in soil are presented in the NRC's Branch Technical Position on "Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations" (Appendix C). The following guidelines were used for comparison with the results:

Natural Uranium (U-238 + U-234 + U-235): 10 pCi/g*

Natural Thorium (Th-232 + Th-228): 10 pCi/g*

*With all daughters present and in equilibrium

These guidelines are expressed in terms of concentrations above normal background levels. Background concentrations of natural uranium and natural thorium were determined by averaging the radionuclide concentrations from the baseline samples that were collected within the vicinity of the plant. The average background concentrations for natural uranium and natural thorium were 3.2 pCi/g and 1.7 pCi/g, respectively. Hence, the sample analysis results, indicating that the NRC guidelines have been exceeded, are 13.2 pCi/g for natural uranium and 11.7 pCi/g for natural thorium. With exception of one sample from the Buildings 4 and 5 Storage area, systematically sampled soils and sediments from this site satisfied these guidelines. However, there are numerous pieces of slag, scattered around the site, both on the surface and covered with fill, which contain activity levels well above the guideline values.

The NRC's Branch Technical Position establishes an exposure rate guideline for open land areas of 10 μR/h, above background, due to thorium and uranium wastes from past operations; this is considered an average level, at 1 m above surface. Based on an average area background level of about 8 μR/h, the guideline value for average total exposure rate would be 18 μR/h, i.e. slightly higher than 2 times background. Gamma radiation levels at the site ranged from 6 to 19 μR/h, with the average satisfying the NRC guideline.

Areas of elevated direct radiation were identified by the gamma scans in all areas surveyed. At the Old Pit, the areas of elevated direct radiation were primarily located west of the remains of the former Reaction Building. Further investigations by ESSAP at this location uncovered subsurface slag, with direct contact radiation levels, ranging up to approximately 15 times the background level. In the northwest portion of the Drum Storage Area, direct radiation levels were generally approximately twice background; this portion of the Drum Storage Area had been remediated and backfilled. Small, shallow trenches were excavated at two locations in the norther half and 42 pieces of contaminated slag were removed by the licensee (two pieces were retained by ESSAP for analysis). Direct radiation levels on contact with the slag ranged up to 20 times the background level. At the Buildings 4 and 5 Storage Area, several isolated spots of elevated direct radiation were detected. The licensee also remediated these locations by the removal of individual pieces of slag, which were just beneath the surface. Two areas of elevated direct radiation were identified near the loading dock at the Warehouse and the contaminated

slag removed. In all cases, removal of pieces of slag was effective in eliminating the source of elevated surface contact radiation, but at most locations the general area direct radiation level remained distinctly elevated above background. This observation suggests that additional deposits of contaminated slag, covered by clean fill, remain at the plant site.

The gross alpha and gross beta concentrations in the water sample from Fire Water Pond were typical of background levels.

SUMMARY

At the request of the Nuclear Regulatory Commission, Headquarters Office of the Division of Industrial and Medical Nuclear Safety, the Environmental Survey and Site Assessment Program of Oak Ridge Associated Universities conducted a confirmatory radiological survey of portions of the Cabot Corporation Revere Plant Site during the period of July 22 through 26, 1991. Areas surveyed were: (1) the Old Pit, (2) the Drum Storage Area, (3) a Storage Area Behind Buildings 4 and 5, and (4) the area surrounding the Warehouse. The survey included surface scans, exposure rate measurements, and the determination of radionuclide concentrations in soil, slag, sediment, and water.

The potential contaminants at the site were confirmed to be natural uranium and natural thorium; the decay series of these radioactive materials were determined to be in secular equilibrium.

With two exceptions, concentrations of total uranium and total thorium in the soil samples were well below the guideline values. Both of these exceptions represented samples obtained from locations near areas where pieces of contaminated slag had been identified and the samples may also have contained some small particles of slag. The average for all soil samples is well below the guideline. Sediment samples also contained less than guideline levels, and the water sample was in the range of typical background concentrations. Surface scans did not identify any areas of elevated direct radiation on remaining walls of the former Blender Building. Average exposure rates at 1 m above the surface satisfy the guideline of the NRC Branch Technical Position.

Gamma scans identified isolated pieces of contaminated slag on or near the surface and generally elevated exposure rates in some areas. The licensee removed pieces of contaminated slag from the surface, during the ESSAP survey; general area radiation levels were not significantly reduced, however, indicating possible buried slag. Several small, shallow exploratory excavations in the areas of generally elevated radiation confirmed the presence of additional slag at about 1 m below the surface at the Old Pit, the Drum Storage Area, and the Buildings 4 and 5 Storage Area.

Although results of the ESSAP confirmatory radiological survey support the findings of the final survey performed by Cabot Corporation and indicate that average surface activity soil concentrations and ambient radiation levels satisfy the Nuclear Regulatory Commission guidelines, discrete pieces of slag, containing uranium and thorium concentrations well above soil guidelines values, remain on and below the surface in those portions of the site surveyed. It is also considered possible that similar conditions may exist at other locations on the Revere Plant Site.

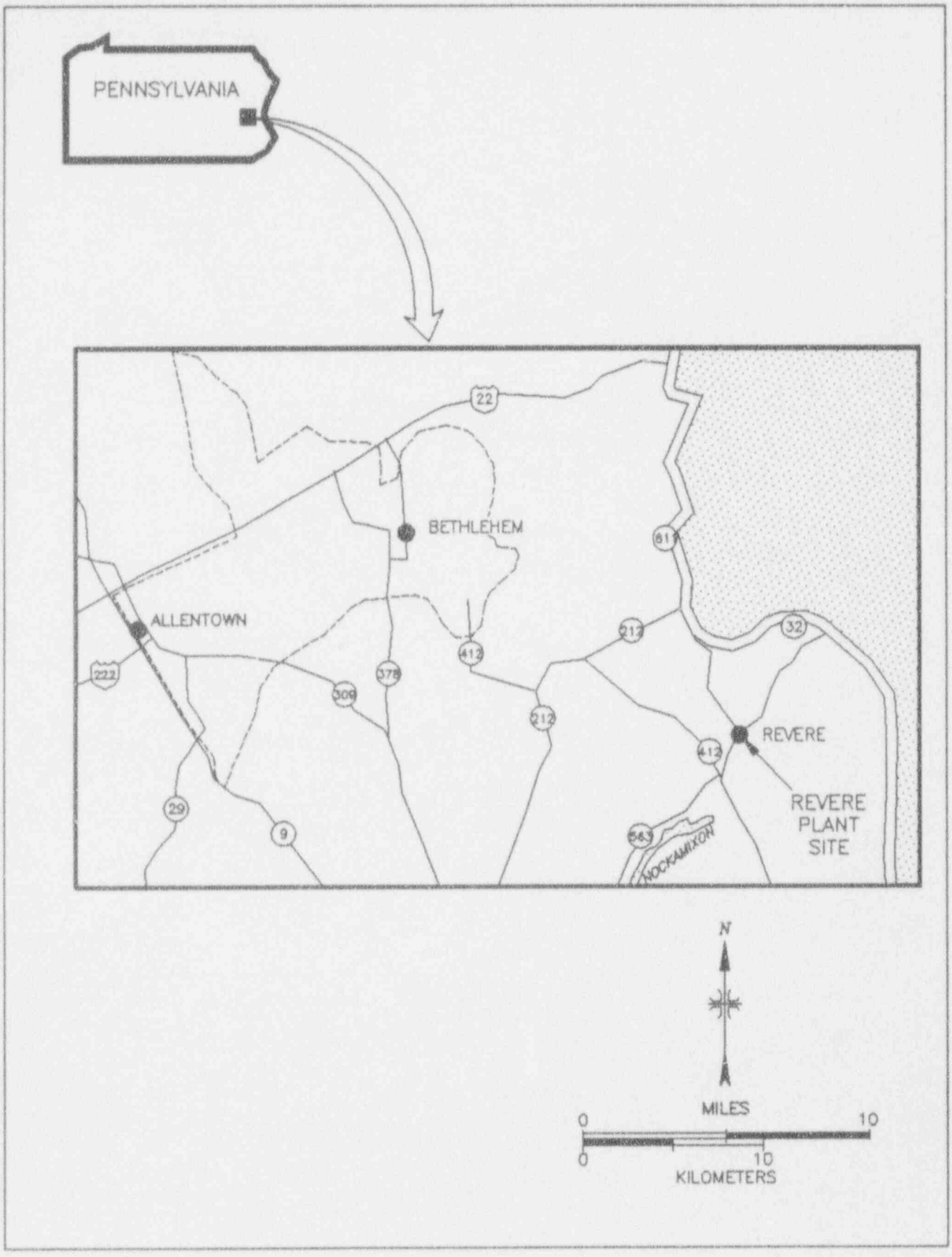

FIGURE 1: Location of the Cabot Corporation Revere Plant, Revere, Pennsylvania

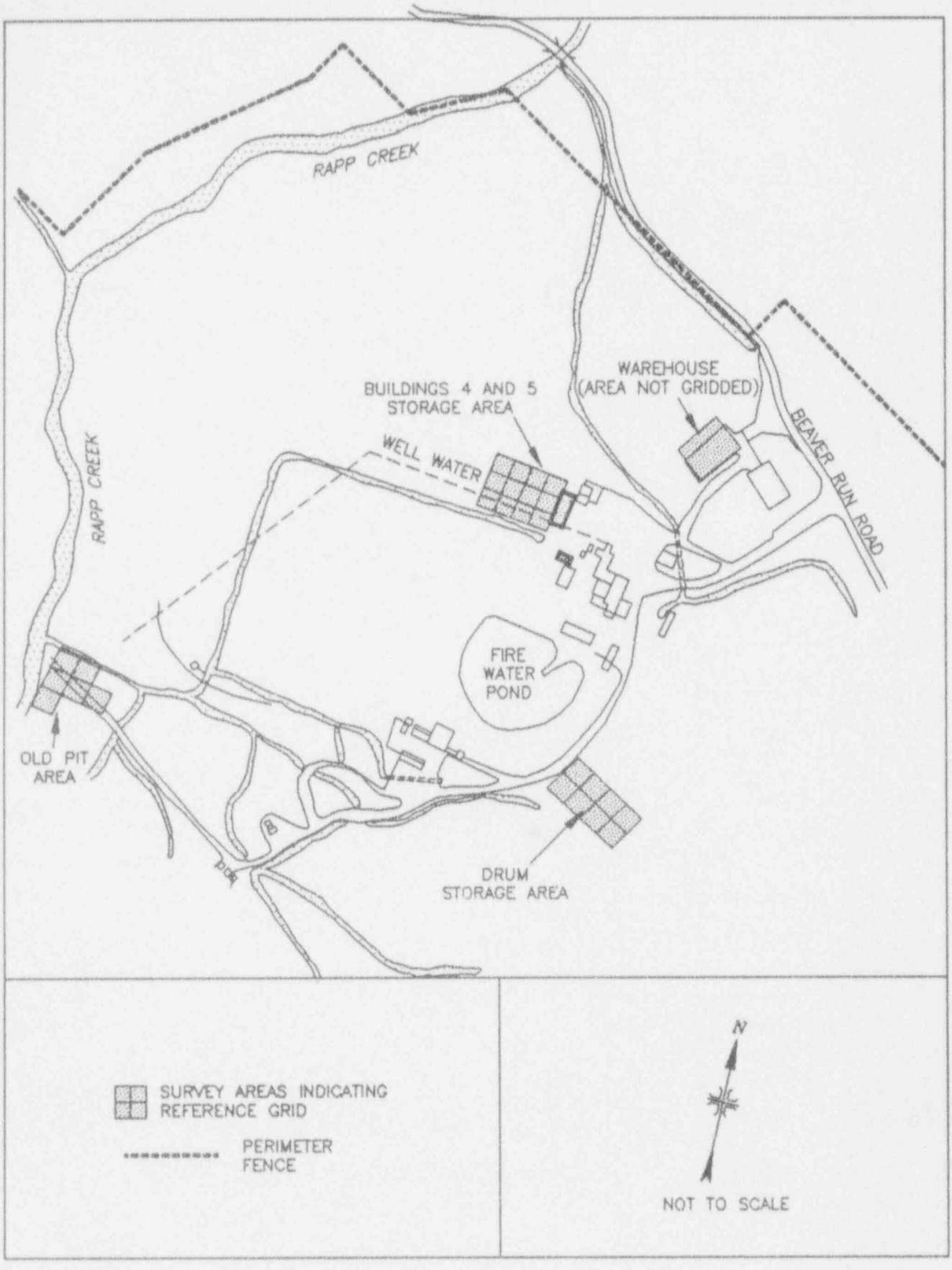

FIGURE 2: Revere Plant – Plot Plan Indicating Surveyed Areas

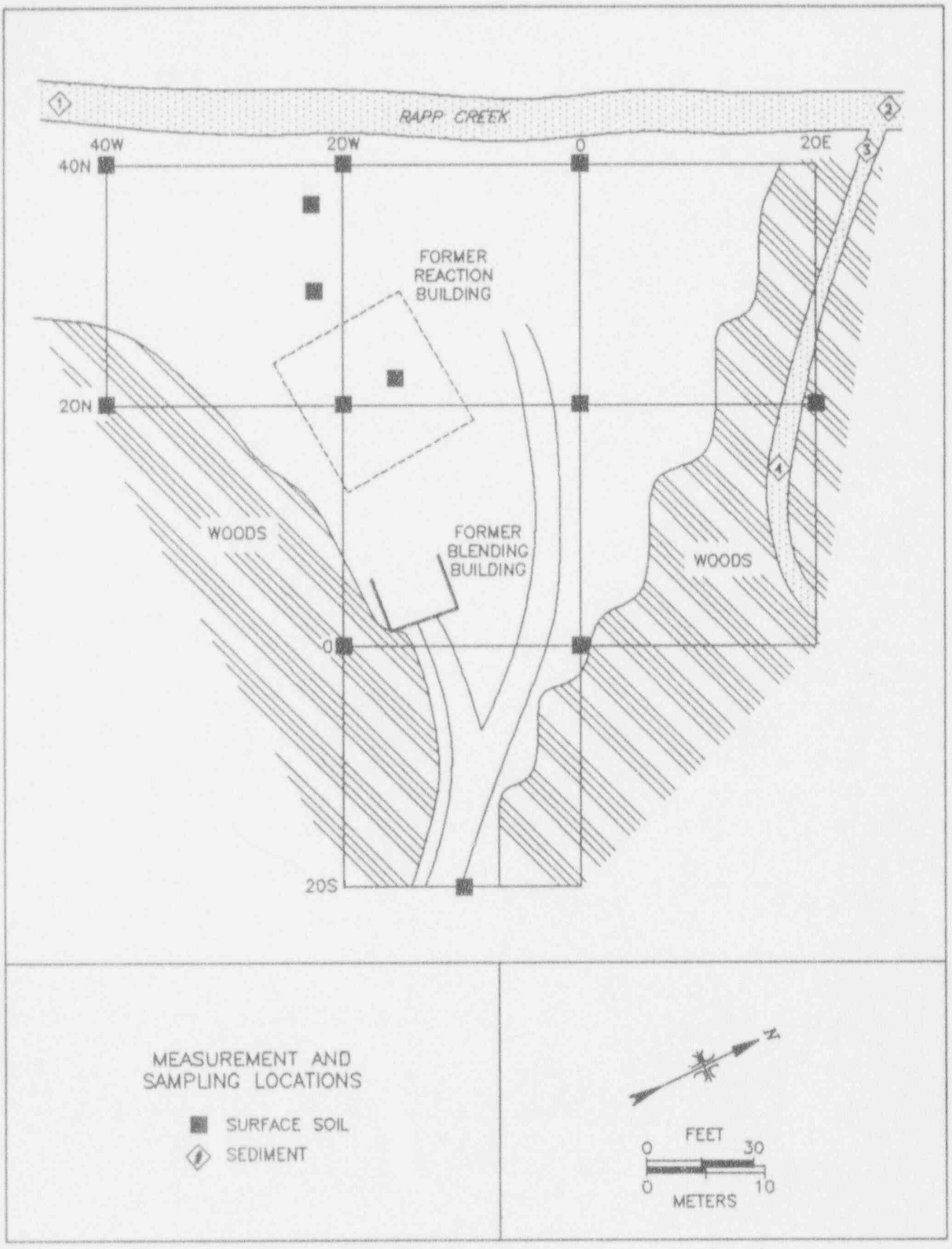

FIGURE 3: Old Pit – Measurement and Sampling Locations

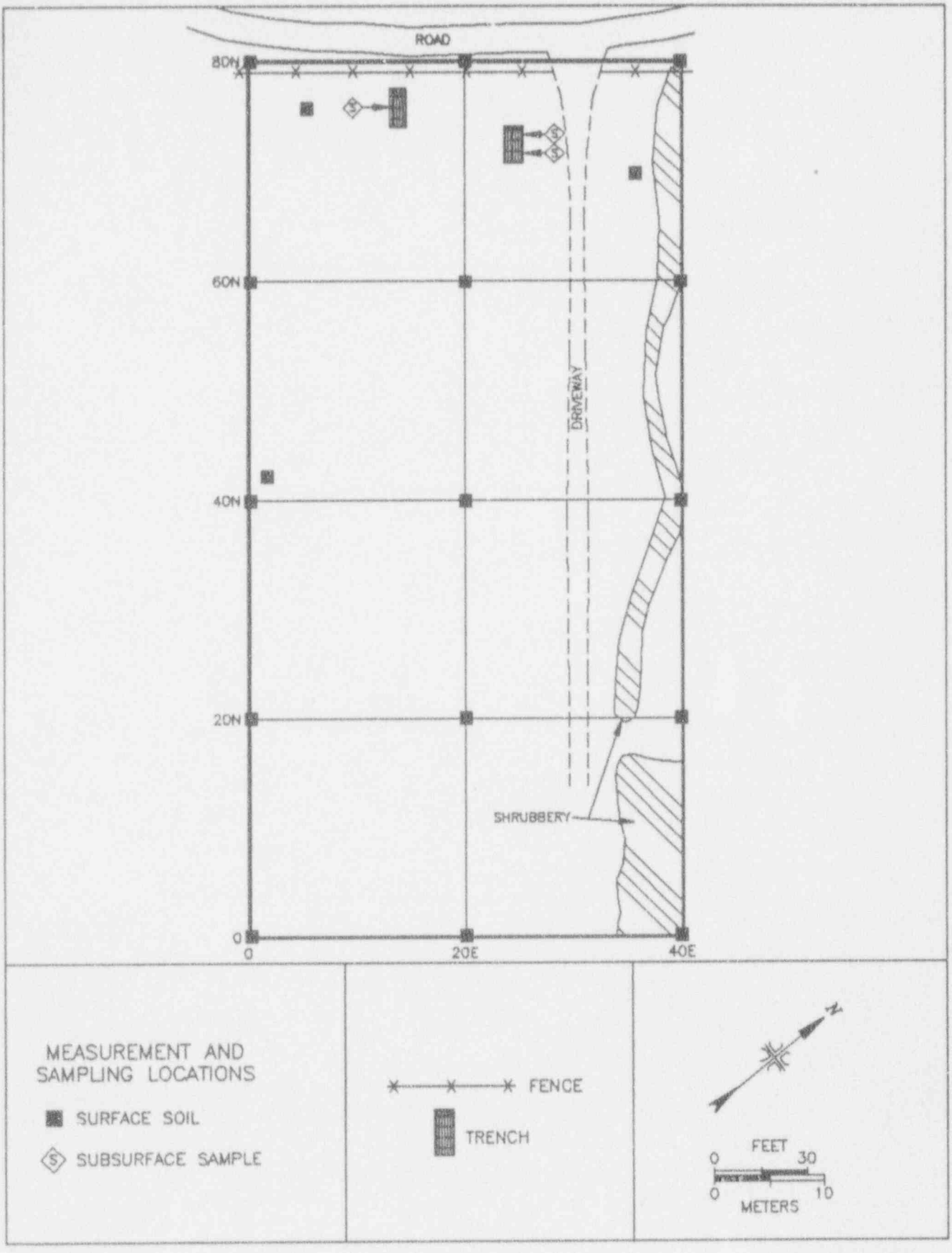

FIGURE 4: Drum Storage Area – Measurement and Sampling Locations

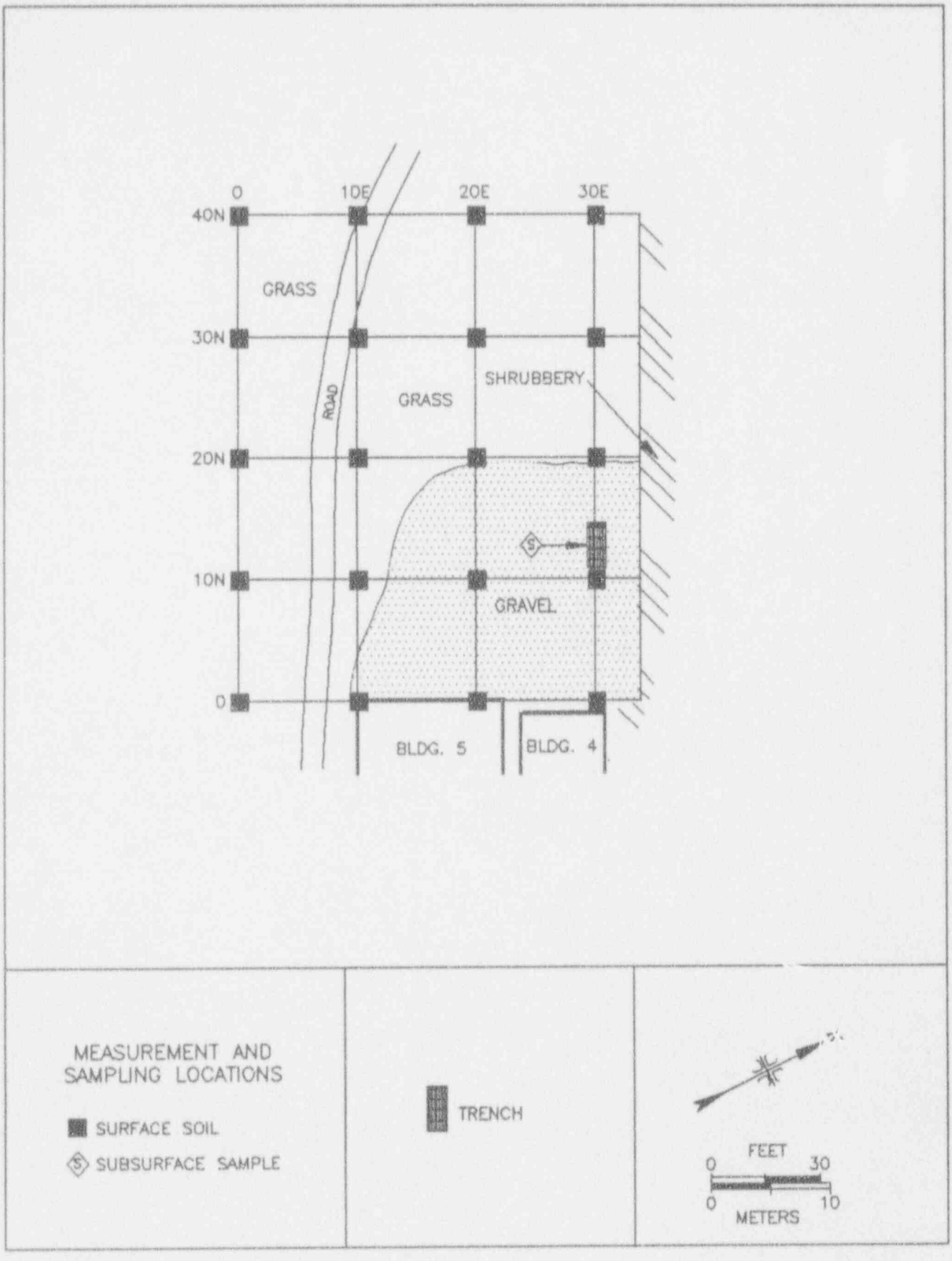

FIGURE 5: Buildings 4 and 5 Storage Area – Measurement and Sampling Locations

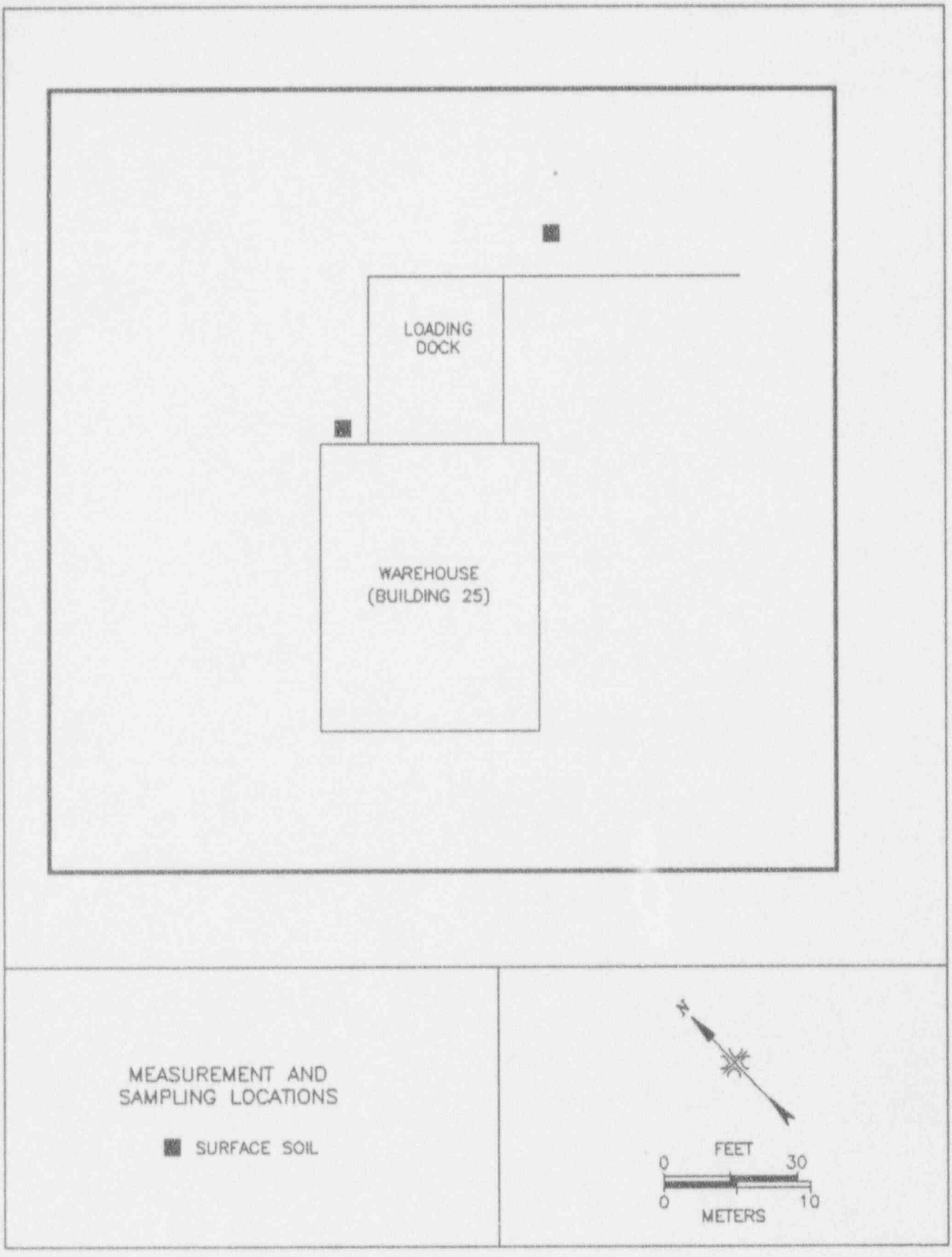

FIGURE 6: Warehouse – Measurement and Sampling Locations

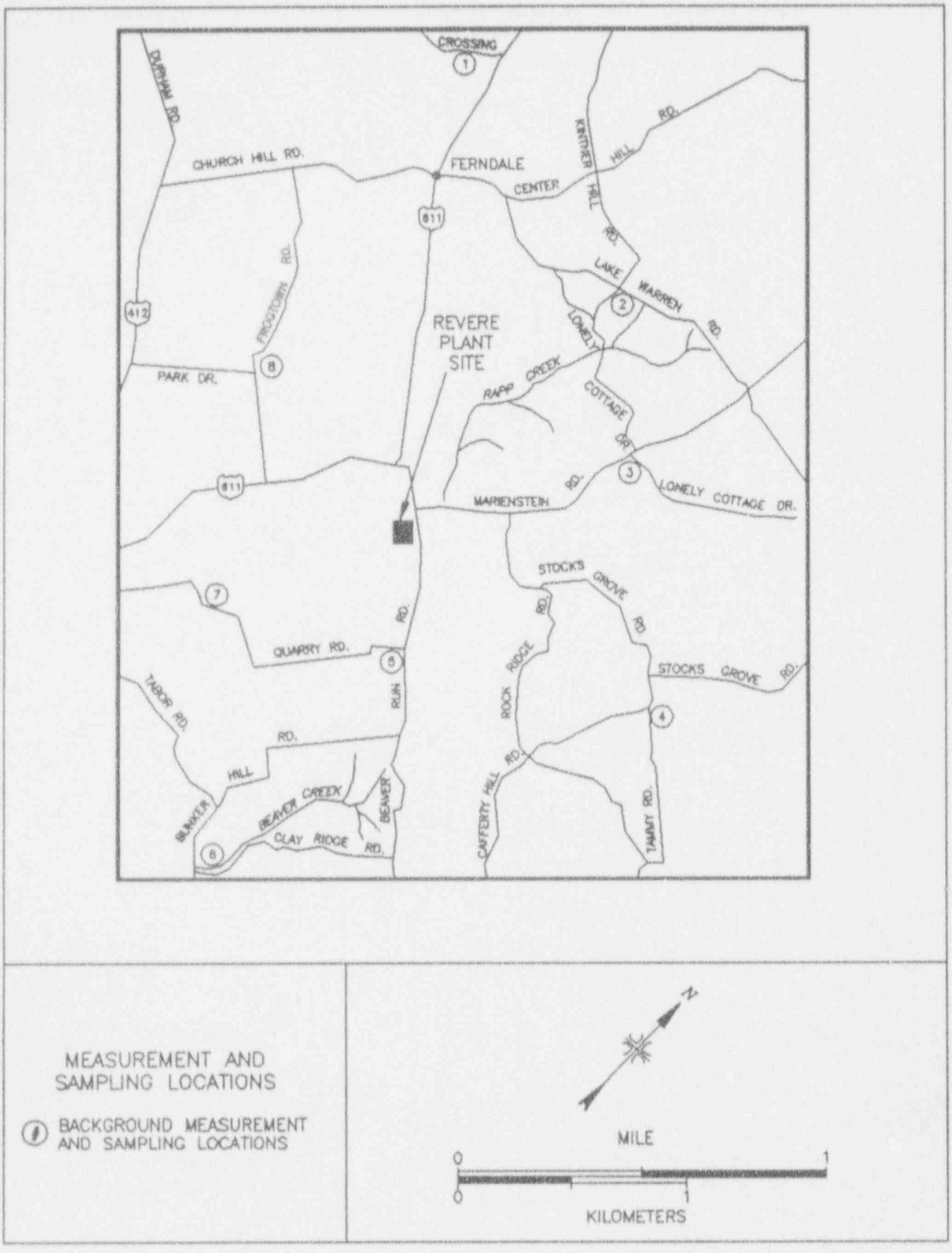

FIGURE 7: Revere Plant – Background Measurement and Sampling Locations

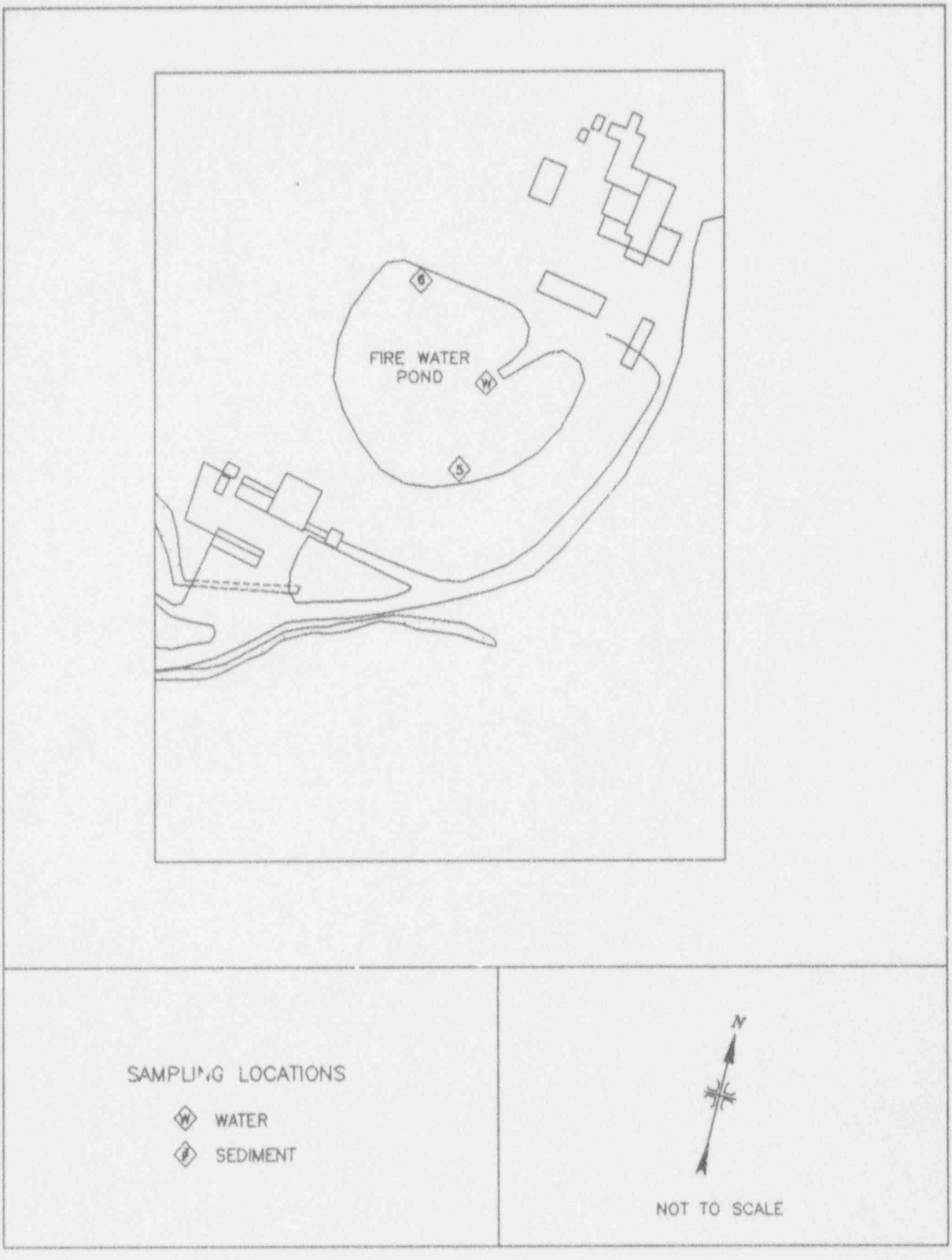

FIGURE 8: Fire Water Pond – Sampling Locations

TABLE 1

BACKGROUND RADIATION LEVELS AND BASELINE URANIUM AND THORIUM CONCENTRATIONS IN SOIL CABOT CORPORATION REVERE PLANT REVERE, PENNSYLVANIA

Location[a] (distance from site)	Exposure Rate (μR/h) at 1 m above Surface	Concentration (pCi/g)	
		Total U	Total Th
1 (4 Km)	10	1.7	1.2
2 (2.1 Km)	5	3.1	1.3
3 (2 Km)	6	1.9	1.6
4 (2.7 Km)	6	5.0	2.2
5 (1.1 Km)	8	4.2	1.6
6 (3.4 Km)	11	3.8	1.6
7 (1.2 Km)	11	2.1	1.8
8 (1.9 Km)	9	<4.0	2.3

[a]Refer to Figure 7.

TABLE 2

RESULTS OF ANALYSES TO DETERMINE URANIUM AND THORIUM EQUILIBRIUM
CABOT CORPORATION REVERE PLANT
REVERE, PENNSYLVANIA

Radionuclide	Sample Concentration (pCi/g)					
	Background Soil Location	Old Pit Soil Grid 40N, 0	Drum Storage Soil Grid 20N, 0	Bldg. 4&5 Soil Grid 40N, 10E	Warehouse Slag[a] North Corner	Drum Storage Slag 75N, 24E[a]
Thorium Series						
Ac-228	0.6 ± 0.2[c]	1.3 ± 0.3	1.5 ± 0.4	1.3 ± 0.4	1450 ± 290	1061 ± 7
Pb-212	0.6 ± 0.5	1.0 ± 0.1	1.2 ± 0.2	1.4 ± 0.2	1290 ± 90	1034 ± 3
Bi-212	<0.7	0.9 ± 0.4	0.3 ± 0.6	1.3 ± 0.7	1160 ± 380	650 ± 13
Tl-208[b]	0.2 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	474 ± 55	410 ± 2
Uranium Series						
Th-234	0.8 ± 0.5	2.0 ± 0.8	2.2 ± 2.0	3.0 ± 1.3	N/D[d]	N/D
Pu-234 m	<9.3	<11	<17	<15	9600 ± 6500	110 ± 80
Bi-214	0.5 ± 0.2	1.4 ± 0.2	1.0 ± 0.3	0.9 ± 0.2	13600 ± 290	75 ± 3
Pb-214	0.5 ± 0.1	1.3 ± 0.2	1.0 ± 0.2	0.9 ± 0.2	13300 ± 260	75 ± 3
U-235	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	500 ± 240	9.7 ± 1.4

[a]Non-standard geometry; data considered approximate.
[b]Concentrations of Tl-208 are approximately 1/3 of other series nuclides, due to branching of decay modes of the Tl-208 precursor, Bi-212.
[c]Uncertainties represent the 95% confidence level, based only on counting statistics.
[d]Not determined; Th-234 analysis not dependable, due to interferences by gamma photons from the Th-232 series.

TABLE 3

SUMMARY OF URANIUM AND THORIUM CONCENTRATIONS IN SYSTEMATIC SOIL SAMPLES CABOT CORPORATION REVERE PLANT REVERE, PENNSYLVANIA

Location	Figure Number	Exposure Rate (μR/h) at 1 m above Surface	Concentration (pCi/g)	
			Total U	Total Th
Old Pit				
20 S, 10 W	3	11	0.3	2.5
0, 0	3	11	3.9	2.5
0, 20 W	3	10	4.7	2.6
20 N, 10 E	3	11	4.2	2.6
20 N, 0	3	6	1.1	<0.6
20 N, 20 W	3	9	3.7	1.6
40 N, 20 E	3	10	<4.8	2.4
40 N, 0	3	11	4.5	2.7
40 N, 20 W	3	11	2.9	1.1
40 N, 40 W	3	9	1.9	2.5
Drum Storage Area				
0, 0	4	9	5.4	2.5
0, 20 E	4	9	5.0	2.7
0, 40 E	4	9	<4.0	3.0
20 N, 0	4	9	6.5	2.9
20 N, 20 E	4	7	<2.6	0.8
20 N, 40 E	4	9	3.8	2.8
40 N, 0	4	9	2.3	1.3
40 N, 20 E	4	9	3.2	2.3
40 N, 40 E	4	10	3.2	2.3

TABLE 3 (Continued)

SUMMARY OF URANIUM AND THORIUM CONCENTRATIONS
IN SYSTEMATIC SOIL SAMPLES
CABOT CORPORATION REVERE PLANT
REVERE, PENNSYLVANIA

Location	Figure Number	Exposure Rate (μR/h) at 1 m above Surface	Concentration (pCi/g)	
			Total U	Total Th
Drum Storage Area				
60 N, 0	4	9	1.9	1.3
60 N, 20 E	4	11	4.1	2.7
60 N, 40 E	4	10	4.2	2.9
80 N, 0 E	4	9	3.8	1.5
80 N, 20 E	4	10	5.7	2.3
80 N, 40 E	4	10	<5.2	2.8
Buildings 4 & 5 Storage Area				
0, 0	5	9	4.3	2.5
0, 10 E	5	10	2.5	2.3
0, 20 E	5	10	13	15
0, 30 E	5	9	2.2	2.4
10 N, 0	5	9	5.3	1.7
10 N, 10 E	5	10	2.6	1.6
10 N, 20 E	5	9	2.9	2.9
10 N, 30 E	5	9	3.9	4.7
20 N, 0	5	9	2.5	2.6
20 N, 10 E	5	9	2.1	2.6
20 N, 20 E	5	9	4.7	3.2
20 N, 30 E	5	9	4.3	3.2

TABLE 3 (Continued)

SUMMARY OF URANIUM AND THORIUM CONCENTRATIONS
IN SYSTEMATIC SOIL SAMPLES
CABOT CORPORATION REVERE PLANT
REVERE, PENNSYLVANIA

Location	Figure Numbers	Exposure Rate (μR/h) at 1 m above Surface	Concentration (pCi/g)	
			Total U	Total Th
Buildings 4 & 5 Storage Area 30 N, 0	5	9	3.3	2.9
30 N, 10 E	5	9	5.5	2.6
30 N, 20 E	5	9	3.8	2.6
30 N, 30 E	5	9	3.9	3.3
40 N, 0	5	10	4.4	3.2
40 N, 10 E	5	9	6.1	2.4
40 N, 20 E	5	9	3.7	2.9
40 N, 30 E	5	9	<3.4	2.7

TABLE 4

SUMMARY OF URANIUM AND THORIUM CONCENTRATIONS
IN SOIL SAMPLES
FROM AREAS OF ELEVATED DIRECT RADIATION
CABOT CORPORATION REVERE PLANT
REVERE, PENNSYLVANIA

Location	Figure Numbers	Exposure Rate (μR/h) at 1 m above Surface	Concentration (pCi/g)	
			Total U	Total Th
Old Pit				
22 N, 15 W	3	19	2.9	1.6
30 N, 25 W	3	14	3.9	2.4
36 N, 24 W	3	14	3.9	2.8
Drum Storage Area				
44N, 3 E	4	10	4.6	1.5
70 N, 35 E	4	10	4.1	1.4
78 N, 5 E	4	14	8.2	5.3
Warehouse				
SE Corner of Loading Dock	6	18	21	15
N Corner of Loading Dock[a]	6	18[b]	10000[b]	2900[b]

[a]Sample was a small piece of rock.
[b]Approximation due to non-standard counting geometry.

TABLE 5

SUMMARY OF URANIUM AND THORIUM CONCENTRATIONS IN SUBSURFACE SAMPLES CABOT CORPORATION REVERE PLANT REVERE, PENNSYLVANIA

Location	Figure Numbers	Type[a]	Concentration (pCi/g)	
			Total U	Total Th
Drum Storage Area 75 N, 15 E	4	S	4.7	2.4
75 N, 24 E	4	SG	20	3.5
75 N, 24 E	4	SG	160[b]	2200[b]
Buildings 4 & 5 Storage Area 11N, 30 E	5	S	4.5	2.6

[a]S = Soil; SG = Slag.

[b]Approximation, due to non-standard counting geometry.

TABLE 6

SUMMARY OF URANIUM AND THORIUM CONCENTRATIONS IN SEDIMENT SAMPLES CABOT CORPORATION REVERE PLANT REVERE, PENNSYLVANIA

Location	Figure #	Concentration (pCi/g)	
		Total U	Total Th
# 1 - Old Pit	3	3.0	2.1
# 2 - Old Pit	3	0.3	2.3
# 3 - Old Pit	3	0.6	1.8
# 4 - Old Pit	3	1.2	1.6
# 5 - Fire Water Pond	8	0.6	2.6
# 6 - Fire Water Pond	8	0.6	2.0

REFERENCES

1. "Final Decontamination and Decommissioning Survey - 1990 for NRC License SMB-920, Docket 40-6940, "Cabot Corporation Revere Pennsylvania Plant, January 1991.

2. Gannon, W. letter to K. McDaniel, Division of Industrial and Medical Nuclear Safety, U.S. Nuclear Regulatory Commission, Dated March 5, 1991.

APPENDIX A

MAJOR INSTRUMENTATION

APPENDIX A
MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or their employers.

DIRECT RADIATION MEASUREMENT

Instruments

Eberline Pulse Ratemeter
Model PRM-6
(Eberline, Santa Fe, NM)

Eberline "Rascal" Ratemeter-Scaler
Model PRS-1
(Eberline, Santa Fe, NM)

Ludlum Ratemeter-Scaler
Model 2221
(Ludlum Measurements, Inc.,
Sweetwater, TX)

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

Detectors

Eberline GM Detector
Model HP-260
Effective Area, 15.5 cm^2
(Eberline, Santa Fe, NM)

Ludlum Gas Proportional Detector
Model 43-68
Effective Area, 100 cm^2
(Ludlum Measurements, Inc.,
Sweetwater, TX)

Victoreen NaI Scintillation Detector
Model 489-55
3.2 cm x 3.8 cm Crystal
(Victoreen, Cleveland, OH)

LABORATORY ANALYTICAL INSTRUMENTATION

Low Background Gas Proportional Counter
Model LB-5110
(Tennelec, Oak Ridge, TN)

High Purity Germanium Coaxial Well Detector
Model GWL-1102010-PWS-S, 23% efficiency
(EG&G ORTEC, Oak Ridge, TN)
Used in conjunction with:
Lead Shield Model G-16
(Applied Physical Technology, Atlanta, GA)
and
Multichannel Analyzer
ND-66/Micro Vax
(Nuclear Data, Schaumburg, IL/Digital Equipment Corp., Maynard, MA)

APPENDIX B

SURVEY AND ANALYTICAL PROCEDURES

APPENDIX B

SURVEY AND ANALYTICAL PROCEDURES

SURVEY PROCEDURES

Surface Scans

Surface scans were performed by passing the probes slowly over the surface; the distance between the probe and the surface was maintained at a minimum - nominally about 1 cm. Identification of elevated levels was based on increases in the audible signal from the recording or indicating instrument. Combinations of detectors and instruments used for the scans were:

Alpha	-	gas proportional detector with ratemeter-scaler
Beta	-	GM detector with ratemeter-scaler
Gamma	-	NaI scintillation detector with ratemeter

Exposure Rate Measurements

Measurements of gamma exposure rates were performed using a pressurized ionization chamber (PIC) or NaI(Tl) scintillation detectors, coupled to portable ratemeters. NaI(Tl) detectors were cross-calibrated with the PIC on-site and a calibration curve was developed from the site data. Count rates for the NaI(Tl) scintillation detectors measurements were then converted to exposure rates (μR/h).

Soil Sampling

Approximately 1 kg of soil was collected at each sample location. Collected samples were placed in a plastic bag, sealed, and labeled in accordance with ESSAP survey procedures.

Sediment Sampling

Approximately 1 kg of sediment was collected at each sample location. Collected samples were placed in a plastic container, sealed and labeled in accordance with ESSAP survey procedures.

Water Sampling

Approximately 3.8 liters of water was collected from each sample location. The samples were transferred to a plastic container, sealed, and labeled in accordance with ESSAP survey procedures.

ANALYTICAL PROCEDURES

Gamma Spectrometry

Soil, sediment, and slag samples were dried, mixed, and/or crushed then placed in an appropriate container chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using high purity intrinsic germanium detectors coupled to a Nuclear Data Model ND-66/Micro VaxII 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. The following gamma emitters from the natural thorium series were quantified:

0.911 MeV from Ac-228
0.583 MeV from Tl-208
0.238 MeV from Pb-212
0.727 MeV from Bi-212

The relative ratios of these radionuclides were compared for a portion of the samples to demonstrate that the Th-232 series is in secular equilibrium at this site.

The following gamma emitters from natural uranium were quantified:

0.093 MeV from Th-234
0.143 MeV from U-235
0.609 MeV from Bi-214
0.351 MeV from Pb-214
1.001 MeV from Pa-234 m

The relative ratios of these radionuclides were compared for a portion of the samples to demonstrate that the U-238 series is in secular equilibrium at this site.

Spectra were also reviewed for other identifiable photopeaks at concentrations above those normally encountered in environmental media.

Water Samples

A known volume of water was acidified with dilute nitric acid, concentrated and dried in a planchet. Samples were counted in a low-background proportional counter.

UNCERTAINTIES AND DETECTION LIMITS

The uncertainties associated with the analytical data presented in the tables of this report represent the 95% confidence level 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 $[2.71 + 4.66\sqrt{Bkgd}]$, the sample concentration was reported as less than the detection limit of the measurement procedures. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument. Additional

uncertainties, associated with sampling and measurement procedures, have not been propagated into the data presented in this report.

CALIBRATION AND QUALITY ASSURANCE

Analytical and field survey activities were conducted in accordance with procedures from the following documents:

- Survey Procedures Manual, Revision 6 (February 1991)
- Laboratory Procedures Manual, Revision 6 (April 1991)
- Quality Assurance Manual, Revision 4 (April 1991)

The procedures contained in these manuals were developed to meet the requirements of ANSI/ASME Nuclear Quality Assurance-1 (NQA-1) and DOE Order 5700.6B for Quality Assurance and contain measures to assess processes during their performance.

Calibration of all field and laboratory instrumentation was based on standards/sources, traceable to NIST, when such standards/sources were available. Portable alpha and beta survey instruments, used for scanning surfaces for presence of residual activity, were calibrated using Th-230 and Tc-99 standards, respectively. The gamma scanning detector was not calibrated for detection efficiency, but response to a Co-60 gamma source was confirmed. Gamma scintillation detectors were also cross-calibrated against a pressurized ionization chamber (which was itself calibrated for a wide range of gamma energies by the manufacturer) and then used for measurement of gamma exposure rates at some site locations.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in EPA and EML laboratory Quality Assurance Programs.

- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

APPENDIX C

GUIDELINES FOR DECONTAMINATION OF FACILITIES AND EQUIPMENT PRIOR TO RELEASE FOR UNRESTRICTED USE OR TERMINATION OF LICENSES FOR BYPRODUCT, SOURCE OR SPECIAL NUCLEAR MATERIALS

AND

GUIDELINES FOR RESIDUAL CONCENTRATIONS OF THORIUM AND URANIUM WASTES IN SOIL

GUIDELINES FOR DECONTAMINATION OF FACILITIES AND EQUIPMENT PRIOR TO RELEASE FOR UNRESTRICTED USE OR TERMINATION OF LICENSES FOR BYPRODUCT, SOURCE, OR SPECIAL NUCLEAR MATERIALS

U.S. Nuclear Regulatory Commission
Division of Fuel Cycle & Material Safety
Washington, D.C. 20555

August 1987

The instructions in this guide, in conjunction with Table 1, specify the radionuclides and radiation exposure rate limits which should be used in decontamination and survey of surfaces or premises and equipment prior to abandonment or release for unrestricted use. The limits in Table 1 do not apply to premises, equipment, or scrap containing induced radioactivity for which the radiological considerations pertinent to their use may be different. The release of such facilities or items from regulatory control is considered on a case-by-case basis.

1. The licensee shall make a reasonable effort to eliminate residual contamination.

2. Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the limits specified in Table 1 prior to the application of the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.

3. The radioactivity on the interior surfaces of pipes, drain lines, or ductwork shall be determined by making measurements at all traps, and other appropriate access points, provided that contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or ductwork. Surfaces or premises, equipment, or scrap which are likely to be contaminated, but are such size, construction, or location as to make the surface inaccessible for purposes of measurement, shall be presumed to be contaminated in excess of the limits.

4. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated with materials in excess of the limits specified. This may include, but would not be limited to special circumstances such as razing of buildings, transfer from premises to another organization continuing work with radioactive materials, or conversion of facilities to a long-term storage or standby status. Such requests must:

    a. Provide detailed, specific information describing the premises, equipment or scrap, radioactive contaminants, and the nature, extent, and degree of residual surface contamination.

    b. Provide a detailed health and safety analysis which reflects that the residual amounts of materials on surface areas, together with other considerations such as prospective use of the premises, equipment, or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table 1. A copy of the survey report shall be filed with the Division of Fuel Cycle, Medical, Academic, and Commercial Use Safety, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, and also the Administrator of the NRC Regional Office having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:

   a. Identify the premises.

   b. Show that reasonable effort has been made to eliminate residual contamination.

   c. Describe the scope of the survey and general procedures followed.

   d. State the findings of the survey in units specified in the instruction.

   Following review of the report, the NRC will consider visiting the facilities to confirm the survey.

TABLE 1
ACCEPTABLE SURFACE CONTAMINATION LEVELS

Nuclides[a]	Average[b,c,f]	Maximum[b,d,f]	Removable[b,e,f]
U-nat, U-235, U-238, and associated decay products	5,000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1,000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm^2	300 dpm/100 cm^2	20 dpm/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000 dpm/100 cm^2	3,000 dpm/100 cm^2	200 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5,000 dpm $\beta\gamma$/100 cm^2	15,000 dpm $\beta\gamma$/100 cm^2	1,000 dpm $\beta\gamma$/100 cm^2

[a]Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

[b]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.

[c]Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

[d]The maximum contamination level applies to an area of not more than 100 cm^2.

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

[f]The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

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 established 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 dose to 170 mrem/yr.
[c]Based on limiting equivalent exposure to 0.02 working level or less.
[d]Based on limiting individual dose to 500 mrem/yr and in case of natural uranium, limiting exposure to 0.02 working level or less.