Prepared by
Oak Ridge Associated Universities

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

Supported by
Safeguards and Materials Program Branch;
Division of Quality Assurance, Safeguards, and Inspection Programs;
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RADIOLOGICAL SURVEY OF THE TEXAS INSTRUMENTS SITE ATTLEBORO, MASSACHUSETTS

L. L. SOWELL

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

FINAL REPORT

January 1985

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Oak Ridge Associated Universities
Post Office Box 117
Oak Ridge, Tennessee 37830

Manpower Education, Research, and Training Division

February 12, 1985

Mr. Jerry Roth
Nuclear Regulatory Commission
Region I
631 Park Avenue
King of Prussia, PA 19406

Dear Mr. Roth:

Enclosed are two copies of the Final Report on the Radiological Survey of the Texas Instruments Site, Attleboro, Massachusetts.

If you should have any questions, please telephone me at FTS 626-3305.

Sincerely,

Jim Berger /ss

James D. Berger, Program Manager
Radiological Site Assessment Program

JDB:sds

Enclosures (2)

cc: Jerry Counts (NRC - Safeguards & Mat. Program Branch)
William Boyle (ORAU - MERT/DIV)
Roger Cloutier (ORAU - MERT/PTP)

RSAP/SMPB-8

RADIOLOGICAL SURVEY
OF THE
TEXAS INSTRUMENTS SITE
ATTLEBORO, MASSACHUSETTS

Prepared for

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Supported by:
Safeguards and Materials Program Branch
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L. L. SOWELL*

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Radiological Site Assessment Program
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Oak Ridge Associated Universities
Oak Ridge, Tennessee 37831-0117

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*Presently with Energetics, Inc., Philadelphia, PA

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RADIOLOGICAL SURVEY
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ATTLEBORO, MA

INTRODUCTION AND SITE HISTORY

The Texas Instruments, Inc., Attleboro, MA, site was owned and operated by Metals & Controls, Inc. (M & C) until 1959, at which time M & C merged with Texas Instruments, Inc. The General Plate Division of M & C began processing nuclear materials in 1952, and between 1952 and 1959 fabricated uranium foils for reactor experiments and fuel components and complete reactor fuel cores for the U.S. Navy. Source material license D-549 was issued permitting acquisition and title to not more than 22.7 kg (50 pounds) of refined source material for use in the production of the uranium foils; and special nuclear materials license No. SNM-23 was issued, permitting acquisition and title to 110 kg of enriched uranium for fabrication of the fuel components and cores. After the merger in 1959, Texas Instruments continued fabricating reactor fuel cores, primarily for research and production reactors. Also, source materials, i.e. natural uranium and thorium, were still being fabricated for sale to various corporations.

A 1964 Texas Instruments health and safety manual states that uranium - and thorium - contaminated noncombustible scrap material and machinery were collected in 55-gallon steel drums and were disposed of through authorized agencies, or were buried on-site in compliance with 10CFR20.304. Burials were made from 1958 to 1961, and the burial site was closed in 1967. Records indicate two known burials, one in 1958 of contaminated ductwork, and one in 1961 of 28.4 mCi of enriched uranium noncombustible scrap. Work with nuclear materials was gradually reduced beginning in 1968 and was terminated in 1974. The interior of the facility was decontaminated and released for unrestricted use by the Nuclear Regulatory Commission (NRC) in 1983. Two outdoor areas were identified as being contaminated: the burial site situated near Building 12, and soil around the loading dock of the main processing area, Building 10.

A survey to assess the radiological conditions on the property was conducted by Texas Instruments personnel from December 1981 through October 1982, and a report was released in January 1983. This report indicates that the facility meets the NRC criteria for release for unrestricted use. Texas Instruments has requested termination of NRC license SNM-23. At the request of the NRC, a radiological survey of portions of the Texas Instruments site was conducted during April and May 1984, by the Radiological Site Assessment Program of the Oak Ridge Associated Universities (ORAU), Oak Ridge, Tennessee. This report presents the findings of that survey.

SITE DESCRIPTION

The Texas Instruments Inc., Attleboro, MA, site is located in North Attleboro, approximately 48 kilometers south of Boston on Route 123 (see Figure 1). There were two areas of the site which were of concern, the burial site located to the southwest of Building 12 (see Figure 2) and the outdoor area surrounding Building 10 (see Figure 3).

The burial site covers approximately 1.1 hectares and is described as being at least 1.2 m deep and covered with a soil cap of unknown thickness. There is no indication that any liner material was used or that any natural liner exists. The site was disturbed during construction of Building 12, and contaminated soil from the burial area may have been distributed over the construction site. For this reason, the area to be surveyed was expanded to approximately 6.1 hectares. This area is fairly level and clear of obstructions, and is bounded by a bog and a pond on the north side.

An area extending approximately 20-30 m out from Building 10 is level, with the only obstructions being dumpsters used for collection of scrap metal along the southwest side of the building.

SURVEY PROCEDURES

Objective

The objective of this survey was to provide a comprehensive assessment of the radiological conditions of the two areas of interest, and included the following:

1. measurement of direct radiation levels.

2. measurement of radionuclide concentrations in surface and subsurface soil.

3. determination of specific locations and depths of buried material.

4. evaluation of radionuclide migration from burial trenches.

Procedures - Building 12 Burial Area

1. A 10 m grid system was established over a 6.1 hectare area, and was subdivided into 5 m grid blocks over the 1.1 hectare suspected burial area (see Figure 4). This work was performed under subcontract by Allen & Demurjian, Inc. of Boston, MA.

2. A walkover surface scan using portable NaI(Tl) gamma scintillation detectors was conducted at 1-2 m intervals over the entire gridded area. Locations of elevated contact radiation levels were noted and are shown on Figure 5.

3. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at every other grid intersection from 50N to 110N, at every grid intersection from 120N to 250N, and at locations of elevated contact radiation levels as identified by the walkover surface scan. These measurements were performed using portable NaI(Tl) gamma scintillation detectors and ratemeters, cross calibrated on-site with a pressurized ionization chamber.

4. Beta-gamma dose rate measurements were made at 1 cm above the surface at each of the locations where exposure rates were measured. These measurements were conducted using thin window (<7 mg/cm^2) "Pancake" G-M detectors with scaler/ratemeters. Measurements were also made with the detector shielded to evaluate contributions of nonpenetrating beta and low-energy gamma radiations.

5. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at every other grid intersection from 50N to 110N, and at every grid intersection from 120N to 250N.

6. Soil samples were collected from various shallow depths (0-40 cm) at locations of elevated contact radiation levels as identified by the walkover surface scan (see Figure 5).

7. A ground penetrating radar survey was performed under subcontract by Detection Sciences Group, Carlisle, MA. This survey technique and the results are described in the radar survey report included as Appendix A.

8. Twenty-five boreholes were drilled in the burial area at locations indicated on Figure 6. Drilling was performed under subcontract by Guild Drill Company of East Providence, R.I. Boreholes B1-B9 were drilled on the perimeter of the suspected burial area, and were drilled to refusal (2.0-3.5 m). Boreholes B10 and B11 were drilled outside of the suspected burial area, and boreholes B12-B25 were drilled into the suspected burial area. The locations of boreholes B10-B25 were based on ground radar survey results and on the analysis of soil samples collected from locations of elevated contact radiation levels.

   Radiation profiles of the boreholes were determined by measuring gamma radiation at 30 cm intervals from the surface to the bottom of the hole, using a collimated NaI(Tl) gamma scintillation detector and a portable scaler.

Ground water samples were collected from twelve of the boreholes.

Soil samples were collected from various depths in each borehole using a split spoon sampler driven through the center of the hollow stem auger.

9. Surface water samples were collected from two bogs on the northeast side of Building 12.

10. Five surface soil and water samples were collected from the Attleboro area (but not on or near Texas Instruments property) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured at the locations where baseline samples were collected. These locations are shown on Figure 7.

Procedures - Building 10 Area

1. A 20 m grid system was established around Building 10. This system, shown on Figure 8, was subdivided into 5 m sections along the southwest side of the building, where the licensee had identified soil contamination during earlier cleanup operations.

2. A walkover surface scan using portable NaI(Tl) gamma scintillation detectors was conducted at 1-2 m intervals over the gridded area. Locations of elevated contact radiation levels were noted and are shown on Figure 9.

3. Gamma exposure rate measurements were performed at the surface and at 1 m above the surface, at each grid line intersection, and at locations of elevated contact radiation levels as identified by the walkover scan. Measurements were performed using portable NaI(Tl) gamma scintillation detectors and ratemeters, cross calibrated on-site with a pressurized ionization chamber.

4. Beta-gamma dose rate measurements were made at 1 cm above the surface at each of the locations where exposure rates were measured. These measurements were made using thin window (<7 mg/cm^2) "Pancake" G-M detectors with scaler/ratemeters. Measurements were also made with the detector shielded to evaluate contributions of nonpenetrating beta and low-energy gamma radiations.

5. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at each grid line intersection and at locations of elevated contact radiation levels as identified by the walkover scan.

6. Eight boreholes were drilled: three at locations of elevated contact radiation levels, three at random locations, and one on either side of the loading dock. The locations of these boreholes are shown on Figure 10.

   Radiation profiles of the boreholes were determined by measuring gamma radiation at 30 cm intervals from the surface to the bottom of the hole, using a collimated NaI(Tl) gamma scintillation detector and a portable scaler.

7. Ground water samples were collected from four of the boreholes.

8. Soil samples were collected from various depths in each borehole using a split spoon sampler driven through the center of the hollow stem auger.

Sample Analysis and Interpretation of Results

Soil samples were analyzed by gamma spectrometry and radionuclides of interest included U-238, U-235, Th-232, and Ra-226. Isotopic uranium analyses were performed on selected soil samples having elevated concentrations of U-235 or U-238.

Water samples were analyzed for gross alpha and beta concentrations and an isotopic analysis was performed on one water sample which exceeded the Environmental Protection Agency (EPA) drinking water standards.

Additional information concerning analytical equipment and procedures is contained in Appendix B.

Results of this survey were compared to the NRC guidelines for disposal or on-site storage of residual thorium or uranium from past operations. (Refer to Appendix C.)

RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and dose rates and baseline radionuclide concentrations in soil and water, determined for five locations in the vicinity of Texas Instruments are presented in Tables 1A, 1B, and 1C. Exposure rates ranged from 10-11 μR/h, both at contact and at 1 m above the surface. Dose rates measured at the surface ranged from 21 to 31 μrad/h. Concentration ranges of radionuclides in soil were: U-235, <0.11 to <0.34 pCi/g (picocuries per gram); U-238, <0.78 to 2.74 pCi/g; Th-232, 0.54 to 1.23 pCi/g; and Ra-226, 0.41 to 0.84 pCi/g. Gross alpha and gross beta concentrations in water ranged from <0.32 to 0.59 pCi/l (picocuries per liter) and 1.42 to 3.07 pCi/l, respectively. These levels and concentrations are typical of those normally occurring in nature.

Results - Building 12 Burial Area

Direct Measurements

Direct radiation levels measured at grid line intersections are presented in Table 2. The gamma exposure rates measured at 1 m above the surface ranged from 10 to 13 μR/h (average 11 μR/h). At surface contact, the exposure rates ranged from 10 to 14 μR/h (average 11 μR/h). Beta-gamma dose rates ranged from 10 to 56 μR/h (average 20 μrad/h). Measurements performed with the detector shielded were not significantly different from those with the unshielded detector. This indicates only a small portion of the surface dose rate is due to nonpenetrating beta or low-energy photon radiations. The exposure rates and dose rates were only slightly higher in the five meter grid (suspected burial) area than in the ten meter grid.

The walkover survey identified numerous small areas with slightly elevated surface radiation levels. These locations are indicated on Figure 5 and direct radiation levels at these locations are presented in Table 3. Contact gamma exposure rates ranged from 16 to 200 μR/h. Gamma exposure rates at 1 m above the surface and beta-gamma dose rates ranged from 11 to 16 μR/h and 18 to 290 μrad/h, respectively. Soil samples were collected at 20 of these locations. Sampling at 12 locations resulted in a decrease in contact exposure rates, suggesting that the contamination at these points was in small discrete deposits and was removed with the sample. Contact exposure rates remained the same after soil sample removal from two locations and increased after soil sample removal from six locations, suggesting the possibility of more diffuse or deeper contamination.

At some locations of elevated contact radiation levels pieces of debris such as slag, metal scrap, rocks, and a pellet were found. In many cases, contact radiation levels decreased to background levels upon removal of such debris.

Radionuclide Concentrations In Surface Soil

Table 4 lists the concentrations of radionuclides measured in surface soil collected at grid line intersections. These samples contained U-235 concentrations ranging from <0.11 to 8.15 pCi/g. The highest level was in the sample from grid point 235N, 165E. Concentrations of U-238 ranged from <0.38 to 44.9 pCi/g; the highest level was from grid point 165N, 125E. Thorium 232 concentrations ranged from 0.13 to 3.56 pCi/g; Radium 226 concentrations ranged from 0.11 to 1.86 pCi/g. The highest concentrations of these two radionuclides were from grid points 195N,115E and 200N,230E, respectively. Radionuclide concentrations in the majority of the samples were within the range encountered in baseline samples; the samples with higher concentrations were collected in the suspected burial area.

Table 5A lists the concentrations of radionuclides measured in soil collected from locations of elevated contact radiation levels. Concentrations of U-235 ranged from <1.78 to 590 pCi/g. The maximum level was in the sample collected at 185N, 149E. Concentrations of U-238 ranged from <46.6 to 887 pCi/g; the maximum level was found in the sample collected at 154N, 111E. Thorium 232 concentrations ranged from 1.04 to 10.2 pCi/g; the maximum level was found in the sample collected at 170N, 129E. Radium 226 concentrations ranged from <0.49 to 0.94 pCi/g which are not significantly higher than levels of baseline Ra-226 soil concentrations.

Gamma spectroscopy was performed on the pieces of debris which were removed from some of the locations of elevated contact radiation levels. Approximate levels of total activity in this debris are presented in Table 5B. Slag and rock contained primarily thorium and the metal pieces contained uranium, ranging in isotopic distribution from depleted to low enriched. A small pellet contained Ra-226; this pellet was similar to those previously used in the luminous indicator and dial industry.

Ground Penetrating Radar Findings

The subcontractor report, summarizing the ground penetrating radar survey results for the Building 12 burial area is provided as Appendix A. This report concluded that the site consisted mainly of fill which had been subjected to extensive disturbances. This made it very difficult to distinguish any waste material from the surrounding fill. Also, the area had many utility service lines including electrical, water, compressed air, liquified natural gas, telephone and sanitary drain lines, and a few additional isolated metal targets. Borings in four locations identified, in Table 1 of the survey report as containing buried objects, produced no evidence of waste material.

Borehole Gamma Logging

The results of gross gamma scintillation logging performed in boreholes B-1 to B-9, drilled on the perimeter of the suspected burial area, indicated no subsurface contamination. Logging performed in boreholes B-10 to B-25, which were drilled into the suspected burial area, indicated subsurface contamination extending to a maximum depth of 180 cm in seven boreholes and no subsurface contamination in nine boreholes. Gamma logging data were not used to quantify radionuclide concentrations in subsurface soil because of the varying ratios of U-235, U-238, and Th-232 occurring in soils from this site.

Radionuclide Concentrations in Subsurface Soil

Radionuclide concentrations in subsurface soils collected from boreholes are presented in Table 6. Radionuclide concentrations in boreholes drilled on the perimeter of the suspected burial area were not significantly different from those encountered in baseline samples.

Boreholes B-10 and B-11 were drilled on the south side of Building 12, at locations where elevated contact radiation levels were identified. Uranium 235 and U-238 concentrations were slightly elevated to a depth of 2 m in borehole B-10. The maximum concentration of U-235 was 1.81 pCi/g and the maximum concentration of U-238 was 17.0 pCi/g. Th-232 and Ra-226 concentrations were not elevated in borehole B-10; there were no elevated radionuclide concentrations in samples from borehole B-11.

Boreholes B-12 to B-25 were drilled into the suspected burial area. Boreholes B-15, B-17, B-19, and B-20 had elevated concentrations of U-235 ranging from 6.03 pCi/gm to 20.6 pCi/gm. The maximum concentration was found in the sample collected at 0.5-1.0 m in borehole B-17. U-238 concentrations were slightly elevated in samples collected from boreholes B-16 and B-25; the maximum concentration was 10.7 pCi/g at the surface in borehole B-25. In boreholes B-15 and B-20, elevated levels of U-238 were found at the surface; concentrations were 45.8 pCi/g and 30.3 pCi/g respectively. Elevated concentrations of U-238 found in boreholes B-17, B-19, B-21, and B-22 ranged from 3.48 pCi/g to 680 pCi/g. The maximum concentration was found in the sample collected at 0.5-1.0 m in borehole B-17. Elevated concentrations of Th-232 were found in boreholes B-17, B-19, and B-21 and ranged from 5.18 pCi/g to 88.7 pCi/g. The maximum concentration was found in the sample collected at the surface in borehole B-17. Radium 226 concentrations were within the range normally encountered in baseline samples.

Small portions of the samples from boreholes B-17 and B-20 were further analyzed by alpha spectrometry, and these results are presented in Table 6B. The relative levels of U-238, U-235, and U-234 indicate isotopic distributions of depleted (B-17) and natural (B-20) uranium.

Radionuclide Concentrations in Subsurface Water

Subsurface water samples were collected from boreholes when available. The gross alpha and beta concentrations in these samples are presented in Table 7. In seven boreholes drilled outside of the suspected burial area, gross alpha and beta concentrations were slightly elevated above baseline concentrations. Gross alpha concentrations ranged from 1.36 to 8.66 pCi/l, and gross beta concentrations ranged from 3.03 to 14.0 pCi/l. Ground water samples were collected from four of the boreholes drilled into the suspected burial area. The gross alpha and beta concentrations were only slightly elevated in three of the samples, with values ranging from 1.21 to 3.96 pCi/l and from 6.20 to 18.7 pCi/l, respectively. In the sample collected from borehole B-17, the gross alpha concentration was 101 pCi/l and the gross beta concentration was 251 pCi/l. This water was further analyzed by alpha spectrometry, and the relative levels of U-238, U-235, and U-234 indicate an isotopic distribution characteristic of depleted uranium.

Radionuclide Concentrations in Surface Water

Two samples of surface water were collected from an area just north of the 250N grid line. The gross alpha and beta concentrations, presented in Table 8, are within the range of baseline concentrations.

Results - Building 10

Direct Measurements

Direct radiation levels, measured at grid line intersections, are presented in Table 9. The gamma exposure rates measured at 1 m above the surface ranged from 10 to 12 μR/h (average 11 μR/h). At surface contact, the exposure rates ranged from 10 to 12 μR/h (average 11 μR/h). Beta-gamma dose rates ranged from 11 to 58 μrad/h (average 24 μrad/h). Measurements performed with the detector shielded averaged approximately 25% less than those with unshielded detector. This indicates only a small portion of the surface dose rate is due to nonpenetrating beta or low-energy photon radiations.

The walkover survey identified eight areas with elevated surface radiation levels. These locations are indicated on Figure 10 and direct radiation levels at these locations are presented in Table 10. Contact gamma exposure rates ranged from 13 to 75 μR/h. Gamma exposure rates at 1 m above the surface and beta-gamma dose rates ranged from 10 to 13 μR/h and 20 to 490 μrad/h, respectively. Soil samples were collected at three of these locations. Removal of soil samples from the three locations resulted in a decrease in contact exposure rates suggesting that the contamination at these points is in small discrete deposits. Pieces of metal and slag were found at a few of the locations.

Radionuclide Concentration in Surface Soil

Table 11 lists the concentrations of radionuclides measured in surface soil collected at grid line intersections. These samples contained U-235 concentrations ranging from <0.12 to 5.60 pCi/g. The highest concentration was in the sample collected from grid point 160N, 25E. Uranium 238 concentrations ranged from <0.39 to 8.37 pCi/g; the highest concentration was from grid point 125N, 25E. Thorium 232 concentrations ranged from 0.30 to 7.18 pCi/g; the highest concentration was from grid point 156N, 25E.

Radium 226 concentrations were within the range encountered in baseline samples.

Table 12A lists the radionuclide concentrations in surface soil collected from locations of elevated contact radiation levels. Three locations were sampled, and concentrations of U-235 and U-238 were elevated in each sample. Thorium 232 and Ra-226 concentrations were within the range normally encountered in baseline samples.

Gamma spectroscopy was performed on the pieces of slag and metal which were removed from some of the locations of elevated contact radiation levels. The radionuclide concentrations found in this debris are presented in Table 12B. The debris contained increased concentrations of U-235 and U-238; isotopic ratios indicate enriched uranium.

Borehole Gamma Logging

The results of gamma scintillation logging performed in boreholes indicated no subsurface contamination in eight of the boreholes drilled. Logging performed in borehole B-33 indicated slightly increased radiation levels extending to a depth of 1.5 m, at which point there was drilling refusal. Gamma logging data were not used to quantify radionuclide concentrations in subsurface soil because of the varying ratios of U-235, U-238, and Th-232 occurring in soils from this site.

Radionuclide Concentrations in Subsurface Soil

Radionuclide concentrations in subsurface soils collected from boreholes are presented in Table 13A. Boreholes B-26, B-27, and B-28 were randomly located, and radionuclide concentrations in these boreholes were within the range encountered in baseline samples. There were increased concentrations of U-235 and U-238 in the surface samples collected from boreholes B-29, B-30 and B-33 which were drilled at locations of elevated contact radiation levels. U-235 concentrations ranged from 1.19 to 28.1 pCi/g and U-238 concentrations ranged from 2.37 to 22.8 pCi/g as determined by gamma spectroscopy.

Boreholes B-31 and B-32 were located on either side of the loading dock on the east side of the building. Contaminated soil had been removed from these areas to a depth of approximately 1.5 m and replaced with clean fill. The U-235 and U-238 concentrations were very slightly elevated above baseline concentrations; Th-232 and Ra-226 concentrations were within the ranges encountered in baseline samples.

Small portions of the surface soil samples from borehole locations B-30 and B-33 were further analyzed by alpha spectrometry, and these results are presented in Table 13B. Relative ratios of U-238 plus U-235 indicate an isotopic distribution characteristic of enriched uranium.

Radionuclide Concentrations in Subsurface Water

Gross alpha and beta concentrations in subsurface water samples collected from four boreholes are presented in Table 14. Gross alpha concentrations ranged from 1.72 to 6.67 pCi/l. Gross beta concentrations ranged from 4.00 to 23.3 pCi/l. All of the samples had concentrations which were slightly elevated above those normally encountered in baseline samples.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The soil guidelines applicable to this site are presented in Appendix C. For processed uranium (uranium without daughter products) the criteria for surface contamination or contamination of soil in areas without use restrictions (Option 1) are 35 pCi/g for depleted uranium and 30 pCi/g for enriched uranium. The acceptable exposure rate at one meter above the surface as determined by the NRC is 10 μR/h above background, or 21 μR/h total for this location.

Building 12 Burial Area

All of the exposure rates at one meter above the surface are less than 10 μR/h above the background level. The average level of 11 μR/h is well within the 21 μR/h criterion.

Based on an average ratio of U-234 to U-235 activity of approximately 21:1, as determined from alpha spectroscopy analyses, nine surface locations at grid line intersections within the burial ground area exceed the uranium soil criteria. In addition, all of the "hot spots" identified by the surface scans exceed these guidelines. The radionuclide concentrations in soil samples collected from boreholes drilled in the perimeter of the suspected burial area were all less than the guideline concentration levels. At borehole locations B-10, B-15, B-19, B-20, and B-25, the surface soil concentrations of uranium exceed Option 1 criteria. Subsurface uranium concentrations in B-12, B-17, B-19, B-20, B-21, and B-22 also exceed that criteria. Subsurface concentrations of enriched uranium and U-238 in borehole B-17 exceed the guidelines under disposal Option 2.

The gross alpha and beta concentrations in the water sample collected from borehole B-17 exceeded the EPA drinking water standards.[1] It should be noted that the EPA standards are used here for comparison purposes only, because this water does not represent a source of drinking water.

Building 10

All of the exposure rates at one meter are less than the 21 μR/h criterion. U-235 and U-238 concentrations in surface soil samples collected from locations of elevated contact radiation levels exceed the maximum concentrations permitted under disposal Option 1. Surface samples from grid intersections 115N,30E; 148N,25E; 159N,26E; 160N,25E; 165N,30E, and 180N,25E also exceed the enriched uranium guideline, based on the observed ratio of U-234 to U-235. The subsurface concentration to 1.5 m deep in borehole B-33 exceeds the Option 1 criteria for enriched uranium but meets the Option 2 guideline.

SUMMARY

A survey of portions of the Texas Instruments site was conducted during April and May, 1984. The survey included surface radiation scans, measurements of direct radiation levels, and analyses of radionuclide concentrations in surface and subsurface soil samples, and in surface and subsurface water. Also, a topographical study of the Building 12 burial area was done to allow comparison of elevations existing at present to those in existence prior to the construction of Building 12.

The results of this survey indicate the presence of isolated areas of surface and subsurface contamination. They were located mainly within the boundaries of the suspected burial site, however there were small areas of surface contamination outside the burial site and in a few locations around Building 10. There is no evidence that migration of the radioactive materials is adversely affecting ground water.

Ground penetrating radar and subsurface investigations did not identify extensive areas of buried debris as had been anticipated. The topographical study indicates that as much as 3-4 m of dirt may have been removed from portions of the burial area during the construction of Building 12. This could explain the proximity of the contamination to the surface as well as the lack of debris which is normally encountered when drilling into burial and landfill areas.

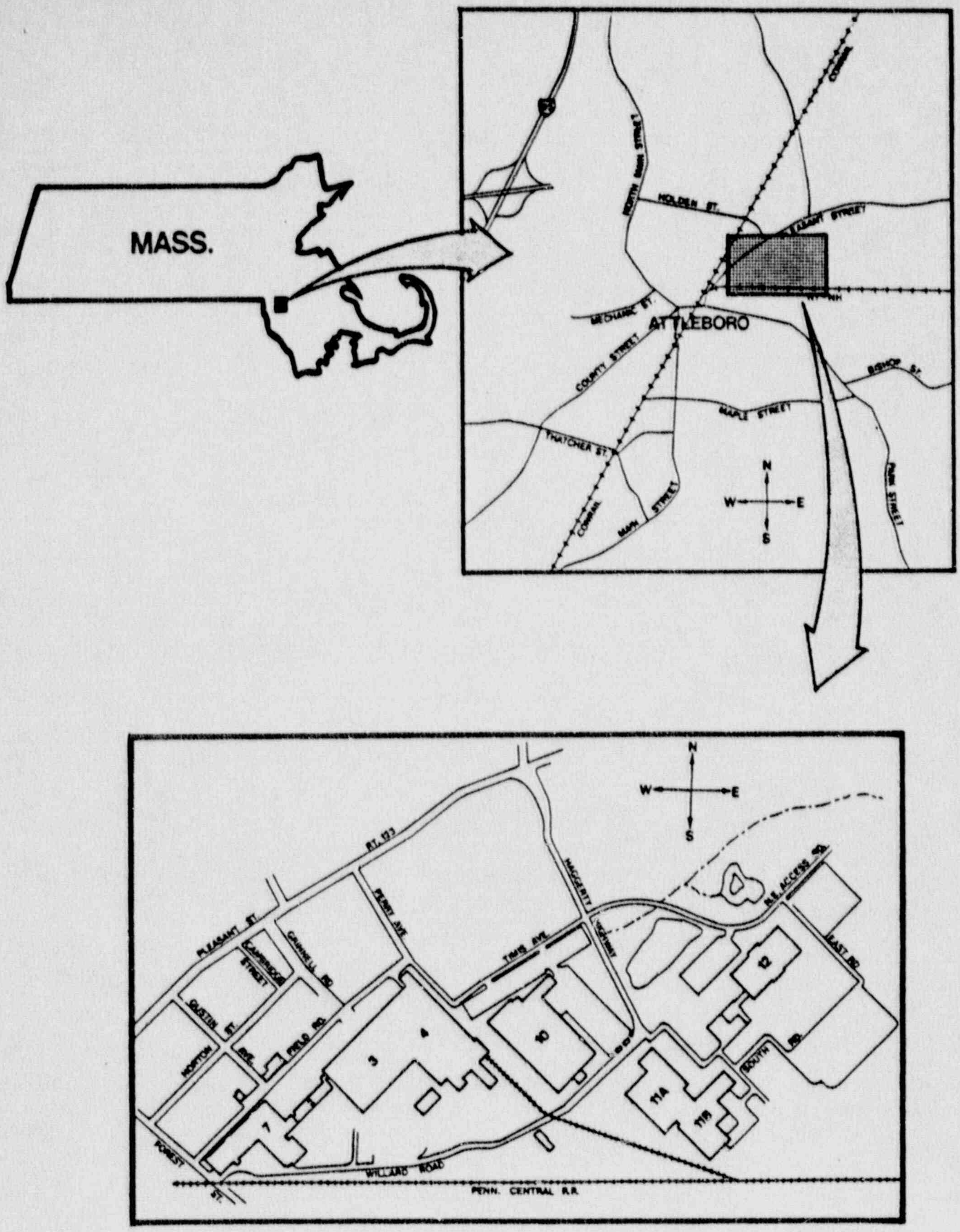

FIGURE 1. Map of Massachusetts and Attleboro Showing Location and Plan View of the Texas Instruments Site.

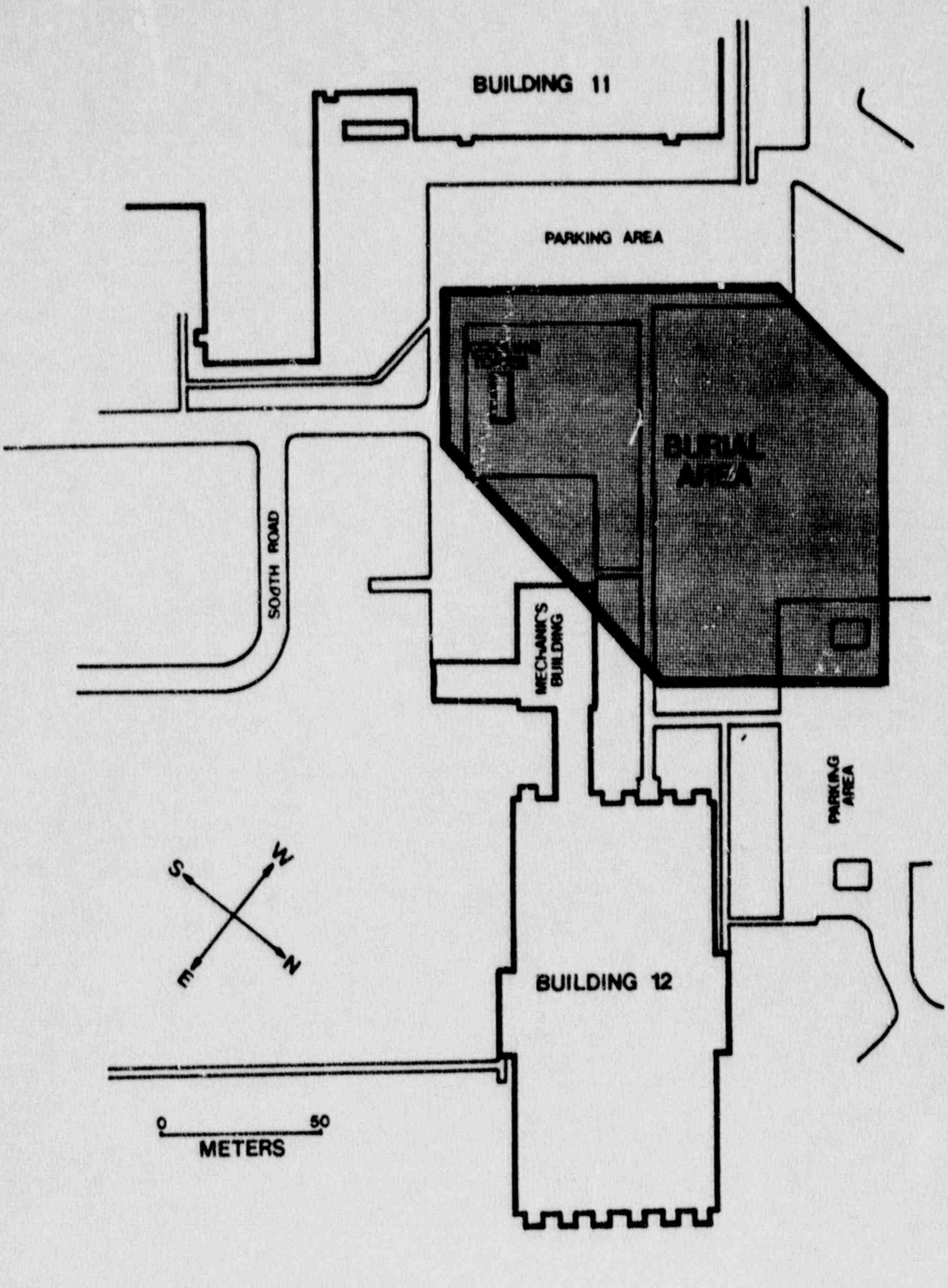

FIGURE 2: Plan View of Suspected Burial Area Southwest of Building 12.

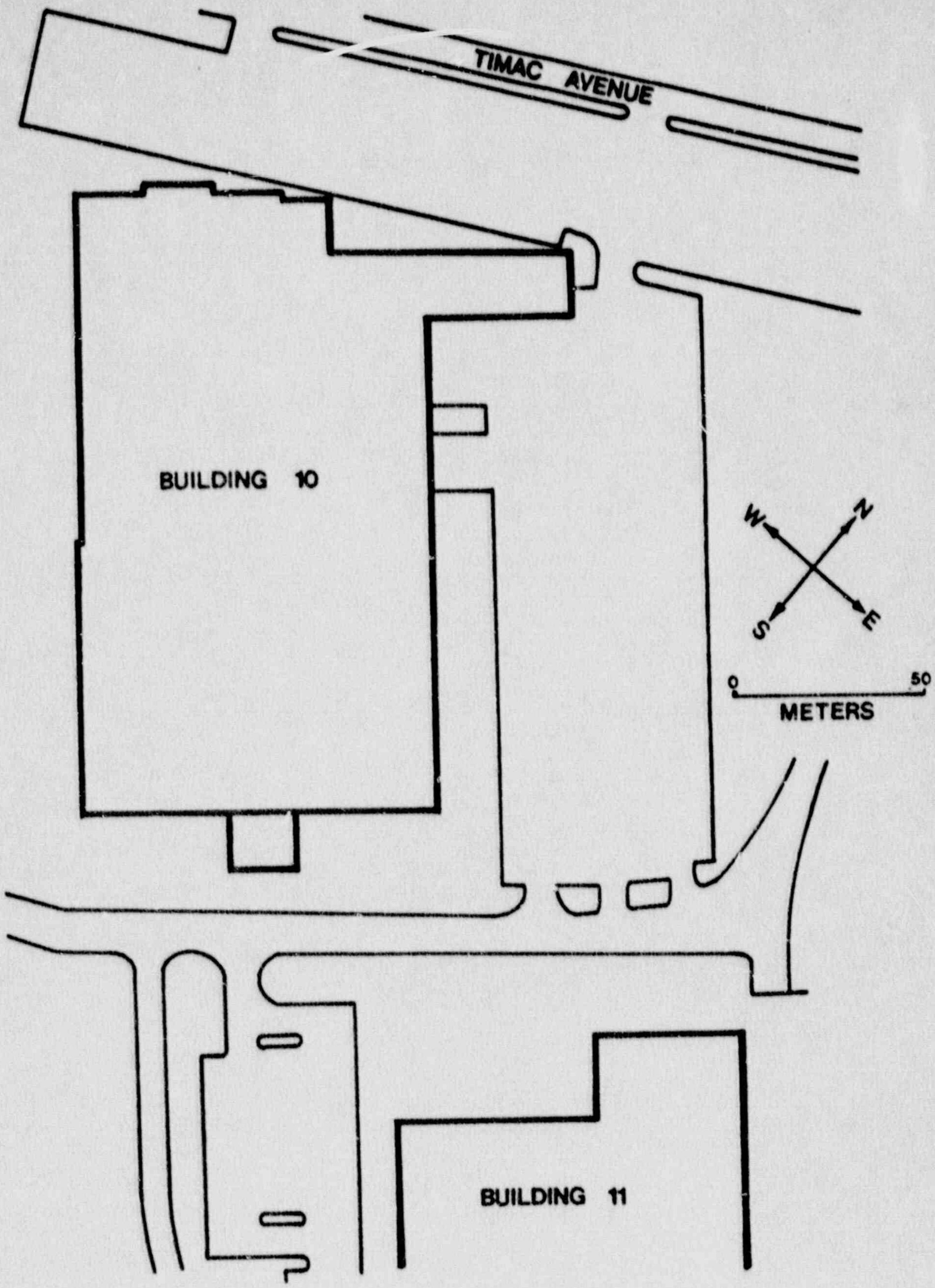

FIGURE 3. Plan View of Area Around Building 10.

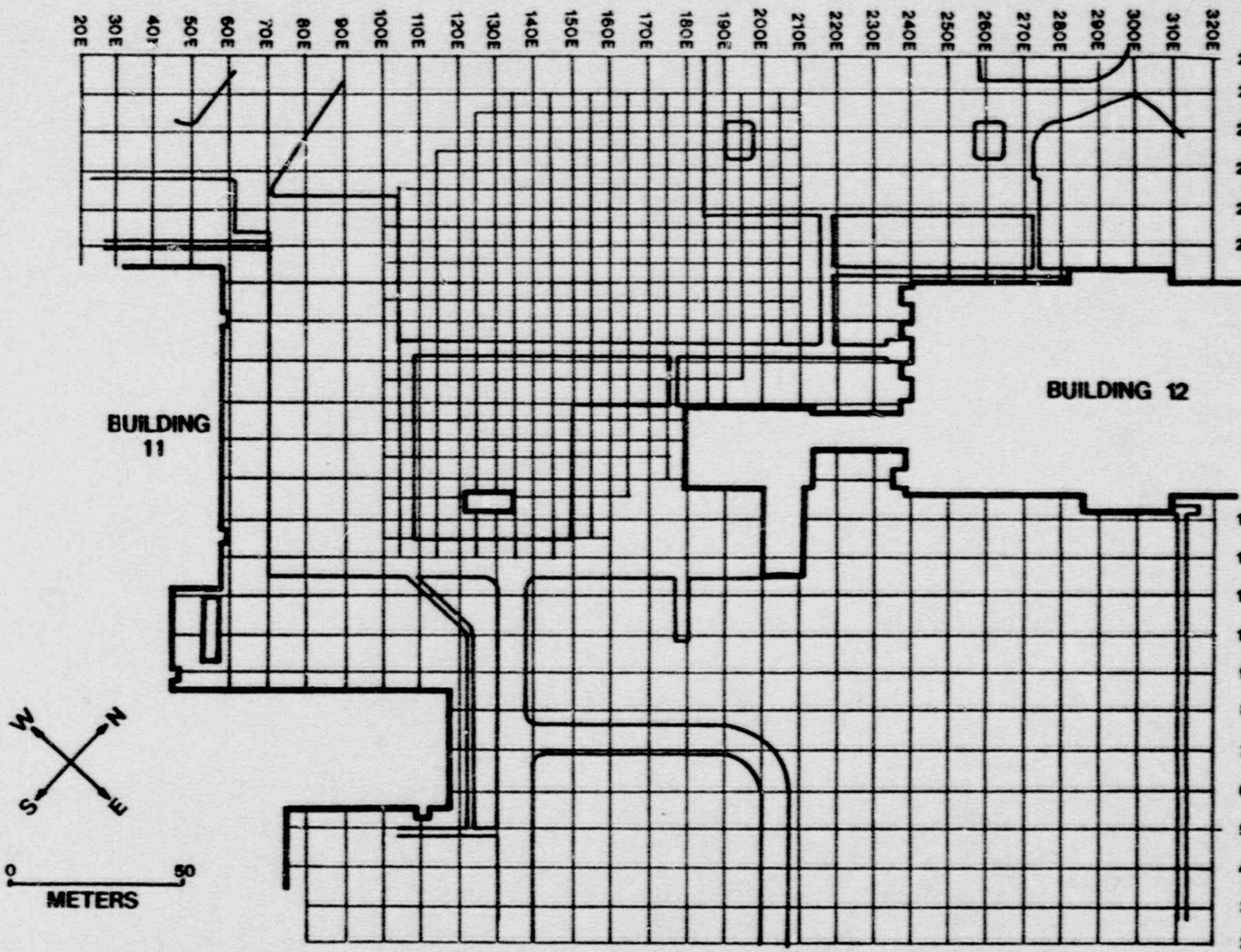

FIGURE 4. Grid of Building 12 Burial Site.

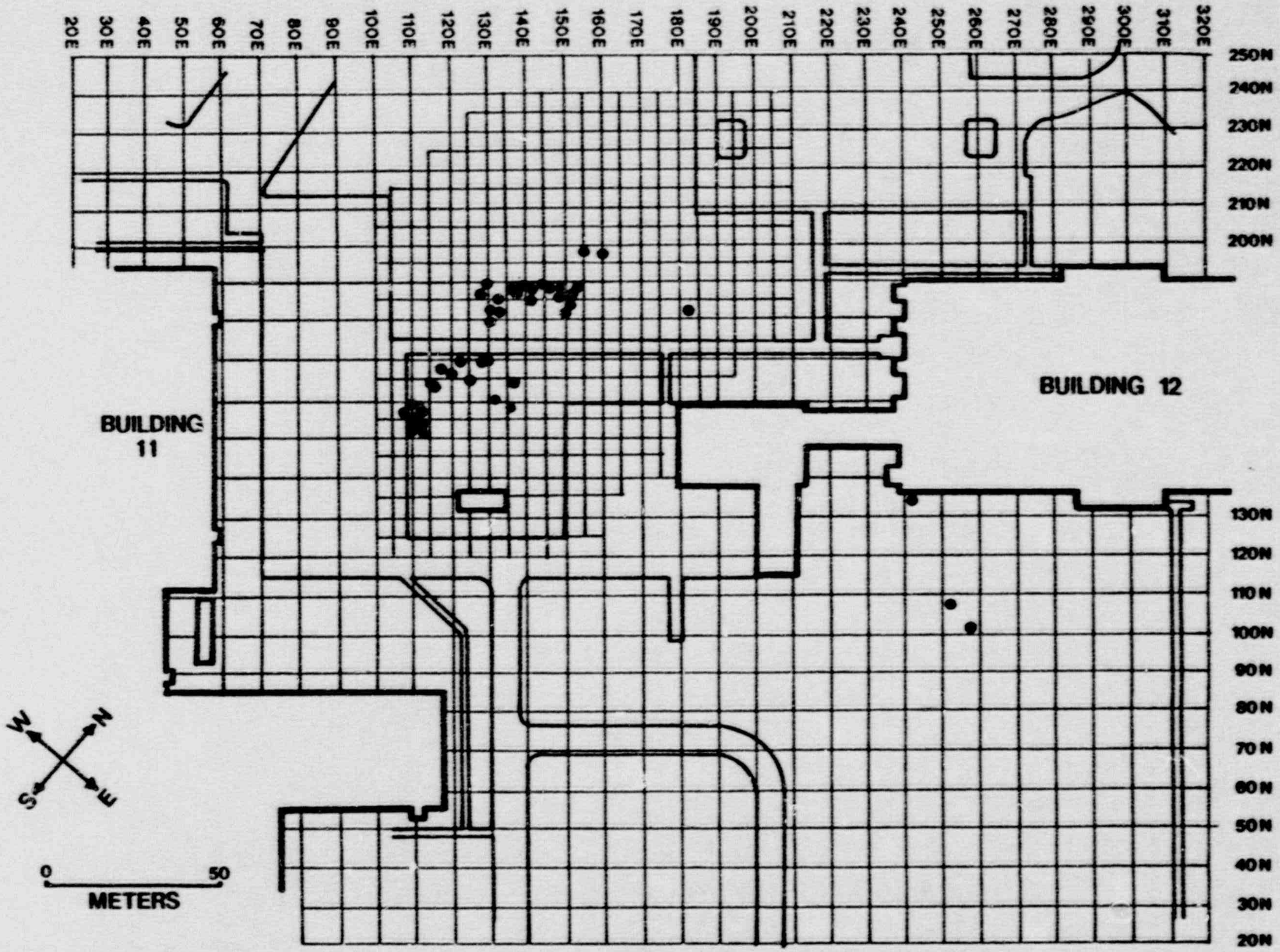

FIGURE 5: Location of Elevated Contact Radiation Levels Around Building 12

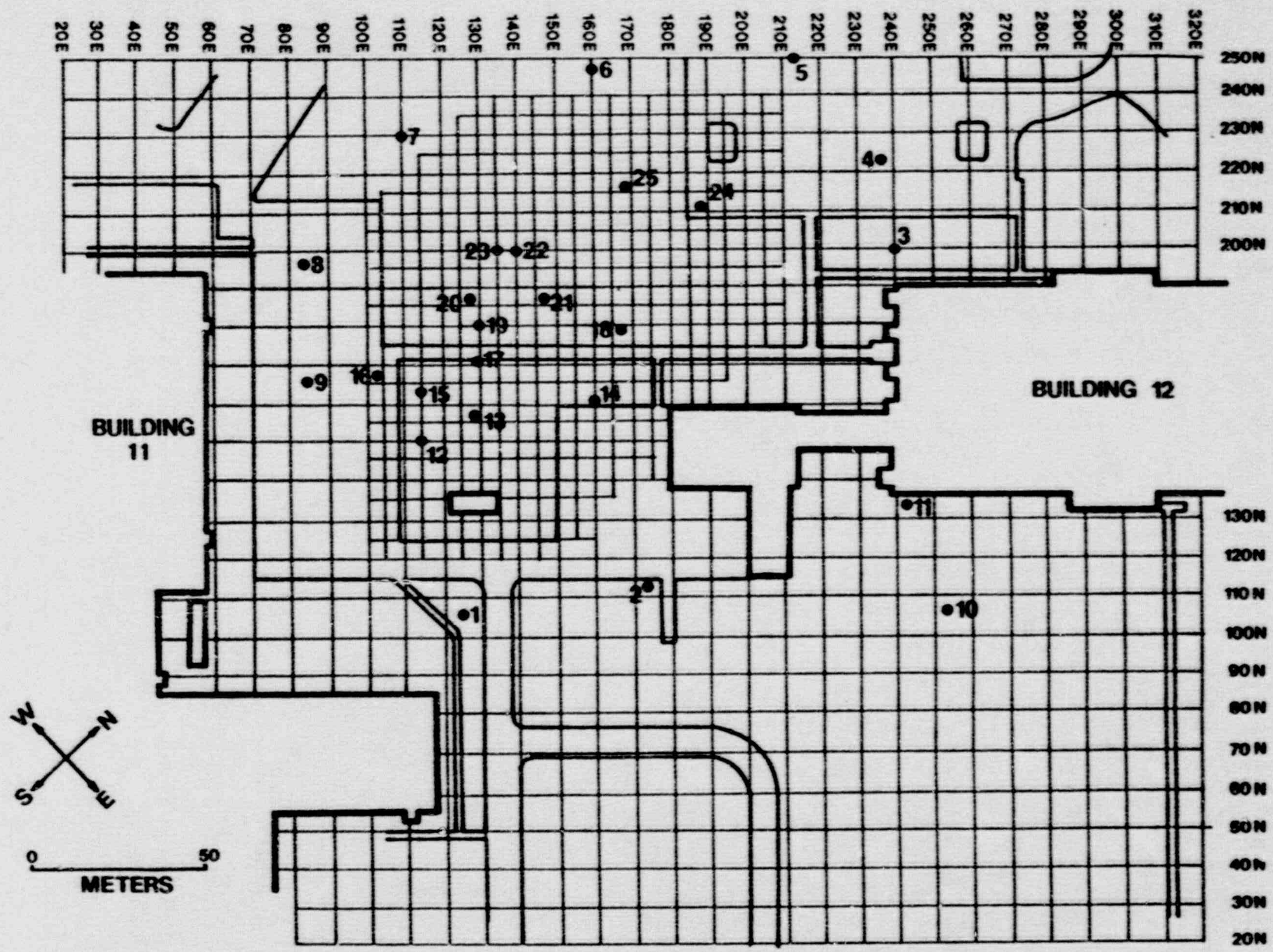

FIGURE 6. Building 12 Boreholes.

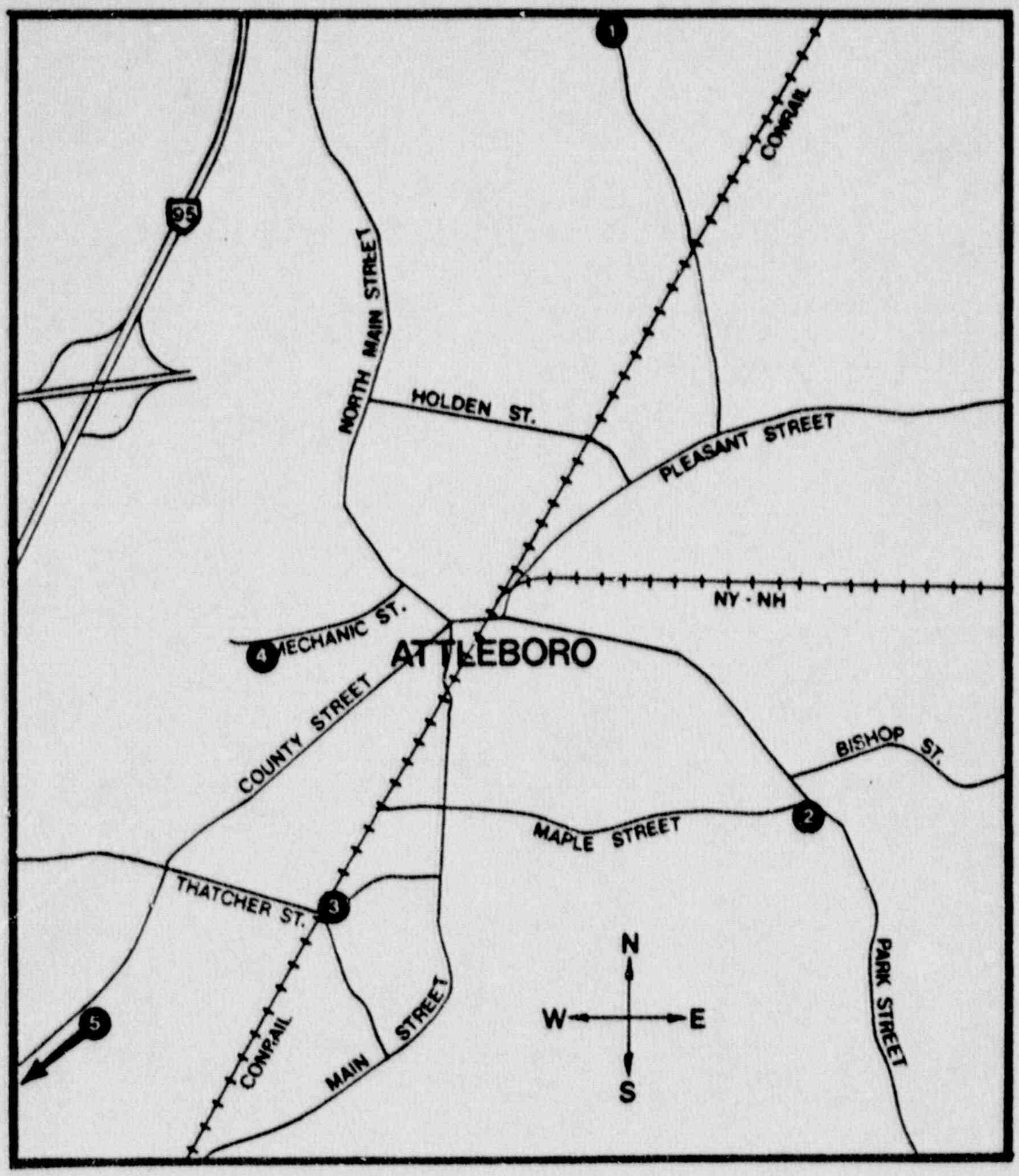

FIGURE 7. Locations of Background Measurements and Baseline Samples in the Attleboro Area.

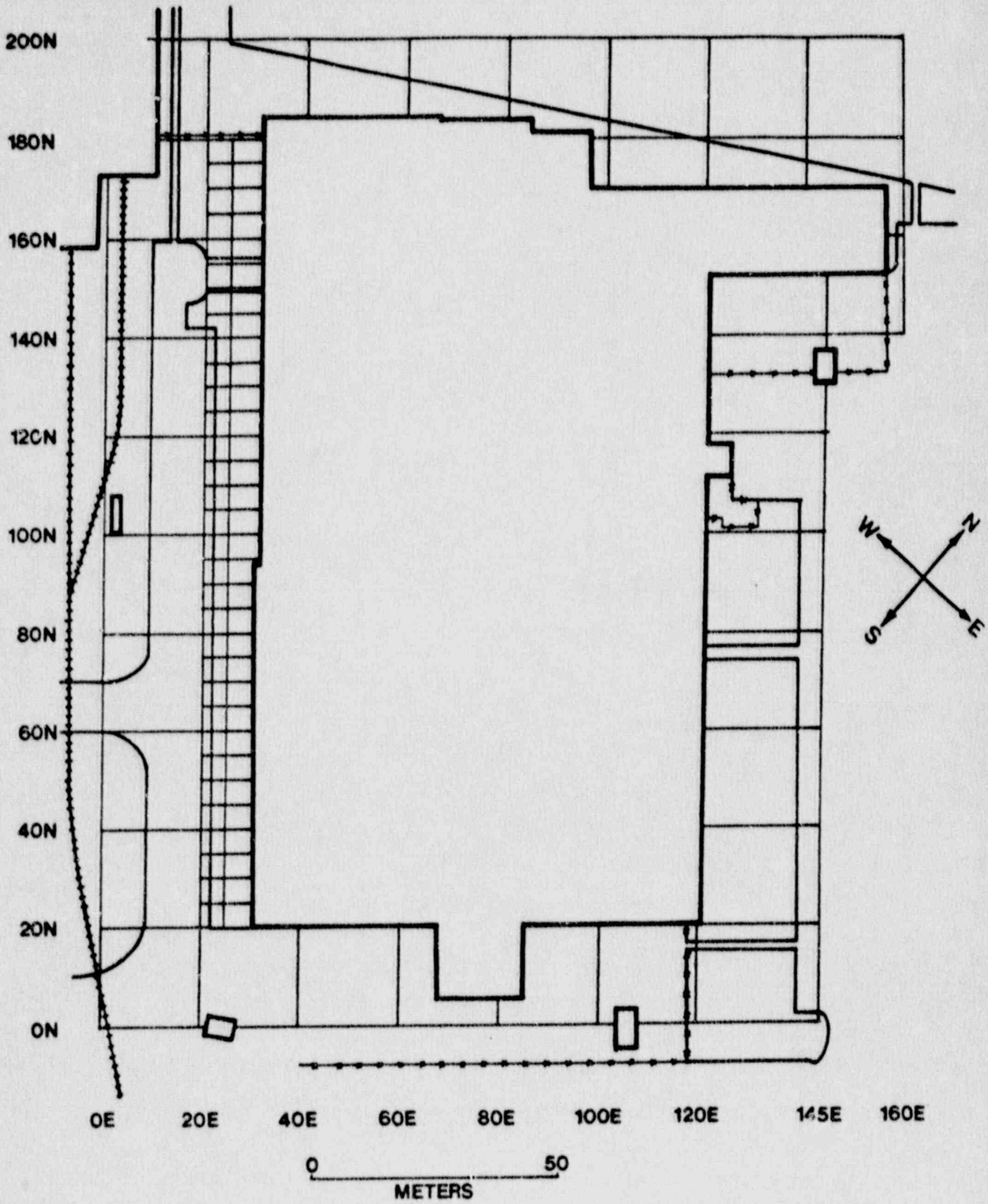

FIGURE 8. Grid System Established For Survey Reference Around Building 10.

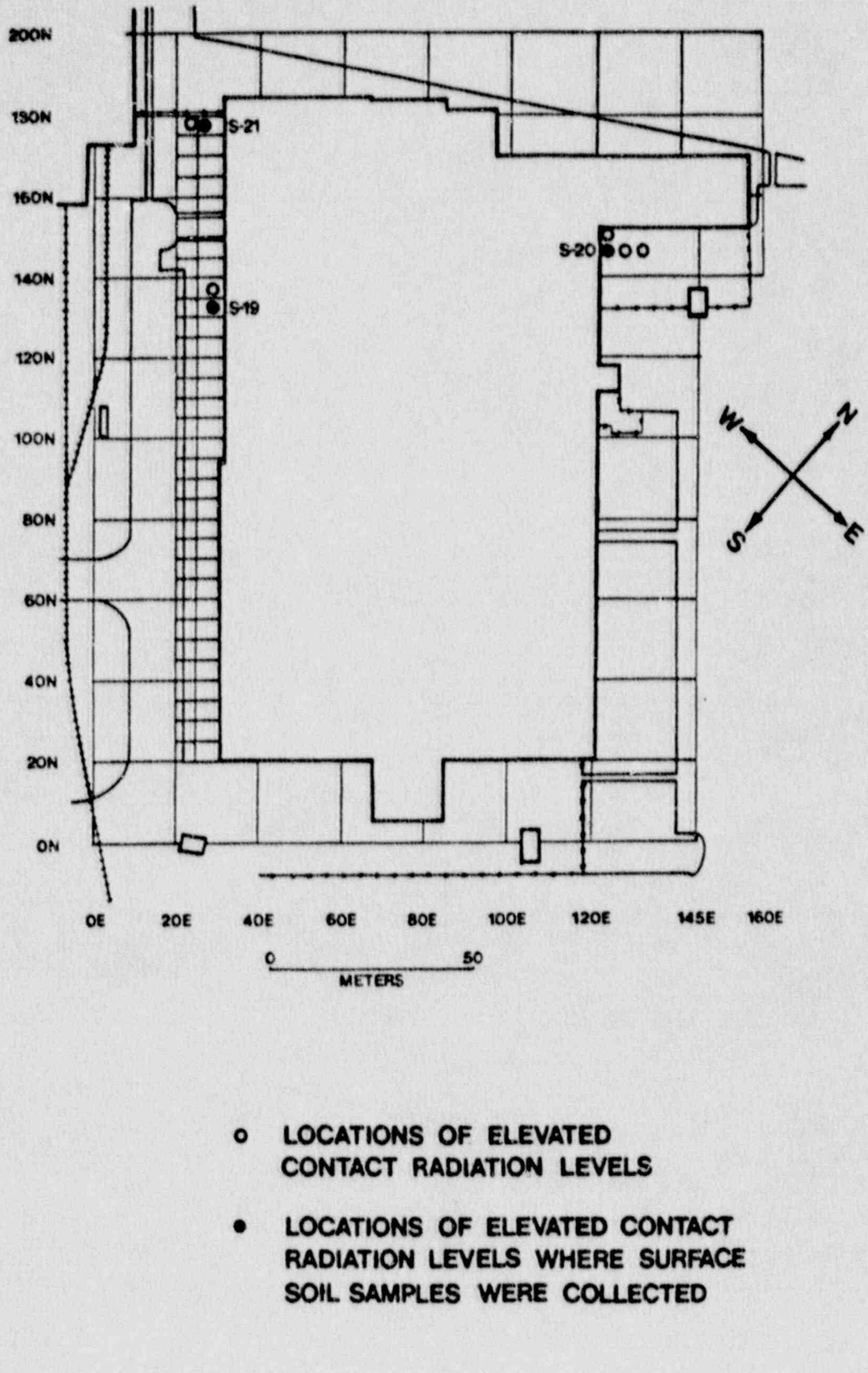

FIGURE 9. Locations of Elevated Contact Radiation Levels - Building 10.

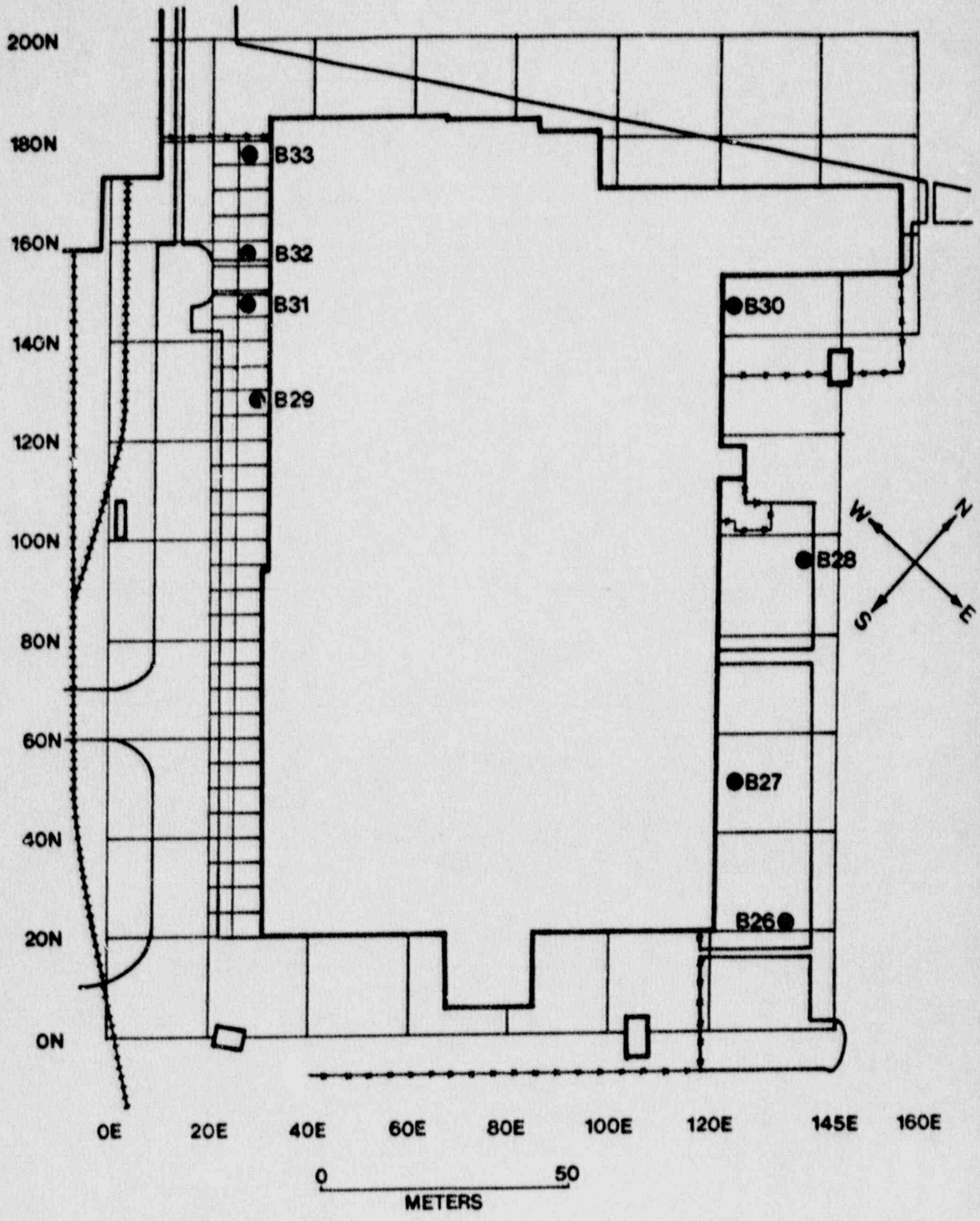

FIGURE 10. Locations of Boreholes Around Building 10.

TABLE 1-A

DIRECT RADIATION LEVELS MEASURED AT BASELINE SAMPLE LOCATIONS

Sample[a] No.	Exposure Rate (μR/h) Contact	1 m Above Surface	Surface Dose Rate (μrad/h)
1	11	11	21
2	10	10	23
3	10	11	28
4	10	10	23
5	10	10	31

[a] See Figure 7.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES

Sample[a] No.	Radionuclide Concentrations (pCi/g)			
	U-235	U-238	Th-232	Ra-226
1	<0.11	0.43 ± 0.40[b]	0.75 ± 0.27	0.41 ± 0.15
2	<0.34	2.74 ± 1.45	1.23 ± 0.50	0.84 ± 0.22
3	<0.32	<1.02	1.23 ± 0.32	0.78 ± 0.24
4	<0.24	<0.92	0.58 ± 0.69	0.54 ± 0.26
5	<0.26	<0.78	0.54 ± 0.38	0.50 ± 0.22

[a] See Figure 7.
[b] Errors are 2σ based on counting statistics.

TABLE 1-C

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Sample[a] No.	Radionuclide Concentrations (pCi/l or x 10^{-9} μCi/ml) Gross Alpha	Gross Beta
1	0.38 ± 0.48[b]	1.42 ± 0.88
2	0.59 ± 0.52	2.45 ± 0.93
3	0.54 ± 0.53	1.97 ± 0.91
4	0.08 ± 0.52	3.07 ± 0.97
5	<0.32	1.55 ± 0.89

[a] See Figure 7.
[b] Errors are 2σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

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)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
50	80	11	11	25
50	100	10	10	16
50	120	11	11	14
50	140	11	11	21
50	160	11	11	30
50	180	11	11	20
50	200	11	11	22
50	220	11	11	24
50	240	11	11	16
50	260	11	11	18
50	280	11	10	13
50	300	10	11	12
60	130	11	11	22
60	150	11	11	11
60	170	11	11	14
60	190	11	11	30
60	210	11	11	27
60	230	11	11	11
60	250	11	11	12
60	270	10	10	10
60	290	10	11	12
60	310	10	11	19
70	120	11	11	28
70	140	11	11	15
70	160	11	11	26
70	180	11	11	27
70	200	11	11	21
70	220	10	10	13
70	240	10	10	20
70	260	10	10	12
70	280	10	11	16
70	300	10	10	12
80	130	11	11	14
80	150	11	11	19
80	170	11	11	18
80	190	10	11	26
80	210	11	11	11
80	230	11	11	11
80	250	11	11	11
80	270	10	10	10
80	290	10	11	11
80	310	11	11	11
90	60	11	11	15
90	80	11	11	11

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
90	100	11	11	21
90	120	11	11	11
90	140	11	11	22
90	160	11	10	18
90	180	11	11	15
90	200	11	11	14
90	220	11	11	29
90	240	10	11	11
90	260	11	11	11
90	280	10	10	10
90	300	10	11	12
100	50	11	11	18
100	70	11	11	26
100	90	11	11	11
100	110	11	11	12
100	130	11	11	11
100	150	11	11	11
100	170	10	11	29
100	190	11	11	11
100	210	10	11	16
100	230	10	11	11
100	250	11	11	19
100	270	11	11	18
100	290	11	11	15
100	310	10	11	11
110	60	11	11	16
110	80	11	11	13
110	100	11	11	29
110	120	11	11	13
110	140	11	11	29
110	160	11	10	10
110	180	11	11	19
110	200	10	11	22
110	220	11	11	12
110	240	10	10	10
110	260	11	11	21
110	280	11	11	27
110	300	11	11	26
120	59	10	11	14
120	70	10	10	38
120	80	11	11	40
120	90	11	11	25
120	100	11	11	42
120	105	11	11	31

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
120	110	10	11	42
120	115	11	10	29
120	120	11	11	41
120	125	11	11	28
120	130	11	11	21
120	135	10	11	15
120	140	10	10	29
120	145	11	11	24
120	150	11	11	19
120	160	10	11	35
120	170	11	11	38
120	180	11	11	15
120	190	11	11	45
120	200	11	11	16
120	211	11	11	11
120	230	11	11	11
120	250	11	11	14
120	270	11	11	12
120	290	11	11	25
120	310	11	11	28
125	100	11	11	38
125	105	11	11	27
125	110	11	11	25
125	115	11	11	12
125	120	11	11	19
125	125	11	11	25
125	130	11	11	18
125	135	11	11	19
125	140	10	11	21
125	145	11	11	17
125	150	11	11	36
125	155	11	10	18
130	60	11	11	12
130	70	10	11	11
130	80	11	11	31
130	90	11	11	27
130	100	11	11	17
130	105	11	11	31
130	110	10	10	10
130	115	11	11	11
130	120	11	11	12
130	125	11	11	11
130	130	11	11	16
130	135	10	11	15

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
130	140	10	11	11
130	145	11	11	14
130	150	10	11	15
130	155	10	11	29
130	160	11	11	23
130	165	11	11	31
130	170	11	11	36
130	180	11	11	17
130	190	11	11	13
130	200	11	11	31
130	211	11	11	14
130	220	11	11	11
130	240	11	11	11
130	260	11	11	19
130	280	11	11	12
130	300	11	11	24
132	290	11	11	11
132	300	11	11	11
135	100	11	11	35
135	105	11	11	33
135	110	10	10	10
135	140	10	11	11
135	145	10	10	26
135	150	11	11	24
135	155	11	11	28
135	160	11	11	11
135	165	10	11	35
136	240	11	11	24
136	250	11	11	11
140	60	11	11	27
140	70	10	10	25
140	80	11	11	38
140	90	11	11	31
140	100	11	11	52
140	105	11	11	27
140	110	11	11	12
140	115	11	11	15
140	120	10	11	11
140	125	11	11	24
140	130	11	11	19
140	135	10	11	14
140	140	10	11	28
140	145	10	11	11
140	150	11	11	19

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
140	155	11	11	22
140	160	10	11	31
140	165	11	11	23
140	170	11	10	16
140	180	11	11	18
140	212	12	12	26
140	230	11	11	24
140	260	13	12	13
140	270	12	12	12
140	280	12	12	22
140	310	13	12	19
145	100	11	11	34
145	105	11	11	31
145	110	10	10	22
145	115	10	11	22
145	120	10	10	10
145	125	11	11	11
145	130	10	11	31
145	135	11	11	11
145	140	10	11	15
145	145	10	11	11
145	150	10	10	20
145	155	11	11	21
145	160	10	11	29
145	165	10	10	23
145	170	10	10	28
145	175	10	10	20
145	180	10	11	22
150	60	10	11	14
150	70	10	11	11
150	80	11	11	26
150	90	11	11	24
150	100	11	11	31
150	105	11	11	31
150	110	11	11	18
150	115	10	11	22
150	120	10	11	11
150	130	10	11	15
150	135	11	11	22
150	140	11	11	18
150	145	11	10	22
150	150	11	11	12
150	155	11	11	19
150	160	11	11	16

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
150	165	11	11	29
150	170	11	11	31
150	175	11	11	29
150	180	11	11	44
155	100	11	11	14
155	105	11	11	42
155	110	11	11	18
155	115	11	11	11
155	130	11	10	10
155	135	11	11	11
155	140	11	11	11
155	145	10	10	19
155	150	10	11	22
155	155	11	11	18
155	160	11	11	17
155	165	10	10	20
155	170	11	11	32
155	175	11	11	22
155	180	11	11	19
158	220	12	12	36
158	230	11	12	22
160	60	11	11	15
160	70	10	10	28
160	80	11	11	22
160	90	11	11	28
160	100	11	11	39
160	105	11	11	27
160	110	11	10	20
160	115	11	11	24
160	120	11	11	17
160	125	11	11	24
160	130	11	11	19
160	135	10	11	15
160	140	11	11	11
160	145	10	11	16
160	150	11	11	25
160	155	11	11	28
160	160	11	10	20
160	165	10	11	19
160	170	11	11	35
160	175	11	11	22
160	180	11	11	15
160	190	11	11	23
160	200	11	11	24

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
160	210	11	11	36
160	220	11	11	11
160	230	11	11	12
160	235	11	11	31
165	100	11	11	44
165	105	11	11	32
165	110	11	11	21
165	115	11	11	31
165	120	11	11	11
165	125	11	11	20
165	130	11	11	22
165	135	11	11	37
165	140	11	11	31
165	145	11	11	11
165	150	11	11	19
165	155	11	11	18
165	160	11	11	19
165	165	11	11	15
165	170	11	10	23
165	175	11	11	14
165	180	11	11	12
165	185	11	11	11
165	190	11	11	14
165	195	11	11	11
170	60	10	11	11
170	70	11	11	11
170	80	11	11	24
170	90	11	11	25
170	100	11	11	28
170	105	11	11	32
170	110	11	11	24
170	115	11	11	16
170	120	11	11	11
170	125	11	11	31
170	130	11	11	27
170	135	11	11	31
170	140	11	11	21
170	145	11	11	22
170	150	11	11	20
170	155	11	11	11
170	160	11	11	17
170	165	11	11	24
170	170	11	11	11
170	175	11	11	21

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
170	180	11	11	14
170	185	11	11	11
170	190	11	11	18
170	195	11	11	21
170	200	11	11	12
170	210	11	11	12
170	220	10	10	10
170	230	11	11	11
170	235	11	11	31
175	100	10	10	19
175	105	11	11	24
175	110	11	11	25
175	115	11	11	18
175	120	11	11	11
175	125	11	11	17
175	130	11	11	29
175	135	11	11	11
175	140	11	11	18
175	145	11	11	25
175	150	11	11	34
175	155	11	11	15
175	160	11	11	21
175	165	11	11	27
175	170	11	11	52
175	175	11	11	24
175	180	11	11	17
175	185	11	11	28
175	190	11	11	11
175	195	11	11	11
175	200	11	11	17
175	205	11	11	34
175	210	11	11	12
180	60	11	11	24
180	70	11	11	11
180	80	11	11	38
180	90	11	11	17
180	100	11	11	25
180	105	11	10	19
180	110	11	11	11
180	115	11	11	14
180	120	11	11	15
180	125	10	11	11
180	130	12	14	28
180	135	11	11	11

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
180	140	11	11	11
180	145	11	11	24
180	150	11	11	14
180	155	10	10	10
180	160	11	11	16
180	165	11	11	11
180	170	11	11	18
180	175	11	11	14
180	180	10	10	12
180	185	11	11	25
180	190	11	11	11
180	195	11	11	22
180	200	11	11	28
180	205	11	11	12
180	210	11	11	15
180	230	11	11	13
180	230	11	11	17
180	235	11	12	25
185	100	11	11	50
185	105	11	11	18
185	110	11	11	12
185	115	11	11	11
185	120	11	10	13
185	125	11	11	13
185	130	11	11	37
185	135	11	11	11
185	140	11	11	25
185	145	11	11	11
185	150	12	12	21
185	155	11	11	18
185	160	11	11	15
185	165	10	11	11
185	170	11	11	11
185	175	11	11	15
185	180	11	11	11
185	185	11	11	11
185	190	11	11	12
185	195	11	11	11
185	200	11	11	34
185	205	11	11	17
185	210	11	11	15
190	60	11	11	17
190	70	11	11	23
190	80	11	11	28

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
190	90	11	11	17
190	100	11	11	11
190	105	10	11	11
190	110	11	11	11
190	115	11	11	11
190	120	11	11	13
190	125	11	11	19
190	130	11	11	25
190	135	11	11	12
190	140	11	11	11
190	145	11	11	11
190	150	11	11	11
190	155	11	11	19
190	160	11	11	17
190	165	11	11	19
190	170	11	11	11
190	175	11	11	11
190	180	11	11	12
190	185	10	11	19
190	190	11	11	12
190	195	11	11	31
190	200	11	13	24
190	205	11	11	11
190	210	11	11	20
190	220	11	11	14
190	230	11	11	18
190	240	11	11	14
190	260	12	12	22
190	270	11	11	21
190	280	11	12	16
192	250	11	11	11
195	100	11	11	24
195	105	10	10	10
195	110	10	10	10
195	115	11	11	11
195	120	10	10	13
195	125	11	11	11
195	130	11	11	22
195	135	11	11	11
195	140	11	11	16
195	145	11	11	11
195	150	10	11	13
195	155	11	11	22
195	160	11	11	11

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
195	165	10	11	11
195	170	11	11	24
195	175	11	11	24
195	180	11	11	25
195	185	10	11	16
195	190	11	11	12
195	195	11	11	21
195	200	11	11	27
195	205	11	11	39
195	210	11	11	21
197	290	10	11	31
197	300	10	11	11
197	310	11	11	31
200	40	10	10	28
200	50	10	10	30
200	60	11	11	29
200	70	11	11	11
200	80	11	11	35
200	90	11	11	22
200	100	11	11	34
200	105	10	10	10
200	110	10	10	10
200	115	10	10	22
200	120	10	10	20
200	125	10	11	11
200	130	10	10	25
200	135	10	11	15
200	140	10	10	10
200	145	10	11	21
200	150	11	11	11
200	155	11	11	11
200	160	10	10	10
200	165	10	10	10
200	170	10	10	13
200	175	10	10	22
200	180	10	10	15
200	185	10	10	10
200	190	10	10	19
200	195	11	11	35
200	200	11	14	23
200	205	11	11	11
200	210	11	11	38
200	220	11	10	10
200	230	10	11	11

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
200	240	10	11	14
200	250	11	11	12
200	260	11	11	11
200	270	11	11	11
200	280	11	11	32
200	290	11	11	28
200	300	10	11	24
200	310	11	11	14
205	100	11	11	21
205	105	10	10	10
205	110	10	10	10
205	115	10	10	22
205	120	10	10	16
205	125	10	10	10
205	130	11	11	21
205	135	10	10	10
205	140	10	10	10
205	145	11	10	18
205	150	11	11	32
205	155	11	10	16
205	160	10	10	10
205	165	10	10	10
205	170	10	11	11
205	175	10	10	10
205	180	10	11	11
205	185	11	11	22
205	190	10	10	13
205	195	11	10	10
205	200	10	12	16
205	205	11	11	11
205	210	10	11	15
210	40	10	11	26
210	50	10	10	12
210	60	11	11	13
210	70	11	11	25
210	80	11	12	49
210	90	11	11	39
210	100	11	11	35
210	105	10	10	14
210	110	10	10	10
210	115	10	10	23
210	120	10	10	27
210	125	10	10	11
210	130	10	10	11

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
210	135	10	10	26
210	140	10	10	23
210	145	10	10	23
210	150	10	10	13
210	155	10	10	10
210	160	10	10	23
210	165	10	10	17
210	170	10	10	13
210	175	10	10	27
210	180	10	10	24
210	185	11	11	28
210	190	11	11	34
210	195	11	11	30
210	200	11	11	34
210	205	11	11	38
210	210	11	11	38
210	220	11	11	33
210	230	11	11	25
210	240	11	11	30
210	250	11	11	51
210	260	11	11	25
210	270	11	11	32
210	280	10	10	19
210	290	10	10	13
210	300	10	10	18
210	310	10	10	17
215	105	10	10	19
215	110	10	10	10
215	115	10	10	13
215	120	10	10	17
215	125	10	10	10
215	130	10	10	10
215	135	10	10	10
215	140	10	11	12
215	145	10	10	12
215	150	10	10	32
215	155	10	10	19
215	160	10	10	26
215	165	10	10	17
215	170	10	11	11
215	175	10	10	19
215	180	10	10	19
215	185	11	11	22
215	190	11	11	25

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
215	195	11	11	11
215	200	11	11	35
215	205	11	11	30
215	210	11	11	35
220	40	11	11	26
220	50	11	11	40
220	60	11	11	35
220	70	11	11	40
220	80	10	10	23
220	90	10	10	10
220	100	10	10	14
220	110	10	10	10
220	115	10	10	16
220	120	10	10	24
220	125	10	10	10
220	130	10	10	10
220	135	10	10	13
220	140	10	10	16
220	145	10	10	22
220	150	10	10	13
220	155	10	10	10
220	160	10	10	19
220	165	10	10	13
220	170	10	10	15
220	175	10	10	22
220	180	10	10	25
220	185	11	11	25
220	190	11	11	43
220	195	11	11	27
220	200	11	11	24
220	205	11	11	35
220	210	11	11	28
220	220	11	11	48
220	230	11	11	16
220	240	11	11	34
220	250	11	11	31
220	260	11	11	27
220	270	11	11	41
220	280	10	10	36
220	290	10	10	14
220	300	10	10	13
220	310	10	10	10
225	115	10	10	22
225	120	10	10	24

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
225	125	10	10	17
225	130	10	10	15
225	135	10	11	11
225	140	11	11	11
225	145	11	11	19
225	150	11	11	21
225	155	11	11	11
225	160	10	10	10
225	165	10	10	19
225	170	10	10	10
225	175	10	10	10
225	180	10	10	13
225	185	11	11	25
225	190	11	11	32
225	195	10	10	12
225	200	11	11	22
225	205	11	11	35
225	210	11	11	30
230	40	11	11	28
230	50	11	11	11
230	60	11	11	23
230	70	11	11	15
230	80	10	10	22
230	90	10	10	10
230	100	10	10	10
230	110	10	10	24
230	120	10	10	23
230	135	10	10	10
230	150	10	10	10
230	155	11	10	12
230	160	11	11	11
230	165	10	11	16
230	170	10	10	16
230	175	10	10	10
230	180	10	10	19
230	185	11	11	11
230	190	11	11	37
230	195	10	10	22
230	200	11	11	11
230	205	11	11	27
230	210	11	11	52
230	220	11	11	32
230	230	11	11	27
230	240	11	11	38

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
230	250	11	11	30
230	260	10	10	17
230	270	11	11	25
230	280	10	10	23
230	290	10	10	13
230	300	10	10	22
230	310	10	10	11
235	135	10	10	20
235	150	10	10	15
235	155	10	10	18
235	160	10	10	25
235	165	10	10	23
235	170	10	10	17
235	175	10	10	10
235	180	10	10	17
235	185	11	11	56
235	190	11	11	38
235	195	11	11	21
235	200	11	11	31
235	205	11	11	38
235	210	11	11	25
240	40	11	11	49
240	50	11	11	44
240	60	11	11	20
240	130	10	10	16
240	140	10	10	18
240	145	10	10	13
240	150	10	10	10
240	155	10	10	10
240	160	10	10	10
240	165	11	11	22
240	170	10	10	32
240	175	11	11	21
240	180	10	10	12
240	185	11	11	18
240	190	11	11	38
240	195	11	11	21
240	200	11	11	22
240	205	11	11	37
240	210	11	11	37
240	220	11	11	38
240	230	11	11	14
240	240	11	11	31
240	250	11	11	28

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
240	260	11	11	34
240	270	11	11	29
240	280	11	11	34
240	290	11	11	38
240	300	10	10	26
240	310	11	11	32
250	40	10	11	19
250	50	11	10	26
250	130	10	10	10
250	140	10	11	18
250	150	11	11	19
250	160	10	10	13
250	170	10	11	15
250	180	10	10	12
250	190	11	11	21
250	200	10	10	20
250	210	10	10	10
250	220	10	10	18
250	230	10	10	24
250	240	10	11	12
250	250	10	10	13
250	260	10	10	25
250	270	10	10	10
250	280	10	10	10
250	300	11	11	22
250	310	10	10	20

[a] Refer to Figure 4.

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS IDENTIFIED
BY THE WALKOVER SURFACE SCAN - BUILDING 12 BURIAL AREA

Grid Location[a]		Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Sample Identification Number	Contact Exposure Rate After Sample Removal (μR/h)
N	E	Contact	1 m Above Surface			
102	257	33	11	45	D1	13
107	252	16	11	18	D2	22
135	241	44	11	78	D3	12
153	114	19	11	60	S1	18
154	111	30	11	63	S2	20
155	112	20	12	58	S3	16
156	112	44	13	290	S4	33
157	112	39	13	130	S5	33
157	113	22	12	39	S6	5
159	135	27	13	110	S7	29
161	133	16	12	26	–	–
164	116	20	11	49	S8	20
164	137	18	11	33	–	–
165	122	19	12	25	–	–
166	120	20	12	46	S9	27
167	118	200	13	240	S10/D4	20
170	129	29	12	72	S11/D5	(>500) b
170	130	20	11	48	–	–
180	130	20	12	29	–	–
181	130	36	14	79	D6	(>500) b
182	182	19	11	53	–	–
183	131	19	13	25	–	–
183	150	18	13	36	–	–
184	151	22	13	35	–	–
185	133	20	12	32	–	–
185	143	26	13	52	S12	89
185	149	44	16	57	S13	89
185	150	23	13	45	S14	(>500) b

TABLE 3 (Continued)

DIRECT RADIATION LEVELS AT LOCATIONS IDENTIFIED
BY THE WALKOVER SURFACE SCAN - BUILDING 12 BURIAL AREA

Grid Location[a]		Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Sample Identification Number	Contact Exposure Rate After Sample Removal (μR/h)
N	E	Contact	1 m Above Surface			
186	138	26	13	26	S15/D7	480
186	149	47	16	48	S16	89
187	128	16	13	19	D8	12
187	142	25	13	53	S17	39
188	140	18	13	20	–	–
188	142	16	13	33	–	–
188	147	27	15	51	S18	160
189	145	120	14	120	D9	16
189	153	18	11	18	–	–
190	130	23	12	23	–	–
198	155	16	11	25	–	–

[a]Refer to Figure 5.
[b]Radiation levels at these locations exceeded capabilities of the instruments used. Measurements made using equipment provided by Texas Instruments indicated 3 mR/h at 170N,129E and 2 mR/h at 185N,150E.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Sample Location		Radionuclide Concentrations (pCi/g)			
N	E	U-235	U-238	Th-232	Ra-226
50	120	<0.27	<0.83	0.93 ± 0.52[a]	0.68 ± 0.21
50	140	<0.16	<0.52	0.81 ± 0.29	0.59 ± 0.18
50	160	<0.14	1.03 ± 0.72	0.93 ± 0.38	0.57 ± 0.13
50	180	<0.13	1.89 ± 0.44	0.84 ± 0.26	0.51 ± 0.14
50	200	<0.14	0.30 ± 0.82	0.71 ± 0.36	0.67 ± 0.16
50	220	<0.29	<0.87	0.72 ± 0.37	0.49 ± 0.21
50	240	<0.21	1.11 ± 1.53	0.70 ± 0.50	0.64 ± 0.18
50	260	<0.29	1.65 ± 1.43	1.13 ± 0.42	0.54 ± 0.29
50	280	<0.26	<0.88	0.75 ± 0.55	0.58 ± 0.18
50	300	<0.19	1.09 ± 1.47	0.76 ± 0.41	0.47 ± 0.14
60	130	<0.20	1.57 ± 1.82	0.92 ± 0.35	0.75 ± 0.18
60	150	<0.26	0.68 ± 0.51	0.72 ± 0.21	0.58 ± 0.30
60	170	<0.13	1.61 ± 0.57	0.71 ± 0.34	0.58 ± 0.16
60	190	<0.26	3.89 ± 1.35	0.88 ± 0.35	0.53 ± 0.14
60	210	<0.26	<0.88	1.20 ± 0.31	0.44 ± 0.19
60	230	<0.14	0.34 ± 0.31	1.02 ± 0.28	0.56 ± 0.16
60	250	<0.23	<0.62	0.79 ± 0.29	0.68 ± 0.21
60	270	<0.22	1.08 ± 1.38	1.31 ± 0.40	0.63 ± 0.22
60	290	<0.23	<0.73	0.76 ± 0.32	0.64 ± 0.15
60	310	<0.21	2.11 ± 1.85	0.51 ± 0.36	0.70 ± 0.22
70	120	<0.16	0.98 ± 0.96	1.04 ± 0.39	0.77 ± 0.19
70	220	<0.21	1.33 ± 1.58	0.62 ± 0.52	0.44 ± 0.19
70	240	<0.17	1.34 ± 1.75	0.71 ± 0.23	0.54 ± 0.18
70	260	0.81 ± 0.45	1.63 ± 0.92	0.92 ± 0.42	0.59 ± 0.33
70	280	<0.28	<0.94	1.21 ± 0.42	0.57 ± 0.18
70	300	<0.19	1.14 ± 1.67	0.72 ± 0.27	0.65 ± 0.25
80	130	<0.21	<0.67	0.95 ± 0.44	0.52 ± 0.18
80	150	<0.21	1.11 ± 1.44	0.88 ± 0.43	0.51 ± 0.19
80	170	<0.14	0.85 ± 0.78	0.74 ± 0.28	0.79 ± 0.16
80	190	<0.18	<0.49	0.74 ± 0.27	0.38 ± 0.16
80	210	<0.12	0.94 ± 0.63	0.71 ± 0.31	0.50 ± 0.16
80	230	<0.19	<0.69	1.09 ± 0.50	0.76 ± 0.24
80	250	<0.20	0.94 ± 1.73	1.12 ± 0.31	0.65 ± 0.19
80	270	<0.21	<0.68	0.90 ± 0.28	0.50 ± 0.19
80	310	<0.23	<0.71	0.90 ± 0.36	0.62 ± 0.19
90	60	<0.17	1.34 ± 1.95	0.47 ± 0.23	0.42 ± 0.18

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
90	80	<0.26	<0.82	0.61 ± 0.41	0.81 ± 0.15
90	100	<0.15	1.46 ± 0.74	0.83 ± 0.30	0.51 ± 0.19
90	120	<0.27	<0.84	0.81 ± 0.46	0.82 ± 0.18
90	140	<0.29	<0.94	1.07 ± 0.44	0.59 ± 0.21
90	160	<0.15	0.77 ± 0.56	0.58 ± 0.27	0.62 ± 0.21
90	180	<0.21	<0.79	0.46 ± 0.55	0.44 ± 0.21
90	200	<0.21	1.24 ± 2.18	0.70 ± 0.43	0.64 ± 0.24
90	220	<0.26	0.95 ± 1.41	1.25 ± 0.39	0.71 ± 0.20
90	240	<0.13	1.02 ± 0.72	1.00 ± 0.27	0.64 ± 0.14
90	260	<0.20	1.31 ± 1.25	0.84 ± 0.30	0.60 ± 0.23
90	280	<0.22	2.66 ± 0.81	0.56 ± 0.30	0.62 ± 0.14
90	290	<0.16	0.73 ± 1.18	0.49 ± 0.34	0.59 ± 0.18
90	300	<0.28	0.98 ± 2.19	0.65 ± 0.38	0.68 ± 0.23
100	50	<0.13	0.82 ± 0.48	0.89 ± 0.26	0.57 ± 0.21
100	70	<0.20	1.84 ± 1.31	0.62 ± 0.26	0.73 ± 0.22
100	90	<0.21	1.32 ± 1.25	0.50 ± 0.44	0.57 ± 0.31
100	110	<0.20	1.22 ± 1.26	0.83 ± 0.39	0.53 ± 0.14
100	130	<0.25	<0.85	1.38 ± 0.28	0.63 ± 0.17
100	150	<0.15	3.10 ± 0.49	0.79 ± 0.31	0.69 ± 0.17
100	170	<0.70	1.99 ± 1.81	0.86 ± 0.48	0.54 ± 0.14
100	190	<0.22	<0.75	0.78 ± 0.42	0.85 ± 0.19
100	210	<0.28	<0.82	0.91 ± 0.45	0.68 ± 0.20
100	230	<0.15	0.72 ± 0.91	0.87 ± 0.24	0.60 ± 0.16
100	250	<0.21	4.93 ± 1.63	0.72 ± 0.24	0.57 ± 0.18
100	270	<0.23	2.72 ± 1.52	0.83 ± 0.26	0.54 ± 0.29
100	290	<0.29	1.01 ± 2.13	0.96 ± 0.38	0.59 ± 0.19
100	310	<0.15	1.32 ± 0.86	0.86 ± 0.33	0.70 ± 1.90
110	60	<0.21	<0.61	0.99 ± 0.41	0.52 ± 0.2
110	80	<0.22	1.22 ± 1.35	1.85 ± 0.42	0.76 ± 0.22
110	100	<0.29	<0.93	0.80 ± 0.51	0.60 ± 0.20
110	120	<0.15	1.44 ± 1.19	0.85 ± 0.49	0.59 ± 0.22
110	160	<0.16	1.17 ± 0.77	0.85 ± 0.47	0.72 ± 0.15
110	220	<0.25	1.24 ± 1.93	0.74 ± 0.55	0.65 ± 0.36
110	240	<0.28	3.1 ± 1.33	1.32 ± 0.41	0.44 ± 0.16
110	260	0.35 ± 0.32	8.6 ± 0.89	0.75 ± 0.31	0.54 ± 0.15

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
110	280	0.50 ± 0.52	18.6 ± 1.69	0.91 ± 0.45	0.81 ± 0.25
110	300	<0.22	2.07 ± 1.46	0.81 ± 0.39	0.73 ± 0.17
120	70	<0.28	<0.90	0.85 ± 0.37	0.55 ± 0.22
120	210	<0.16	0.89 ± 0.56	0.74 ± 0.36	0.65 ± 0.16
120	230	<0.20	<0.64	0.59 ± 0.45	0.38 ± 0.21
120	250	<0.19	1.25 ± 1.40	1.07 ± 0.36	0.63 ± 0.20
120	270	<0.28	<0.94	1.12 ± 0.42	0.74 ± 0.22
120	290	<0.15	4.06 ± 0.37	1.01 ± 0.42	0.62 ± 0.17
120	310	<0.29	1.42 ± 0.86	0.94 ± 0.31	0.90 ± 0.21
125	110	<0.20	1.27 ± 1.25	0.51 ± 0.28	0.67 ± 0.20
125	115	<0.27	2.73 ± 2.07	1.09 ± 0.32	0.44 ± 0.13
125	120	<0.15	0.24 ± 0.53	0.92 ± 0.30	0.53 ± 0.13
125	125	<0.22	1.74 ± 1.61	1.18 ± 0.40	0.60 ± 0.23
125	130	<0.20	<0.71	0.79 ± 0.27	0.48 ± 0.25
125	135	<0.31	1.55 ± 2.35	0.88 ± 0.38	0.73 ± 0.23
125	140	<0.16	2.88 ± 0.82	0.86 ± 0.33	0.61 ± 0.14
125	145	<0.22	1.96 ± 1.02	0.92 ± 0.38	0.71 ± 0.24
130	60	<0.24	1.03 ± 0.84	0.79 ± 0.36	1.85 ± 0.84
130	110	<0.24	<0.86	0.39 ± 0.31	0.62 ± 0.19
130	115	<0.15	1.84 ± 0.55	0.77 ± 0.31	0.60 ± 0.21
130	120	0.33 ± 0.46	2.55 ± 1.69	1.23 ± 0.44	0.76 ± 0.30
130	125	<0.23	1.74 ± 1.54	0.82 ± 0.52	0.58 ± 0.21
130	130	<0.31	1.33 ± 2.09	1.15 ± 0.42	0.72 ± 0.20
130	135	<0.16	1.23 ± 0.56	1.14 ± 0.36	0.60 ± 0.21
130	140	<0.22	1.44 ± 1.76	0.53 ± 0.43	0.45 ± 0.24
130	145	<0.22	1.42 ± 1.54	0.72 ± 0.52	0.49 ± 0.34
130	210	<0.28	<0.95	0.95 ± 0.34	0.66 ± 0.20
130	220	<0.13	0.45 ± 0.43	0.77 ± 0.30	0.46 ± 0.15
130	240	0.16 ± 0.58	1.44 ± 1.25	0.88 ± 0.32	0.67 ± 0.20
130	260	<0.22	0.78 ± 1.40	0.95 ± 0.54	0.61 ± 0.22
130	280	<0.31	2.72 ± 1.70	0.94 ± 0.55	1.47 ± 0.86
130	300	<0.14	0.89 ± 0.54	0.79 ± 0.26	0.66 ± 0.15
136	240	<0.18	1.56 ± 0.87	0.97 ± 0.67	0.66 ± 0.17
136	250	<0.24	1.46 ± 1.69	0.74 ± 0.38	0.52 ± 0.15
136	260	<0.31	<0.97	1.36 ± 0.39	0.78 ± 0.23
136	270	0.15 ± 0.25	0.71 ± 0.69	0.58 ± 0.31	0.42 ± 0.16

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
136	280	<0.19	2.12 ± 1.56	0.66 ± 0.32	0.57 ± 0.21
136	290	<0.24	1.55 ± 1.49	0.74 ± 0.33	0.48 ± 0.25
136	300	<0.29	<0.91	1.17 ± 0.49	1.02 ± 0.22
136	310	<0.13	0.37 ± 0.73	0.69 ± 0.20	0.57 ± 0.20
135	110	<0.21	3.17 ± 1.34	0.76 ± 0.29	0.51 ± 0.23
135	115	<0.20	2.71 ± 1.62	0.85 ± 0.39	0.54 ± 0.22
135	120	<0.27	2.37 ± 1.27	0.95 ± 0.34	0.58 ± 0.18
135	140	<0.10	0.22 ± 0.34	0.79 ± 0.26	0.50 ± 0.11
140	70	<0.19	<0.63	0.63 ± 0.36	0.62 ± 0.15
140	110	<0.19	0.69 ± 1.34	0.96 ± 0.52	0.42 ± 0.12
140	115	<0.36	3.87 ± 1.88	0.13 ± 0.60	0.56 ± 0.23
140	120	<0.15	1.19 ± 0.50	0.54 ± 0.37	0.78 ± 0.15
140	125	<0.22	<0.66	0.95 ± 0.40	0.66 ± 0.18
140	130	<0.21	2.19 ± 1.50	0.69 ± 0.34	0.57 ± 0.18
140	135	<0.33	1.65 ± 1.64	1.13 ± 0.45	0.83 ± 0.21
140	140	<0.14	0.64 ± 0.34	0.67 ± 0.24	0.48 ± 0.18
140	145	<0.20	1.79 ± 1.49	0.87 ± 0.49	0.60 ± 0.27
140	211	<0.23	<0.77	1.01 ± 0.36	0.70 ± 0.18
140	230	<0.32	<0.94	0.67 ± 0.37	0.59 ± 0.18
145	110	<0.14	1.56 ± 0.73	0.53 ± 0.34	0.35 ± 0.23
145	115	<0.19	1.66 ± 1.66	0.60 ± 0.50	0.57 ± 0.17
145	120	<0.22	<0.77	0.98 ± 0.41	0.47 ± 0.18
145	125	<0.29	3.31 ± 1.66	0.93 ± 0.61	0.77 ± 0.20
145	130	<0.19	1.02 ± 0.55	1.05 ± 0.41	0.62 ± 0.16
145	135	<0.23	2.66 ± 0.99	0.80 ± 0.28	0.58 ± 0.23
145	140	<0.20	1.98 ± 2.32	0.55 ± 0.36	0.63 ± 0.16
145	145	<0.26	<8.13	0.92 ± 0.32	0.37 ± 0.18
150	60	<0.22	1.50 ± 1.49	0.87 ± 0.60	0.48 ± 0.22
150	70	<0.19	0.49 ± 2.07	1.05 ± 0.29	0.62 ± 0.21
150	110	0.51 ± 0.38	5.15 ± 1.31	0.86 ± 0.25	0.46 ± 0.15
150	115	<0.21	<0.60	1.03 ± 0.31	0.65 ± 0.15
150	120	0.39 ± 0.49	1.80 ± 1.81	0.89 ± 0.49	0.65 ± 0.26
150	130	0.30 ± 0.48	<0.73	0.87 ± 0.36	0.53 ± 0.19
150	135	<0.19	0.74 ± 1.61	0.78 ± 0.27	0.52 ± 0.17
150	140	<0.27	1.37 ± 1.53	0.72 ± 0.34	0.61 ± 0.21
150	145	<0.14	0.54 ± 1.12	0.46 ± 0.19	0.62 ± 0.15
155	110	<0.23	5.19 ± 1.20	0.77 ± 0.28	0.48 ± 0.17
155	115	0.65 ± 0.52	3.33 ± 2.00	0.87 ± 0.35	0.63 ± 0.30
155	130	<0.32	2.49 ± 1.68	1.17 ± 0.49	0.61 ± 0.23

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
155	135	<0.14	1.78 ± 0.60	0.86 ± 0.26	0.54 ± 0.15
155	140	<0.27	2.15 ± 0.98	1.15 ± 0.37	0.37 ± 0.14
155	145	<0.21	<0.67	0.73 ± 0.39	0.67 ± 0.19
160	50	<0.14	0.42 ± 0.45	0.89 ± 0.41	0.64 ± 0.17
160	70	<0.19	<0.64	0.63 ± 0.26	0.67 ± 0.21
160	110	<0.21	2.49 ± 1.58	0.66 ± 0.51	0.39 ± 0.14
160	115	<0.23	2.70 ± 1.76	0.43 ± 0.37	0.61 ± 0.27
160	120	0.81 ± 0.94	13.8 ± 2.8	0.98 ± 0.48	0.32 ± 0.16
160	125	0.88 ± 0.59	13.4 ± 2.2	0.93 ± 0.55	0.59 ± 0.17
160	130	<0.29	4.79 ± 1.55	0.92 ± 0.42	0.52 ± 0.18
160	135	<0.17	2.48 ± 0.84	0.93 ± 0.33	0.60 ± 0.13
160	140	<0.26	2.04 ± 1.77	1.00 ± 0.48	0.78 ± 0.27
160	145	0.33 ± 0.39	2.13 ± 2.30	1.17 ± 0.37	0.59 ± 0.23
160	150	<0.25	2.22 ± 1.02	0.75 ± 0.35	0.74 ± 0.13
160	155	0.33 ± 0.42	3.23 ± 0.94	0.76 ± 0.30	0.56 ± 0.19
160	160	<0.18	<0.62	0.77 ± 0.28	0.47 ± 0.20
160	165	<0.19	1.27 ± 1.50	1.09 ± 0.43	0.49 ± 0.16
160	170	<0.14	0.46 ± 0.35	0.54 ± 0.23	0.50 ± 0.15
160	180	<0.21	1.19 ± 1.25	0.77 ± 0.40	0.64 ± 0.18
160	190	<0.23	1.73 ± 1.00	1.23 ± 0.49	0.56 ± 0.25
160	200	<0.20	6.93 ± 2.21	1.18 ± 0.34	0.54 ± 0.18
160	210	<0.21	1.65 ± 1.62	1.03 ± 0.32	0.59 ± 0.19
160	210	<0.20	1.47 ± 1.68	0.81 ± 0.49	0.84 ± 0.22
160	230	<0.34	2.37 ± 2.11	0.72 ± 0.79	0.59 ± 0.34
165	110	<0.22	0.99 ± 1.61	0.81 ± 0.32	0.48 ± 0.16
165	115	<0.28	<0.92	1.20 ± 0.63	0.43 ± 0.16
165	120	0.46 ± 0.40	13.6 ± 1.2	0.53 ± 0.40	0.56 ± 0.19
165	125	1.88 ± 0.69	44.9 ± 2.5	1.26 ± 0.43	0.75 ± 0.26
165	130	<0.24	4.97 ± 1.94	1.03 ± 0.43	0.49 ± 0.21
165	135	<0.23	3.32 ± 3.14	0.91 ± 0.46	0.71 ± 0.18
165	140	<0.30	3.55 ± 1.72	1.11 ± 0.60	0.59 ± 0.15
165	145	0.34 ± 0.31	4.90 ± 0.73	0.93 ± 0.27	0.62 ± 0.15
165	150	0.40 ± 0.47	7.69 ± 1.20	0.96 ± 0.35	0.69 ± 0.23
165	155	<0.27	7.45 ± 1.58	0.90 ± 0.38	0.65 ± 0.24
165	160	0.96 ± 0.56	12.7 ± 2.6	1.54 ± 0.48	0.51 ± 0.15
165	165	<0.15	16.7 ± 0.8	0.81 ± 0.28	0.65 ± 0.21
165	170	<0.25	1.51 ± 1.56	0.84 ± 0.53	0.73 ± 0.18
165	180	<0.20	1.57 ± 1.38	1.11 ± 0.41	0.44 ± 0.19
165	185	1.80 ± 0.71	32.2 ± 3.3	1.05 ± 0.37	0.72 ± 0.19
165	190	<0.14	2.58 ± 0.65	0.79 ± 0.26	0.54 ± 0.13

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
165	195	<0.20	1.75 ± 0.88	0.82 ± 0.35	0.69 ± 0.21
170	60	<0.19	0.82 ± 1.26	0.84 ± 0.45	0.58 ± 0.15
170	70	<0.22	<0.65	[illegible] ± 0.47	0.49 ± 0.14
170	110	<0.24	1.85 ± 1.03	0.76 ± 0.33	0.51 ± 0.21
170	115	<0.31	2.54 ± 1.64	1.15 ± 0.36	0.61 ± 0.26
170	120	<0.23	2.00 ± 1.41	1.20 ± 0.31	0.51 ± 0.13
170	125	<0.17	1.20 ± 0.56	0.87 ± 0.43	0.53 ± 0.17
170	130	<0.11	0.91 ± 0.39	0.70 ± 0.29	0.34 ± 0.12
170	135	<0.20	1.00 ± 1.08	0.65 ± 0.24	0.40 ± 0.12
170	140	<0.18	1.15 ± 1.11	0.74 ± 0.13	0.69 ± 0.17
170	145	<0.24	<0.77	0.73 ± 0.27	0.41 ± 0.19
170	150	<0.15	1.67 ± 0.53	0.80 ± 0.33	0.51 ± 0.16
170	155	<0.20	<0.62	0.66 ± 0.47	0.57 ± 0.18
170	160	<0.21	1.40 ± 1.27	0.71 ± 0.35	0.58 ± 0.25
170	165	<0.34	2.72 ± 2.17	0.87 ± 0.47	0.62 ± 0.19
170	170	<0.13	0.89 ± 0.46	0.68 ± 0.32	0.52 ± 0.16
170	180	0.47 ± 0.63	29.4 ± 2.4	1.08 ± 0.20	0.66 ± 0.23
170	185	0.41 ± 0.31	1.36 ± 1.70	0.44 ± 0.31	0.63 ± 0.26
170	190	<0.29	1.36 ± 1.59	1.11 ± 0.36	0.57 ± 0.25
170	195	0.20 ± 0.62	0.95 ± 1.51	0.79 ± 0.56	0.70 ± 0.21
170	200	<0.18	1.22 ± 0.84	0.72 ± 0.36	0.64 ± 0.17
170	210	<0.19	1.67 ± 0.98	0.91 ± 0.42	0.74 ± 0.21
170	220	<0.27	<0.91	0.43 ± 0.31	0.38 ± 0.19
170	230	<0.40	<1.32	0.84 ± 0.63	0.49 ± 0.25
170	235	<0.20	<0.45	0.65 ± 0.52	0.28 ± 0.29
175	105	<0.19	0.79 ± 1.23	0.25 ± 0.05	0.37 ± 0.24
175	110	<0.18	0.70 ± 1.37	0.81 ± 0.24	0.39 ± 0.12
175	115	<0.24	1.50 ± 0.75	0.92 ± 0.25	0.61 ± 0.16
175	120	<0.15	0.94 ± 0.48	0.65 ± 0.23	0.47 ± 0.17
175	125	<0.11	0.79 ± 0.50	0.68 ± 0.30	0.45 ± 0.12
175	130	<0.18	<0.57	0.62 ± 0.42	0.52 ± 0.18
175	135	<0.23	0.88 ± 1.31	0.50 ± 0.49	0.45 ± 0.15
175	140	<0.23	1.57 ± 1.23	0.86 ± 0.39	0.46 ± 0.21
175	145	<0.16	<0.47	0.70 ± 0.29	0.35 ± 0.13
175	150	<0.18	0.61 ± 1.22	0.56 ± 0.21	0.52 ± 0.16
175	155	<0.20	1.62 ± 1.27	0.84 ± 0.31	0.54 ± 0.17
175	160	<0.27	<0.84	0.79 ± 0.60	0.66 ± 0.21
175	165	<0.11	0.39 ± 0.34	0.56 ± 0.31	0.60 ± 0.14
175	170	<0.21	1.62 ± 1.16	0.89 ± 0.36	0.60 ± 0.20
175	175	<0.20	<0.68	0.93 ± 0.32	0.62 ± 0.16

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	U-235	U-238	Th-232	Ra-226
		Radionuclide Concentrations (pCi/g)			
175	180	<0.27	1.75 ± 0.84	1.16 ± 0.43	0.65 ± 0.16
175	185	<0.13	1.10 ± 0.76	0.19 ± 0.40	0.62 ± 0.15
175	190	<0.19	1.28 ± 1.65	0.75 ± 0.28	0.47 ± 0.22
175	195	<0.29	2.35 ± 1.34	0.81 ± 0.37	0.52 ± 0.16
175	200	<0.12	0.97 ± 0.45	0.78 ± 0.49	0.52 ± 0.16
175	205	0.24 ± 0.47	1.49 ± 1.78	1.04 ± 0.33	0.64 ± 0.27
180	60	<0.24	1.56 ± 1.39	0.75 ± 0.28	0.62 ± 0.27
180	70	<0.28	<0.85	0.78 ± 0.32	0.69 ± 0.21
180	105	<0.23	1.51 ± 1.48	0.75 ± 0.43	0.32 ± 0.22
180	110	<0.22	1.25 ± 2.14	0.84 ± 0.64	0.90 ± 0.21
180	115	<0.33	8.32 ± 2.13	0.85 ± 0.54	0.65 ± 0.18
180	120	0.36 ± 0.55	2.41 ± 1.56	0.99 ± 0.41	0.65 ± 0.17
180	125	<0.23	0.94 ± 2.77	0.78 ± 0.44	0.64 ± 0.20
180	130	0.64 ± 0.54	6.37 ± 1.36	1.09 ± 0.63	0.92 ± 0.27
180	135	0.48 ± 0.40	7.09 ± 0.89	1.02 ± 0.34	0.65 ± 0.22
180	140	<0.21	1.22 ± 2.01	0.58 ± 0.48	0.61 ± 0.22
180	145	<0.23	1.39 ± 1.79	0.62 ± 0.33	0.50 ± 0.22
180	150	<0.27	4.12 ± 1.22	1.04 ± 0.43	0.48 ± 0.18
180	155	<0.15	<0.38	0.37 ± 0.36	0.48 ± 0.13
180	160	0.74 ± 0.45	2.02 ± 0.89	1.20 ± 0.47	0.53 ± 0.21
180	165	<0.17	1.11 ± 1.34	0.71 ± 0.30	0.70 ± 0.19
180	170	<0.29	1.52 ± 0.96	1.03 ± 0.34	0.78 ± 0.18
180	175	<0.15	0.65 ± 0.51	0.69 ± 0.23	0.53 ± 0.16
180	180	<0.21	1.47 ± 0.77	0.66 ± 0.38	0.69 ± 0.17
180	185	<0.21	1.43 ± 1.67	1.00 ± 0.33	0.61 ± 0.20
180	190	<0.28	<0.90	0.99 ± 0.37	0.80 ± 0.19
180	195	<0.14	1.52 ± 0.74	0.90 ± 0.31	0.53 ± 0.16
180	200	<0.20	1.62 ± 1.27	0.61 ± 0.35	0.81 ± 0.20
185	105	<0.25	<0.73	0.63 ± 0.39	0.44 ± 0.26
185	110	<0.54	<1.65	1.15 ± 0.55	0.79 ± 0.36
185	115	<0.15	1.65 ± 0.78	0.91 ± 0.31	0.57 ± 0.15
185	120	0.41 ± 0.57	1.23 ± 1.30	0.86 ± 0.34	0.68 ± 0.31
185	125	3.32 ± 0.86	2.68 ± 2.05	1.17 ± 0.54	0.64 ± 0.22
185	130	1.29 ± 1.17	10.6 ± 2.9	1.55 ± 0.39	0.12 ± 0.62
185	135	<0.16	2.66 ± 0.63	0.66 ± 0.30	0.50 ± 0.17
185	140	<0.22	1.07 ± 1.21	0.61 ± 0.27	0.65 ± 0.21
185	145	<0.26	1.77 ± 1.66	1.07 ± 0.37	0.63 ± 0.17
185	150	0.84 ± 0.62	9.64 ± 2.46	1.08 ± 0.41	0.44 ± 0.24
185	155	<0.15	1.49 ± 0.56	0.89 ± 0.27	0.35 ± 0.17
185	160	0.45 ± 0.50	1.63 ± 1.85	1.06 ± 0.44	0.54 ± 0.23

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Sample Location		Radionuclide Concentrations (pCi/g)			
N	E	U-235	U-238	Th-232	Ra-226
185	165	<0.24	1.10 ± 1.99	0.76 ± 0.40	0.55 ± 0.18
185	170	<0.33	<1.07	1.53 ± 0.44	0.58 ± 0.24
185	175	0.23 ± 0.32	0.27 ± 0.51	0.10 ± 0.10	0.68 ± 0.19
185	180	0.30 ± 0.49	1.25 ± 1.51	0.78 ± 0.50	0.78 ± 0.50
185	185	<0.24	<0.73	1.02 ± 0.55	0.62 ± 0.20
185	190	<0.28	1.36 ± 1.90	1.04 ± 0.37	0.78 ± 0.16
185	195	<0.16	1.29 ± 0.75	0.92 ± 0.26	0.66 ± 0.21
190	60	<0.19	0.93 ± 2.04	1.11 ± 0.39	0.88 ± 0.20
190	70	<0.24	1.14 ± 1.19	1.19 ± 0.40	0.51 ± 0.15
190	105	<0.33	1.66 ± 1.72	1.98 ± 2.75	0.52 ± 0.16
190	110	<0.24	1.40 ± 2.0	0.74 ± 0.35	0.60 ± 0.30
190	115	0.32 ± 0.57	2.65 ± 1.91	0.72 ± 0.52	0.54 ± 0.23
190	120	<0.26	1.07 ± 2.00	1.14 ± 0.36	0.39 ± 0.14
190	135	0.54 ± 0.50	3.61 ± 3.30	1.20 ± 0.39	0.77 ± 0.24
190	130	1.49 ± 0.32	1.18 ± 1.10	1.30 ± 0.32	0.48 ± 0.12
190	135	0.61 ± 0.53	6.81 ± 3.17	1.00 ± 0.49	0.59 ± 0.20
190	140	0.33 ± 0.62	7.48 ± 1.40	1.41 ± 0.36	0.47 ± 0.31
190	145	0.57 ± 0.69	8.52 ± 2.41	1.50 ± 0.43	0.68 ± 0.19
190	150	0.31 ± 0.40	3.82 ± 0.71	0.62 ± 0.50	0.60 ± 0.14
190	155	0.55 ± 0.60	3.05 ± 1.14	0.93 ± 0.61	0.78 ± 0.20
190	160	0.45 ± 0.54	3.23 ± 0.98	0.84 ± 0.38	0.61 ± 0.18
190	165	<0.31	2.30 ± 1.73	0.87 ± 0.46	0.87 ± 0.30
190	170	0.26 ± 0.43	1.31 ± 1.02	0.79 ± 0.29	0.76 ± 0.17
190	175	<0.24	2.11 ± 0.89	0.66 ± 0.66	0.90 ± 0.23
190	180	<0.26	1.61 ± 1.71	0.81 ± 0.66	0.85 ± 0.28
190	185	<0.28	<1.00	0.83 ± 0.46	0.83 ± 0.19
190	190	<0.16	1.11 ± 0.52	1.01 ± 0.22	0.65 ± 0.17
195	105	<0.24	<0.73	0.45 ± 0.46	1.18 ± 0.33
195	110	<0.27	<0.95	0.49 ± 0.33	0.44 ± 0.26
195	115	0.83 ± 0.47	7.86 ± 1.78	3.56 ± 0.62	0.96 ± 0.21
195	120	<0.14	0.63 ± 0.52	0.84 ± 0.29	0.56 ± 0.16
195	125	0.40 ± 0.48	2.87 ± 1.79	0.98 ± 0.37	0.73 ± 0.21
195	130	0.54 ± 0.60	2.69 ± 2.09	1.34 ± 3.54	0.59 ± 0.18
195	135	1.78 ± 0.70	2.70 ± 2.29	0.85 ± 0.23	0.77 ± 0.20
195	140	0.37 ± 0.35	1.41 ± 0.55	0.88 ± 0.49	0.11 ± 0.08
195	145	<0.25	1.57 ± 1.74	0.85 ± 0.47	0.74 ± 0.28
195	150	<2.59	1.41 ± 1.01	1.10 ± 0.34	0.47 ± 0.23
195	155	0.61 ± 0.65	2.23 ± 1.62	1.44 ± 0.49	0.75 ± 0.22
195	160	<0.18	1.80 ± 0.63	0.91 ± 0.63	0.53 ± 0.22
195	165	<0.24	1.19 ± 1.76	0.99 ± 0.41	0.58 ± 0.20

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Sample Location		Radionuclide Concentrations (pCi/g)			
N	E	U-235	U-238	Th-232	Ra-226
195	170	<0.27	2.10 ± 2.18	1.03 ± 0.51	0.88 ± 0.25
195	175	<0.24	2.36 ± 1.88	0.71 ± 0.61	0.53 ± 0.19
195	180	<0.36	3.60 ± 1.36	1.46 ± 0.51	0.86 ± 0.30
195	185	<0.13	0.90 ± 0.50	0.99 ± 0.33	0.65 ± 0.16
195	190	<0.21	1.28 ± 1.35	1.74 ± 0.45	0.83 ± 0.23
200	105	<0.26	1.21 ± 1.46	0.78 ± 0.36	0.55 ± 0.18
200	110	5.24 ± 0.80	4.19 ± 0.89	0.57 ± 0.43	0.68 ± 0.15
200	115	<0.26	3.11 ± 1.02	0.82 ± 0.37	0.61 ± 0.21
200	120	<0.26	2.12 ± 1.08	1.16 ± 0.42	0.70 ± 0.24
200	125	<0.30	1.63 ± 1.06	1.22 ± 0.35	0.72 ± 0.25
200	130	0.33 ± 0.33	1.10 ± 1.10	1.00 ± 0.34	0.56 ± 0.13
200	135	<0.22	1.04 ± 0.89	1.13 ± 0.60	0.73 ± 0.23
200	140	<0.21	1.33 ± 1.41	0.97 ± 0.64	0.53 ± 0.18
200	145	<0.31	2.13 ± 1.01	0.62 ± 0.26	0.55 ± 0.22
200	150	<0.28	4.26 ± 0.83	0.80 ± 0.34	0.48 ± 0.18
200	155	<0.18	0.85 ± 1.48	0.75 ± 0.25	0.49 ± 0.13
200	160	<0.26	2.71 ± 1.43	0.29 ± 0.39	0.79 ± 0.18
200	165	<0.28	5.33 ± 1.98	1.04 ± 0.42	0.72 ± 0.22
200	175	<0.14	0.75 ± 1.13	0.73 ± 0.47	0.51 ± 0.19
200	180	<0.36	4.69 ± 1.60	1.83 ± 0.61	1.32 ± 0.29
200	185	<0.21	<0.67	0.43 ± 0.23	0.49 ± 0.19
200	190	<0.32	4.19 ± 1.32	1.10 ± 0.40	0.77 ± 0.33
200	220	<0.19	2.27 ± 0.62	0.88 ± 0.32	0.67 ± 0.19
200	230	<0.25	0.98 ± 1.41	1.17 ± 0.66	1.86 ± 0.38
200	240	<0.25	1.38 ± 1.39	0.91 ± 0.41	0.89 ± 0.25
200	250	<0.29	3.23 ± 2.15	1.05 ± 0.31	0.64 ± 0.29
200	255	0.41 ± 0.34	1.32 ± 0.51	0.72 ± 0.26	0.50 ± 0.16
200	260	<0.20	1.25 ± 1.31	0.73 ± 0.41	1.06 ± 0.25
200	270	<0.20	<0.64	0.68 ± 0.48	0.62 ± 0.18
200	280	<0.27	2.07 ± 1.71	1.09 ± 0.37	0.60 ± 0.18
200	290	<0.14	1.35 ± 0.56	0.82 ± 0.37	0.48 ± 0.14
200	300	<0.21	<0.64	1.08 ± 0.43	0.65 ± 0.22
200	310	<0.25	<0.76	0.65 ± 0.43	0.66 ± 0.25
205	105	<0.42	<1.08	0.67 ± 0.40	0.64 ± 0.27
205	110	<0.15	1.91 ± 0.53	0.53 ± 0.22	0.45 ± 0.16
205	115	<0.25	1.38 ± 1.42	0.90 ± 0.38	0.62 ± 0.16
205	120	<0.25	0.18 ± 1.40	0.80 ± 0.36	0.66 ± 0.19
205	125	<0.50	<1.63	2.12 ± 0.55	1.08 ± 0.43
205	130	<0.14	1.43 ± 0.87	0.79 ± 0.32	0.53 ± 0.16
205	135	<0.22	<0.77	0.58 ± 0.36	0.57 ± 0.17

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED AT GRID LINE INTERSECTIONS -
BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	U-235	U-238	Th-232	Ra-226
		Radionuclide Concentrations (pCi/g)			
205	140	<0.19	0.85 ± 0.19	0.63 ± 0.48	0.42 ± 0.20
205	145	2.51 ± 0.77	11.2 ± 3.0	1.24 ± 0.44	0.66 ± 0.18
205	150	0.93 ± 0.42	5.44 ± 0.82	1.37 ± 0.39	0.55 ± 0.17
205	155	<0.19	1.64 ± 1.76	0.87 ± 0.34	0.56 ± 0.26
205	160	0.56 ± 0.66	3.93 ± 1.25	0.78 ± 4.28	0.48 ± 0.28
205	165	<0.29	<8.68	1.60 ± 0.42	0.57 ± 0.19
205	170	<0.13	1.74 ± 0.47	0.74 ± 0.28	0.47 ± 0.14
205	175	0.46 ± 0.50	1.93 ± 1.85	0.79 ± 0.29	0.83 ± 0.30
205	180	<0.20	1.09 ± 1.58	1.22 ± 0.39	0.53 ± 0.18
205	185	<0.34	<1.08	1.21 ± 0.58	1.32 ± 0.23
205	190	0.20 ± 0.29	1.04 ± 0.49	0.77 ± 0.36	0.41 ± 0.15
205	195	<0.21	1.69 ± 0.89	0.84 ± 0.38	0.49 ± 0.20
205	200	<0.22	1.39 ± 1.65	0.86 ± 0.51	0.64 ± 0.72
205	205	<0.30	<0.97	0.82 ± 0.38	0.69 ± 0.28
205	210	<0.16	0.81 ± 0.90	0.78 ± 0.44	0.50 ± 0.20
210	40	<0.19	<0.62	0.51 ± 0.45	0.44 ± 0.17
210	50	<0.19	0.66 ± 1.39	1.21 ± 0.36	0.56 ± 0.18
210	60	<0.36	2.87 ± 1.18	1.66 ± 0.39	1.53 ± 0.30
210	105	<0.16	1.20 ± 0.66	0.65 ± 0.65	0.40 ± 0.26
210	110	<0.92	3.43 ± 6.26	1.80 ± 0.26	0.89 ± 0.14
210	115	<0.29	<0.92	0.64 ± 0.69	0.34 ± 0.27
210	120	<0.22	1.50 ± 0.88	0.77 ± 0.39	0.56 ± 0.28
210	125	<0.26	0.68 ± 1.70	1.09 ± 0.28	0.56 ± 0.21
210	130	<0.18	1.07 ± 1.15	0.83 ± 0.56	0.39 ± 0.22
210	135	<0.21	2.50 ± 1.53	0.72 ± 0.39	0.65 ± 0.22
210	140	1.11 ± 0.54	6.24 ± 1.22	1.12 ± 0.36	0.60 ± 1.28
210	145	<0.16	2.53 ± 0.66	0.88 ± 0.34	0.55 ± 0.16
210	150	<0.25	2.16 ± 1.60	1.47 ± 5.14	0.44 ± 0.17
210	155	0.63 ± 0.59	4.02 ± 2.24	1.24 ± 4.43	0.50 ± 0.18
210	160	0.58 ± 0.51	6.96 ± 2.03	0.83 ± 0.33	0.54 ± 0.20
210	165	0.25 ± 0.38	4.41 ± 0.72	0.12 ± 0.09	0.50 ± 0.13
210	170	<0.23	2.78 ± 1.81	1.05 ± 0.38	0.73 ± 0.23
210	175	0.54 ± 0.64	0.55 ± 0.24	0.89 ± 0.36	0.63 ± 0.47
210	180	<0.33	2.26 ± 3.86	1.03 ± 0.45	0.50 ± 0.15
210	280	<0.13	1.45 ± 0.44	0.77 ± 0.30	0.48 ± 0.15
210	290	<0.18	1.47 ± 1.56	0.80 ± 0.29	0.62 ± 0.16
210	300	<0.21	<0.66	0.60 ± 0.24	0.51 ± 0.20
210	310	<0.33	<1.09	1.48 ± 0.47	0.59 ± 0.22
215	105	<0.14	0.21 ± 0.46	0.91 ± 0.26	0.53 ± 0.15

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
225	135	<0.22	<0.80	1.00 ± 0.49	0.98 ± 0.34
225	140	<0.27	1.63 ± 2.94	0.89 ± 0.43	0.53 ± 0.34
225	145	<0.46	1.74 ± 0.24	0.16 ± 0.11	0.25 ± 0.07
225	150	<0.28	2.20 ± 3.59	0.69 ± 0.32	0.85 ± 0.28
225	155	0.26 ± 0.74	4.76 ± 1.88	0.94 ± 0.38	0.61 ± 0.20
225	160	<0.53	0.77 ± 1.14	2.00 ± 0.60	0.72 ± 0.47
225	165	<0.38	2.90 ± 4.15	0.95 ± 0.52	0.37 ± 0.41
225	170	<0.25	1.26 ± 2.62	1.29 ± 0.72	0.56 ± 1.76
225	175	<0.33	7.89 ± 2.21	0.97 ± 0.39	0.82 ± 0.22
225	180	<0.26	1.45 ± 1.69	1.27 ± 0.48	0.78 ± 0.25
230	80	<0.21	1.19 ± 1.62	0.98 ± 0.43	0.68 ± 0.20
230	90	<0.23	0.65 ± 1.33	0.54 ± 0.39	0.51 ± 0.17
230	100	<0.28	2.57 ± 2.23	0.90 ± 0.85	0.46 ± 0.30
230	110	<0.24	1.71 ± 1.84	1.31 ± 0.74	0.68 ± 0.37
230	120	<0.42	<1.18	1.14 ± 0.50	0.79 ± 0.27
230	125	0.51 ± 0.70	3.41 ± 2.10	0.79 ± 0.67	0.34 ± 0.39
230	130	<0.29	1.22 ± 1.81	1.12 ± 0.56	0.65 ± 0.31
230	135	<0.32	<1.17	0.95 ± 0.40	0.78 ± 0.19
230	150	<0.22	1.58 ± 2.20	0.74 ± 0.46	0.70 ± 0.29
230	155	0.56 ± 0.65	3.44 ± 2.32	0.47 ± 0.52	0.67 ± 0.35
230	160	1.03 ± 0.69	12.1 ± 4.0	1.56 ± 0.69	1.10 ± 0.29
230	165	0.50 ± 0.49	3.83 ± 0.91	1.02 ± 0.41	0.66 ± 0.18
230	170	0.57 ± 0.54	2.73 ± 1.97	1.34 ± 0.42	0.80 ± 0.23
230	175	<0.22	2.61 ± 1.50	0.72 ± 0.35	0.47 ± 0.16
230	180	0.63 ± 0.48	3.45 ± 1.94	1.13 ± 0.34	0.73 ± 0.18
230	280	<0.12	1.05 ± 0.46	0.83 ± 0.25	0.41 ± 0.18
230	290	<0.21	1.46 ± 2.80	0.50 ± 0.31	0.56 ± 0.21
230	300	<0.26	2.95 ± 1.96	0.94 ± 0.60	0.58 ± 0.17
230	310	<0.28	3.35 ± 2.66	1.34 ± 0.46	0.65 ± 0.21
235	125	<0.13	1.43 ± 0.83	0.79 ± 0.33	0.45 ± 0.12
235	130	<0.22	0.87 ± 1.80	0.72 ± 0.43	0.53 ± 0.26
235	135	<0.20	1.53 ± 1.90	1.18 ± 0.66	0.41 ± 0.20
235	150	<0.33	<1.05	0.94 ± 0.39	0.72 ± 0.31
235	155	0.87 ± 0.44	3.20 ± 0.71	0.98 ± 0.39	1.05 ± 0.22
235	160	0.68 ± 0.48	1.35 ± 2.85	0.86 ± 0.42	0.82 ± 0.21
235	165	8.15 ± 1.27	6.53 ± 1.90	0.99 ± 0.43	0.55 ± 0.25
235	170	0.94 ± 0.62	2.63 ± 1.95	1.12 ± 0.39	0.73 ± 0.17
235	175	0.33 ± 3.26	1.66 ± 0.79	0.71 ± 0.29	0.48 ± 0.12
235	180	<0.23	2.76 ± 2.07	1.04 ± 0.45	0.57 ± 0.28
240	80	<0.26	<0.79	0.79 ± 0.58	0.58 ± 0.21

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 12 BURIAL AREA

Sample Location		Radionuclide Concentrations (pCi/g)			
N	E	U-235	U-238	Th-232	Ra-226
215	110	<0.29	2.38 ± 1.57	0.64 ± 0.30	0.62 ± 0.20
215	115	<0.21	1.94 ± 1.49	0.95 ± 0.47	0.70 ± 0.16
215	120	<0.27	1.98 ± 0.98	1.01 ± 0.33	0.71 ± 0.19
215	125	<0.14	0.98 ± 0.51	0.83 ± 0.36	0.53 ± 0.16
215	130	0.27 ± 0.53	1.05 ± 1.06	0.75 ± 0.51	0.44 ± 0.22
215	135	<0.23	<0.69	0.45 ± 0.37	0.52 ± 0.15
215	140	0.93 ± 0.87	9.95 ± 2.43	1.52 ± 0.39	1.13 ± 0.29
215	145	<0.15	1.38 ± 0.55	0.94 ± 0.34	0.50 ± 0.17
215	150	<0.17	0.50 ± 1.21	0.72 ± 0.39	0.51 ± 0.15
215	155	0.23 ± 0.46	1.15 ± 1.81	1.55 ± 0.50	0.62 ± 0.19
215	160	1.79 ± 0.53	11.5 ± 2.3	1.35 ± 0.41	0.47 ± 0.16
215	165	0.30 ± 0.49	4.94 ± 0.73	0.99 ± 0.28	0.06 ± 0.05
215	170	2.01 ± 1.40	7.66 ± 1.49	1.19 ± 0.42	0.71 ± 0.25
215	175	<0.22	3.03 ± 0.98	1.06 ± 0.28	0.64 ± 0.20
215	180	<0.26	3.16 ± 1.15	0.99 ± 0.31	0.73 ± 0.16
220	80	<0.21	0.83 ± 1.25	0.65 ± 0.34	0.41 ± 0.23
220	90	<0.37	<1.46	0.87 ± 0.67	0.47 ± 0.43
220	100	<0.19	1.27 ± 1.38	0.52 ± 0.22	0.43 ± 0.19
220	110	<0.24	1.36 ± 1.17	0.76 ± 0.21	0.40 ± 0.15
220	115	0.15 ± 0.24	0.57 ± 1.39	0.53 ± 0.35	0.32 ± 0.13
220	120	<0.21	<0.64	0.78 ± 0.37	0.53 ± 0.16
220	125	<0.25	<0.85	0.71 ± 0.54	0.68 ± 0.24
220	130	<0.23	<0.65	0.65 ± 0.27	0.58 ± 0.17
220	135	<0.28	<0.86	0.93 ± 0.37	0.71 ± 0.17
220	140	0.53 ± 0.50	2.56 ± 2.39	0.86 ± 0.59	0.49 ± 0.14
220	145	<0.32	7.33 ± 1.48	0.88 ± 0.39	0.78 ± 0.23
220	150	<0.22	3.80 ± 1.60	0.70 ± 0.59	0.60 ± 0.18
220	155	0.46 ± 0.56	1.04 ± 1.82	0.91 ± 0.57	0.42 ± 0.22
220	160	<0.30	1.97 ± 1.73	0.73 ± 0.38	0.58 ± 0.29
220	165	<0.27	2.78 ± 1.62	1.07 ± 0.41	0.74 ± 0.31
220	170	0.49 ± 0.65	3.62 ± 2.02	1.05 ± 0.46	0.47 ± 0.26
220	175	<0.35	5.09 ± 1.76	0.99 ± 0.37	0.73 ± 0.33
220	180	<0.21	1.78 ± 0.94	0.98 ± 0.37	0.38 ± 0.14
220	280	<0.21	1.35 ± 2.00	0.50 ± 0.35	0.50 ± 0.17
220	290	<0.30	0.99 ± 1.54	1.17 ± 0.49	0.75 ± 0.23
220	300	<0.24	<0.81	0.71 ± 0.59	0.70 ± 1.96
220	310	<0.25	1.35 ± 1.92	1.06 ± 0.76	0.57 ± 0.18
225	115	<0.29	<0.84	0.69 ± 0.54	0.61 ± 0.18
225	120	<0.24	<0.90	0.69 ± 0.32	0.50 ± 0.19
225	125	<0.17	<0.60	0.74 ± 0.34	0.48 ± 0.25
225	130	<0.35	<1.08	1.64 ± 0.49	0.54 ± 0.03

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED AT GRID LINE INTERSECTIONS
BUILDING 12 BURIAL AREA

Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
240	90	<0.22	2.00 ± 1.67	0.62 ± 0.26	0.65 ± 0.29
240	130	<0.15	0.61 ± 0.57	0.81 ± 0.36	1.33 ± 0.24
240	140	<0.20	2.15 ± 1.37	0.72 ± 0.38	0.34 ± 0.24
240	145	<0.26	1.61 ± 2.12	0.71 ± 0.40	0.63 ± 0.26
250	190	<0.23	2.47 ± 1.59	0.87 ± 0.29	0.53 ± 0.16
250	200	<0.27	<0.93	1.42 ± 0.31	0.72 ± 0.24
250	210	<0.17	1.78 ± 0.58	0.69 ± 0.38	0.72 ± 0.21
250	220	<0.20	2.46 ± 0.92	0.86 ± 0.37	0.42 ± 0.21
250	230	<0.25	1.41 ± 2.34	1.02 ± 0.62	0.46 ± 0.29
250	240	<0.31	1.55 ± 3.43	1.26 ± 0.45	0.67 ± 0.17
250	250	<0.15	1.34 ± 0.84	1.03 ± 0.35	0.66 ± 0.19
250	260	<0.25	3.14 ± 1.08	0.70 ± 0.30	0.61 ± 0.23
250	270	<0.27	4.07 ± 2.86	0.8[illegible] ± 0.56	0.46 ± 0.20
250	280	<0.41	12.5 ± 2.7	1.47 ± 0.40	1.16 ± 0.24
250	290	<0.14	0.66 ± 1.12	0.82 ± 0.35	0.65 ± 0.15
250	310	<0.21	1.34 ± 1.58	0.70 ± 0.29	0.62 ± 0.18

[a] Errors are 2σ based on counting statistics.

TABLE 5A

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
COLLECTED FROM LOCATIONS OF ELEVATED CONTACT RADIATION LEVELS
BUILDING 32 BURIAL AREA

Sample[a] Identification No.	Grid Location N	Grid Location E	Depth	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
S-1	153	114	10 - 15 cm.	14.9 ± 1.6[b]	92.2 ± 4.2	3.89 ± 0.74	0.74 ± 0.26
S-2	154	111	2 - 12 cm.	114 ± 6	887 ± 16	22.4 ± 1.8	0.65 ± 0.53
S-3	155	112	2 - 10 cm.	53.7 ± 3.5	198 ± 8	2.94 ± 0.65	0.57 ± 0.37
S-4	156	112	2 - 10 cm.	70.9 ± 1.7	379 ± 5	1.04 ± 0.85	0.32 ± 0.32
S-5	157	112	2 - 10 cm.	53.2 ± 1.8	483 ± 7	8.07 ± 0.87	0.44 ± 0.34
S-6	157	113	2 - 15 cm.	6.48 ± 1.8	561 ± 10	1.74 ± 0.47	0.94 ± 0.34
S-7	164	116	2 - 15 cm.	125 ± 3	271 ± 6	2.29 ± 0.47	0.51 ± 0.30
S-8	166	120	10 - 25 cm.	<2.75	194 ± 50	299 ± 5	<0.74
S-9	167	118	5 - 15 cm.	<1.78	110 ± 36	80.7 ± 3.0	<0.49
S-10	170	129	35 - 40 cm.	<40.2	<867	10,240 ± 176	<22.2
S-11	184	151	2 - 15 cm.	12.8 ± 1.8	460 ± 9	4.85 ± 0.74	0.80 ± 0.42
S-12	185	143	15 - 30 cm.	<32.1	<433	2,135 ± 66	<10.7
S-13	185	149	10 - 15 cm.	590 ± 8	488 ± 14	3.38 ± 0.78	0.66 ± 0.46
S-14	185	150	30 - 35 cm.	<9.12	309 ± 188	1,213 ± 20	<2.74
S-15	186	138	20 - 30 cm.	<2.45	<46.6	722 ± 7	<0.97
S-16	186	149	10 - 15 cm.	250 ± 6	222 ± 9	5.93 ± 0.90	0.54 ± 0.27
S-17	187	142	2 - 15 cm.	<9.38	<114	772 ± 16	<2.53
S-18	188	147	15 - 20 cm.	22.9 ± 3.2	330 ± 9	57.1 ± 2.1	0.67 ± 0.55

[a] Refer to Figure 5 for sample locations and to Table 3 for direct radiation levels.
[b] Errors are 2σ based on counting statistics.

TABLE 5B

ACTIVITY LEVELS IN DEBRIS COLLECTED FROM
LOCATIONS OF ELEVATED CONTACT RADIATION LEVELS -
BUILDING 12 BURIAL AREA

Sample[a] Identification No.	Grid Location N	Grid Location E	Type of Sample	Weight (Grams)	Activity Levels (pCi) U-235	U-238	Th-232	Ra-226
D-1	102	257	Metal	[illegible]	12×10^{4}[b]	30×10^{4}	---	---
D-2	107	252	Metal	[illegible]	6.2×10^{4}	540×10^{4}	---	---
D-3	135	241	Pellet	[illegible]	---	---	---	8.3×10^{4}
D-4	167	118	Rock	[illegible]	---	---	79×10^{4}	---
D-5	170	129	Metal	126	6.1×10^{4}	123×10^{4}	---	---
D-6	181	130	Slag	52	---	---	8.1×10^{4}	---
D-7	186	138	Rock	8	---	---	1.2×10^{4}	---
D-8	187	128	Metal	43	1.4×10^{4}	40×10^{4}	---	---
D-9	189	145	Metal	184	69×10^{4}	1250×10^{4}	---	---

a Refer to Table 3 for sample locations and direct radiation levels.

b Values in table are approximate, as samples were of nonstandard geometry and possibly not homogeneous.

TABLE 6A

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
FROM BUILDING 12 BURIAL AREA

Borehole[a] No.	Borehole Location N	Borehole Location E	Depth (Meters)	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
B1	107	127	Surface	<0.20	1.49 ± 1.52[b]	0.92 ± 0.27	0.69 ± 0.37
			1.5 - 2.0	<0.33	1.58 ± 2.16	1.55 ± 0.46	0.99 ± 0.22
			3.0 - 3.5	<0.27	2.32 ± 1.31	1.06 ± 0.36	0.78 ± 0.16
B2	113	174	Surface	<0.25	1.47 ± 0.89	0.74 ± 0.43	0.52 ± 0.23
			1.5 - 2.0	<0.27	2.23 ± 1.30	1.57 ± 0.47	0.80 ± 0.19
			3.0 - 3.5	<0.08	0.91 ± 0.46	1.19 ± 0.39	0.71 ± 0.14
B3	200	240	Surface	<0.32	1.23 ± 1.86	1.83 ± 0.61	0.72 ± 0.18
			1.5 - 2.0	<0.36	2.70 ± 1.89	1.65 ± 0.58	0.81 ± 0.32
			3.0 - 3.5	<0.21	0.77 ± 1.28	0.77 ± 0.40	0.61 ± 0.23
B4	223	237	Surface	<0.17	1.14 ± 1.44	0.31 ± 0.37	0.66 ± 0.16
			1.5 - 2.0	<0.28	<0.85	1.02 ± 0.35	0.65 ± 0.16
			3.0 - 3.5	<0.17	1.77 ± 0.55	0.91 ± 0.33	0.94 ± 0.18
B5	250	212	Surface	<0.33	<1.04	1.06 ± 0.43	0.82 ± 0.22
			1.5 - 2.0	<0.14	<0.38	0.59 ± 0.35	0.57 ± 0.18
			3.0 - 3.5	<0.38	3.19 ± 1.86	1.89 ± 0.56	1.31 ± 0.37
B6	246	160	Surface	0.25 ± 0.39	2.55 ± 0.95	0.93 ± 0.29	0.59 ± 0.19
			1.5 - 2.0	<0.38	5.59 ± 1.97	2.36 ± 0.54	1.16 ± 0.30
			3.0 - 3.5	<0.19	<0.60	0.65 ± 0.47	0.40 ± 0.15
B7	230	110	Surface	<0.19	1.65 ± 1.50	0.78 ± 0.46	0.60 ± 0.21
			1.5 - 2.0	<0.17	0.98 ± 1.22	0.81 ± 0.31	0.35 ± 0.23
			3.0 - 3.5	<0.23	1.18 ± 1.11	1.27 ± 0.52	0.56 ± 0.14

TABLE 6A (Continued)

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
FROM BUILDING 12 BURIAL AREA

Borehole No.	Borehole Location N	Borehole Location E	Depth (Meters)	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
B8	197	84	Surface	0.60 ± 0.53	2.10 ± 1.50	1.47 ± 0.33	0.63 ± 0.17
			1.5 - 2.0	<0.16	0.26 ± 0.45	1.05 ± 0.42	0.57 ± 0.17
B9	165	86	Surface	<0.18	1.79 ± 1.09	0.70 ± 0.36	0.61 ± 0.17
			1.5 - 2.02	<0.21	1.16 ± 1.60	1.20 ± 0.30	0.76 ± 0.18
B10	107	252	Surface	1.81 ± 0.72	17.0 ± 2.9		0.69 ± 0.34
			1.5 - 2.0	1.27 ± 0.40	16.3 ± 1.2	0.64 ± 0.22	0.74 ± 0.18
			3.0 - 3.5	<0.21	2.30 ± 1.02	0.63 ± 0.33	0.81 ± 0.21
			4.5 - 5.0	<0.25	1.96 ± 1.86	1.22 ± 0.45	0.90 ± 0.23
B11	134	242	Surface	<0.27	1.43 ± 1.74	0.84 ± 0.32	0.69 ± 0.23
			1.5 - 2.0	<0.14	0.64 ± 0.43	1.10 ± 0.33	0.48 ± 0.13
			3.0 - 3.5	<0.20	1.17 ± 1.82	0.76 ± 0.28	0.80 ± 0.23
B12	150	115	Surface	<0.29	0.94 ± 2.22	0.82 ± 0.39	0.59 ± 0.22
			0.3 - 1.0	<0.14	4.00 ± 0.65	0.96 ± 0.23	0.53 ± 0.14
			1.0	0.34 ± 0.50	14.4 ± 1.6	0.77 ± 0.48	0.82 ± 0.21
			1.5 - 2.5	1.59 ± 0.68	84.3 ± 5.1	0.41 ± 0.22	0.59 ± 0.21
			3.0 - 3.5	<0.23	4.04 ± 1.12	0.97 ± 0.38	0.76 ± 0.18
B13	156	134	Surface	0.52 ± 0.62	1.36 ± 1.79	0.94 ± 0.42	0.47 ± 0.18
			0.5 - 1.0	<0.27	<1.08	1.40 ± 0.36	0.67 ± 0.14
			1.5 - 2.5	0.76 ± 0.35	15.4 ± 1.1	0.92 ± 0.32	0.72 ± 0.15
			3.0 - 3.5	<0.25	9.07 ± 2.47	0.92 ± 0.30	0.68 ± 0.18

TABLE 6A (Continued)

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
FROM BUILDING 12 BURIAL AREA

Borehole No.	Borehole Location N	Borehole Location E	Depth (Meters)	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
B14	160	160	Surface	<0.27	1.21 ± 2.03	0.61 ± 0.27	0.67 ± 0.24
			0.3 - 1.0	<0.27	3.75 ± 1.02	0.90 ± 0.37	0.50 ± 0.13
			1.5 - 2.5	<0.15	1.55 ± 0.85	1.30 ± 0.47	0.57 ± 0.16
			3.0 - 3.5	<0.23	3.23 ± 1.00	0.82 ± 0.37	0.92 ± 0.28
B15	163	115	Surface	12.3 ± 1.2	45.8 ± 3.1	1.25 ± 0.63	0.83 ± 0.23
			0.3 - 0.5	<0.16	2.02 ± 0.77	0.74 ± 0.29	0.60 ± 0.16
			0.5 - 1.0	<0.22	3.15 ± 1.66	0.75 ± 0.36	0.65 ± 0.20
			1.0 - 2.0	0.29 ± 0.56	1.31 ± 1.58	1.25 ± 0.35	0.91 ± 0.25
B16	167	104	Surface	<0.27	<0.84	1.09 ± 0.32	0.52 ± 0.13
			0.3 - 0.6	0.24 ± 0.35	4.32 ± 0.71	0.91 ± 0.29	0.59 ± 0.17
			0.6 - 1.1	0.56 ± 0.61	7.21 ± 1.95	0.73 ± 0.41	0.74 ± 0.29
			1.1 - 2.0	0.50 ± 0.64	4.81 ± 2.10	1.14 ± 0.38	0.70 ± 0.21
B17	170	129	Surface	<0.46	7.85 ± 2.34	5.18 ± 0.89	0.97 ± 0.22
			0.15	2.87 ± 0.59	56.0 ± 2.1	88.7 ± 2.8	0.51 ± 0.17
			0.30	2.38 ± 2.09	148 ± 5	8.04 ± 0.87	0.72 ± 0.63
			0.3 - 0.5	12.9 ± 1.6	274 ± 7	0.94 ± 0.27	0.66 ± 0.35
			0.5 - 1.0	20.6 ± 1.4	680 ± 10	2.55 ± 0.96	0.76 ± 0.37
			1.0 - 2.0	17.2 ± 1.4	526 ± 9	2.81 ± 0.60	0.46 ± 0.33
			2.0 - 2.5	6.03 ± 0.88	69.7 ± 3.1	3.49 ± 0.62	0.96 ± 0.23
B18	179	169	Surface	<0.37	<1.13	1.81 ± 0.47	0.84 ± 0.25
			0.3 - 1.0	<0.18	2.13 ± 0.60	0.68 ± 0.27	0.50 ± 0.16
			1.5 - 2.5	<0.28	3.19 ± 2.44	0.98 ± 0.48	0.85 ± 0.20

TABLE 6A (Continued)

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
FROM BUILDING 12 BURIAL AREA

Borehole No.	Borehole Location N	Borehole Location E	Depth (Meters)	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
B19	181	130	Surface	2.72 ± 1.30	74.3 ± 4.2	12.0 ± 1.3	0.65 ± 0.35
			0.15	4.02 ± 2.05	69.9 ± 5.1	42.2 ± 1.9	0.52 ± 0.29
			0.3	1.78 ± 1.00	8.74 ± 1.71	2.47 ± 0.54	0.61 ± 0.20
			0.3 - 0.5	0.79 ± 0.75	25.6 ± 2.2	1.57 ± 0.37	0.60 ± 0.25
			0.5 - 1.0	<0.16	3.14 ± 0.66	0.94 ± 0.36	0.63 ± 0.17
			1.0 - 2.0	1.14 ± 0.62	21.2 ± 2.0	1.24 ± 0.34	0.72 ± 1.18
			3.0 - 3.5	0.38 ± 0.47	5.48 ± 0.86	2.43 ± 0.46	0.68 ± 0.20
B20	186	128	Surface	16.5 ± 0.8	30.3 ± 1.9	2.01 ± 0.33	0.57 ± 0.17
			0.5 - 1.0	2.87 ± 0.91	3.68 ± 1.22	0.62 ± 0.25	0.80 ± 0.23
			1.0 - 2.0	1.36 ± 0.78	2.11 ± 1.62	1.14 ± 0.36	0.85 ± 0.23
B21	187	147	Surface	0.50 ± 0.51	1.10 ± 1.31	3.13 ± 0.57	0.55 ± 0.19
			0.14	1.90 ± 1.21	9.20 ± 3.89	11.9 ± 1.0	0.61 ± 0.31
			0.7	2.78 ± 1.12	37.7 ± 3.1	10.8 ± 0.98	1.06 ± 0.28
			1.5 - 2.0	2.74 ± 1.12	10.9 ± 2.30	8.89 ± 0.83	0.64 ± 0.28
B22	200	140	Surface	0.61 ± 0.52	12.0 ± 1.35	0.69 ± 0.40	0.55 ± 0.20
			0.3 - 1.0	3.1 ± 0.95	44.3 ± 3.1	0.51 ± 0.51	0.48 ± 0.24
			0.5 - 1.0	<0.24	3.71 ± 1.26	0.79 ± 0.51	0.87 ± 0.23
			1.0 - 2.0	4.53 ± 0.73	45.4 ± 2.6	1.06 ± 0.38	0.69 ± 0.24
B23	206	134	Surface	<0.16	1.58 ± 0.59	0.78 ± 0.36	0.52 ± 0.19
			0.3 - 1.0	<0.32	4.31 ± 3.08	1.41 ± 0.56	0.49 ± 0.32
			1.5 - 2.5	<0.19	1.06 ± 1.52	0.99 ± 0.28	0.37 ± 0.19

TABLE 6A (Continued)

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
FROM BUILDING 12 BURIAL AREA

Borehole No.	Borehole Location		Depth (Meters)	Radionuclide Concentrations (pCi/g)			
	N	E		U-235	U-238	Th-232	Ra-226
B24	211	189	Surface	<0.10	0.65 ± 0.76	0.78 ± 0.24	0.38 ± 0.14
			0.3 - 1.0	<0.19	1.08 ± 0.68	1.12 ± 0.36	0.45 ± 0.17
			1.5 - 2.0	<0.16	<0.54	0.74 ± 0.33	0.54 ± 0.17
B25	216	169	Surface	2.39 ± 0.80	10.7 ± 0.6	1.07 ± 0.60	0.60 ± 0.20
			0.5 - 1.0	<0.29	2.41 ± 1.36	1.44 ± 0.39	0.64 ± 0.23

[a] Refer to Figure 6 for locations.
[b] Errors are 2σ based on counting statistics.

TABLE 6B

ISOTOPIC URANIUM CONCENTRATIONS IN BOREHOLE SOIL SAMPLES
BUILDING 12 BURIAL AREA

Borehole[a] No.	Sample Type	Depth (Meters)	Radionuclide Concentrations (pCi/g) U-238	U-235	U-234	$\frac{U-238}{U-235}$*	$\frac{U-234}{U-235}$
B17	Soil	Surface	95.8 ± 2.5[b]	2.32 ± 0.39	49.3 ± 1.8	41.2	21.2
B17	Soil	0.30	229 ± 8	5.61 ± 1.21	120 ± 6	40.9	21.5
B17	Soil	0.5 - 1.0	1238 ± 53	28.9 ± 7.2	527 ± 31	42.7	18.2
B17	Soil	1.0 - 2.0	1627 ± 44	38.6 ± 6.0	614 ± 24	42.1	17.9
B20	Soil	Surface	836 ± 70	38.3 ± 15.0	940 ± 77	21.8	24.5

[a] Refer to Figure 6 for locations.
[b] Errors are 2σ based on counting statistics.

* $\frac{U-238}{U-235}$ For natural uranium = 22

$\frac{U-238}{U-235}$ For depleted uranium = > 22

$\frac{U-238}{U-235}$ For enriched uranium = < 22

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES COLLECTED FROM BOREHOLES - BUILDING 12 BURIAL AREA

Borehole[a] No.	Grid Location N	Grid Location E	Radionuclide Concentrations (pCi/l or x 10^{-9} μCi/ml) Gross Alpha	Gross Beta
B1	107	127	8.66 ± 1.85[b]	14.0 ± 1.9
B2	113	174	3.82 ± 1.06	5.80 ± 1.11
B4	223	237	1.39 ± 0.76	4.14 ± 1.03
B5	250	212	7.00 ± 1.27	11.2 ± 1.28
B6	246	160	1.36 ± 0.62	3.03 ± 0.96
B7	230	110	2.50 ± 0.78	6.51 ± 1.10
B10	107	252	7.71 ± 1.36	14.2 ± 1.4
B12	150	115	3.96 ± 0.88	18.7 ± 1.47
B14	160	160	1.21 ± 0.70	6.20 ± 1.10
B17	170	129	101 ± 8 [c]	251 ± 9 [c]
B19	181	130	1.97 ± 0.67	7.06 ± 1.11

[a] Refer to Figure 6 for locations.
[b] Errors are 2σ based on counting statistics.
[c] Isotopic Uranium levels were:
U-238: 57.4 ± 1.9 pCi/l
U-235: 2.45 ± 0.39 pCi/l
U-234: 36.7 ± 1.5 pCi/l

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN SURFACE WATER SAMPLES
BUILDING 12 BURIAL AREA

Sample Location	Radionuclide Concentrations (pCi/l or x 10^{-9} μCi/ml)	
	Gross Alpha	Gross Beta
Bog NE of Bldg. 12 West of Road	0.23 ± 0.54[a]	1.08 ± 0.88
Bog NE of Bldg. 12 North of Road	0.14 ± 0.50	2.23 ± 0.93

[a] Errors are 2σ based on counting statistics.

APPENDIX A

GROUND PENETRATING RADAR SURVEY
OF BURIED WASTE MATERIAL
TEXAS INSTRUMENTS, INC.
ATTLEBORO, MASSACHUSETTS

TABLE 9

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS -
BUILDING 10

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
0	0	11	11	20
0	20	11	12	58
0	40	12	12	35
0	60	11	11	38
0	80	11	11	31
0	100	11	11	41
0	120	11	11	18
0	145	11	11	33
20	0	11	11	22
20	20	11	11	11
20	25	11	11	32
20	30	11	11	30
20	40	10	11	32
20	60	10	11	22
20	100	11	11	41
20	122	11	11	24
20	145	11	11	24
25	20	11	11	25
25	25	11	11	40
25	30	12	12	43
30	20	11	11	31
30	25	11	11	22
30	30	12	12	18
35	20	10	11	15
35	25	11	11	27
35	30	12	12	25
40	0	11	11	32
40	20	11	11	31
40	25	11	11	24
40	30	12	12	19
40	122	11	11	14
40	145	11	11	27
45	20	10	10	20
45	25	11	11	24
45	30	12	12	32
50	20	10	11	19
50	25	11	11	17
50	30	12	12	32
55	20	10	10	25
55	25	11	11	28
55	30	12	12	35
60	0	11	11	24

TABLE 9 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 10

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
60	20	11	11	16
60	25	11	11	18
60	30	12	12	23
60	122	10	11	11
60	145	11	11	40
65	20	10	11	19
65	25	11	11	25
65	30	12	12	15
70	20	11	11	11
70	25	11	11	34
70	30	12	12	23
75	20	11	11	22
75	25	11	11	35
75	30	12	12	45
80	0	10	11	21
80	20	11	11	25
80	25	11	11	30
80	30	12	12	46
80	122	10	11	27
80	145	11	11	18
85	20	11	11	22
85	25	11	11	17
85	30	12	12	31
90	20	10	10	26
90	25	11	11	19
90	30	12	12	23
95	20	10	11	29
95	25	11	11	38
95	30	12	12	35
100	0	11	11	19
100	20	10	10	13
100	25	11	11	11
100	30	12	12	13
100	122	10	11	19
100	145	11	11	32
105	20	10	11	19
105	25	11	11	14
105	30	12	12	29
110	20	10	11	28
110	25	11	11	14
110	30	12	12	18
115	20	10	10	16

TABLE 9 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 10

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
115	25	11	11	28
115	30	12	12	15
120	0	10	11	11
120	20	10	10	22
120	25	11	11	32
120	30	12	12	39
120	122	10	11	24
120	145	11	11	45
125	20	10	10	26
125	25	11	11	40
125	30	12	12	32
130	20	10	10	15
130	25	11	11	11
130	30	11	11	31
135	20	10	11	16
135	25	11	11	24
135	30	12	12	28
140	0	11	11	24
140	20	11	11	19
140	25	11	11	42
140	30	12	12	16
140	122	10	11	23
140	145	11	11	25
140	160	11	11	24
145	20	11	11	18
145	25	11	11	22
145	26	11	11	11
145	27	11	11	28
145	28	11	11	20
145	29	11	11	11
145	30	12	12	28
146	25	11	11	27
146	26	11	11	11
146	27	11	11	27
146	28	11	11	25
146	29	11	11	17
146	30	12	12	12
147	25	11	11	13
147	26	11	11	27
147	27	11	11	21
147	28	11	11	21
147	29	11	11	34

TABLE 9 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 10

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
147	30	12	12	19
148	25	11	11	14
148	26	11	11	35
148	27	11	11	32
148	28	11	11	21
148	29	11	11	21
148	30	12	12	18
149	25	11	11	22
149	26	11	11	29
149	27	11	11	11
149	28	11	11	19
149	29	11	11	29
149	30	12	12	18
150	20	11	11	11
150	25	11	11	11
150	26	11	11	27
150	27	11	11	41
150	28	11	11	53
150	29	11	11	23
150	30	12	12	23
155	20	11	11	28
155	25	11	11	12
155	26	11	11	25
155	27	11	11	21
155	28	11	11	11
155	29	11	11	41
155	30	11	12	33
156	25	11	11	21
156	26	11	11	24
156	27	11	11	12
156	28	11	11	31
156	29	11	11	18
156	30	12	12	22
157	25	11	11	14
157	26	11	11	14
157	27	11	11	20
157	28	11	11	17
157	29	11	11	28
157	30	12	12	28
158	25	11	11	39
158	26	11	11	21
158	27	11	11	18

TABLE 9 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 10

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
158	28	11	11	25
158	29	11	11	21
158	30	12	12	35
159	25	11	11	31
159	26	11	11	18
159	27	11	11	20
159	28	11	11	31
159	29	11	11	20
159	30	12	12	29
160	0	11	12	27
160	20	11	11	27
160	25	11	11	28
160	26	11	11	41
160	27	11	11	25
160	28	11	11	31
160	29	11	11	27
160	30	12	12	22
160	158	10	11	11
160	160	11	11	19
165	20	11	11	29
165	25	11	11	15
165	30	12	12	28
170	20	11	11	29
170	25	11	11	28
170	30	12	12	31
170	100	11	12	30
170	120	11	12	35
171	140	11	11	20
172	0	11	12	29
175	12	10	11	29
175	20	11	11	28
175	25	11	11	18
175	30	11	11	20
180	12	10	11	28
180	20	11	11	11
180	25	11	11	21
180	30	11	12	33
180	100	11	11	19
180	120	11	11	17
180	140	11	11	31
180	158	11	11	11
180	160	11	11	31

TABLE 9 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS - BUILDING 10

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
186	40	12	12	45
186	60	12	12	12
186	80	12	12	25
200	20	11	11	19
200	40	11	11	41
200	60	11	11	28
200	80	11	11	24
200	100	11	11	27
200	120	11	11	18
200	140	11	11	33
200	160	11	12	33

TABLE 10

DIRECT RADIATION LEVELS AT LOCATIONS IDENTIFIED
BY THE WALKOVER SURFACE SCAN - BUILDING 10

Grid Location[a]		Exposure Rate (µR/h)		Surface Dose Rate (µrad/h)	Sample Identification Number	Contact Exposure Rate After Sample Removal (µR/h)
N	E	Contact	1 m Above Surface			
128	28	22	11	43	S19	13
132	27	15	10	22	–	–
146	123	27	13	47	S20/D10	20
146	125	13	10	21	–	–
146	128	27	10	33	D11	15
151	123	75	13	490	D12	22
177	26	17	10	20	S21	13
179	25	16	10	29	–	–

[a]Refer to Figure 9.

TABLE 11

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 10

Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
0	120	<0.24	1.69 ± 0.39[a]	0.94 ± 0.42	0.58 ± 0.20
20	25	<0.29	4.82 ± 1.45	0.85 ± 0.18	0.88 ± 0.20
20	30	<0.23	0.82 ± 1.73	0.87 ± 0.72	0.59 ± 0.18
20	121	<0.16	1.38 ± 0.86	1.08 ± 0.40	0.97 ± 0.19
25	25	<0.15	0.92 ± 0.76	0.61 ± 0.48	0.67 ± 0.15
25	30	<0.29	1.23 ± 1.69	0.82 ± 0.35	0.70 ± 0.18
30	25	<0.20	1.17 ± 1.41	0.77 ± 0.36	0.55 ± 0.20
30	30	<0.13	0.75 ± 0.44	0.95 ± 0.45	0.64 ± 0.14
40	0	<0.16	<0.44	1.07 ± 0.36	0.56 ± 0.14
40	25	<0.31	<1.02	1.37 ± 0.35	0.78 ± 0.17
40	30	<0.22	1.87 ± 1.48	0.64 ± 0.32	0.64 ± 0.18
40	121	<0.27	<0.94	0.96 ± 0.34	0.72 ± 0.21
45	25	<0.14	0.91 ± 0.79	0.77 ± 0.28	0.61 ± 0.17
45	30	<0.27	2.1 ± 1.57	1.48 ± 0.39	0.71 ± 0.18
50	25	<0.23	6.49 ± 1.96	0.49 ± 0.42	0.52 ± 0.19
50	30	<0.12	1.07 ± 0.73	0.75 ± 0.36	0.51 ± 0.14
55	25	<0.23	1.21 ± 1.42	0.84 ± 0.31	0.67 ± 0.24
55	30	<0.20	0.71 ± 0.78	0.53 ± 0.38	0.46 ± 0.21
60	0	<0.19	<0.68	0.64 ± 0.27	0.57 ± 0.14
60	25	<0.31	<0.88	0.97 ± 0.47	0.57 ± 0.14
60	30	<0.20	<0.65	0.85 ± 0.28	0.55 ± 0.17
60	121	<0.24	2.44 ± 1.41	0.91 ± 0.43	0.60 ± 0.20
65	25	<0.14	<0.39	0.99 ± 0.33	0.65 ± 0.17
65	30	<0.28	0.93 ± 1.92	0.87 ± 0.37	0.65 ± 0.21
70	25	<0.19	<0.65	0.88 ± 0.39	0.51 ± 0.31
70	30	<0.14	0.99 ± 0.94	0.82 ± 0.30	0.44 ± 0.15
75	25	<0.23	<0.68	1.16 ± 0.41	0.72 ± 0.23
75	30	<0.22	<0.67	0.58 ± 0.36	0.37 ± 0.17
80	0	<0.19	<0.58	0.90 ± 0.32	0.55 ± 0.15
80	25	<0.28	<0.92	1.12 ± 0.41	0.65 ± 0.16
80	30	<0.25	<0.74	0.73 ± 0.36	0.64 ± 0.23
80	121	<0.21	<0.63	0.84 ± 0.33	0.45 ± 0.17
85	25	<0.15	1.51 ± 0.76	0.83 ± 0.27	0.67 ± 0.18
85	30	<0.26	<0.84	0.95 ± 0.43	0.66 ± 0.16
90	25	<0.21	1.22 ± 1.19	0.54 ± 0.24	0.66 ± 0.24
95	30	<0.18	0.92 ± 0.70	0.80 ± 0.42	0.67 ± 0.19
100	0	<0.25	2.29 ± 1.88	0.91 ± 0.33	0.66 ± 0.16
100	25	<0.32	7.32 ± 1.52	0.80 ± 0.41	0.68 ± 0.28
100	30	0.54 ± 0.33	1.43 ± 1.70	0.78 ± 0.61	0.71 ± 0.14
100	121	<0.21	0.61 ± 1.28	1.02 ± 0.38	0.75 ± 0.18
105	25	<0.17	2.07 ± 1.06	0.87 ± 0.38	0.59 ± 0.19
105	30	0.47 ± 0.67	1.97 ± 1.76	0.86 ± 0.29	0.76 ± 0.21

TABLE 11 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 10

Sample Location N	Sample Location E	U-235	U-238	Th-232	Ra-226
110	25	<0.25	1.22 ± 1.79	3.11 ± 0.59	0.75 ± 0.25
110	30	<0.25	1.68 ± 0.92	0.91 ± 0.49	0.68 ± 0.20
115	25	<0.23	1.88 ± 1.44	0.51 ± 0.48	0.72 ± 0.23
115	30	1.87 ± 0.56	6.05 ± 2.06	1.32 ± 0.32	0.94 ± 0.20
120	25	<0.33	<1.02	1.85 ± 0.72	0.84 ± 0.22
120	30	<0.21	0.92 ± 1.74	0.63 ± 0.49	0.61 ± 0.24
125	25	0.25 ± 0.45	8.37 ± 1.04	0.74 ± 0.38	0.64 ± 0.19
125	30	0.94 ± 0.58	7.14 ± 2.10	0.86 ± 0.34	0.80 ± 0.23
130	25	0.59 ± 0.63	3.12 ± 1.75	0.82 ± 0.43	0.68 ± 0.19
135	25	0.79 ± 0.79	3.50 ± 1.36	0.98 ± 0.39	0.50 ± 0.22
135	30	<0.30	4.49 ± 1.53	0.99 ± 0.33	0.77 ± 0.28
140	25	<0.33	2.93 ± 2.11	0.87 ± 0.27	0.73 ± 0.25
140	30	<0.24	3.10 ± 2.32	0.72 ± 0.64	0.62 ± 0.20
145	20	<0.21	<0.75	1.05 ± 0.39	0.49 ± 0.20
145	25	0.49 ± 0.38	2.30 ± 0.59	0.78 ± 0.32	0.51 ± 0.16
145	26	0.46 ± 0.48	1.17 ± 1.76	0.97 ± 0.41	0.51 ± 0.20
145	27	<0.29	<0.93	0.92 ± 0.13	0.95 ± 0.21
145	28	<0.25	2.09 ± 1.42	0.72 ± 0.30	0.53 ± 0.24
145	29	0.31 ± 0.52	1.78 ± 0.63	0.70 ± 0.33	0.70 ± 0.20
145	30	<0.21	1.95 ± 2.16	0.78 ± 0.29	0.54 ± 0.26
146	25	<0.18	0.91 ± 1.35	1.07 ± 0.40	0.70 ± 0.20
146	26	0.46 ± 0.48	1.17 ± 1.76	0.97 ± 0.41	0.51 ± 0.20
146	27	<0.15	0.58 ± 1.29	0.63 ± 0.34	0.52 ± 0.15
146	28	0.52 ± 0.51	2.25 ± 1.70	0.91 ± 0.34	0.79 ± 0.17
146	29	<0.20	1.53 ± 0.90	0.02 ± 0.43	0.56 ± 0.20
146	30	1.08 ± 0.54	8.76 ± 1.75	1.72 ± 0.65	0.58 ± 0.13
147	25	<0.24	1.00 ± 1.44	0.87 ± 0.39	0.42 ± 0.27
147	26	<0.32	1.70 ± 1.73	1.25 ± 0.39	0.90 ± 0.18
147	27	<0.20	0.98 ± 1.55	0.49 ± 0.23	0.77 ± 0.23
147	28	0.22 ± 0.31	1.99 ± 0.59	0.81 ± 0.30	0.49 ± 0.20
147	29	<0.22	1.06 ± 2.03	0.70 ± 0.40	0.63 ± 0.20
147	30	0.60 ± 0.41	2.32 ± 0.62	0.68 ± 0.39	0.53 ± 0.19
148	25	4.66 ± 0.84	1.42 ± 2.78	1.05 ± 0.38	0.56 ± 0.17
148	26	<0.15	0.46 ± 0.53	0.85 ± 0.35	0.[illegible]5 ± 0.19
148	27	<0.21	1.14 ± 1.37	0.75 ± 0.33	0.57 ± 0.24
148	28	0.33 ± 0.44	2.61 ± 2.35	0.78 ± 0.40	0.62 ± 0.17
148	29	<0.32	2.47 ± 1.79	1.40 ± 0.40	0.88 ± 0.16
148	30	0.53 ± 0.32	2.66 ± 1.63	0.72 ± 0.65	0.65 ± 0.21
149	26	<0.19	<0.72	0.68 ± 0.36	0.57 ± 0.17
149	27	<0.27	1.57 ± 0.84	0.95 ± 0.44	0.65 ± 0.22
149	28	<0.26	2.00 ± 2.41	0.46 ± 0.54	0.87 ± 0.21
149	29	<0.19	2.22 ± 0.76	1.05 ± 0.42	0.76 ± 0.19

Radionuclide Concentrations (pCi/g)

TABLE 11 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 10

Sample Location		Radionuclide Concentrations (pCi/g)			
N	E	U-235	U-238	Th-232	Ra-226
149	30	0.41 ± 0.50	2.51 ± 1.98	0.83 ± 0.39	0.46 ± 0.20
156	25	<0.16	1.04 ± 0.86	7.18 ± 0.33	0.42 ± 0.21
156	26	<0.21	0.90 ± 1.46	1.06 ± 0.42	0.36 ± 0.23
156	27	<0.13	0.68 ± 0.45	0.78 ± 0.38	0.56 ± 0.18
156	28	<0.28	<0.89	0.85 ± 0.34	0.49 ± 0.19
156	29	<0.20	1.70 ± 1.27	0.62 ± 0.44	0.70 ± 0.20
156	30	<0.27	1.11 ± 2.25	0.71 ± 0.42	0.61 ± 0.15
157	25	<0.22	1.58 ± 0.99	0.30 ± 0.26	0.47 ± 0.25
157	26	<0.29	0.87 ± 1.35	1.54 ± 0.40	0.66 ± 0.19
157	27	<0.18	1.21 ± 1.21	0.66 ± 0.33	0.55 ± 0.31
157	28	<0.15	1.09 ± 0.75	0.82 ± 0.35	0.50 ± 0.19
157	29	<0.19	<0.69	0.66 ± 0.37	0.37 ± 0.17
157	30	<0.15	1.09 ± 0.82	0.77 ± 0.26	0.34 ± 0.12
158	25	<0.21	1.30 ± 0.82	0.81 ± 0.32	0.63 ± 0.16
158	26	<0.15	<0.41	0.62 ± 0.24	0.47 ± 0.17
158	27	<0.20	<0.66	0.58 ± 0.32	0.46 ± 0.22
158	28	<0.23	0.72 ± 1.76	0.40 ± 0.26	0.65 ± 0.24
158	29	<0.27	1.49 ± 1.64	0.73 ± 0.27	0.68 ± 0.22
158	30	0.40 ± 0.47	<0.70	0.48 ± 0.27	0.58 ± 0.25
159	25	0.56 ± 0.71	<0.97	1.14 ± 0.36	0.40 ± 0.24
159	26	3.15 ± 1.04	3.12 ± 1.40	0.65 ± 0.39	0.71 ± 0.23
159	27	<0.28	0.37 ± 1.42	1.02 ± 0.31	0.82 ± 0.20
159	28	<0.20	<0.72	0.80 ± 0.34	0.62 ± 0.17
159	29	<0.16	1.81 ± 1.35	0.74 ± 0.42	0.50 ± 0.17
159	30	<0.23	1.06 ± 1.95	0.86 ± 0.38	0.72 ± 0.19
160	20	<0.19	<0.75	0.77 ± 0.41	0.51 ± 0.17
160	25	5.60 ± 1.59	4.42 ± 2.53	0.92 ± 0.27	0.53 ± 0.14
160	26	0.58 ± 0.67	2.47 ± 2.17	0.98 ± 0.46	0.58 ± 0.25
160	27	<0.13	0.71 ± 0.49	0.70 ± 0.45	0.47 ± 0.16
160	29	<0.20	2.37 ± 1.06	0.57 ± 0.20	0.56 ± 0.20
160	30	<0.31	1.41 ± 1.38	0.77 ± 0.49	0.59 ± 0.26
160	157	<0.20	<0.64	0.93 ± 0.45	0.49 ± 0.13
160	160	<0.26	1.09 ± 0.80	1.25 ± 0.37	0.73 ± 0.18
165	20	<0.34	3.35 ± 2.07	1.53 ± 0.41	1.13 ± 0.23
165	25	0.47 ± 0.50	2.06 ± 1.54	0.93 ± 0.39	0.54 ± 0.23
165	30	1.95 ± 0.56	2.37 ± 0.81	0.82 ± 0.40	0.67 ± 0.21
170	20	<0.15	1.34 ± 0.53	0.58 ± 0.34	0.73 ± 0.19
170	25	<0.22	0.89 ± 1.34	1.20 ± 0.33	0.51 ± 0.22
170	30	<0.29	3.06 ± 1.90	0.70 ± 0.27	0.69 ± 0.24
170	100	<0.12	0.69 ± 0.43	0.66 ± 0.23	0.53 ± 0.15
170	120	<0.19	<0.60	0.81 ± 0.49	0.60 ± 0.15
170	140	<0.20	<0.56	0.71 ± 0.31	0.40 ± 0.19
170	160	<0.50	2.46 ± 3.11	0.40 ± 0.25	

TABLE 11 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - BUILDING 10

Sample Location		Radionuclide Concentrations (pCi/g)			
N	E	U-235	U-238	Th-232	Ra-226
175	20	<0.20	0.81 ± 1.36	0.49 ± 0.31	0.50 ± 0.18
175	25	<0.29	<0.97	0.49 ± 0.22	0.71 ± 0.20
175	30	<0.22	0.82 ± 1.63	0.67 ± 0.58	0.55 ± 0.21
180	20	0.46 ± 0.57	2.12 ± 2.19	1.04 ± 0.49	0.70 ± 0.18
180	25	2.68 ± 0.58	2.94 ± 0.89	0.83 ± 0.36	0.59 ± 0.21
180	30	1.49 ± 0.83	1.07 ± 1.96	0.86 ± 0.40	0.71 ± 0.15
180	100	<0.25	<0.80	1.15 ± 0.36	0.59 ± 0.17
180	120	<0.12	1.00 ± 0.68	0.56 ± 0.38	0.49 ± 0.18
185	40	<0.18	1.55 ± 0.58	0.60 ± 0.40	0.53 ± 0.15
185	60	<0.36	2.52 ± 1.51	1.13 ± 0.52	0.47 ± 0.33
185	80	<0.24	1.58 ± 1.95	0.84 ± 0.44	0.65 ± 0.24
200	20	<0.31	0.74 ± 2.24	0.75 ± 0.57	0.74 ± 0.25

[a] Errors are 2σ based on counting statistics.

TABLE 12A

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES COLLECTED FROM LOCATIONS OF ELEVATED CONTACT RADIATION LEVELS - BUILDING 10

Sample[a] Identification No.	Sample Location N	Sample Location E	Depth	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
S19	128	28	0-10 cm	64.9 ± 3.85[b]	4,450 ± 19.1	<0.48	0.73 ± 0.60
S20	146	122	0-10 cm	37.2 ± 1.99	84.4 ± 5.42	0.89 ± 0.37	0.49 ± 0.18
S21	177	26	0-10 cm	149 ± 3.39	93.4 ± 6.77	1.70 ± 0.40	0.60 ± 0.20

[a] See Figure 9 for locations and Table 10 for direct radiation levels.

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

TABLE 12B

RADIONUCLIDE CONCENTRATIONS IN DEBRIS COLLECTED FROM LOCATIONS OF ELEVATED CONTACT RADIATION LEVELS – BUILDING 10

Sample[a] Identification No.	Grid Location N	Grid Location E	Type of Sample	Weight (Grams)	Activity Levels (pCi) U-235	U-238	Th-232	Ra-226
D-10	146	123	Metal	11	6.4×10^4[b]	5.8×10^4	---	---
D-11	146	128	Slag	11	9.0×10^4	8.3×10^4	---	---
D-12	151	123	Slag	53	116×10^4	71×10^4	---	---

[a] Refer to Table 10 for sample locations and direct radiation levels.
[b] Values are approximate, as samples were of nonstandard geometry and possibly not homogeneous.

TABLE 13A

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES - BUILDING 10

Borehole No.[a]	Sample Location N	Sample Location E	Depth (Meters)	Radionuclide Concentrations (pCi/g) U-235	U-238	Th-232	Ra-226
B26	20	128	Surface	<0.12	1.55 ± 0.60[b]	0.95 ± 0.35	0.53 ± 0.19
			1.5 - 2.0	<0.31	1.22 ± 1.30	0.42 ± 0.80	0.63 ± 0.50
			3.0 - 3.5	<0.19	1.45 ± 1.34	0.78 ± 0.38	0.58 ± 0.19
B27	50	25	Surface	<0.12	0.36 ± 0.37	0.81 ± 0.33	0.43 ± 0.17
			1.5 - 2.0	0.31 ± 0.39	0.49 ± 0.15	0.70 ± 0.41	0.56 ± 0.22
			3.0 - 3.5	<0.20	0.69 ± 1.10	0.67 ± 0.16	0.48 ± 0.17
			4.5 - 5.0	<0.24	3.54 ± 1.55	0.65 ± 0.12	0.50 ± 0.12
B28	95	130	Surface	<0.37	2.87 ± 1.93	1.24 ± 0.66	0.79 ± 0.22
			1.5 - 2.0	<0.09	0.31 ± 0.82	0.79 ± 0.30	0.63 ± 0.16
			3.0 - 3.5	<0.21	2.37 ± 1.40	1.25 ± 0.43	0.88 ± 0.24
B29	128	29	Surface	1.19 ± 0.69	8.23 ± 1.43	0.40 ± 0.47	0.59 ± 0.17
			1.5 - 2.0	<0.31	2.60 ± 1.29	1.42 ± 0.46	0.71 ± 0.24
B30	146	122	Surface	28.1 ± 1.4	22.8 ± 2.5	0.85 ± 0.26	0.52 ± 0.13
			1.5 - 2.0	<0.16	1.12 ± 0.67	0.89 ± 0.49	0.53 ± 0.14
			3.0 - 3.5	<0.17	1.65 ± 1.06	0.63 ± 0.22	0.95 ± 0.15
			4.5 - 5.0	<0.23	<0.74	1.07 ± 0.35	0.65 ± 0.20
B31	147	27	Surface	0.20 ± 0.53	0.83 ± 2.06	0.84 ± 0.43	0.40 ± 0.22
			1.5 - 2.0	<0.28	3.47 ± 0.93	1.09 ± 0.51	0.68 ± 0.19
			3.0 - 3.5	<0.15	1.11 ± 0.53	1.06 ± 0.30	0.82 ± 0.25

TABLE 13A (Continued)

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES - BUILDING 10

Borehole No.	Sample Location		Depth (Meters)	Radionuclide Concentrations (pCi/g)			
	N	E		U-235	U-238	Th-232	Ra-226
B32	156	27	Surface	<0.28	<0.87	0.60 ± 0.29	0.55 ± 0.26
			1.5 - 2.0	1.31 ± 0.47	4.89 ± 0.89	0.77 ± 0.36	0.43 ± 0.17
			3.0 - 3.5	<0.20	1.60 ± 1.27	1.14 ± 0.39	0.70 ± 0.20
B33	177	26	Surface	15.5 ± 1.4	2.37 ± 2.74	0.98 ± 0.45	0.55 ± 0.18
			1.0 - 1.5	2.48 ± 0.73	2.96 ± 2.58	0.68 ± 0.40	0.43 ± 0.22

[a] See Figure 10 for locations.
[b] Errors are 2σ based on counting statistics.

TABLE 13B

ISOTOPIC URANIUM CONCENTRATIONS IN BOREHOLE SOIL SAMPLES BUILDING 10

Borehole No.	Depth (Meters)	Radionuclide concentrations (pCi/g) U-238	U-235	U-234	U-238* / U-235	U-234 / U-235
B30	Surface	64.1 ± 6.3[b]	65.1 ± 7.5	1874 ± 33	1.0	28.8
B33	Surface	40.8 ± 1.4	19.4 ± 1.1	622 ± 6	2.1	32.1

[a] Refer to Figure 10 for locations.
[b] Errors are 2σ based on counting statistics.

* $\frac{U\text{-}238}{U\text{-}235}$ For natural uranium ≈ 22

$\frac{U\text{-}238}{U\text{-}235}$ For depleted uranium ≈ > 22

$\frac{U\text{-}238}{U\text{-}235}$ For enriched uranium ≈ < 22

TABLE 14

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE WATER SAMPLES
BUILDING 10

Borehole[a] No.	Sample Location N	Sample Location E	Radionuclide Concentrations (pCi/l or $\times 10^{-9}$ $\mu Ci/ml$) Gross Alpha	Gross Beta
B26	20	128	6.62 ± 1.91[b]	4.00 ± 1.02
B27	50	25	4.66 ± 0.90	8.03 ± 1.15
B29	128	29	6.67 ± 1.87	23.3 ± 2.5
B30	146	122	1.72 ± 1.01	8.42 ± 1.24

[a] See Figure 10 for locations.
[b] Errors are 2σ based on counting statistics.

REFERENCES

1. Title 40, Code of Federal Regulations, Part 141, Interim Primary Drinking Water Standards, Federal Register, July, 1976.

APPENDIX B

INSTRUMENTATION AND ANALYTICAL PROCEDURES

APPENDIX B

INSTRUMENTATION AND ANALYTICAL PROCEDURES

Gamma Scintillation Measurements

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) crystals. Count rates were converted to exposure rates (μR/h) using factors determined by comparing the response of the scintillation detectors with that of a Reuter Stokes model RSS-111 pressurized ionization chamber at several locations on the surveyed property.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal" PRS-1 portable ratemeters with Model HP-260 G-M probes. Dose rates (μrad/h) were determined by comparison of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes for soils containing elevated uranium and thorium concentrations.

Borehole Logging

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe, connected to a Ludlum Model 2200 portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 x 7 mm holes evenly spaced around the region of the scintillation detector. The probe was lowered into each hole using a tripod holder with a small winch. Measurements were performed at 30 cm intervals. The logging data were used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of U-235, U-238, and Th-232, there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

Soil Sample Analysis

Gamma Spectrometry

Soil samples were dried, mixed, and a portion sealed in a 0.5-liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 400 to 800 g of soil. Net soil weights were determined and the samples counted using Ge(Li) and intrinsic 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:

Th-232 - 0.911 MeV from Ac-228*
U-235 - 0.143 MeV
U-238 - 0.094 MeV from Th-234 or 1.001 MeV from Pa-234m*
Ra-226 - 0.609 MeV from Bi-214*

*Secular equilibrium was assumed.

Alpha Spectrometry

Uranium was separated by a process of high temperature fusion, acid dissolution, precipitation, redissolution, and solvent extraction. The uranium was then precipitated with cerium fluoride onto counting discs. Relative quantities and yields were determined by the use of uranium 232 as a tracer. Surface barrier detectors coupled to a Nuclear Data Model ND 680 pulse height analyzer enabled identification of the characteristic alpha energy peaks and activity determination.

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration througyh 0.45 μm membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. Aliquots were then evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter. Alpha spectroscopy was performed using a similar procedure as that used for soil samples.

Calibration and Quality Assurance

All survey and laboratory instruments were calibrated with NBS-traceable standards. Quality control procedures on all instruments included daily background and check-source measurements to confirm acceptable equipment operations. The ORAU laboratory participates in the EPA Quality Assurance Program.

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 concentration guidelines.

DETECTION SCIENCES GROUP

FINAL REPORT

GROUND-PENETRATING RADAR SURVEY
OF BURIED WASTE MATERIAL,
TEXAS INSTRUMENTS, INC.
ATTLEBORO, MASSACHUSETTS

DETECTION SCIENCES GROUP
496 HEALD ROAD CARLISLE, MASSACHUSETTS 01741 (617)369-7999

FINAL REPORT

GROUND-PENETRATING RADAR SURVEY OF BURIED WASTE MATERIAL, TEXAS INSTRUMENTS, INC. ATTLEBORO, MASSACHUSETTS

Prepared for

OAK RIDGE ASSOCIATED UNIVERSITIES, INC.
Oak Ridge, Tennessee 37830

Purchase Order No. C-35383
Dated February 2, 1984
Purchase Order No. C-35383-001
Dated April 5, 1984

Report No. J173-84

August, 1984

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Illustrations

INTRODUCTION AND SUMMARY

On April 7-12, 1984, Detection Sciences Group conducted a ground-penetrating radar survey of the area north and west of Building 12 on the property of Texas Instruments, Inc. Attleboro, Massachusetts. The purpose of the survey was to search for buried waste and to inspect boring locations. The survey was performed in accordance with Oak Ridge Associated Universities, Inc. Purchase Order No. C-35383, dated February 2, 1984, and per field instructions of Linda Sowell, Team Leader.

The radar equipment is a SIR System-8 ground-penetrating radar system with proprietary modifications which increase the depth of penetration by a factor of 2.5 over the standard version of this equipment. The antenna is a 120 MHz antenna with proprietary low-noise, high-gain electronics incorporating switch-selectable gain and limiting networks.

Radar survey lines were run with a north-south and east-west grid orientation using a nominal 5-meter spacing between survey lines. To avoid interference with the wood stakes marking the grid, the radar survey lines were run with a 1-meter offset from the principal grid lines.

The radar survey lines are shown by Drawing Number 173-84-001. The location and extent of all buried material is also shown by this drawing.

A total of 37 biased boring locations were inspected by radar, as listed in **Table I**. Of these 37 locations, 11 were located near utility lines or services. We did not relocate any of the biased borings because the bias reading could be caused by a small object which would not be found if the boring were to be moved to an adjacent location. At 16 of the biased locations, we observed buried objects at shallow depths. These shallow objects were observed directly under the pin flag marking the biased location or in close proximity to the pin flag, and are likely to be the source of the biased reading. For the 11 biased locations that were located near pipes or utilities, we recommended digging by hand in lieu of relocating these borings.

Following the radar survey, a conference was held with the Team Leader, Linda Sowell, to review the worksheet showing the radar results. During this conference, systematic boring locations were also chosen. These locations were positioned at intersections of the radar survey grid lines. For each proposed location, the radar graphic charts were reviewed for possible drilling obstacles. The final position of these systematic borings were placed at the intersections of surveys lines which did not show any potential obstacles.

DESCRIPTION OF THE SURVEY

The 120 MHz radar antenna was hand-pulled along each of the survey lines shown on Drawing Number 173-84-001. The numbering of the survey lines on the drawing is the sequence in which the survey was run. A hand-held electronic event marker was used to generate a vertical dashed line on the radar graphic record when the center of the radar antenna passed each grid stake at 5-meter intervals. At intervals of 50 meters at grid lines 100E, 150E, 200E, 150N, 200N and 250N, a double mark was made on the radar record. This technique provides an independent me nod of confirming the grid location in the event of a missed mark or a misplaced mark. In general, the use of redundant information provides an independent back-up to eliminate possible record-keeping errors.

All data was tape-recorded on a Hewlett-Packard Model 3964A 4-channel instrumentation tape recorder. The magnetic tapes are permanently stored in our project archives should the need arise for the radar data to be duplicated in the future.

Inspection of all biased boring locations was accomplished by running the radar antenna directly over the bias location in both a north-south and an east-west direction. A surveyor's tape laid on the ground was used to mark off 2-meter intervals along each survey line. A double mark was used when the center of the antenna passed directly over the bias location. The survey lines extend a distance of 6 meters on either side of the bias location, for a total length of 12 meters. Where there were obstacles or buildings to limit the 12-meter length of the survey line, the line was run to the limit imposed by the particular obstacle.

The systematic boring locations were chosen to be placed at intersection points of the radar survey lines, and did not require separate survey runs to inspect these locations.

All radar survey lines are run with an offset of 1 meter from the line of grid stakes so as to keep the radar antenna clear of the wood stakes marking the grid. The locations of the radar survey lines relative to the grid are drawn to scale on Drawing Number 173-84-001, and are further identified by the survey line number and the grid location of the survey line (for example, #1 - 231N, indicates that the first survey line was run along grid line 231 North).

METHODOLOGY

In most cases, using ground-penetrating radar to locate buried materials is a relatively easy task. Natural soils typically have horizons which can be observed with radar. Any excavation shows as an interruption in these horizons, or horizontal strata. When the fill is placed back in the excavation, the original layers inevitably become mixed, and the fill appears jumbled, or chaotic, relative to the more orderly layering that is observed in the surrounding soils. Usually, any waste material that is placed in the excavation has a radar signature that is significantly different than the fill. Under these circumstances, we have two independent methods for locating buried material: the interruption of the natural strata, and the contrast offered by the buried material.

Such was not the case at this site. Nearly all of the area covered by the radar survey consisted of fill which has been extensively worked and reworked. Moreover, the buried waste material does not offer any strong contrast to the surrounding fill. Initially, it seemed to be a hopeless task to be able to distinguish the waste material from the surrounding fill. The only ray of hope was that we did see some characteristic signatures of buried metal. Clean fill should not contain metal, but industrial waste material would likely have some metal. In effect, the presence of metal can be used as a "tracer" to signal the presence of waste material.

There are strong limitations to this approach, however, because the characteristic "ringing" signal which uniquely identifies metal occurs only under special circumstances. These circumstances arise when the length of the piece of buried metal allows the metal to resonate in reponse to being irradiated with radar energy. The analogy is like a hammer hitting a bell and causing the bell to resonate, or ring, at a characteristic frequency that is determined by the size of the bell. In this case the "hammer" is the impulse of radar energy emitted by the radar antenna. The impulse, which lasts for about 13 nanoseconds, has a peak frequency of about 120 MHz (hence the description of the antenna as being a 120 MHz antenna). The frequency spectrum, which has a Gaussian distribution, extends more than two octaves above and below the center frequency of 120 MHz, covering the range from about 30 MHz to 480MHz. Any piece of metal whose length makes it capable of resonating in this frequency regime will broadcast a characteristic "ringing" signal which is a unique identifier of metal. Although 30 to 480 MHz covers a broad range, a piece of metal can easily be too large, too small, or have the wrong geometry to exhibit resonant characteristics within these frequency limits. Also, the range of frequencies capable of being detected by the radar receiver is most strongly centered at 120 MHz, falling off in sensitivity both above and below this frequency. The net effect is that the characteristic "ringing" signal which is a unique identifier of buried metal occurs only in a minority of cases. Most buried metal will not exhibit ringing, either because the characteristic ringing frequency falls outside the frequency response of the radar system, or that geometry does not allow the piece of metal to resonate in response to the radar impulse.

At this point, we focused our attention on the locations where there were dense concentrations of biased readings. Presumably these biased readings signaled the presence of buried waste material. It was found that the area to the west of the shrubs, centered around 110E at 155N, did have a distinct radar contrast compared to the site at large. The radar signals at this location were darker and more dense than most places on the site. In searching for other locations with a relatively high concentration of biased readings that might also have an observable radar contrast, a peculiar phenomenon was noted. The waste material seemed to extend deeper into the ground than the surrounding material. Because the site is underlain with shallow bedrock at an average depth of about 10 feet, this observation was puzzling, because it implied that the bedrock had been excavated, which did not make sense. A more logical explanation is that we are observing late-arriving radar echoes. These echoes are due to multiple reflections which arrive at a later time than direct reflections, thereby giving the impression of being deeper than they really are. Again, we turn to buried metal for an explanation:

Most materials are semi-tranparent to radar energy, hence the ability of ground-penetrating radar to penetrate many layers in the ground. Metals, on the other hand, are completely opaque to radar signals, but have the property of reflecting all of the incident radiation. This property of metals applies to all metals, including aluminum, brass, copper, steel, and other metals commonly used in industry. As a result of metal being virtually 100 percent reflective, radar signals are reflected with very little loss, thus paving the way for multiple reflections if there are a number of pieces of metal in proximity to each other. Waste material having any significant content of metal thus creates a favorable enviornment for these multiple reflections to occur. It is these late-arriving multiple reflections that give the appearance of coming from below the top of the bedrock.

Reviewing the entire set of radar data, we mapped all of the locations where the radar signals appeared to be deeper than the upper surface of the bedrock. This worksheet showed excellent correlation with the locations of the biased readings. There was also good correlation with the magnetometer data generated by a previous survey of this site (Roy F. Weston, Inc., Concord, New Hampshire, June, 1983). It should be noted that the magnetometer data is limited to magnetic materials, whereas the radar response to metals applies to all metals, including aluminum, copper, brass and other common industrial metals which are not magnetic.

The final product of the analysis is a map (Drawing Number 173-84-001) showing the distribution of buried waste material containing metal scrap. In some instances, the buried material has sufficient contrast with the surrounding fill so as to be identifiable by this fact alone. In a few instances, we can observe the "trenching effect" of having made an excavation in the ground. But overall, the majority of buried material was identified by mapping locations of the multiple reflections shown by buried metal.

The validity of this approach can be shown in three ways: First, the fact that ringing occurs only in a minority of cases indicates that considerably more metal is present than the pieces that produce the ringing. Second, we observe the ringing signal in areas where the multiple reflections are present. Third, we do not observe ringing in the areas where there are no late-arriving multiple reflections. This later observation also indicates that the fill is essentially free of scrap metal.

Considering all of the evidence, we believe that the interpretive methods used on this project provide a reliable approach for locating the buried waste material.

RESULTS OF THE SURVEY

The Grid Survey.

The results of the grid survey are shown on Drawing Number 173-84-001. At two locations, the buried material extends to the edges of landscaped areas which are densely planted with shrubs and pine trees. These areas were inaccessible for the large, 45-inch wide 120 MHz radar antenna and therefore could not be investigated by radar.

In particular, the densely-shrubbed area bounded by 145N to 164N, extending from 115E to 129E, is highly suspect of containing buried material. On the west side of these shrubs is an area which shows the most dense concentration of buried material observed during the radar survey. This strip along the west side of the shrubs also has a dense concentration of biased locations. Similarly, along the north side of the shrubs the radar shows a dense concentration of buried materials with a correspondingly high concentration of biased locations. On the east side, burials are observed on the northern end, but not on the southern end. There are no burials immediately south of the shrubs. It appears that the southeastern portion of these shrubs may be free of buried material.

A similar situation seems to exist within the strip of densely-planted pine trees from about 216N to 233N, extending to 174E. The buried material is observed along the south boundary of these trees as far as 95E, and is observed on the east end as well as on the north side of this strip of trees. From what we could learn about the history of the site, we believe that the landscaped areas were planted after the waste material had been buried. Though we are lacking the radar data to back up these assertions, the circumstancial evidence strongly suggests there is waste material buried under each of these two landscaped areas.

In all cases the buried material appears to have minimal cover, and appears to extend in depth down to the shallow bedrock which underlies the site.

Inspection of Biased Boring Locations.

A total of 37 biased locations were inspected by radar. The radar antenna was run directly over the location of each biased reading, extending 6 meters north, south, east and west of the location. The hand-held electronic event marker was used to generate a vertical dashed line at increments of 2 meters along the survey lines, with the insertion of a double mark at the exact location of the biased reading. The results of the radar inspection of these biased boring locations are listed in Table I. At the 11 locations where the biased reading was located near a buried utility line or service, we would normally recommend that the boring be moved to a nearby location. If the biased reading were caused by a small object, however, moving the location of the boring would result in the object being missed. We therefore recommended that these locations be hand-dug, or otherwise investigated with proper caution for the buried pipes and utilities. At 16 locations we observed a shallow buried object directly under the pin flag marking the bias location or in close proximity to the pin flag. It is likely that these shallow buried objects are the source of the biased reading. The depth and exact location of each of these objects is also listed in Table I.

TABLE I

BORING LOCATIONS DETERMINED BY RADAR

BIASED BORINGS

Boring Number	Coordinate Location	Recommendation	Comments
B1	101.5N, 255.9E	-	
B2	135.0N, 241.2E	-	Buried Object @ 134.5N, 1.8' Deep.
B3	153.4N, 111.0E	-	
B4	156.6N, 111.3E	-	Small Object @ 111.6E, 1.0' Deep. Buried Object @ 111.0E, 0.9' Deep.
B5	163.3N, 115.3E	Dig by hand.	Vicinity of Buried Utility.
B6	163.5N, 137.1E	Dig by hand.	Vicinity of Buried Utility.
B7	165.7N, 115.7E	-	Small Object, 0.7' Deep.
B8	165.5N, 119.9E	-	
B9	166.5N 118.0E	Dig by hand.	Small Object 0.7' Deep. Vicinity of Buried Utility.
B10	165.0N, 122.3E	Dig by hand.	Small Object 165.3N, 1.4' Deep Pipe @ 166.0N, 3.2' Deep.
B11	170.0N, 129.0E	Dig by hand.	Vicinity of Buried Utility.
B12	181.0N, 130.0E	-	
B13	183.9N, 151.0E	-	
B14	185.0N, 148.6E	-	
B15	188.3N, 145.0E	-	Small Object 0.6' Deep.
B16	198.2N, 154.5E	-	
B17	180.1N, 130.1E	-	
B18	185.0N, 132.4E	-	Small Object 1.3' Deep.
B19	186.5N, 128.0E	-	Three Objects 186.8/188.0N 1.8' Deep.
B20	187.2N, 129.2E	-	
B21	188.5N, 130.4E	-	Buried Object 0.8' Deep.
B22	186.2N, 138.0E	Dig by hand.	Vicinity of Buried Utility. Pipe @ 185.2N, 1.5' Deep.

TABLE I (CONTINUED)

Boring Number	Coordinate Location	Recommendation	Comments
B23	188.1N, 140.0E	Dig by hand.	Vicinity of Buried Utility.
B24	187.0N, 141.4E	-	Pipe @ 186.0N, 1.0 Deep.
B25	187.7N, 141.8E	-	
B26	185.2N, 143.2E	-	Buried Object 0.8' Deep.
B27	187.5N, 146.4E	-	Buried Object 0.6' Deep.
B28	184.7N, 149.7E	-	
B29	166.7N, 118.8E	Dig by hand.	Vicinity of Buried Utility.
B30	107.0N, 252.1E	-	
B31	187.2N, 141.8E	-	See B24 & B25
B32	166.4N, 141.9E	Dig by hand.	Pipe @ 142.9E, 2.2' Deep. Vicinity of Buried Utility.
B33*			
B34*			
B35*			
B36*			
B37	154.5N, 111.5E	-	Buried Object 1.4' Deep.
B38	156.1N, 111.3E	-	Buried Object 1.0' Deep.
B39	156.6N, 112.8E	Dig by hand.	Buried Object @ 111.8E, 1.2' Deep. Vicinity of Buried Utility.
B40	156.6N, 113.2E	Dig by hand.	Buried Object @ 111.7E, 1.2' Deep. Vicinity of Buried Utility.
B41	152.5N, 114.0E	-	

* Not examined by radar.

RADAR EQUIPMENT

Detection Sciences Group owns a modified SIR SYSTEM-8 radar system with an integral Motorola M6800 microprocessor unit. Our proprietary modifications to the radar system have provided increased range and sensitivity, as well as improving the overall efficiency of the data-gathering process. Detection Sciences Group has also developed special auxiliary equipment to facilitate our radar surveys. The individual components of the radar equipment are:

- GSSI Model 4800 Control Unit. The control unit contains the bulk of all the radar electronics and system controls, and has an oscilloscope display.

- Motorola Model M68MM01A/1A2 Monoboard Microcomputer. The microcomputer has real-time processing capability for background removal, digital filtering, running averages, and other radar signal-processing algorithms.

- Hewlett-Packard Model 3964A Instrumentation Tape Recorder. This high quality, four-channel tape recorder provides master tapes of all data recorded in the field.

- EPC Laboratories, Inc. Model 2800 Chart Recorder. This scanning chart recorder generates the hard-copy radar graphic charts (vertical profiles) used to interpret the radar data.

- GSSI Radar Antenna Units. The radar antennas operate at different frequencies; the depth requirements of the survey determine the operating frequency selected for the survey:

  [ ] 900 MHz [ ] 600 MHz [ ] 300 MHz [X] 120 MHz [ ] 80 MHz [ ] 10 MHz

- Sears 500VA Solid State Inverter. This power supply unit provides both 120 volt ac power as well as 12 volt dc power for operating all field equipment from the survey vehicle's electrical system.

- Honda 500VA Genertor. This gasoline-powered generator is used for surveys in remote locations where vehicle access is not possible.

- Remote Stop/Start Unit. The remote stop/start feature allows the operator to control the radar system from the antenna location.

- Odometer Wheel Assembly. This "fifth wheel" attached to the survey vehicle provides automatic logging of incremental distance traveled along the survey path, and automatically logs the ground stations on the radar charts.

- Support Equipment. The various support equipment includes the Micro-computer Control Box, the Remote Control/Market Unit, Hand-held Market Unit, towing sleds, towing harnesses and miscellaneous electrical cables and connectors.

PRINCIPLES OF OPERATION

The ground-penetrating radar system is an echo-location system which emits a brief impulse of radio energy lasting only a few billionths of a second. The time that it takes for the echoes to return to the radar antenna corresponds to the depth below the surface. By recording these depth-dependent echoes on a scanning time-based chart recorder, a vertical profile of the ground is generated which shows the longitudinal distribution of subsurface strata and other features over which the radar antenna has passed.

The radar impulse travels into the ground at an average speed of about 40 percent of the speed of light in air. The exact speed depends on the nature of the material through which the impulse is traveling. The slowest medium is water, where the speed is about 11 percent of the speed of light. The fastest material is dry sand, where the speed is about 50 percent of the speed of light. In air, such as an underground cavity, the radar impulse travels exactly at the speed of light, taking one nanosecond (one billionth of a second) to travel one foot.

The ground-penetrating radar equipment is designed to measure and display the time-based echoes down to a fraction of a nanosecond. To convert to depth, it is necessary to know the exact velocity of the radar impulse as it travels through the ground. By using published tables for various materials, it is normally possible to estimate the velocity to within 10 percent. The radar system can also be calibrated by external means, such as a boring or a test trench. Other methods involve triangulation and geometric relationships that are time-consuming to perform in the field but are inherently accurate.

At the interface of two materials, the radar impulse typically undergoes an abrupt change in velocity. It is this change in velocity which causes some of the radar energy to be reflected back to the surface of the ground, where it is detected by the antenna. The amount of energy that is reflected, or the reflection coefficient, depends on the contrast between the two materials; i.e., the difference between their respective radar velocities.

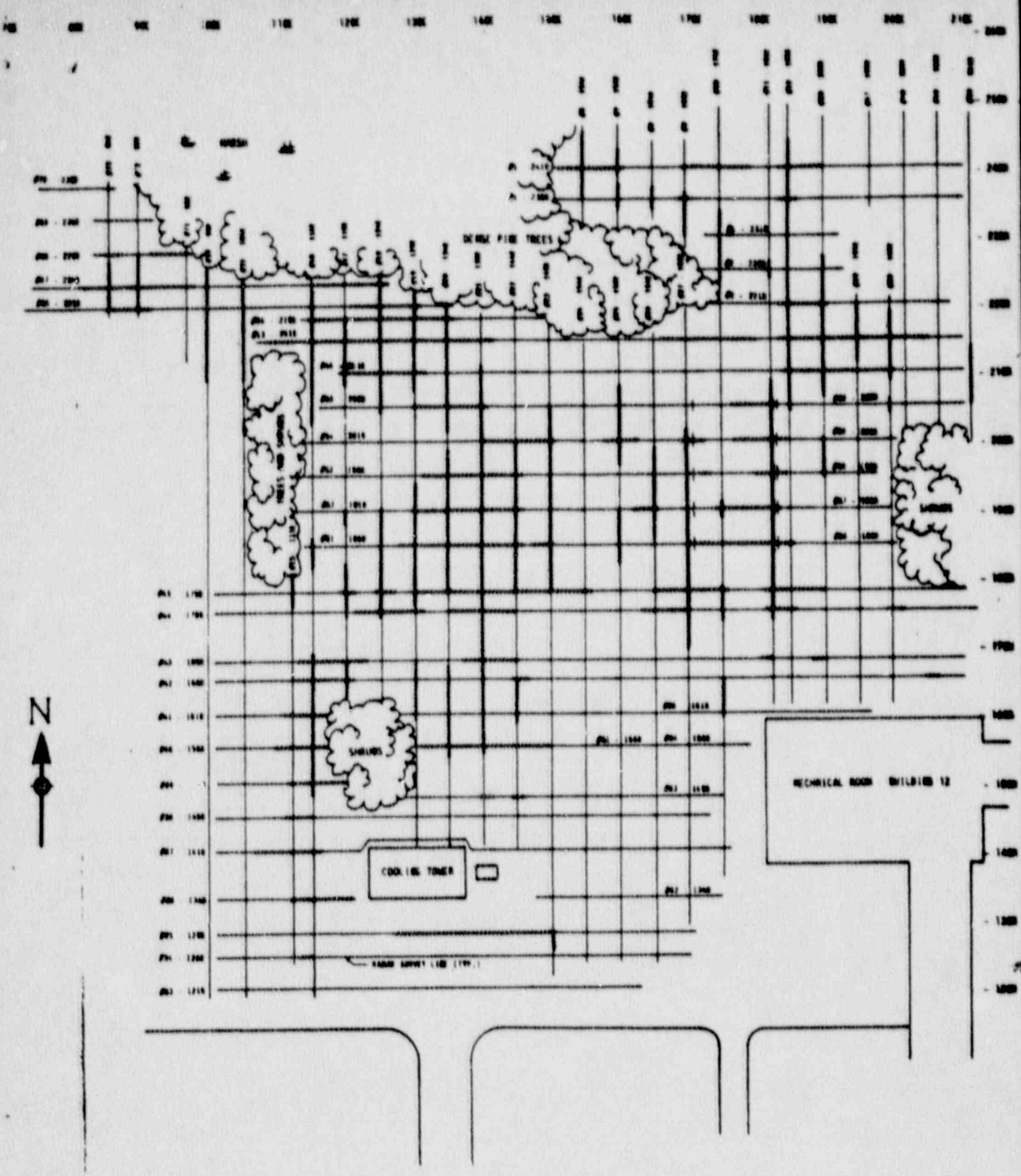
All materials with the exception of metals are relatively transparent to the passage of radar energy. Metals reflect all of the energy striking the surface, so that buried metal objects like pipes or metal containers make excellent targets. The fact that most materials are relatively transparent means that the radar impulse can continue to send back reflection after reflection as it propagates downward into the ground, thus revealing the various subsurface strata and profiles.

In effect, the radar functions as a "difference meter", by drawing a boundary at the interface of two different materials. The strength of the reflected signal is a measure of the difference between the two materials, but the radar system does not provide any kind of physical assay as to the nature of the two materials. Experience in interpreting radar charts is helpful, as the "texture" of the material can sometimes provide clues as to the nature of the material. Glacial till, moisture-laden organic material, clay and gravel are examples of materials that have radar signatures that are relatively easy to recognize. On the other hand, interspersed layers of organic silt, silty sand, etc., are impossible to identify without direct inspection by means of a test trench or core sample. What is important here is that test borings or other test methods can be used as an aid to the identification of subsurface materials, and the radar can show the distribution of the material over the length of the path traversed by the radar antenna. In this regard, it is useful to think of the radar system as a means of making closely spaced "electronic borings", corresponding to each sequence of echoes processed by the radar. Operating at a speed of 52 vertical soundings per second, the radar is capable of generating millions of these "electronic boreholes" in the course of a day.

The penetration depth of the radar system depends on the operating frequency and the electrical conductivity of the ground. For shallow penetration of a few feet, the optimum choice is an operating frequency of 600 MHz. This small, lightweight antenna can penetrate to a depth of about 5 feet under the most adverse ground conditions, and as much as 25 to 30 feet under good conditions. "Adverse" refers to highly conductive materials having a resistivity of less than 20 ohm-meters. Good radar conditions would be resistivities of several hundred ohm-meters or more.

Shifting to a lower operating frequency provides greater penetration, the improvement being the square root of the ratio of the respective wavelengths. An operating frequency of 120 MHz is a good general-purpose frequency for reaching depths that are beyond the capability of the 600 MHz antenna. There is a corresponding loss of detail, or spatial resolution, due to the longer wavelength. The optimum is to use as high an operating frequency as possible, consistent with the operating depth requirements, thus providing the best possible detail under the operating conditions. The useful range of ground-penetrating radar frequencies is limited to about 10 MHz at the lower end, and about 1000 MHz (1 GHz) at the upper end. The penetration of the 1 GHz antenna is limited to a few inches. The 10 MHz antenna can penetrate hundreds of feet into the ground, but the corresponding loss of detail limits its usefulness to large features, such as geologic strata.

The discussion regarding penetration depth assumes that all antennas have the same power. The penetration depth at any given frequency can be improved with increased power, but the improvement suffers from inverse-square losses as a function of depth, so that a quantum jump in power is necessary to gain any significant improvement. For this reason, Detection Sciences Group has focused its research efforts on improving the sensitivity of the radar receiver and reducing the internal noise of the receiver. These efforts have paid off by more than doubling the penetration depth of our equipment compared to standard, commercially-available systems. The present electronics are now operating close to the theoretical limits for the sensitivity of non-crogenically cooled electronics. This improved capability allows **Detection Sciences Group** to obtain data under conditions that were previously impossible for the operation of ground-penetrating radar.



LEGEND

BURIED WASTE MATERIAL

RADAR SURVEY LINES AND LOCATION OF
BURIED WASTE MATERIAL

GROUND-PENETRATING RADAR SURVEY
TEXAS INSTRUMENTS, ATTLEBORO, MASSACHUSETTS

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